The “Infrastructures Roads & Territory” laboratory is part of a task of creation of virtual laboratories started and developed successfully by the Marconi University in last years (Rinaldi, 2015; Martini, Fontana, 2015; Recchia, 2016; Bellone, 2014). In particular, the idea behind the laboratory was born one year ago from extensive research on teaching methods effectiveness and from the multi-year experience of Marconi teachers and technicians in this field. Thanks to these analyses had come to light as there could be enhancement areas as part of interdisciplinary. Therefore it came out, the need to provide students an educational moment in which he could use all didactic information learned during the courses as part of Civil Engineering degree. The laboratory main goals are:

- to provide a method of planning of a road infrastructure, starting from theoretical basis provided during Construction of Roads Railways and Airports course, adding technical and professional aspects, in order to provide a method that is both effective and strong
- to give to the student an implementation moment to communicate the importance of interdisciplinary in road design and in civil engineering in general (Kaushik, et al., 2010). This moment should be both a time of learning and of transition to a professional growth, through a moment of reflection in which the student could make choices independently and then check the outcomes

For this purpose was therefore chosen the topic of roads construction as the subject best suited to provide, in the design field, moments of reflection and application of interdisciplinary knowledge.

**KEYWORDS:** Civil Engineering, Laboratory, STEM, Virtual laboratory

**Methodology for Road Infrastructure Design**

As mentioned above, the first aim of the laboratory is to provide a methodology for the design of road infrastructures. Therefore, the key point of the laboratory is represented by the logical framework, which reflects the method that we want to convey to the students. In this phase the main objective is not to provide theoretical concepts to the student – which have been learned during the entire degree course – but to put this concepts into a logical framework clearly defined, able to promote the correlation of all different theoretical notions. Therefore there is the need to hand over to the students the “vision” of design as an iterative process divided by step, logically and sequentially concatenated.
In this process the student starts with land analysis, getting familiar with the main environmental and regulatory constraints. In parallel (and partially in correlation) with this analysis must be defined the main design parameters of the infrastructure (type, section, capacity, design speed, etc.), useful to perform the next step of methodology, the planimetric and altimetric design. After this initial survey phase, the student can start with the planimetric and altimetric design of the road. As will be better specified in the description of operational tool, at this stage, the student will be free to choose the alignment without any territorial constraints. This approach allows students to have a high degree of freedom in terms of road design, thus causing an high quality of the road project itself. Otherwise, the student would be inclined to follow excessively the land constraints. This approach in order to respect all territorial constraints could drastically reduce the functionality of the infrastructure and, more important, could reduce the level of safety of infrastructure. This would involve the need to introduce, for example, speed limits in stretches of road that cannot be geometrically verified, denying the principles of good and correct road design. To avoid this approach in road design but, at the same time, to allow in any case to ensure an integrated design with the environment, a subsequent design phase, that assumes a key role has been introduced: the iterative verification. Iterative approach play a key role in all road design method (National Cooperative Highway Research Program, 2003). Once the road design has been carried out by following the highest standards of design and safety, and after being checked by the technical point of view in terms of fairness and consistency of track, is it possible to switch to the verification of environmental and territorial constraints. At that time the student can modify what have already planned in an effort to improve the project from an environmental perspective. The verification phase of the project will move slightly the “design optimum” toward a lower level, reaching however a “global optimum” – allowing them iteratively to balance the design aspects with the environmental, bearing in mind the priority of functionality and safety aspects. After the optimization process, the student can analyze aspects of interdisciplinary study in order to “mitigate” and improve aspects of correlation between the infrastructure and the environmental and territorial constraints. In the following paragraphs will be exposed the project of laboratory from an operational standpoint, complying the proposed methodology through specific tools and applications included in the “Virtual Laboratory Infrastructures Roads & Territory”.

Figure 1. Logical Framework
THE CHOSEN ROAD INFRASTRUCTURE AND THE INTERVENTION TYPE

Once defined the methodology it has been necessary to choose the case study. Primary aspects to analyze, in that sense, were both the choice of the type of road infrastructure and the choice of the local context. From the infrastructure point of view, in general terms, that choice affects both the project standards (such as the plano-altimetric sizes) and the relationships that can occur between the infrastructure, the network and the area. From the didactic point of view, the planning of a two rural highway infrastructure has turned out to be more effective, providing further insights in terms of territorial relationships. This type of infrastructure even though reveals less strict design standards in comparison to an highway, is definitely more complex to verify especially in terms of plano-altimetric homogeneity. From the territorial point of view, priority should be given to a “whole” orographic context which can offer roadway various configurations (road embankments, dugouts retaining walls, viaducts etc.) and at the same time a significant presence of territorial and environmental constraints which can bring out the need of specific studies during the project editing. Bearing in mind this facet it has been proposed to focus the analysis on a two rural highway, able to meet the above-mentioned issues. For this purpose as a planning practice a modernization of the 609 “Carpinetana” state highway has been realized.
The road, about 42 km, is located to the south of the town of Rome, begins in Colleferro town, and runs through the towns of Montelanico, Carpinento Romano, and Priverno, occupying the area of the Lepine Mountains valley, to engage the SS156.

From the territorial point of view, some aspects that have been taken into account in the laboratory planning replicated in terms of maps or themes are shown below:

- Geology
- Hydrogeology
- Hydrography
- Lithology
- Protected Natural Areas
- Territorial Constraints
- Road Network
- Boundaries and administrative limits
- Presence of population in city centers / centers of interest
- Presence and relationships with other infrastructure
MAIN DESIGN PARAMETERS AND SCENARIO CASES

As defined by the methodology, once presented the main issue of the territory will be presented to the student the main inputs of the infrastructure project under consideration. These data will be presented to the student as fixed parameter, but will be specified that, these aspects derive anyway from integrated analysis of territorial and economic assessments.

After that will be presented the stretches of road to be designed. In particular will be presented three different type of scenario with three different characteristics in term of territorial constrains. In example, the Scenario A present an high orographic complexity instead the Scenario B present an urban bypass. All the scenarios are planned to allow the student to relate with different problems that usually occur in road design process. Figure 4 shows an example of this stretch.

In addition to such information will be provided to the student data about the size of the road section chosen, the data about traffic flows of the infrastructure and the verification of the capacity of section, in line with current regulations.

PLANIMETRIC AND ALTIMETRIC DESIGN

Once defined the territorial aspects and the main project inputs the student will start the planimetric and altimetric design of the road infrastructure in those stretches of road proposed, as defined in the above paragraph.

The first step of the method involves a schematic planimetric design of the road. Therefore the student will refer to the information assumed about the presence of physical constraints (housing, crossing rivers or watercourses etc.), and the terrain details (curve level). This information will enable then to have simultaneously planimetric and altimetric design (by analyzing level curves), in order to guide students toward layouts that can be as homogeneous as possible in terms of horizontal and vertical alignment.
Once defined the basic design, the student will proceed to the design of the geometric elements of road infrastructure, also providing a first verification of the compliance with the regulation (Ministero delle Infrastrutture e dei Trasporti, 2001).

As shown in Figure 6 by defining the radius, the program can compute the main design parameters (such as deviation angle, the length of arcs, etc.) and give a graphical feedback on the stretch of road designed. Furthermore in this phase is also included the main information on transition curves (clothoid) in order to design a road consistent with the current legislation.
In the same way it will be possible to perform the design of the vertical alignment defining the longitudinal slope of the road.

This allow to design the grades of the vertical profile and also the parabolic curves. By setting the vertical radius the student can consequentially provide a verification with the current regulations as shown in Figure 9.
After the road design the student will perform the main verification in compliance with the current regulations, such as the analysis in the sequence between arcs or between arcs and straights, the verification of sight distance for stopping and overtaking etc. etc. If the above verifications were to fail, the student will be able to re-design the road project, in view of a comprehensive assessment of the entire planned layout.

**Verification of Road Layout Related to the Territorial Constraints**

After verify the project from a technical point of view, the student can overlay the project on thematic maps in order to verify compliance between the project and the main constraints imposed by the territory. Some constraints are such that the student will necessarily have to make a new design of road stretches, in line with the iterative improvement of the project proposed by the methodology. Thus beginning a “second phase” design, as shown in Figure 10.
For other constraints the student can decide if to redesign the road stretch or to use specific technique aimed to resolve the constrains. This evaluation will be made through the application of knowledge from other disciplines. As an example, if the road stretch cross an landslide risk area, the students can decide to redesign the stretch or, alternatively, apply innovative technologies useful to mitigate and/or eliminate the risk of landslides.

This approach allows the student to use interdisciplinary knowledge gained in other courses through the application of specific study boards.

INTERDISCIPLINARY APPROACH

Last goal of the laboratory is related to the ability to provide students with elements and ideas of interdisciplinarity. After the verification shown in the previous stage it is possible to provide the student with an opportunity for reflection on all aspects involved in road design, not only related to the technical design of infrastructure, but to other issues as environmental and territorial.

On such occasions special sheets will be made consisting of elements of the current matter, providing design ideas for overcoming the constraints encountered. By way of example, possible elements of interdisciplinarity will cover the following topics:

- **Geotechnics**: i.e. the analysis of ground involved in terms of performance of substrate, explaining improvement techniques such as the stabilizations with use of cement or with lime.
- **Slope Stability**: i.e. analysis of slopes in terms of stabilization of landslide, presenting the different technologies to be implemented depending on the case;
- **Environmental design**: all aspects related to environmental mitigation, providing way of analysis of the territory in which the infrastructure is engaged and planning actions;
- **Innovative technologies in road construction**: i.e. techniques related to the use of innovative materials to overcome problems such as the weight of the structure (lightweight materials such as foam concrete or glass foam) or pack size of the road section (steeper slopes of embankments through the use of “Prati Armati” etc. etc.);
- **Project of small structures**: i.e. retaining walls, storm drain, etc.
This list is intended to provide only an idea of the possible applications that can be developed and that are still being implemented, in order to expand the interdisciplinary aspects of the laboratory.

It will be possible to integrate the study forms with additional specific design tool, increasing and integrating the technical knowledge of the student, through, for example, tools for the design of the elements of hydraulic protection of the road platform, for the design of structures, for verification the stability of the ground etc.

Again by way of example, in the future developments of the laboratory it will be possible to integrate, in addition to the technical aspects, also the regulatory aspects in relation to specific topics of interest. This will also give students the procedural aspects as well as those technical construction of all aspects of road design.
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