MODELING INFORMATION FLOWS FOR AUTOMATED ROAD REHABILITATION PROCESS

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Abstract: This paper introduces information flow models for the total process of automated road rehabilitation. Only superstructure layers of roads are considered in this examination. The practical processes and tools used in the common construction processes in Finland and Italy are examined. The purpose is to demonstrate the comprehensive development of automation into rehabilitation processes.

Keywords: Automation, old road structures, rehabilitation.

1. INTRODUCTION

In most industrialized countries, the basic road network has already been built. Therefore, today's challenge is the maintenance of this strategic part of the national wealth. It has been estimated that already 85% of Europe's road construction projects today have different rehabilitation operations. Both in Finland as well as in Italy the activities of road construction have already strongly concentrated on the rehabilitation of old road structures.

Automation is one of the present means for improving the process efficiency and product quality, also in the domain of road rehabilitation. The various latent but achievable benefits of automation will be produced through the total process of construction activities. Automated process means numeric controlled process. In road construction the numeric control of a process must be built on the three-dimensional geometric management of different work operations.

Figure 1. Road rehabilitation process begins with existing road damage – a case in Finland.

Considering the total process of road construction from the automation point of view, we can observe a process consisting of five parts (Fig. 1): 1) initial data measurements, 2) product design, 3) site operations including dimension measurements and machine control operations, and 4) quality control measurements.

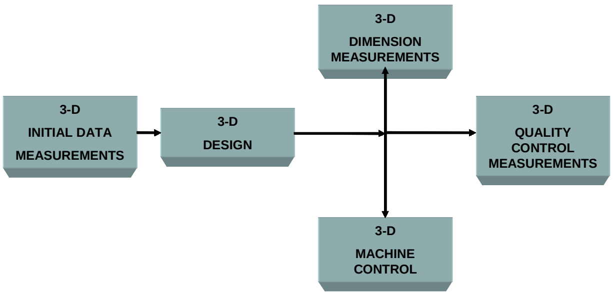

Figure 2. The main work phases of road construction process.

2. ROAD REHABILITATION PROCESS IN FINLAND – STATE OF THE ART

The basic phases of road rehabilitation are road data collection, problem diagnosis, rehabilitation design and dimensioning, construction, and quality control. The survey methods providing the basic information for the rehabilitation design are as follows: a) GPR (ground penetrating radar) for thickness surveys and detecting reasons for damages, b) FWD (falling weight deflectometer) for stiffness measurements of structural layers and subgrade, and c) profilometer or laser scanning techniques to collect information from the road surface. All of these techniques need very accurate positioning systems in order to produce precise 2-D or 3-D road models. Positioning will be much easier in the future through the new national Digiroad GIS data bank system. In addition to the above mentioned survey techniques, sampling is still needed for laboratory analysis and for optimum proportioning of the rehabilitated road structures. In Finland digital video is also used to provide information about the road and its surroundings.
After the data collection, the road survey data is analyzed and a problem diagnosis is made using Road Doctor for Win or Road Doctor Designer software packages. In this phase it is also possible to link different types of data, such as pavement distress data and rutting, and also IRI history from the Finra road register and road condition (KURRE) data bases. This search and linking can be made using RDA software developed for Finra. After the cause(s) of the problems for the rehabilitated road have been solved, Road Doctor programs can also be used for the rehabilitation design.

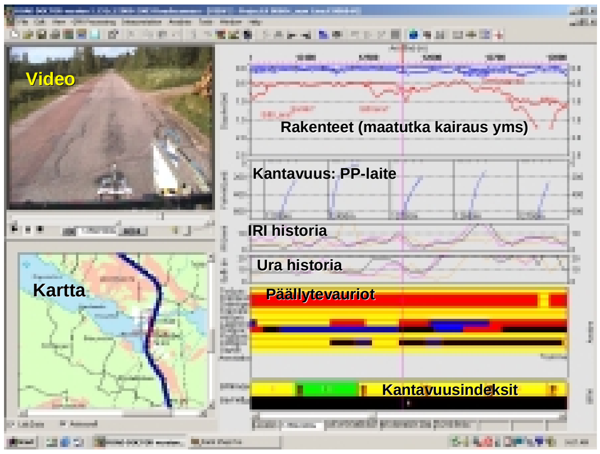

Figure 3. Road Doctor software tool for road rehabilitation design – Finland.

According to the new procurement policy, Finra is now moving towards design and building contracts that allow more innovative solutions for the contractors. That is why Finra has developed an internet version of RDA. This enables contractors to download the road survey data results as well as other technical and commercial contract documents to their own computer systems. After the rehabilitation design has been completed, contractors download the bidding documents back to the Finra database.

Figure 4. The first milling machine in Finland which has been equipped with an automated machine control system.

The current R&D work in Finland is now focusing on transforming the design data for road construction machinery. During the first phase the goal is to transfer the design data from

Road Doctor Designer to cutter and stabilization machines.

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Figure 5. Testing the first Finnish 3-D machine control system for asphalt spreader – Summer 2004 Finland.

3. ROAD REHABILITATION PROCESS IN ITALY– STATE OF THE ART

To illustrate the complete working process, currently used technologies and practices, developed processes, methods, field observations, test results, etc., we prefer to use the Road Cadastre (C.S.) as a guideline. This has a more complex meaning than a Digital Road GIS data bank. A 1992 law instituted the C.S. Then in 1993 the new Highway Code introduced the obligation for the Onwers, motorway companies, national company or agency for statel roads, and regional and local administrations to set up and maintain the C.S., which would manage the road network and program the rehabilitation interventions, while a National Record of roads was set up and managed by the Central Administration. The practical set-up of C.S. began in June of 2001. Within two to five years all roads, from motorways to country roads less than 5.5 meters long, had been recorded. Between 1992 and 2001 many tests and experiments were performed by motorway companies, national agencies, software houses, regional administrations, and universities, in order to have databases with geographical information, maps, images, and all the required data in order to acquire data by GPS, aerophotogrammetry, videocameras, laser scanning, FWD or GPR's, and other methods and systems.

The target of C.S. is to define the inventory of a road's property; to supply support for the management of road property, and to plan its development, particularly for the following: classification of the road, administration management, adjustment projects, maintenance project management, and terrestrial navigation. The C.S. data is the element to which all other information in the data information system must be related. The C.S.'s interests are represented by an "entity function" whose characteristics are described by "attributes". The rules of C.S. specify the entities and their attributes; the global attribute is referred to as the global road, while the split up attributes are related to variable characteristics on the road. Fig. 7 illustrates the attributes of the C.S.

The survey types of these events can be divided into the following groups: 1) survey of structural-functional characteristics, 2) qualitative survey, 3) survey of geometric characteristics, and 4) morphologic survey (Fig.5). The methodologies of the first group include FWD (Falling Weight Deflectometer), GPRS (Ground Penetration Radar System), APL (Analaizateur du Profile en Long), SCRIM (Sideway Force Coefficient Routine Investigation Machine), SUMMS (survey Machine for Macrotexture and Skid), and Texture Meter. The methodologies of the second group are based on video cameras. The survey methodologies for geometric characteristics include the traditional optical instruments, GPS, aerophotogrammetry, and LIDAR, while the methodologies of the last group include the traditional optical instruments and Laser Scanner.

Some owners, such as Autostrade s.p.a. and ANAS, respectively the main motorway company and the national company for state roads, have a long tradition and deep and active experience in road maintenance and its quality control, while the introduction of C.S. has also awakened small owners and administrations. Recently we have witnessed in professional journals and magazines examples of the use, by technical staff of sensitive local administrations and related construction firms, of modern technologies (such as FEM, GPS, GPRS, FWD, etc.) to study the whole cycle of the renewing asphalt process, design, recycling, and the quality control of work. Taking into consideration the methodologies of C.S. software for CAD, GIS, and imaging and also its recent practical introduction, we can conclude that the Onwers and construction firms are receptive to automation for road rehabilitation. The related methodologies are perhaps not common but “accepted” for the three stages shown in figures 3 and 4: a) initial data measurement; b) CAD design, analysis of measurements, product design, and modeling ways, etc.; and c) quality measurements.

Other methodologies, such as Automated Machine Control and Quality Documentation, Machine control Modeling, and typical computer integrated road construction technologies, now seem to be unknown objects or topics, ma we could be denied just tomorrow. That isn’t a critical opinion, but a simple recognition made speaking with university researchers and teachers working on transportation and road construction. The technical staff of the road machines makers is aware of or knows these topics, in particular the machine control by GPS or 3D Laser Total Station, but they are less sensitive for the data exchange technology. Probably this lack of sensitivity depends on the market conditions.

4. FUTURE STEPS TOWARDS AUTOMATED ROAD REHABILITATION PROCESSES - CONCLUSION

In Italy all the national and local road data banks have opened and consolidated the use of information technologies and sensors/instrument systems in road management, but the entry of automation in the road maintenance depends on the level of the technological knowledge, technical skill and involvement of the Owners. Moreover some systems or methodologies to measure asphalt and road parameters haven’t supported by national standards, so it’s difficult to compare all the methods and values.
Really, in Italy we focus our attention on other problems that the IT in road maintenance allows to put in evidence. The high density and the heavy commercial and touristy traffic, the young and unstable geology of Italian territory make necessary the continuous maintenance of tunnels, viaducts, bridges and road paving with heavy impact on the traffic. So the mobile yards for road paving maintenance should be short, with short feedback in space and time for the quality control of processes and remotely managed. To integrate and automated the road machinery, to make short the yard, improve the on-line and on site control of processes quality could be a research activity in road rehabilitation automation.

In Finland many companies have already abilities to extensive initial data measurements and also smart rehabilitation design. However, in the total process of road rehabilitation this more accurate “smart” rehabilitation method is today not yet collectively understood. A rehabilitation design can also not yet be processed to machine control models to be utilized in the control of different work machines. That requires also more development activity. In future, the main benefits of automation will be attained through the total process of rehabilitation. All of the workers in different phases of road rehabilitation should develop automation together.

There are several advantages when automated road rehabilitation process is completely working. The rehabilitation structures can be optimized in both longitudinal and transverse section, which mean more uniform and sustainable rehabilitation solutions. The method allows also the design for shorter sections and also thickness can be changed more frequent. These can result major cost savings. Automated rehabilitation process allows also faster machinery work which reduces the time of closures and reduces the road users costs.

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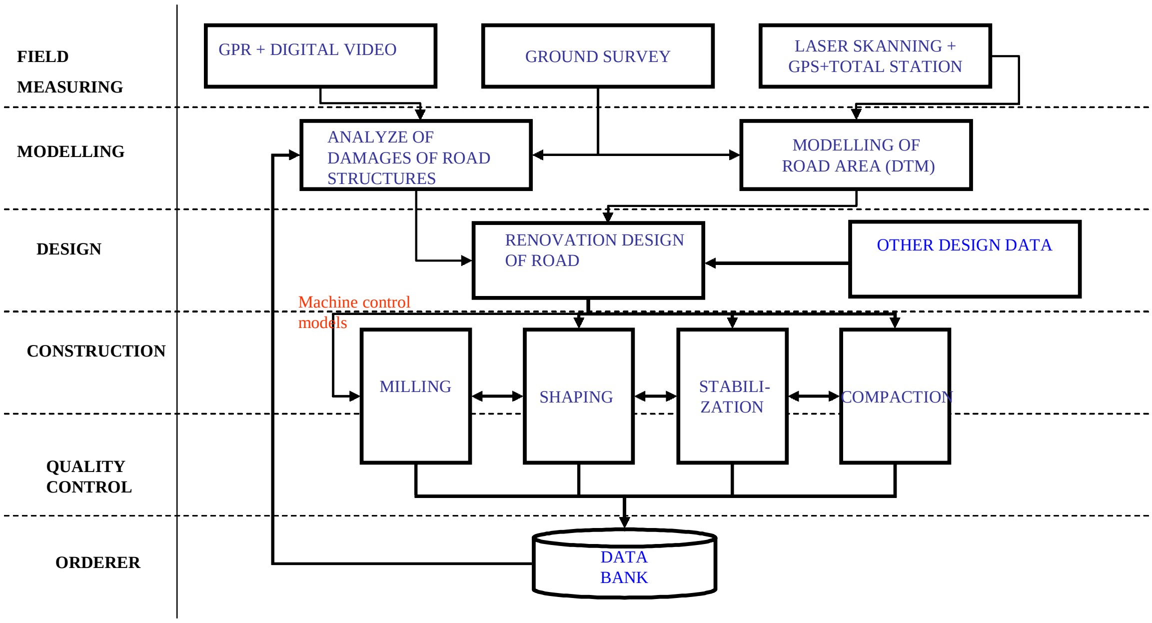

Figure 6. Process model of road rehabilitation - Finland.

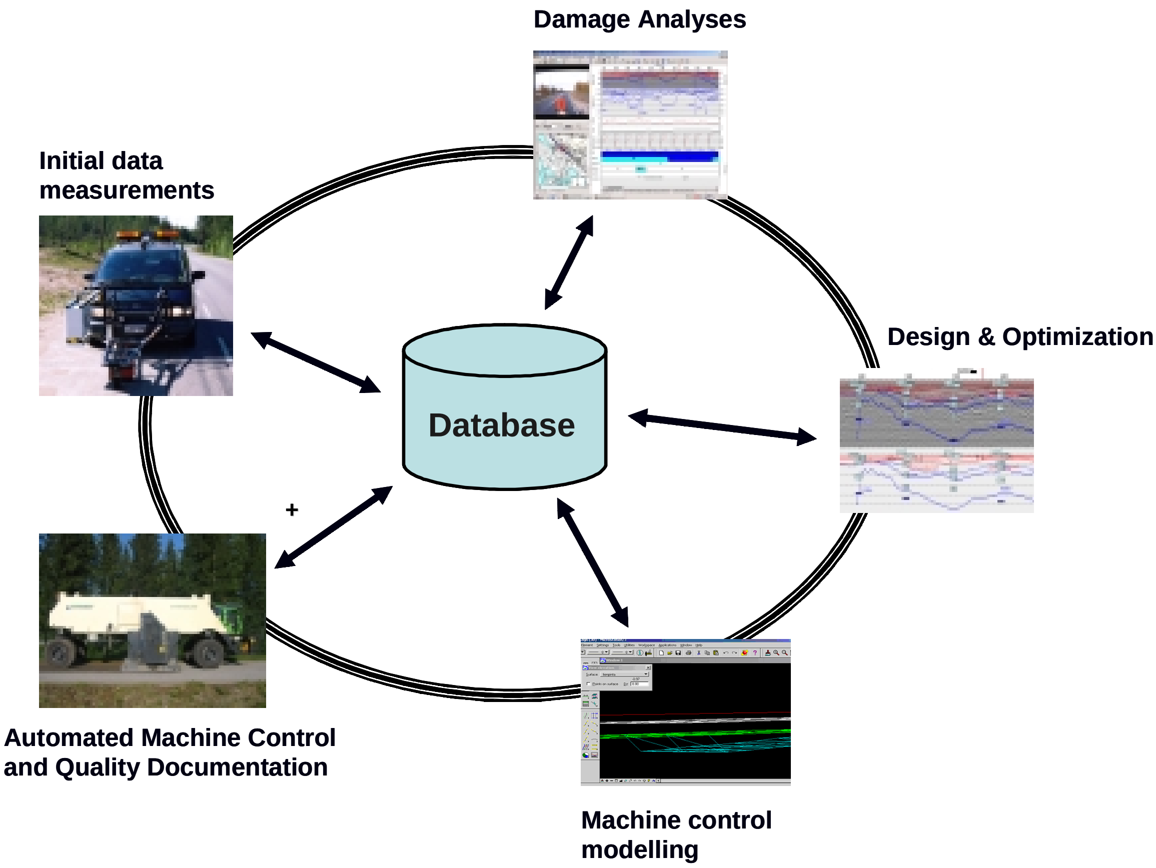

Figure 7. Total process of road rehabilitation - Finland.

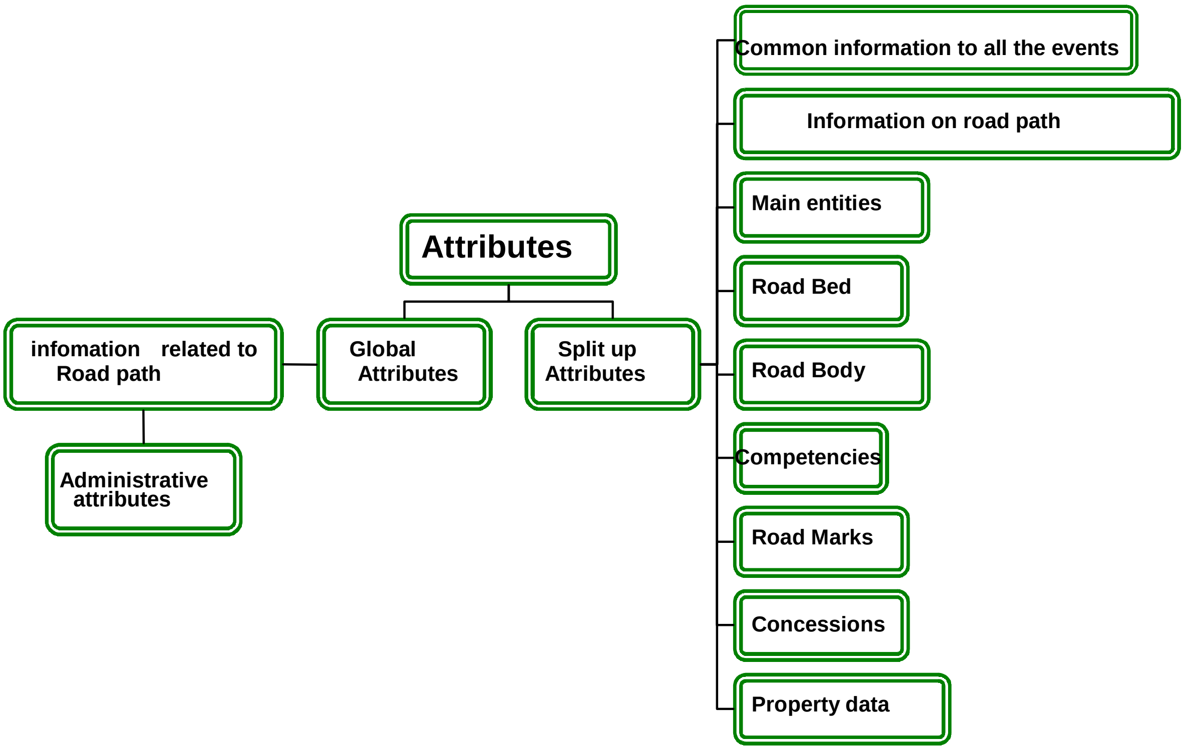

Figure 7. Global and Split up Attributes – Italy.

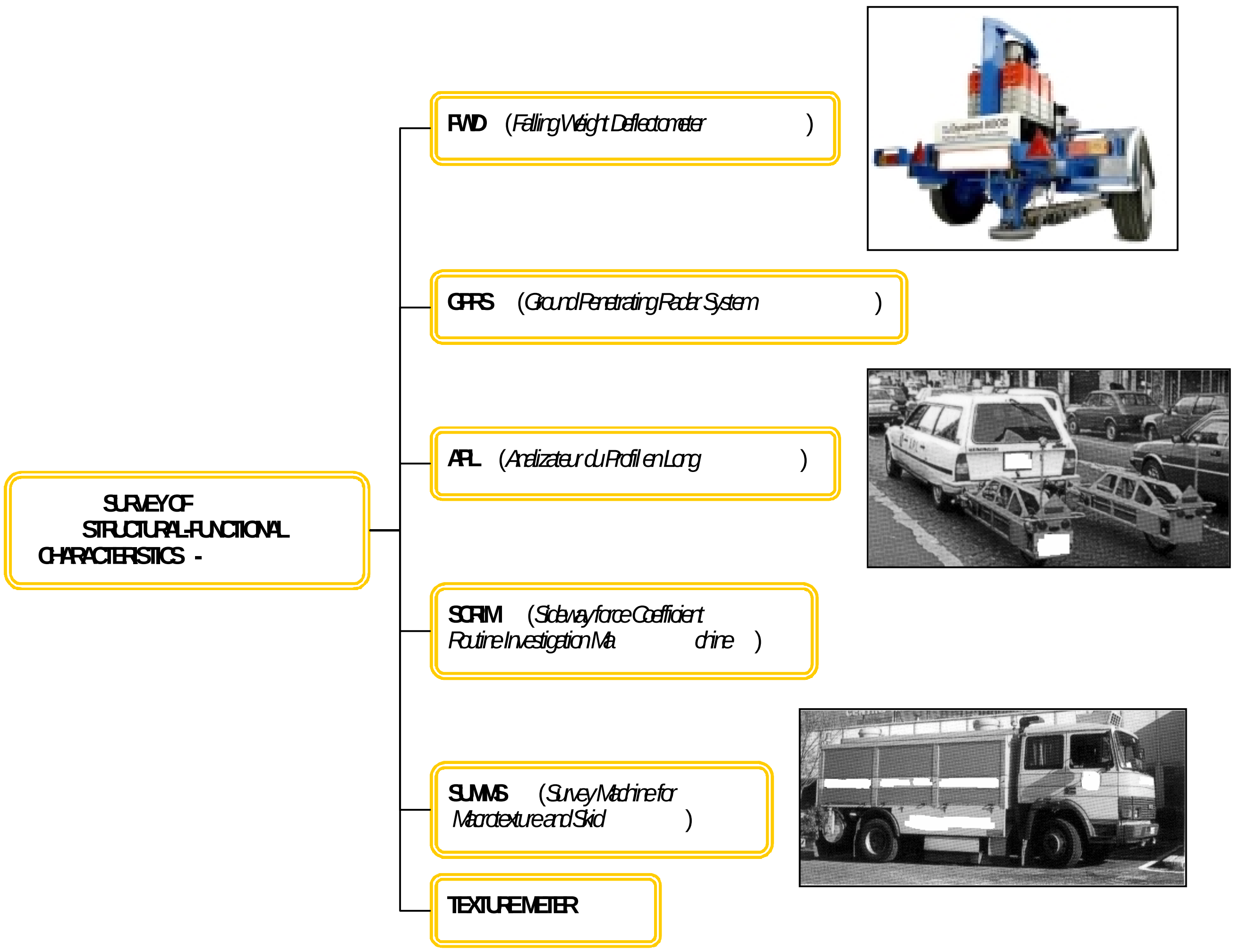

Figure 8. Methodologies for survey of the structural-functional characteristics – Italy.

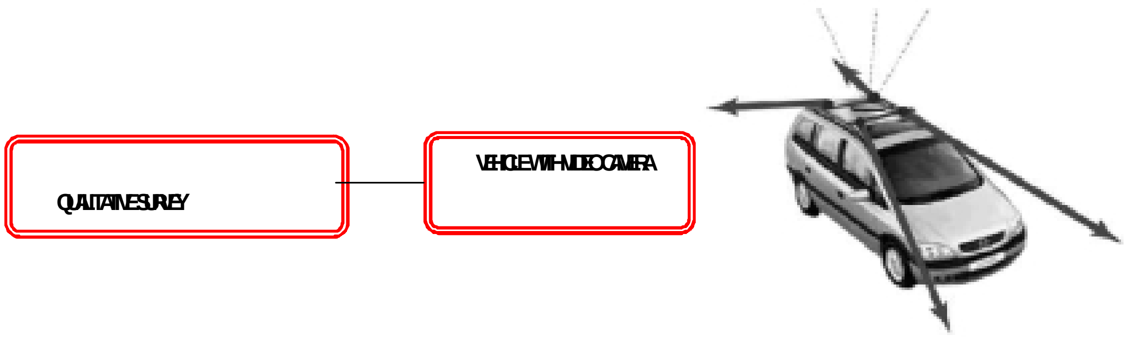

Figure 9. Methodologies for qualitative survey – Italy.

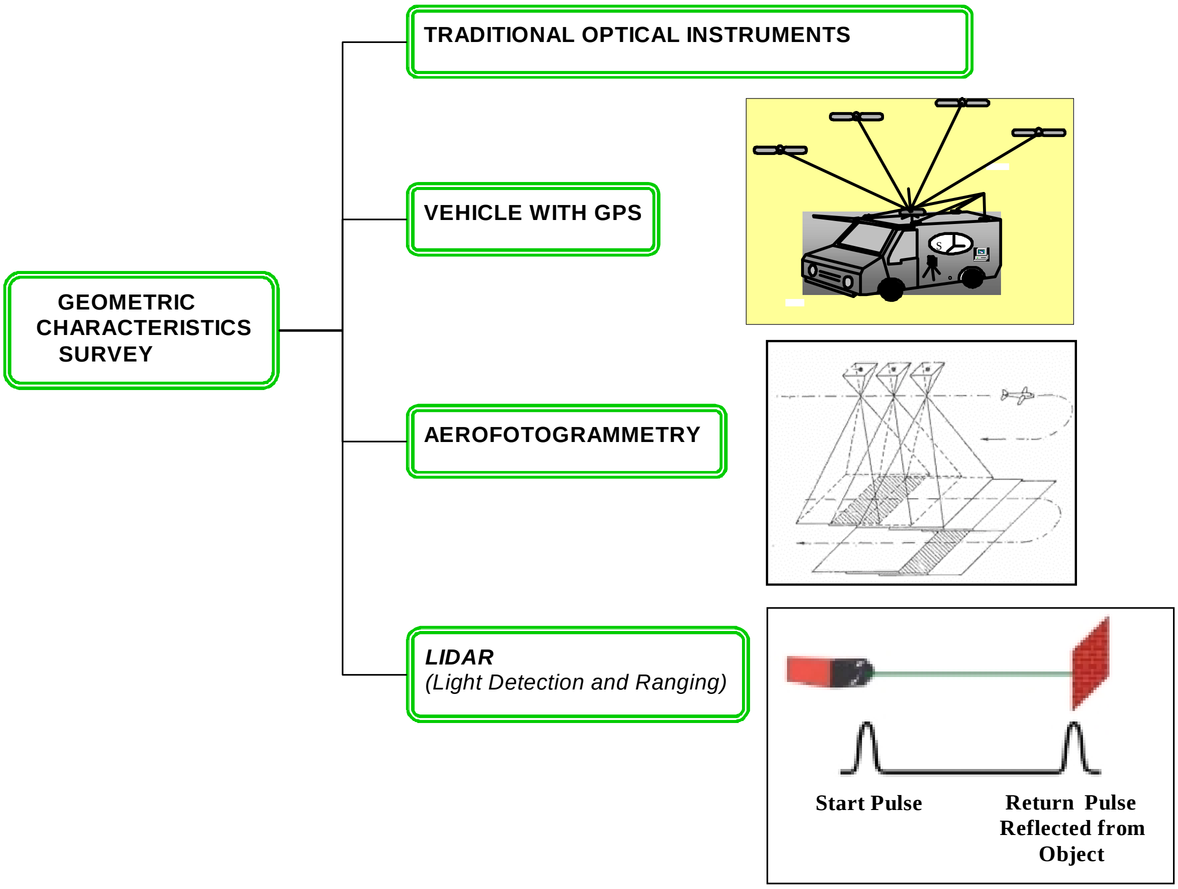

Figure 10. Methodologies for geometrical characteristics – Italy.

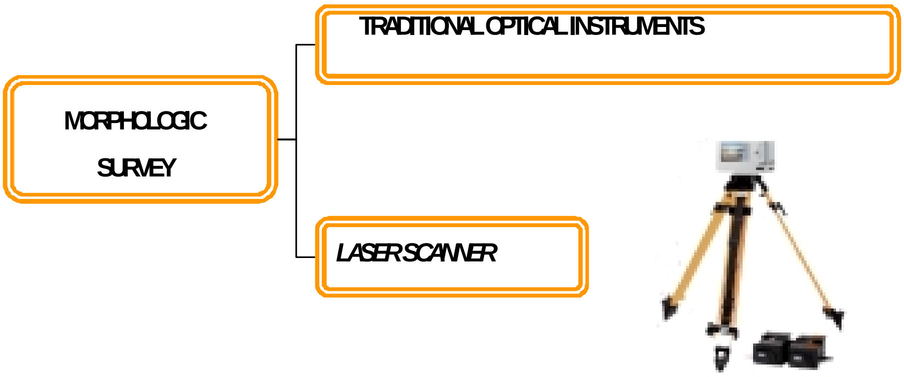

Figure 11. Methodologies for the morphologic survey – Italy.