INTEGRATION OF LIDAR AND TERRESTRIAL MOBILE MAPPING TECHNOLOGY FOR THE CREATION OF A COMPREHENSIVE ROAD CADASTRE

L. Amoureus, M.P.H. Bomers, R. Fuser, M. Tosatto

KEY WORDS: GIS, LiDAR, Mapping, Surveying, Modelling, GPS/INS, Laser scanning

ABSTRACT:

The integration of MMS and LiDAR technology is a comprehensive solution for generating and managing geometrical and thematic information of roads. The FLI-MAP 400 airborne LiDAR system has extensively been used for surveying and mapping tasks throughout the world. The FLI-MAP system shows advanced capabilities: a pulse frequency of 150,000 Hz, a multiple (4) return measurement possibility and a standard deviation of 1.5 cm. Final products that are extracted from the LiDAR point cloud include 3D object oriented maps, DTMs, DEMs and orthophotomosaics. The FLI-MAP system allows to accurately map the roads and all the signals, lampposts and other assets along the roads. DAVIDE (Data Acquisition Vehicle and Inertial DGPS Equipment) is a Mobile Mapping System used for generating road databases. The data is collected by integrated and synchronized sensors. The standard configuration includes 3 modules: localization module, video module and road surface module. All data is geo-referenced and is useful for tasks such as maintenance, monitoring, management, analysis and testing of roads resources. DAVIDE has surveyed more than of 20.000Km of road in Italy. Further to this, a DAVIDE survey can be adopted in order to capture a wide range of attribute information, referenced still photos and referenced video of the roads and along standing assets. The FLI-MAP products and DAVIDE data are geo-referenced, in Italy to the Gauss-Boaga projection. Both data sources can be combined into a detailed road cadastral system. The integrated data sets can be stored, analyzed, manipulated and visualized in Geographic Information Systems.

1. INTRODUCTION

The maintenance of roads represents a considerable task for Public Bodies and for companies involved in road management: appropriate traffic regulation and good condition of the roads are indispensable for flow of the traffic and safety on the roads.
The first step for road maintenance is the knowledge of the state of them. It means that it is necessary to have detailed and complete information of road resources. The integration of aerial LiDAR technology and terrestrial Mobile Mapping System Technology is a promising solution for the creation of a road cadastre and in general for roads management and maintenance.
In particular, as a result of an Italian law -Decreto Min. 01/06/01- the Public Bodies are required to create a Road Cadastre including all their roads, which can be integrated in a national information system.
A MMS -Mobile Mapping System- using several digital sensors (GPS, video and photo cameras, inertial platform, odometers etc), is able to acquire detailed and accurate road data: in particular, a MMS can provide most of the information required by law for creation and updating of road cadastres.
Specifically, based on the Decreto Min. 01/06/01 each Public Body has to create an information system of its complete road system: the road geometry ("road graph") with street names and progressive distance, including geo-referenced road elements required by law (signals, advertising placards, traffic lights etc.) and relative attributes. Furthermore, thanks to the MMS data the very precise measurement of several dimensions (road width, clearance width, sidewalks width etc.) is possible.
Besides surveying all data as required by law, thanks to the integration of other sensors like TPL and a laser profile meter, more information could be available: profile elevation, rut depth, road surface profile and roughness. In this way, in just one single survey the Public Body collects most of the necessary data and obtains further information useful for ordinary and extraordinary road maintenance.
Even though the latest generation mobile mapping technology is available, the Italian law Decreto Min. 01/06/01 demands to report some information that is difficult or impossible to acquire using a MMS, for example referring to measurements of lateral slopes and barriers, bridges and viaducts, crossing rivers etc. A traditional terrestrial survey could be carried out in this case, but it would be very time consuming and dangerous for the surveyors, and at last it could turn out to be rather expensive.
Thanks to recent developments in the LiDAR technology an MMS survey can now be complemented with an aerial laser scan survey. It means laser scan technology integrated with other sensors (GPS, Inertial Measurement Unit, video cameras) mounted on a helicopter: the accuracy and the level of detail are comparable to traditional terrestrial survey methods, but the system is faster, safer and in the end more cost effective. Furthermore, the data acquired by FLI-MAP can be used for generating large scale topographic maps, contour maps, Digital Surface Models and Digital Elevation Models.
The integration of a MMS and a LiDAR system is an extremely comprehensive solution for satisfying law requirements in Italy and, in general, for generating detailed

and complete data bases and Geographic Information Systems of roads and maps of the roads assets.
In this way the Italian company GIOVE Srl and the Dutch company Fugro Inpark BV work closely together to offer integrated surveying services, using the MMS technology DAVIDE and the LiDAR system FLI-MAP.

2. DAVIDE - MOBILE MAPPING SYSTEM

DAVIDE -acronym of Data Acquisition Vehicle with Inertial and DGPS Equipment- is a technology developed by R&D Department of GIOVE, based on collecting and geo-referencing images and other road data collected by the sensors synchronized and integrated into one system.
The system is specifically used in order to create roads graphs and data bases for monitoring, management, analyse, testing and maintenance of the roads.

Figure 1. MMS DAVIDE

2.1 The Technology

The standard configuration of DAVIDE includes three main synchronised modules:

- Localization module (GPS, inertial platform and odometers)
- Video module (digital cameras)
- Road Surface module (laser profilometer and TPL)

The system's architecture is studied to permit the integration of any other sensor allowing to geo-reference any dynamically measurable dataset (e.g. the measurement of the variations of electromagnetic fields, the performance of illumination systems, etc).

The localization module includes a dual frequency GPS receiver which, used in differential mode (DGPS), establishes the position of the moving vehicle with decimetre accuracy.
In case of poor satellite constellation, the position is also calculated using data obtained from an inertial platform, that includes 1 tri-axial fibre-optic gyroscope and 3 accelerometers, and from impulse generation odometers placed on the non-driving wheels.

The integration of post-processed data using Kalman filters reconstructs the vehicle's path, with UTM, Gauss-Boaga or WGS84 coordinates. Knowing the precise position of the vehicle at each moment, thanks to a Synchronising Unit, it is possible to geo-reference all the information collected by the various data acquisition modules.

Figure 2. GPS and odometer

2.1.1 Using the video module, during the surveys, digital images are acquired and transformed into real time digital videos from at least 5 video cameras.
In the standard set-up two different configurations are integrated: one gives precedence to the highest quality of the acquired images, while the other allows a higher frequency of acquisition.
One front camera and two lateral cameras, oriented at 45°, record with a resolution of at least 1024x768 and at a frequency of 25 frames per second: thanks to this resolution, the details of the elements can be recognised and several measures (width of the road, height of constructions, dimensions of a panel, etc) can be determined on calibrated images.
Two lateral cameras 90° oriented, record continuously at a frequency of 25 frames per second (it means that at speed of 50 km/h, one image is obtained every 50 cm): these images permit the precise geographical positioning of the recognised and measured objects.

Figure 3. Video cameras

The front camera is used in particular to recognise and position the horizontal road markings (texts, pedestrian crossings, etc.) and to capture imagery that can be used in a photogrammetric environment. The algorithms used, thanks to the internal and external calibration of the video cameras, allow for retrieval of 3D structures from these images, and measurement of point-to-point distances with decimetre accuracy.
The full control over the system allows flexibility in the configuration of the video cameras, in order to respond to the specific requirements of each project.

2.1.2 The road surface module includes a LASER profile meter and a TPL (Traverse Profile Logger).
The LASER profile meter is made up of a laser emitter, a sensor for measuring the reflected ray, accelerometer and an encoder for distance measurement.

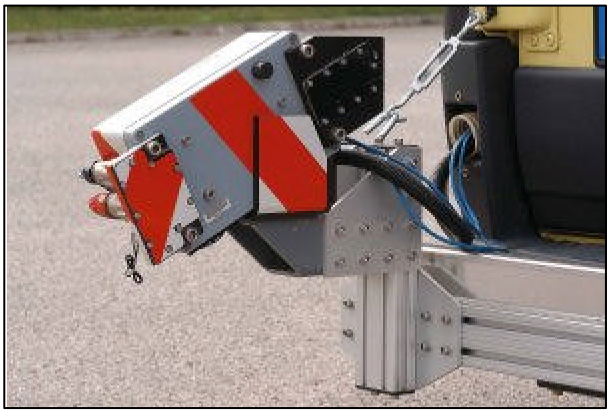

Figure 4. Laser profile meter

The data obtained from the sensors is integrated and used in the calculation of the IRI (International Roughness Index): an index, standardized by the World Bank, that expresses the regularity of the longitudinal profile of the road surface. The laser receiver measures the vertical displacement, while the accelerometer registers the influence of the vertical acceleration on the sensors. The system is able to determine distance from the ground with sub-millimetre precision.
Data processing allows determination of the longitudinal profile.

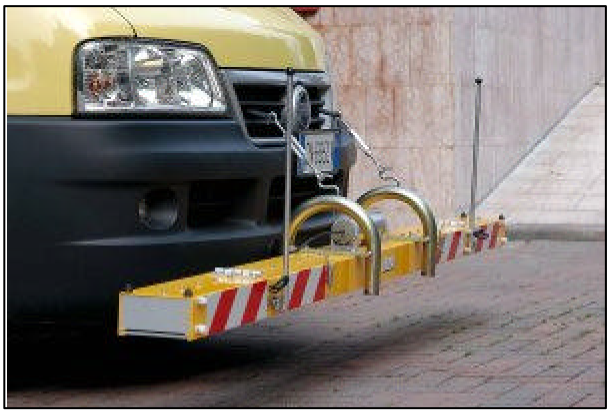

Figure 5. TPL - Traverse Profile Logger

Furthermore, the TPL allows for measuring transversal (cross) profiles, and to calculate with millimetric precision the rut depth - i.e. the deviation from the average profile - which is a very significant parameter in evaluating the regularity of the road surface. The TPL also allows for determination of the transversal slope of the road surface.

2.2 Operative survey

While working, DAVIDE covers the streets in both directions, at the normal traffic speed depending on the kind of road (without obstructing the traffic or compromising road safety), gathering all information from the on board sensors (Localization Module, Video Module and Road Surface Module) for both driving directions.
The sensors used during the survey (GPS, inertial platform, odometers, cameras, laser profile meter and TPL, other possible sensors) are synchronized and are set up before surveying commences, in order to collect data in accordance with the specification of the project depending on the requests of each client. The data collected are post-processed for creating the data base.

2.3 The post-processing

The operative survey mode allows high efficiency and precision in creating the road database. Furthermore, the Quality Certification ISO 9001:2000 guarantees high standard in the process for data bases generation. At need it's possible to increase the completeness and depth of the information.

- The process of creating a database, once the raw data has been acquired by the MMS, includes the following steps.
- Construction of accurate roads geometry: reconstruction of the road axis obtained from integration of the DGPS data, Inertial System, and odometers), initialization and generation of the progressive distance datum and generation of the road graph;
- Association of the georeferenced video images to the road graph;
- Identification and localisation of all recognisable elements from the georeferenced images by easy and repeatable processing procedures: in fact all elements are "surveyed" on the collected images, it means they are identified (thanks to high resolution images), located (thanks to high frequency of images) and measured ;
- Measurement of all defined dimensions (road width, clearance width, sidewalks width, constructions, billboard dimensions, etc.);
- Processing and geo-referencing of the data acquired by the Laser Profilometer, TPL or other sensors, thanks to the synchronisation of the sensors with the localization module;

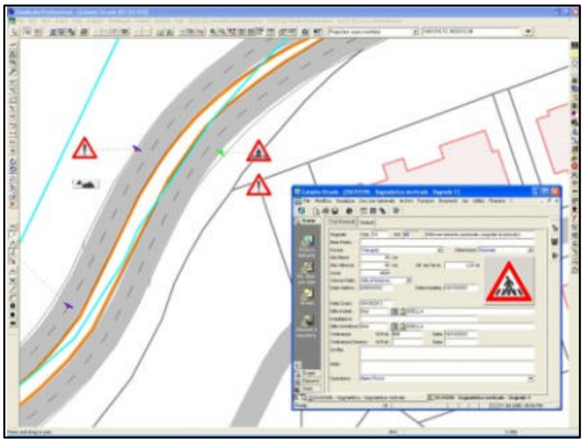

Figure 6. Object oriented map in a GIS

- Creation of a relational Database in GIS (Geographical Information System) environment, containing all the processed information;
- Optimization of the use and management of the data for the end user, thanks to the creation of a territorial database within a RIS (Road Information System).

3. FLI-MAP 400 AIRBORNE LIDAR SYSTEM

The FLI-MAP 400 system is operated at a maximum altitude of 400 meters and is mostly used in combination with a rotary wing aircraft. The 60 degree scan angle results in a flying height to data swath ratio of 1.15. The maximum operating altitude of 400 meters produces a sufficiently wide swath-width for most applications and also yields considerable benefits to the ease of acquisition, particularly in any urban environments where Aviation Authorities regulations restrict low-level flying below 250 m. The high point densities and the high accuracies allow for detailed topographic mapping on the basis of FLI-MAP data.
The laser scanner of the FLI-MAP 400 system was designed by the laser manufacturer especially to meet the strict requirements set by Fugro. The design of the scanner is such that it is especially suitable for operation in low-level environments.
The FLI-MAP 400 consists of 3 components:

- Airborne Component
- Base station Component
- Field processing Component

The term 'airborne component' is applied to all equipment that is mounted in and on the helicopter. The 'base station component' consists of all means and equipment that is required to operate the (virtual) GPS reference stations. The term 'field processing component' is applied to the computer processing equipment that is carried in flight cases and which is used by the field crew during the survey. The fourth component is based in the home office and contains the infrastructure that is needed to generate the final products.

3.1 Airborne Component

The FLI-MAP frame provides an aircraft independent and stable platform to hold all system sensors (see figure 7). The sensors on board are:

- A laser range finder, pulse frequency 150.000 Hz;
- An inertial measurement unit (IMU);
- Two digital video cameras;
- Two digital still photo cameras;
- One line scan camera;
- Two dual frequency GPS receivers;
- One Omnistar DGPS system.

Figure 7. The FLI-MAP 400 system

Inside the helicopter an electronics rack is installed. The electronics rack holds the time-code equipment, the digital video and photo recorders, GPS and DGPS receivers and several onboard computers. Finally the helicopter pilot is provided with an interface that holds 3 light bars and a multifunctional display used for navigating on pre-programmed flight lines, waypoints or as an aid in positioning on a target.
The FLI-MAP frame is FAA certified for several types of helicopters including the popular Bell Jetranger, Longranger, AS-350 and the (dual engine) AS355. For installing the system existing hard points on the helicopter are used and no permanent modifications to the aircraft are necessary. This results in fast and easy mobilisation and transportation. The rigid frame approach enables the system to be transported throughout the world and be matched to a suitable helicopter in the survey area. The sensor rack serves as a fixture, to which all sensors are rigidly connected. Therefore no onsite calibrations are necessary before commencing a FLI-MAP survey. These surveys are generally possible until wind force 6 but should be postponed in cases of rain, snow and fog.

3.1.1 GPS and IMU

FLI-MAP incorporates two rover GPS receivers. The GPS data that is logged during a survey flight is used to calculate the accurate flight path of the helicopter. This is done after completion of a flight. All Receivers are dual frequency L1/L2 receivers. Kinematic GPS processing techniques provide an

accurate (cm level) position of the aircraft. An Omnistar DGPS satellite receiver is used to collect differential corrections to be able to navigate the aircraft with sub-meter accuracy.
An Inertial Navigation System (INS) is integrated in the FLI-MAP system. The INS provides accurate positioning and attitude information. It uses the IMU data supported by GPS data. The IMU consists of 3 fibre optic gyros and three acceleration meters. It provides information on pitch, roll and heading as well as the accelerations along the three axes. The IMU is tightly coupled with the laser sensor and the downlooking cameras.

3.1.2 Laser

The laser is a reflectorless rangefinder scanning 150 lines per second with 1000 laser beams per line. The pulses are fired in a 60-degree angle perpendicular to the flight path. In total, this adds up to 150,000 points per second.
The point density will vary between 8 laser hits per square meter at very high altitudes and with high flying speeds to well over 200 hits per square meter if desired. The laser scans lines alternately 7 degrees forward, to nadir, then 7 degrees aft and then again to nadir. In this way shadowing effects are minimised. The laser is a so called Class 1 laser; it is completely eye safe from the aperture and up. Therefore no safety precautions regarding the laser are necessary during the flight.

3.1.3 Imagery

Two high resolution photo cameras are integrated in the FLI-MAP frame. The interval at which images are taken depends on flying height and speed but is regulated automatically by the software. Further to the still images, two rigid mounted, fixed focussed digital video cameras are used in the system. The video is slaved to GPS time and converted onboard into an AVI digital video stream that is recorded onto rugged hard drives. One camera is facing forward in an oblique angle. The other one is facing down showing roughly the covered area by the laser.

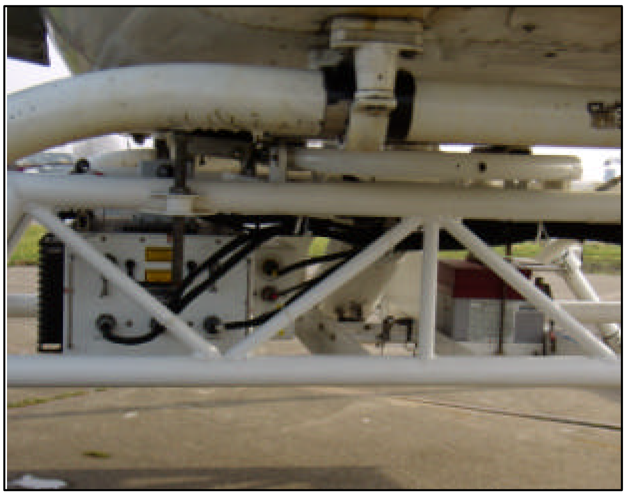

Figure 8. The sensor rack attached to an AS350 helicopter

The hardware of the FLI-MAP 400 system has been summarized in table 1.

Sensor		FLI-MAP 400
Laser	Scanner type	Rotating mirror
	Scan angle	60 degree
	Eye Safe	At aperture
	Effective pulse frequency	150,000 Hz
	Scan frequency	150 Hz
	Returns per pulse	max. 4
	Minimum target separation	< 1 m
	Operational altitude (AGL)	5 – 400 m
	Range Accuracy (1 sigma)	1 cm
	Scan direction	Forward – Nadir – Aft
Video	Format	MPEG-4
	Resolution (dwn and fwd)	720x576
Images	Resolution (dwn and fwd)	4000x2672
GPS	Positioning rate	10 Hz

Table 1. Overview of FLI-MAP specifications

3.2 Base stations

During a FLI-MAP survey GPS receivers are used on the ground to serve as base stations. The base stations are set up on known reference points along the flight path. The raw GPS data, collected by the base stations, is used to calculate accurate baselines to the two rover antennas on the helicopter. Using least squares adjustment techniques the flight path of the helicopter during the survey is accurately calculated. Whenever possible, virtual base stations are used in stead of physical base stations. The use of virtual base stations is now possible in almost all European countries thanks to the availability of permanent active GPS networks.

Three different sets of base stations are used: one set of Trimble and two sets of Topcon. The set-up of a base station consists of a flight case with the receiver, laptop for data storage, external battery and a dedicated un-interruptible power supply. The software to log raw GPS data at 10 Hz interval is developed by Fugro, especially for FLI-MAP operations.
During a FLI-MAP survey base stations are operated by staff that is able to move directly between known reference points. Like this the planning of flights is not dependable on fixed base stations. During the survey of larger areas base stations are remotely controlled via modem by a land-line network or cell phone.

3.3 Field Processing

One of the strengths and benefits of the use of FLI-MAP is the quick delivery of high quality data. To achieve this, real time data processing is performed in the field during project operations. For this purpose a field office is set up near the location of survey. The field office consists of a dedicated workstation set up, which is built in transportable flight cases. In case of large projects, with long corridors, the field office is relocated several times during the project, in order to stay close to the location where the actual FLI-MAP survey takes place. The field office enables the field processing team to deal with the collected data. During the field data processing three major steps are performed: data back up, real time quality control and GPS/INS processing.

In the airborne part of the FLI-MAP system raw INS data (derived from GPS and IMU), laser data and imagery is stored on system integrated hard drives. In the first step of field processing the raw data, together with the GPS data of the base stations is copied to removable hard drives. For the benefit of data management, the data is now organized in a predefined structure. As the raw data is the basis for all further processing this step is of utmost importance and very critical.

In a second step the raw data is analyzed as to assess the overall quality of the collected laser data. During this real time QC the data is checked for coverage and point density. For this assessment, dedicated quality control software tools were developed. The real time QC makes it possible to judge whether the project requirements and specifications are met. If necessary the flight plan for the next project day can be adjusted to be able to re-fly problem areas. This procedure makes the FLI-MAP operations very flexible and enables to guarantee a 'first time good' service.

During the third step of data field processing the exact helicopters flight path is calculated using the logged INS data. The calculation is done with dedicated software that combines the raw GPS data (both from helicopter and base stations) and the raw IMU data. Firstly, baselines are calculated from each base station to the two rovers of the helicopter resulting in an accurate representation of the flight path of the helicopter with a frequency of 10 Hz. The IMU data is used to calculate the position of the helicopter with a much higher frequency: 200 Hz. Integration of GPS data and IMU data is done in a Kalman filter. The resulting flight path is called Smoothed Best Estimated Track (SBET) which in turn is the basis for calculating (X,Y,Z) points for all the laser points.

In this stadium the quality of relative and absolute accuracy is analyzed. If the quality is accepted the processed data is again copied to back-up hard drives and ready to be used for generation of final products.

3.4 Accuracy

Although beyond the scope of this article, a brief overview of the accuracy of the system could be given. The authors however feel that accuracy statements on the FLI-MAP accuracy should best be made by both Fugro *and* external specialists. Here is referred to (Burton and Scott, 2006), Rijkswaterstaat (2007) and (Brügelmann and De Lange, 2001).

The accuracy of the system is generally split in two components: a relative accuracy component, which depends mostly on the ranging accuracy of the laser scanner and the accuracy of the Inertial Measurement Unit. Secondly the accuracy is affected by an absolute component, which depends mostly on GPS inaccuracies. After the upgrade from FLI-MAP II to FLI-MAP 400, both the ranging accuracy and the IMU accuracy have been improved. Improved techniques for GPS processing have also reduced the absolute errors. The relative accuracy of a single laser point is therefore now approximately σ = 1.5 cm in all three directions (x,y,z). The absolute error of a single laser point is quoted on 4 – 5 cm for (x,y,z). By using ground control patches, based on which the laser point cloud can be adjusted, this absolute accuracy can be improved to 2 -3 cm (z)

4. COMBINING DAVIDE AND FLI-MAP 400

A complete and accurate knowledge of roads, road assets and their environments is fundamental for efficient management by relevant public bodies. In particular precise information concerning state of road surface, barriers and road signals is indispensable data for road maintenance, management and planning works. In fact, the road management bodies have to guarantee good condition of the existing net (proper planning maintenance works), but furthermore they have to plan construction of new roads where and when it is necessary. The goal is to assure regular flow of the traffic and try to reduce road accidents: the big task is to organize the roads net so that it becomes “comfortable” and safe for motorists and pedestrians.

When the need is not only concerning maintenance of existing roads, but overall the construction of streets or dual carriageways, or a new organization of (a part of) the roads net, an efficient planning is necessary, therefore very accurate and precise topographic data related to existing roads and surrounding are required. In this case an aerial LiDAR technology system, like FLI-MAP, can do what a MMS can’t do or can’t do within the topographic accuracy requirements. For instance data concerning barriers and lateral slopes or bridges and viaducts, and all topographic information can be collected by FLI-MAP. These measurements can be used in support for engineering, monitoring and planning. It should be borne in mind that the laser data (together with high resolution images) allow to generate accurate 3D maps, digital elevation models, contour maps, which are a “realistic” representation of the surveyed area. The ortho-rectified images allow creating orthophoto mosaics of the road or area of interest, again as a support for engineering tasks, monitoring or planning purposes. Furthermore, the FLI-MAP system delivers high res videos, which can serve as additional supporting visual information. So the data collected by the system provide the user with a representation of the interested area from “many points of view”. On the other hand, a mobile mapping system like DAVIDE is more precise and efficient for acquisition of thematic information like texts on road signals and other attribute information. Thanks to the high res and high frequent imagery, the roads elements can be identified, located and measured. Moreover, relevant data related to road surface condition can be acquired. In this way a complete cadastre can be integrated in a road information system for all useful road management activities: the knowledge of state of art is the first and basic step in scheduling the traffic flow.

These considerations point out that the integration of an aerial LiDAR technology system like FLI-MAP and a Mobile Mapping System like DAVIDE provide a comprehensive and accurate data set that can serve as input for an efficient roads information system. Such a system is used for roads monitoring, maintenance and planning, specifically in compliance with the Italian Decreto Min. 01/06/01.

Table 2. shows in more detail which elements are required to be surveyed by DM 01/06/01 and which kind of technology can be used: the "M" is used for terrestrial Mobile Mapping System technology, the sign "L" for aerial LiDAR technology, the sign "D" for documentation (it means the element is obtained from documents and therefore not surveyed directly in the field).

In addition to the minimum legal requirements, the table includes more elements, which are always measured by DAVIDE or FLI-MAP and that were proven to be very useful for authorities managing roads.

Elements required for by the Italian law DM 01/06/01		**Surveying technology**
Junction	Official name	D
	Conventional name	D
	Kind of junction	M L
Road element	Official name	D
	Conventional name	D
	Owner's name	D
	Owner's code	D
	Administrative classification	D
	Technical/functional classification	D
	Measured length	M
	Carriageways	M L
	Directions	M L
Cross sections	Carriageway width	M L
	Shoulder	M L
	Shoulder width	M L
	Pavements width	M L
	Kind of middle barrier	M L
	barrier width	M L
	Bike track width	M L
	Number of lanes	M L
Pavement	Kind of surface	M
	Pavement of shoulder	M L
	Kind of shoulder surface	M L
Superstructure	Kind of superstructure	M L
	Delimitation	M L
	Scarp slope	L
	Max. scarp height	L
	Kind of supports	L
	Max. support height	L
Bridges, viaducts and	Official name	D
	Conventional name	D
	Class	D
Tunnels and overpasses	Official name	D
	Conventional name	D
	Center clearance height	M
	Edge clearance height	M L
	Ventilation system	D
Bump	Kind of bump (form)	M L
	Max. width	M L
	Max. hight/depth	M L
Embankments	Embankment width	M L
Protection of superstructure	Kind of protection	M L
Environmental protection	Kind of protection	M L
Lighting system	Arrangement	L
Stop areas	Width	L
Barriers	Kind of barrier	M L
	Min. distance from carriageway edge	M
Services areas	Official name	D
	Conventional name	D
	Kind of service	(M L) D
	Presence of acceleration-deceleration lanes	M L
	Total area dimension	L
Hydraulic structure	Kind of work	M L
Accesses	Gradient of the access referring to road	L
	Kind of access	M
	Use of area	(M L) D
Kilometric distance sign	Km value	M
Elements NOT required for by DM 01/06/01 but useful for roads management bodies		**Surveying technology**
Road track	Straight stretch	M L
	Steady gradient	M L
	Plan metric bend	M L
	Elevation bend	M L
Crossing	Kind of crossing	M L
	Kind of roads	M L D
	Structure of crossing	M L
	Dimension	M L
	Right of way	M L
Pavement	Condition of Pavement	M
	IRI	M
	Rut depth	M
Parapets	Position	L
Vertical traffic signs	Position	M
	Kind of sign	M
Horizontal traffic signs	Position	M L
	Kind of sign	M L
Traffic lights	Position	M L

Advertising placards	Position	M L
Station for traffic monitoring		M L
Rubbish		M L
Facilities (power lines, railroads, telephone lines antennas)	Kind of facility	L
	Point of road intersection	L
Green areas	Dimension of area	L
	Solitary trees	L
	Rows of trees	L
Rivers	Point of intersection with road	L
Obstacles	Kind of obstacle	M L
Roadman houses	Presence	L
	Official name	D

Table 2. MMS and LiDAR comparison

5. CONCLUSIONS

Table 2. shows that some elements and attributes could be surveyed with both the technologies, MMS and LIDAR, but with different approaches. Some measurements, for instance, could be done with MMS, but with low accuracy (e.g. height and width of a speed bump) or to the contrary the MMS photogrammetric system allows to recognize and measure some attributes the LIDAR system can't survey.
The FLI-MAP system is used for absolute geometric measurements and in situations where accuracy at centimetre level is required. This information is used for generation of Digital Elevation Models, Contour maps and topographic maps. The ortho images and the video supply the user with the possibility to collect thematic information to a certain extent. Detailed information like road surface conditions and texts on traffic signs cannot be determined in most situations, although in some situation, the forward camera of FLI-MAP is used for reading the traffic signs. The DAVIDE system is especially suitable for acquisition of geometrical data of elements where accuracy requirements are at decimetre level. The geometric information that is acquired with DAVIDE is generally related to the road axis: the elements are assigned a chainage and an offset. Furthermore, the array of videos on board DAVIDE allows for obtaining thematic information: texts on road signs, types of lamp posts, types of barriers, etc. The laser profile meter is normally used for measurements of the condition of the road surface. The two systems together are capable of collecting all the information that is useful for authorities or private parties concerned with road management.

References:

Brügelmann, R. and Lange, R. De, 2001. Airborne laserscanning versus airborne InSAR - a quality comparison of DEM's. OEEPE Workshop on Airborne Laserscanning and InSAR, Stockholm 2001

Burton, T. and Scott, D., Dec. 2006/Jan. 2007. Flood Defence. *Geoconnexion International*.

Rijkswaterstaat (Adviesdienst Geo-Informatie en ICT), 2007. Internal report on FLI-MAP accuracies for production of a DTM-design