# USE OF GIS TECHNOLOGY IN THE CHECKLIST MANAGEMENT

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## ABSTRACT

The use of the methodology "Road Safety Review" in the road safety analysis has been spread for a long time. These methodologies are used to analyze in detail the different components of the streets and to see which the elements are that affect adversely the road safety. Checklists are drawn up in form of technical questionnaire and classified by topic, each in turn divided by sub-topic. It's clear that topics to be considered depend on the element to be analyzed, whether it is an arc or a node. Indeed, checklists are divided in two main macro areas, one for the arcs analysis and the other for the nodes analysis. In this way, it is possible to study in detail each part of the road network and identify the most critical areas. It is important to carry out on-visits in any arc and node, as well as to draw up the checklists.

Once completed, a large number of data is available, but they are often difficult to be read. In this study, we wanted to develop a management system checklist more fluid and functional, whose main goal is to have an immediate overview of the network situation under consideration.

The summary procedure can be resumed through the drawing up of the checklist with the answers "yes", "no", "in part", "n.a", giving to each answer a score - according to its influence on the road safety; calculating a weighted average for each subcategory and finally, for each category.

The result of this analysis is then managed on a GIS platform and represented in graphics. In this way, it is possible to have in real time an overview of the entire network under consideration.

In this way, it will be possible to create a more efficient and manageable use of the checklists.

## 1. INTRODUCTION

In recent years, mobility has increased significantly, projecting the most part of transport demand on road and increasing the number of vehicles. Over time, this phenomenon has caused significant negative effects, including those related to the road safety. For this reason, preventive interventions have been defined as a priority at international level with the purpose of achieving the goal to improve road safety.

The European Union, at the time of its establishment, highlighted the legislative instruments aimed at identifying and preparing the necessary measures within the road safety, the last one concerns the Directive 2008/96/CE.

At international level, actions aimed at improving safety in all phases of design (from planning to management) have been developed through, for example, the following tools:

- Road Safety Impact Assessment, for the planning phase;
- Road Safety Audit, for the project phase;
- Network Safety Management and Road Safety Review, for the management phase, the first one addressed to the network layer, the other directed specifically to existing roads.

Some of these measures have been implemented also in Italy, where the operational guidelines for carrying out road safety analysis are listed in the Circular of the Ministry of Public Works No. 3699 8$^{th}$ June 2001, "Guidelines for the road safety analysis”. They define the road safety analysis as a "formal project review of a new road, a traffic plan, an existing road or any project which interacts with the road users, in which an independent and qualified group of examiners report the potential danger of accidents and the performance in terms of safety”, by means of a report in the form of problem/solution [3].

The safety analysis is a preventive process, originally developed in order to verify road projects, both of new infrastructures, and of adjustment of existing roads, later extended to the check of the characteristics of existing roads; hence these analysis are divided into Road Safety Audit, if referred to design, and Road Safety Review, if referred to existing roads.

The paper reports the results of a study on road safety having as its goal the analysis of crossroads of a rural road network in order to verify which of those were more dangerous.

The reference of this study was the procedures of the Road Safety Review. As it often happens in carrying out such analysis, especially on an entire road-network and not on a single element (stretch or crossroad), a huge amount of data is collected that, because of its extent, is difficult to manage.

For this reason, a procedure to handle this amount of data in a functional way has been developed by using the GIS technology. In the paper, the fundamental principles of the Road Safety Review are reported firstly and subsequently it is possible to find the main points in which research and results have been articulated.

## 2. SAFETY ANALYSIS OF EXISTING ROADS: Road Safety Review

The Road Safety Review is aimed at identifying those aspects of the road environment that can be improved to reduce the accidents number or unsafe road conditions through interventions generally conducted with reduced time and cost.

It constitutes one of the methodologies that can be implemented to identify:

- "existing faults" actually observed in the infrastructure, those relating to the infrastructure itself and those arising from the interaction between users and the road landscape;
- "possible faults", those suggested by the type of accident (following a detailed analysis of accidents in terms of quantity and type).

These studies allow to highlight those aspects of infrastructure and traffic conditions that are the strongest potential cause of accidents. It is interesting to note that some Countries such as United Kingdom, Australia and New Zealand that apply a systematic safety analysis procedure have recorded a significant decrease in number of road accidents, despite the increase on vehicles number and road transport in general.

For the preliminary examination procedure to be effective, it is fundamental to have some criteria, as exhaustive as possible, with which the analysis itself can be led.

From the thematic point of view, they allow to integrate into the pre-assessment, the following aspects:

- **visibility**, the number of visual information that the user must acquire in time (depending on his and other users speed and location) so he can adapt his behaviour;
- **readability**, the property of the road environment to provide an accurate and understandable image of the covered path;
- **vehicle dynamic balance**, the full set of considerations that establish limit values to be respected, otherwise an infrastructure cannot guarantee the basic principles of vehicle dynamic balance;
- **passive safety**, with particular attention to margins arrangement;
- **consistency** of all road elements.

### 2.1. Road Safety Review framework

The procedure of Road Safety Review involves three main stages:

1. *preliminary analysis*: the study of documentation (traffic data, accident rate, and so on) made available by the managing authority; according to these data it is possible to perform some preliminary studies to detect, for example, the sites with the highest concentration of accidents or abnormal accident rate as well as types of accident or risk factors statistically significant;

2. *site inspection,* during day and night, is designed to detect, even through the use of photos and videos, the main issues detectable through the inspections;

3. *analysing of issues* and *drafting of an analysis report*, after the site inspection, there is a phase of comparison on detected issues, and for each one of those, a discussion on possible corrective actions.

2.2. Checklist

The drawing up of the checklists of checklists is fundamental in the process of the Road Safety Review. In fact, these are a useful tool for identifying critical issues and defining measures aimed at reducing them. They are written in the form of technical questionnaire and classified by topic, each in turn divided by sub-topic. Topics and their checklists will vary depending on the element that has to be analyzed either an stretch or a crossroad, in urban or rural roads.

| Item | Issues to be considered | Answer |
|---|---|---|
| **Pavement Defects** | Is the pavement free of defects [eg. excessive roughness or rutting, potholes etc.] which could result in safety problems [eg. loss of steering control]? | |
| **Skid Resistance** | Does the pavement appear to have adequate skid resistance, especially on steep descents? | |
| **Ponding** | Is the pavement free of areas where ponding or sheet flow of water may occur, with resultant safety problems? | |
| **Loose Screenings** | Is the pavement free of loose screenings? | |

**Figure 1 – Example of a part of pavement checklist**

The figure is an example of a part of the checklist concerning the road pavement analysis, from which it is possible to note how questions are formulated and which is the analysis detail level.

## 3. CASE OF STUDY

The study in question is focused on the implementation of the Road Safety Review procedure to analyze the major crossroads within the Provinces of the Medio Campidano (Sardinia, Italy) and identify the most critical in relation to the road safety level offered, with the objective of proposing action plans aimed at reducing or removing detected problems.

The study was born from the need to provide a study tool of the current situation concerning the status of critical issues relating to road safety of crossroads within the territory taken into consideration.

It was mainly divided into the following phases:

- ✓ territorial framework and study definition;
- ✓ identification of the main intersections on the network;

- ✓ summary of the geometric characteristics and design of crossroads on the network, data analysis on accident rate referred to the last five years and detection of transport needs (supply and demand of transport);
- ✓ detection of users' behaviour (speed and traffic flow) on the crossroads to be examined;
- ✓ definition of minimum crossroads safety standards and preliminary measures so that they can be guaranteed;
- ✓ analysis of specific risk factors and definition of actions aimed at eliminating or reducing them.

The article focuses on the development of this last point. We took into consideration all at-grade intersections along the state highways, all roads crossroads, major intersections between state highways, provincial and local roads.

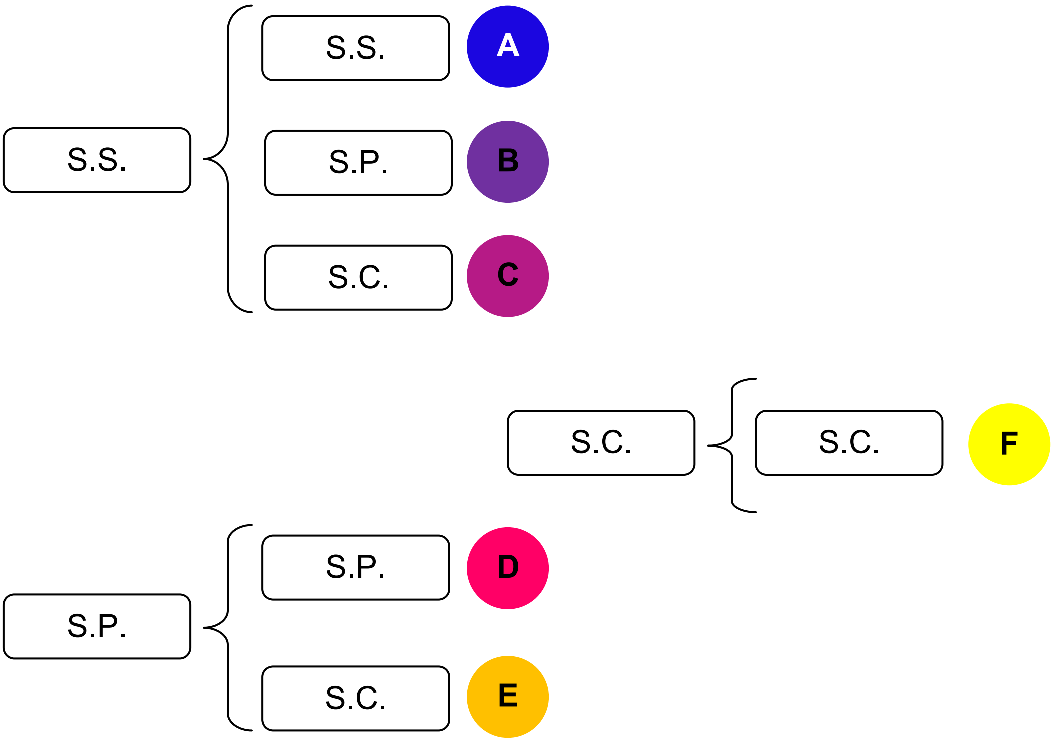


**Figure 2 – Graph of the hierarchy of intersections**

The crossroads are numbered in ascending order and, in relation to the hierarchy each number is followed by a letter that indicates the type of road that intersects, namely:

- A → state highway crossroads;
- B → crossroads of state highways and provincial roads;
- C → crossroads of state highways and local roads;
- D → crossroads of provincial roads;
- E → intersection of provincial roads and local roads;
- F → intersection of local roads.

The first phase of the study has concerned the mapping of all intersections in the area in question. Then, it proceeded with the technical mapping to identify the traffic between the crossroads according to the hierarchical scheme described and represented in the figure above.

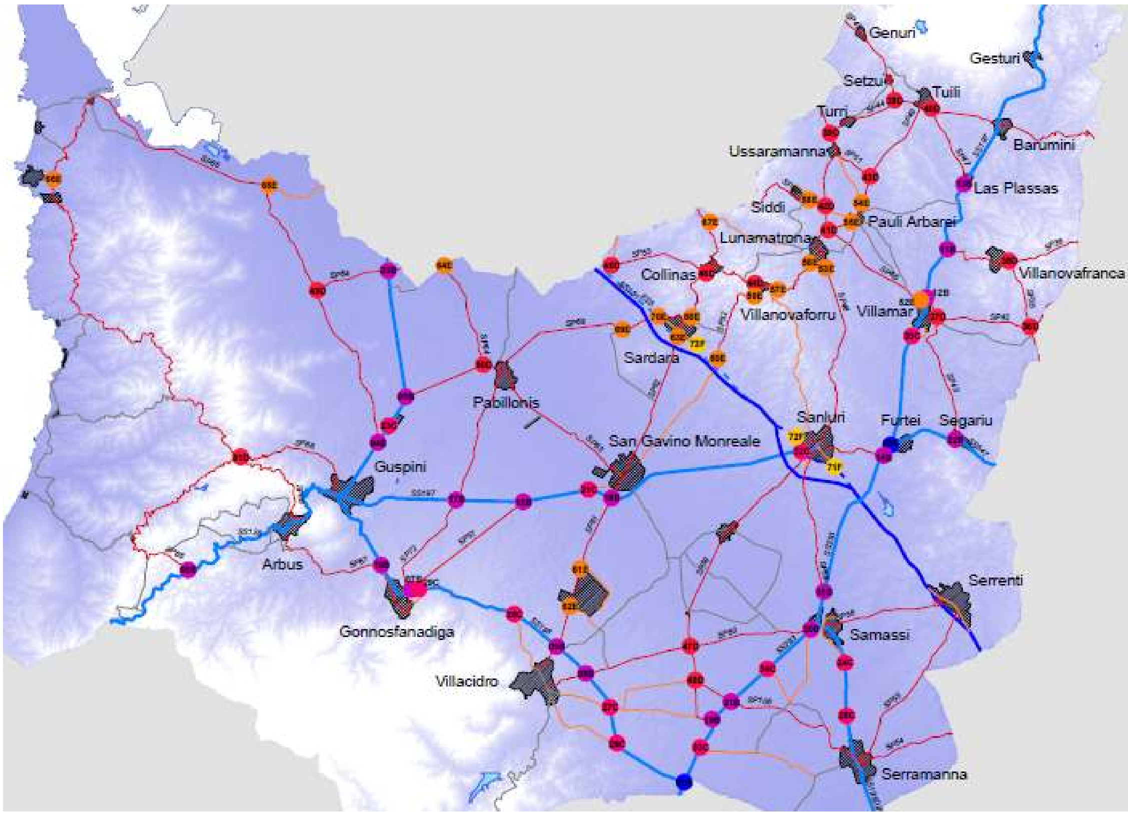


**Figure 3 – Location of the intersections in exam**

The next step has concerned the inspection of the site, both in daylight and at night, during which checklists were used for existing roads contained within the "Guidelines for the road safety analysis" (*"Linee guida per le analisi di sicurezza delle strade"*) [3], document provided by the Ministry of Infrastructure and Transport.

The following is a summary of the main themes in each checklist used in the study and the related information for the traffic safety analysis.

### 3.1. Crossroads

The checklist "Crossroads" has not been drawn up because the target of this study is to identify the most critical elements of the network that are object of the next project interventions. So, it has been fundamental the decision that considers only the at-grade intersections of the area in question, because these certainly have more critical aspects than the staggered ones. The topics taken into consideration are:

a. *location*: the position of the intersections must be controlled as well as the possibility of making safety improvements;

b. *visibility*: it must be checked to ensure day and night visibility in all directions and for all categories of users;

c. *readability / ease of understanding*: it is fundamental to check that the intersection functioning is clear to all users avoiding moments of uncertainty;

d. *specialized lanes*: the acceleration/deceleration lanes should be controlled in the aspects concerning the geometry (length, width, layout and visibility);

e. *manoeuvres*: they must be monitored and evaluated in order to verify the users behaviour, for example, the waiting time.

3.2. Roadsigns and lighting

The purpose of this list is the analysis of traffic signs and road markings as well as the lighting.
With regard to road markings, size regularity is verified as well as location, coherence of performance, etc.

Concerning traffic signs, the monitoring is focused on features (readability, visibility and user's signs understanding) and the structural configuration of the signs (for example, the structure above ground of each signs must not be a risk for the user, as a physical barrier on the edge of the roadway).

Concerning lighting, if any, and / or necessary (if the item in question is within the urban field and no pedestrian traffic has been detected so as lighting systems is not considered necessary), the monitoring is focused on system suitability to traffic safety necessities.

In detail, topics covered in the list under consideration are:

a. *road markings*: it is fundamental to verify that they are clearly visible during daylight and at night in all weather conditions as well as congruent with no old signs and in good maintenance conditions;

b. *traffic signs*: readability, visibility, position, consistency and maintenance have to be checked;

c. *speed limits*: they must be checked, for example, speed limit road signs have to be correctly placed;

d. *delineation*: proper installation must be checked as well as the effectiveness and the maintenance conditions;

e. *traffic lights* should be checked for the users visibility, even in particular atmospheric conditions (dawn and dusk) and that needs of pedestrians are respected;

f. *lighting*: night visibility must be checked, with special attention to the areas with higher risk (pedestrian crossings, intersections) and the transitional areas (tunnels).

3.3. Margins

Road restraint systems assume no little importance in road safety analysis. In fact, it is important not only to evaluate purely technical aspects, such as supports or drainage systems, but also the connection between safety systems and surrounding environment. The control checklist "Margins" is patterned on the base of this consideration and the following topics are covered:

a. *unprotected obstacles*: all cases in which an unprotected obstacle is placed dangerously must be reported and provide a good way to eliminate them or to protect users;
b. adequacy of *crash barrier classes*;
c. *transitions between different types of crash barriers and terminals*;
d. *crash barriers installation* conditions: they must be checked for the length, distance from the objects to be protected, curves (which might prevent proper functioning), etc.;

e. *interactions* between crash barriers and other objects: the proper interaction between barriers and factors such as light poles, traffic signs, etc, must be checked;
f. *maintenance*: the performance of a correct maintenance has to be checked (for example, if a crash barrier is damaged or removed, it should be restored).

3.4. Pavement

As often pointed out, pavement features, in other words, weave, adherence and regularity, have a strong impact on road safety. In this regard, the checklist concerns:

a. *weave*: it is important to verify whether the roughness is appropriate to the type and the volume of traffic;
b. *grip*: it must be verified that there are no zones with low grip, especially in the presence of water and that singular points of the route (pedestrian crossings, curves, intersections) have a stronger grip;
c. *water veil*: an efficient disposal of rainwater has to be ensured, for example, checking the transverse and longitudinal gradients and that there are no elements that could impede the water disposal;
d. *state of road surface*: it is fundamental to check that there are no irregularities that could affect safety.

3.5. Pedestrians, cyclists and motorcyclists

During the analysis of individual network elements, it is necessary to take into consideration the needs of pedestrians, cyclists and motorcyclists, especially where it is plausible to predict a significant presence of them (for example, pedestrians near buses stops). The topics covered in the checklist are:

a. *pedestrian crossings*: day and night visibility must be checked as well as the continuity of pedestrian paths, the compatibility with the width of the carriageway and the speed of the motorized flow, the adequacy of the waiting space, the presence of ramps for disable, tactile strips for pedestrian with visually impairments, etc.;
b. *pedestrian paths*: it is fundamental to verify the presence of sidewalks, their width compared with the flow of pedestrians, the adequacy of the surface, etc.;
c. *cyclists*: the flow of cyclist has to be checked with the purpose of evaluating whether cycle routes are necessary or not;
d. *motorcyclists: flooring, joints, gratings for drainage, etc., have to be inspected.*

## 4. ANALYSIS OF THE NETWORK UNDER CONSIDERATION

In the present study, a total of 73 intersections have been analyzed, for each of those, the relevant checklist has been drawn up.

For each crossroad identified in the road network in question, the checklists have been drawn up. It is clear that a lot of data organized in this way are unreadable. Indeed, it is difficult to quickly identify which element is the most critical for a given topic compared with others.

The purpose of the compilation was to qualitatively identify the main problems emerged from surveys and facilitate the comparison of different elements.

Questions in the lists are organized in such a way that the only possible answers are "YES", "NO", "IN PART". In order to compare the data between them, a value to each type of answer was given first with the following criteria:

- 0 if the answer is positive for safety (there is not any issue);

- 1 if the answer indicates the presence of an issue;

- 0.5 if the answer indicates the partial presence of an issue;

- N.A. if the question is not applicable.

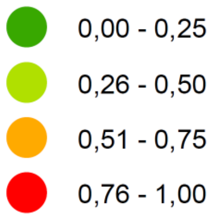


**Figure 4 – Values symbol**

The values arithmetic means for each intersection of the micro topics of each list have been subsequently calculated and macro topics, the arithmetic mean has been used to identify the severity level of existing problems.

The score range is from 0 (no critical points) to 1 (highly critical) with intervals of 0.25. So, the more the value for a particular topic is close to 1 the more that element presents critical aspects on the topic examined.

As it has already been said, each list (General aspects  Geometry, Roadsigns and lighting, etc.) can be divided into "sub-topics. Hence, a comprehensive database of all questions with values associated to the answers has been created and then it has been included in the software GRASS. This allowed the preparation of data for each topic and to draw different maps, whose some examples are reported below.

A summary map for each list has been prepared in which the average values for each sub-topic have been reported (for example, "General Aspects - Mean"), later a map for each sub-topic (for example, traffic, weather conditions, surrounding landscape, etc.) is inserted so that the reader can quickly identify for each topic concerning the road safety which are the most critical crossroads or stretch, and if it wishes to go into the topic, it may also observe the maps on the sub-topics with the most number of critical points. Each crossroads will have a color associated with the severity of the problems identified for each micro and macro topic.

Finally a summary document with the overall mean values has been written. It makes possible to identify the crossroads with the most critical points.

## 5. RESULTS

As a whole, as also seen in the document "Analysis of crossroads" strong road safety issues have been detected in a few crossroads. Most of them were located along the state and provincial network.

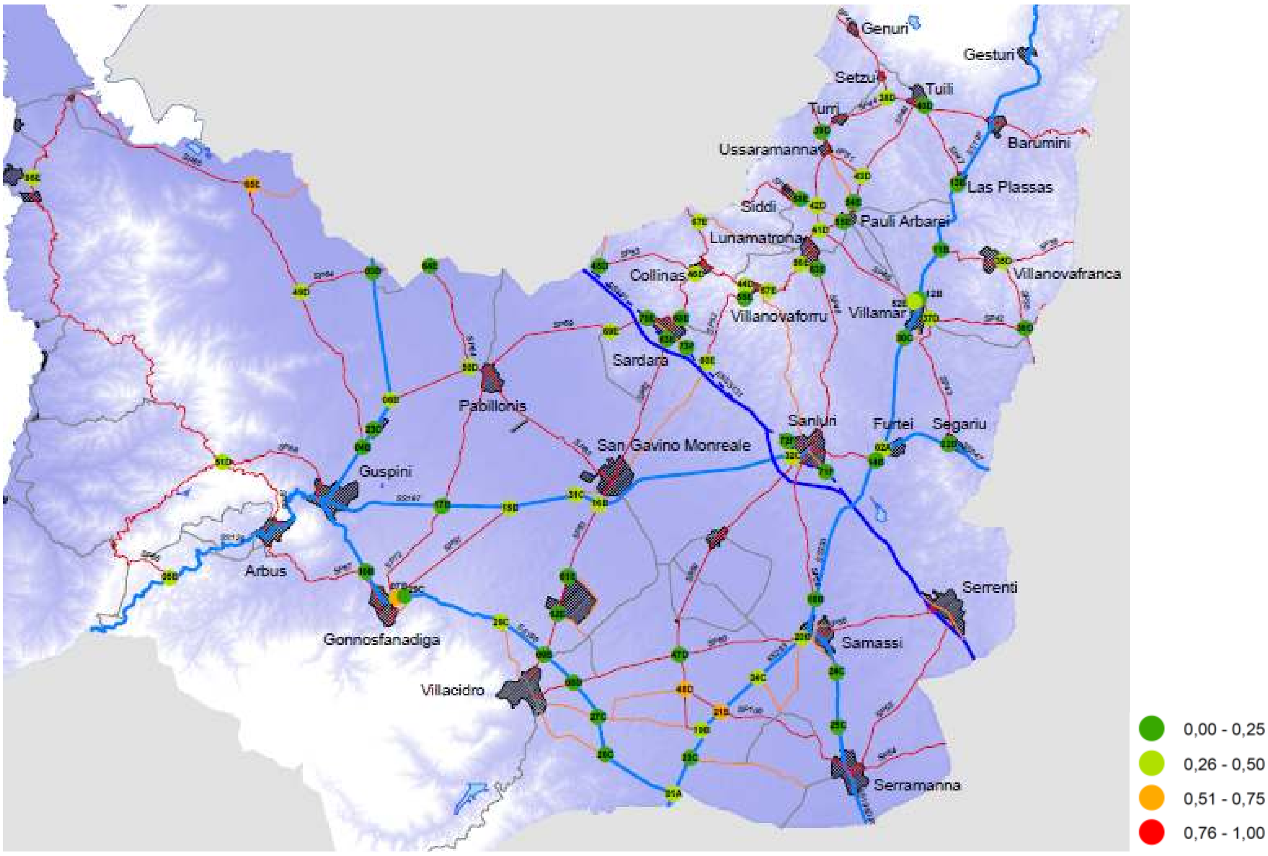


**Figure 5 – Map on Crossroads**

As it is possible to note in the document "Crossroads" (Figure 5), the most critical crossroads are those placed along the state highways. Among other issues addressed in the reference checklist, the most part of intersections has revealed critical issues in the following points:

- ✓ LOCATION;
- ✓ READABILITY AND USER-FRIENDLY;
- ✓ MANOEUVRES (Figure 6);
- ✓ CROSSROADS WITH THE RIGHT OF WAY.

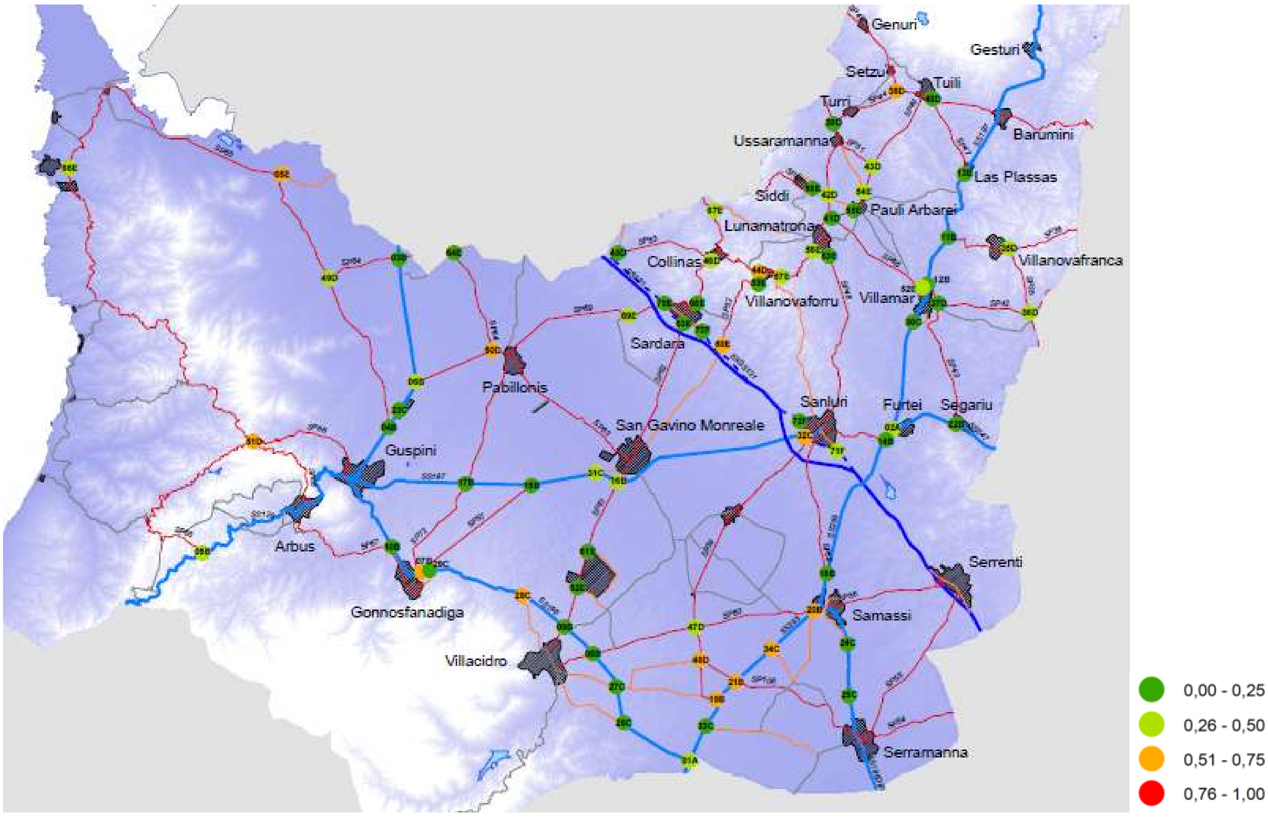


**Figure 6 – Map on Manoeuvres**

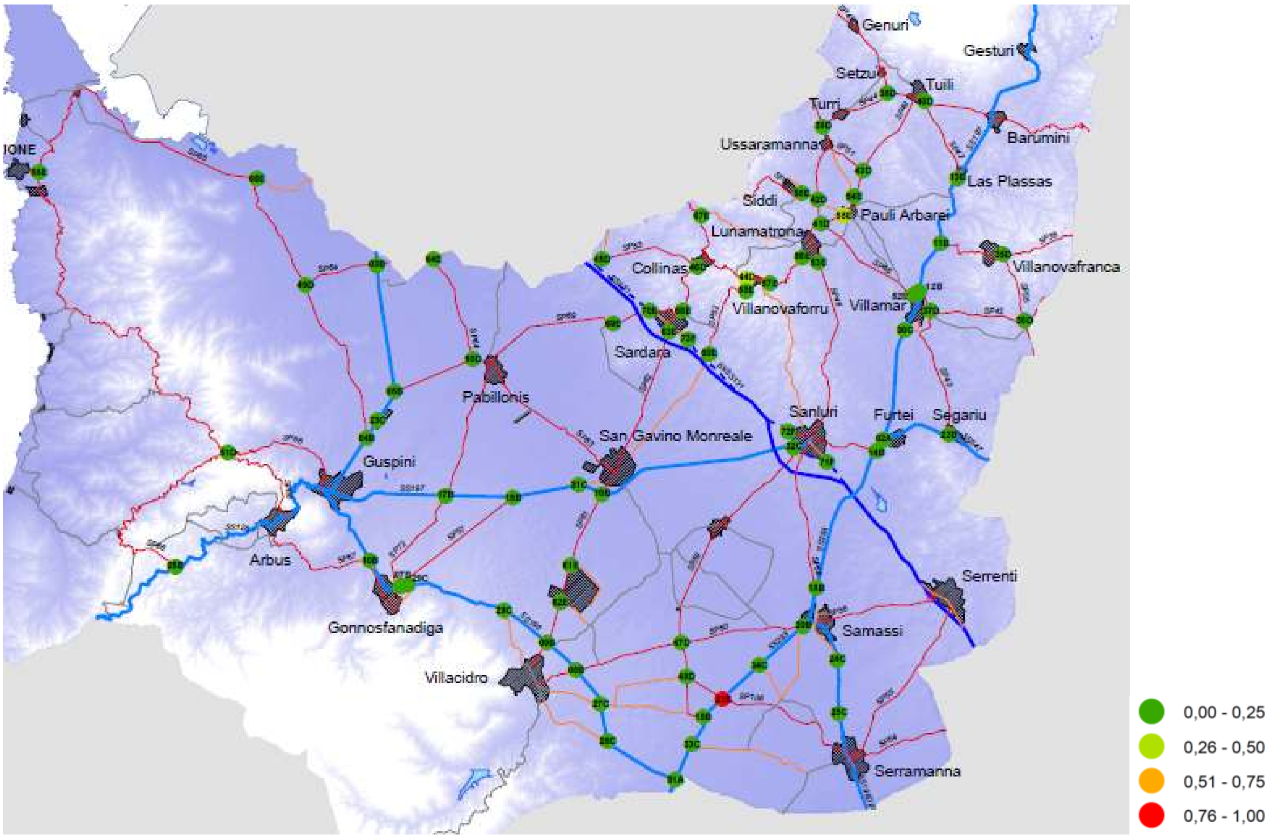


**Figure 7 – Map on Roadsigns and lighting**

Concerning "roadsigns and lighting" (Figure 7), the most critical issues were found in "road marking" (Figure 8). Indeed, more than half of all intersections examined need road markings improving actions.

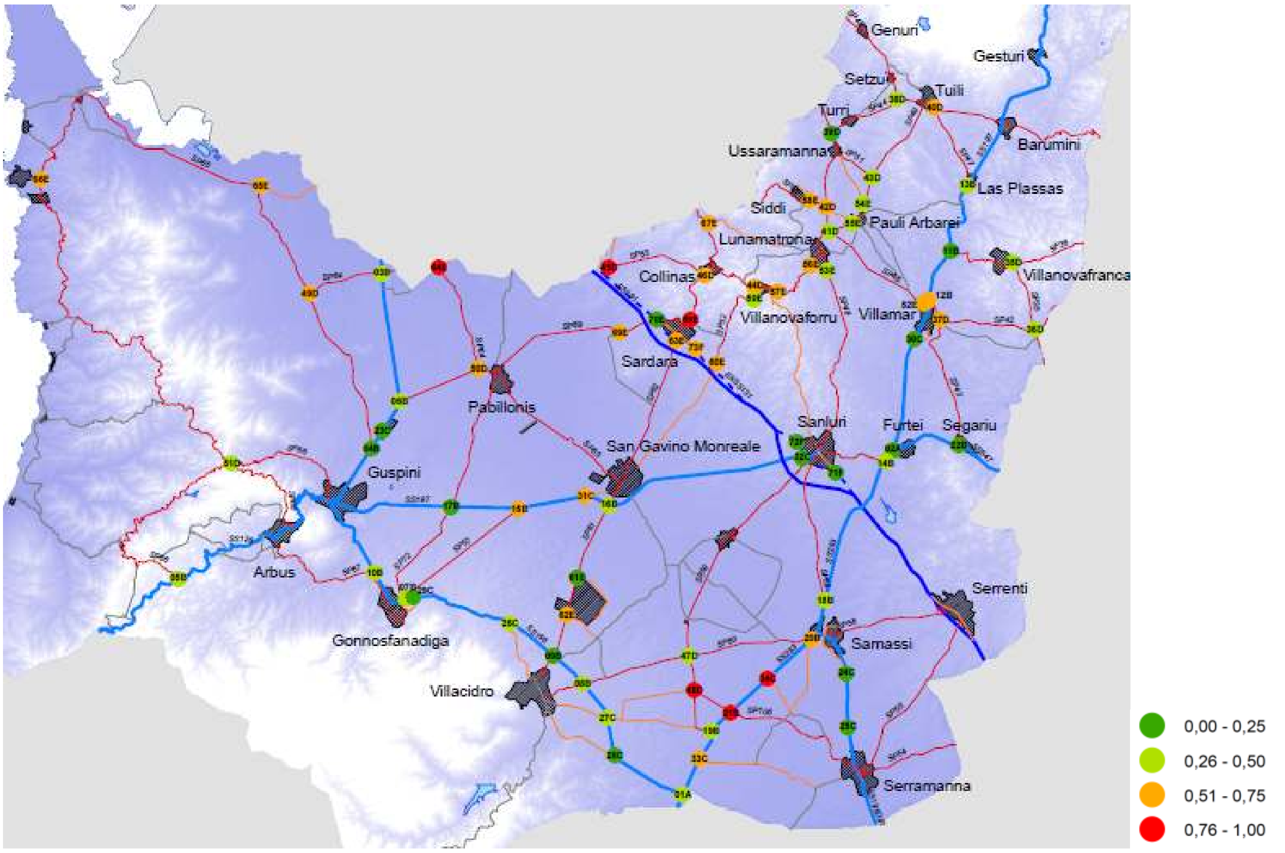


**Figure 8 – Map on Road marking**

Strong problems have also emerged from the checklists related to "speed limits" (Figure 9). It is clear that the crossroads with the most critical values are the ones in proximity to the state highways where the difference in speed between the main and secondary legs is particularly high.

The document on the "Pavement" (Figure 10) highlights how the most part of intersections stronger or less critical points concerning the superficial surface of the road pavement. The main issues have been observed for what concerns:

- ✓ WEAVING;
- ✓ GRIP;
- ✓ WATER VEIL.

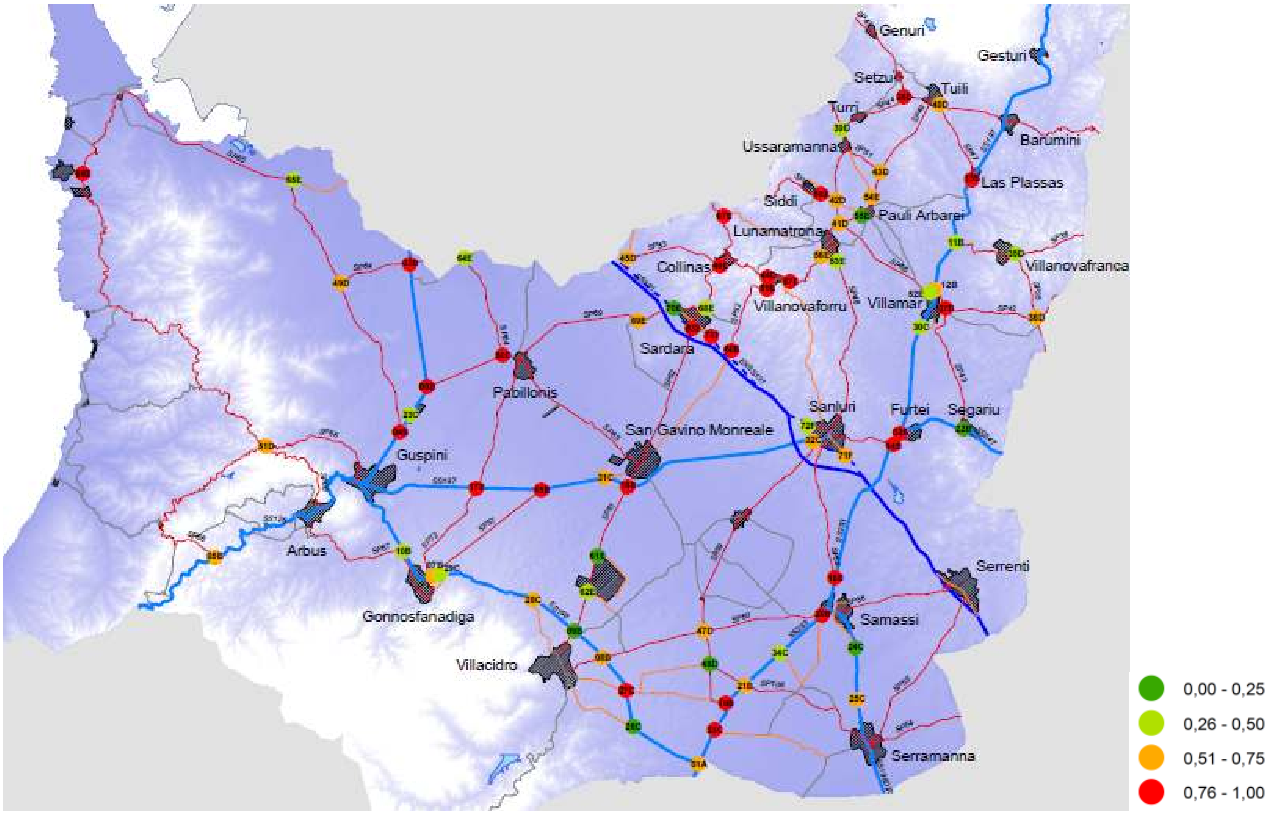


**Figure 9 – Map on Speed limits**

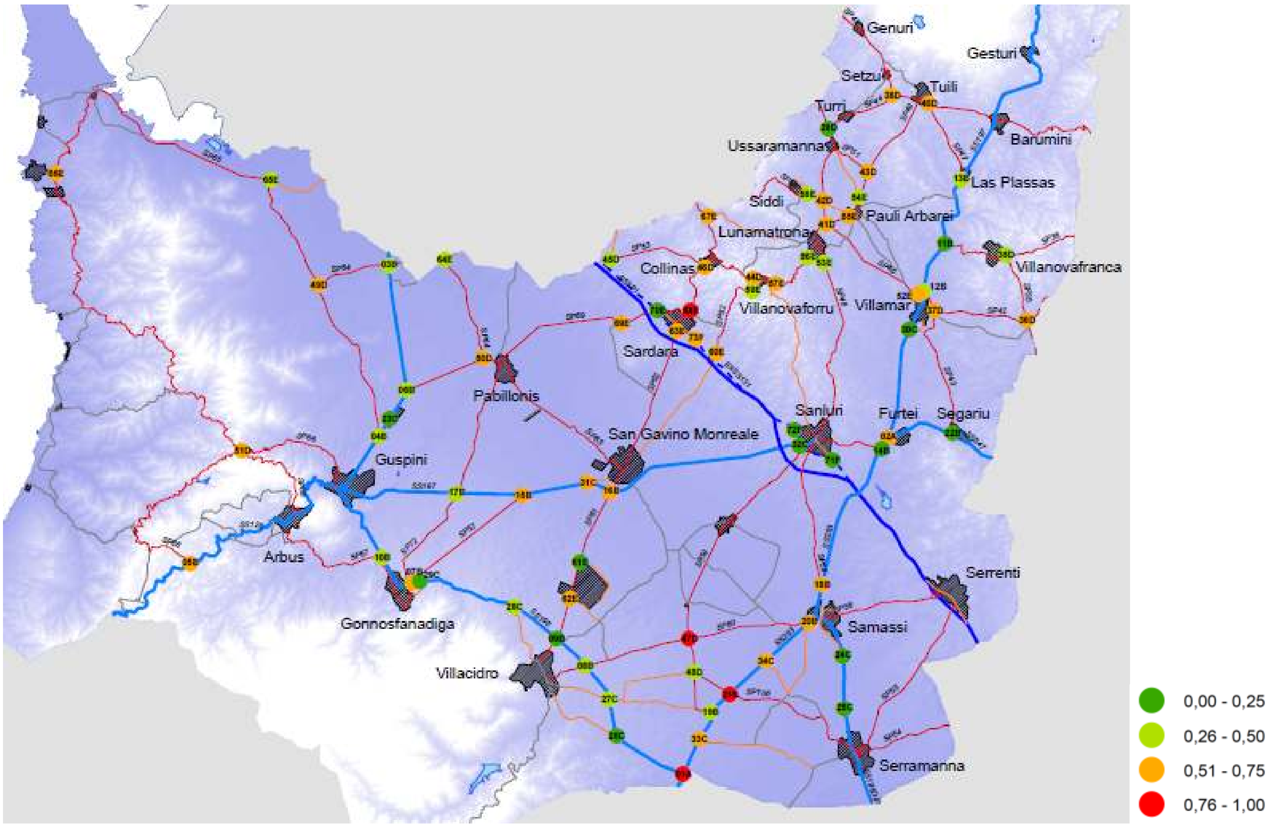


**Figure 10 – Map on Pavement**

## CONCLUSIONS

This study has shown, with the help of the checklists, the crossroads of a rural road network examined within the Province of Medio Campidano, representing the highest critical points.

The most critical points were found in the crossroads along the state and some provincial highways. In general, strong critical issues have been found in relation to speed, margins, and road surface.

The purpose of the drawing up of checklists was to qualitatively identify the main issues emerged from surveys and facilitate the comparison of different road elements. Please refer to the subsequent project phases to verify the individual elements of the path on which it is intended to intervene.

The use of GIS technologies through the software “Grass” has allowed the use of the checklist in a more functional way, even when applied to large numbers of elements. In fact, it has been possible to quickly identify which were the most critical intersections and state which aspects affected adversely the road safety (for example, visibility, margins, etc.).The results from the analysis can then be used by the managing authority responsible for the road safety and to plan interventions aimed at reducing or eliminating the critical points found. Furthermore, the management of data through a dynamic database allows data to be implemented over time, thus creating a very useful non-static monitoring in road safety management.

The safety analysis aimed at identifying the technical, geometric and functional features that can contribute to cause accidents and, once introduced in a systematic approach to road safety audit of existing assets, it may also represent the first phase of a process divided into further detailed levels. For this reason, the analysis procedure represents a useful operational tool to manage the road safety both at network level and in terms of road and, as well as an important source of data and references for identifying infrastructure needs and maintenance.

In general, the fact that a road has been well designed does not necessarily mean that all users will perceive the limitations that road requires, in other words, even warning them, they respect such limitations.

The accident rate on the roads is therefore a controlled but not eliminable phenomenon because it is a direct consequence of the driving freedom, main feature of the road transport.

Concerning roads in operation, safety and verification analysis may require various articulated studies (by extension and close examination level) in relation to the particular fixed goal. It is important to remember that safety analysis of existing roads does not replace the analysis of the accident rate and the identification of sites with high accidents concentrations, but it is fundamental to identify risk factors that, even not in case of accidents, it is advisable to remove or reduce.

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