METHODOLOGICAL PROPOSAL FOR ROAD NETWORK FUNCTIONAL UPGRADING

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ABSTRACT

The answer provided to the need to transport persons, goods and information has been prevalently that of road and motorway building based of local and sectorial requirements, with plans drawn up in the absence of compulsory building rules.

In today's situation it is not difficult to predict that in the short- to medium term roads will continue to absorb most of the traffic of persons and goods. This raises questions of management and upgrading of the roads being used; this is especially important owing to their impact on productive sectors and the consequences they have from the social and environmental standpoints. Thus the need to proceed to the functional upgrading of the existing network is being emphasized more and more since it is a part of the vaster issue of the management of the roads now in use.

Improvement in the quality of the service offered and road safety requires overall or local works to be implemented with a series of coordinated actions to follow a sustainable approach also from the environmental and economic viewpoints.

The overall issue of mobility requires an innovative and original effort with respect to the traditional vision of roads limited to layout only, one that is capable of taking into account all present and future aspects of mobility, proposing trends, programmes and work priorities in the definition of new proposals and in the conservation and improvement of the existing road network. The transportation system and within this the road network must be upgraded in the light of the socioeconomic realities and future development of the region it serves while safeguarding and making the best use of its historical and environmental peculiarities coherently with overall economic planning.

This paper presents the results of research conducted by the University of Cagliari on an existing infrastructure network.

The methodology adopted in the study provides indications and examples concerning the different stages in the analysis of an existing network: from the indication of objectives to the identification of critical situations and consequently the definition of design alternatives capable of reaching the objectives set.

Keywords: accessibility, upgrading, level of service.

1. INTRODUCTION.

The starting point of the study was a preliminary analysis of the area under examination for the purpose of identifying its main socioeconomic features and the impact that these have on the existing network.

Figure 1 shows a diagram of the methodology used in the analysis of the study area. The starting point is represented by studies of:

- the main current socioeconomic dynamics;
- possible future consequences;
- mobility and traffic.

The study of the region was used to delineate its principal exigencies and consequently the objectives to assign to the project for rehabilitation of the network. Correspondence to the objectives constituted the means for evaluating design alternatives.

The study of the network was for the most part performed by means of a traffic survey and evaluation of the design characteristics of the roads. The analysis of traffic data together with the critical situations encountered, led to the identification of the most critical points in the network. Once identified, the works to be performed were studied and variations in level of service before and after performance of such works were evaluated.

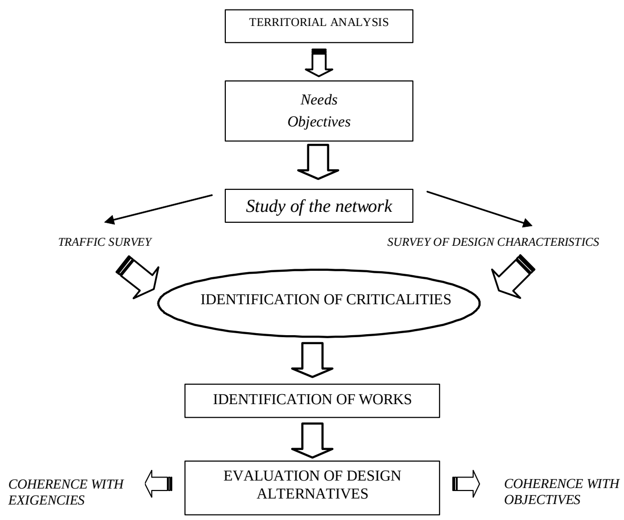

Figure 1: Methodologies used in the study

Moreover, in consideration of the vastness of the region analyzed and the study of the different problems encountered, it was considered necessary to use GIS technology both for the collection and display of data and as an instrument for analysing and processing of same datas.

2. TERRITORY ANALYSIS

As concerns the analysis of the area, the data considered necessary in delineating current dynamics required:

- a demographic analysis of the population;
- a study of the labour market, entrepreneurship and productive structures;
- a study of services;
- an analysis of mobility.

The region involved in the study is the northeast area of Sardinia. The municipalities in this region have recently been grouped into a new province which has among its priorities that of evaluating the characteristics of the existing network, identifying any critical points it may contain and the works required for its improvement.

The area under examination differs from the rest of Sardinia for certain characteristics:

- a large number of houses with a low rate of occupation;
- low indices of old age and dependency;
- high per capita income compared to the regional average;
- a noteworthy degree of local entrepreneurship.

On going into detail concerning the internal dynamics of the study area, it was found that the main feature (which to a certain extent also represents a critical point) is the presence of considerable differences between coastal and inland areas. Along the coast we find towns with the largest resident populations on the increase and with a low percentage of the aged. The dynamicity of the coastal area is mostly due to growth in the holiday industry. Tourism represents the driving sector of the area's economy: 35% of Sardinia's hotel guests are concentrated here.

The importance of the holiday industry is reflected both in the consistency of the number of houses, with a high percentage of those that are vacant, and in the productive structure: the coastal towns are the ones that always present a large number of local units.

The inland part of the study area is instead characterized by the presence of small towns, in some cases with a high percentage of the aged. This division is also reflected in labour market statistics: the highest rates of unemployment are concentrated in the interior.

The system of services in the area was also evaluated to complete the socioeconomic analysis. The concentration of the latter creates the service centres which attract the largest amount of traffic. As expected, the service centres in the area are also concentrated along the coast and it is along the coast that we find the major flows. However, data on traffic leads to some underestimation since the movement of tourists was not included in the statistical analyses: in the summer season it is tourist traffic that congests the existing network.

From the analysis of the area it was thus possible to identify a first series of objectives and conclusions:

- the need to design a new organization of the region, in particular by improving the conditions of accessibility to the internal areas and connecting the latter to the coastal system of services and productive activities;

- the need to improve the conditions of the network by evaluating present levels of service, especially in the summer season when congestion is at a peak;
- the need to bring the physical and design characteristics of the network into line with socioeconomic changes in progress.

With such objectives in mind, an in-depth analysis of the network was performed to evaluate its efficiency both in ordinary conditions during the winter months and in heavy traffic conditions during the summer.

3. TRAFFIC SURVEYS

In the light of the objectives set for the study of the upgrading of the network, attention was focused on all the roads (provincial and regional) surrounding the provincial capital (Figure 2). The considerations in this case were:

- the network under scrutiny is the main connection between the provincial capital, the northern part of the study area and the areas in the interior where there are serious problems caused by both high traffic flows and a lack of infrastructures;
- the sections and roads surveyed are the ones that play a key role in ensuring the functionality of the entire region;
- Olbia represents one of the main traffic terminals not only in the study area but in all of Sardinia as well. For this reason the road network that branches out from the town assumes strategic importance at provincial and regional levels.

The use of traffic surveys together with the analysis of the characteristics of the network represents the first step in evaluating its criticalities and the level of same.

Surveys were performed on typical weekdays (from Tuesday through Thursday) in May 2006 and were repeated in the months of June, July, August and October so as to monitor the network over three seasons.

Eleven road sections were surveyed; their location, which was decided on the basis of the considerations cited above, is shown in Figure 2.

In particular, the surveys were carried out in two time intervals considered as being those of the heaviest traffic:

- from 7:00 to 10:00 am;
- from 5:00 to 10:00 pm;

The times of loading and discharging passenger ships in the port of Olbia were also taken into account in choosing the times of the survey.

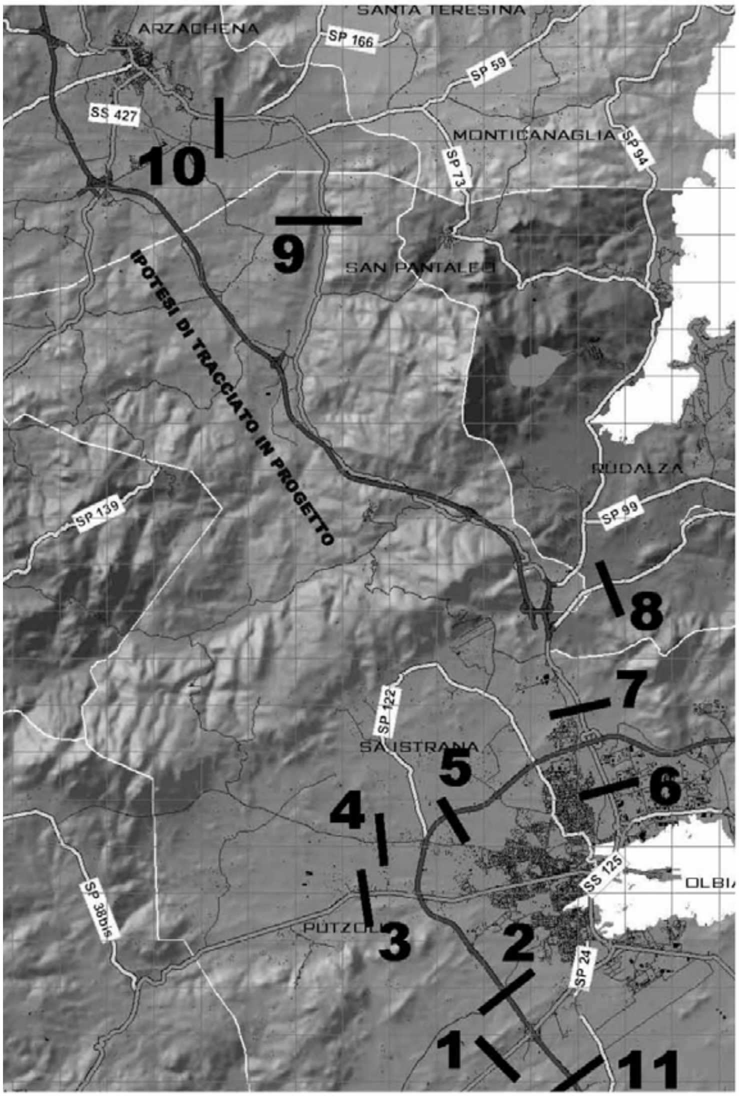

Figure2 – Location of the survey sections

Results of the processing of traffic survey data are shown briefly in Figures 3 and 4 below.

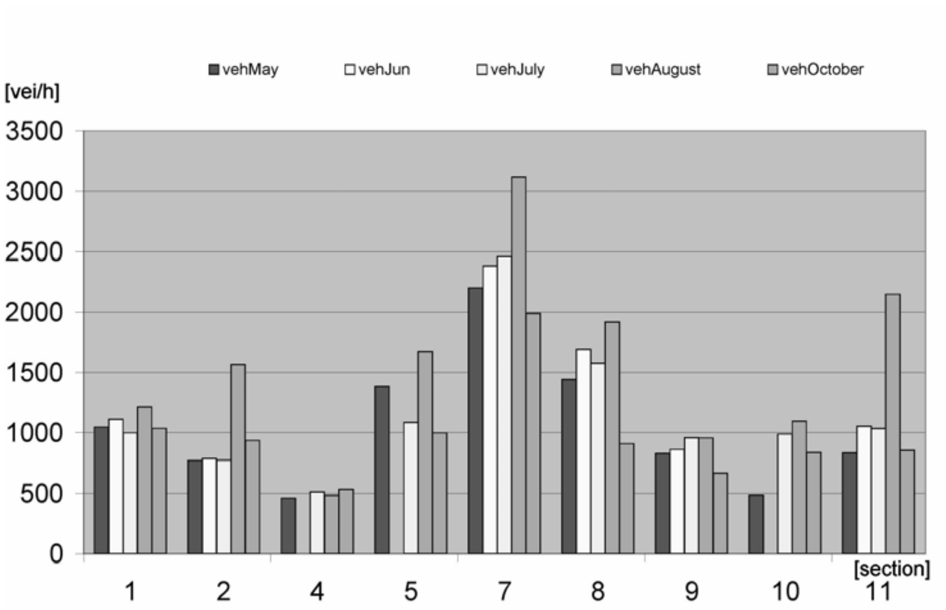

Figure 3 – Comparison of traffic volumes in the different survey sections

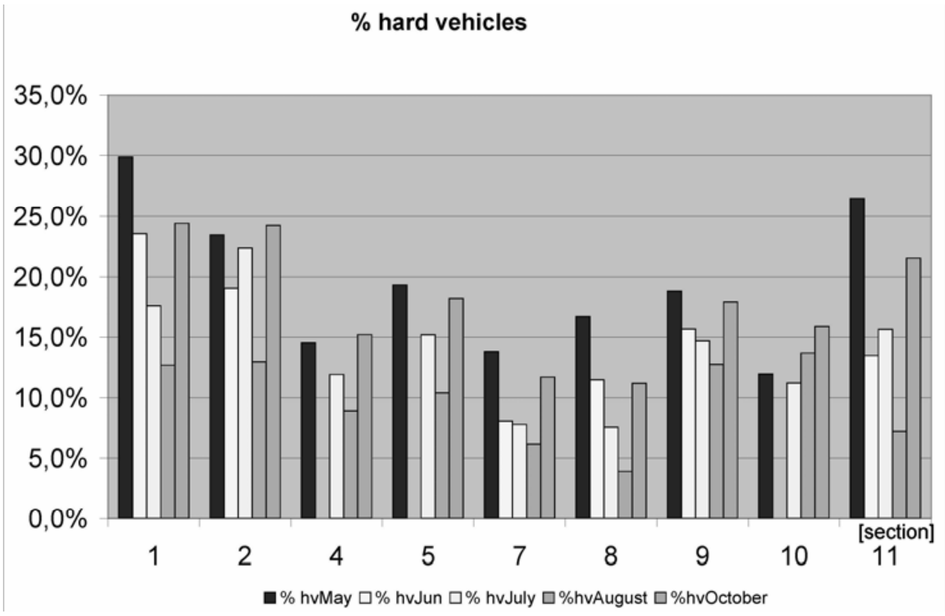

Figure 4 – Comparison of percentages of heavy vehicle

In Figure 3 we see the equivalent volumes at rush hours. As is evident from the graphs:

- section 7 carries the heaviest traffic in all months of the survey: at the daily rush hour it showed values of approximately 2200 vehicle eq/h. These values increase in June and July, with a peak in August with 3120 vehicle eq/h, an increase of 41%.
- as concerns heavy vehicles in section 7, the percentage goes from 13.8% in May to 8% in June, to 7.8% in July and to 6.2% in August, while in October we see an increase up to 11.7%.

From these data for section 7 and from others in the other sections it is found that the summer flows in arrival are for the most part composed of passenger vehicles, with a reduction in the percentage of heavy vehicles rather than in their absolute values: indeed, at the end of the tourist season the overall flow decreases and the percentages of heavy vehicles return to their initial value.

4. SURVEY OF NETWORK DESIGN CHARACTERISTICS

The second step in arriving at a complete definition of criticality was the analysis of network characteristics performed:

- by point-by-point surveys for the analysis of geometric characteristics and the condition of paving;
- by GIS-implemented procedures for the analysis of the design characteristics of roads and itineraries.

As concerns the first step, the network is composed of roads with a single roadway with two lanes, assimilable to type F1 (in accordance with the D.M. 05/11/2001), with the exception of State Road (SS) 131 (section 11) with a divided roadway. The objective analysis showed that the paving was in good condition in all sections.

As concerns the second step, an operating procedure based on GIS technology was devised, which made it possible to attribute a travelling speed to each element of the road network based on the design characteristics of the planimetry.

The method also made it possible to represent for each itinerary the design characteristics of the infrastructures (curvatures, radii of curvatures, kickback, and so on) as well as the travelling speed of an isolated vehicle. As an example, in the figure below we can see the graphs of State Road 125 (sections 7, 9 and 10).

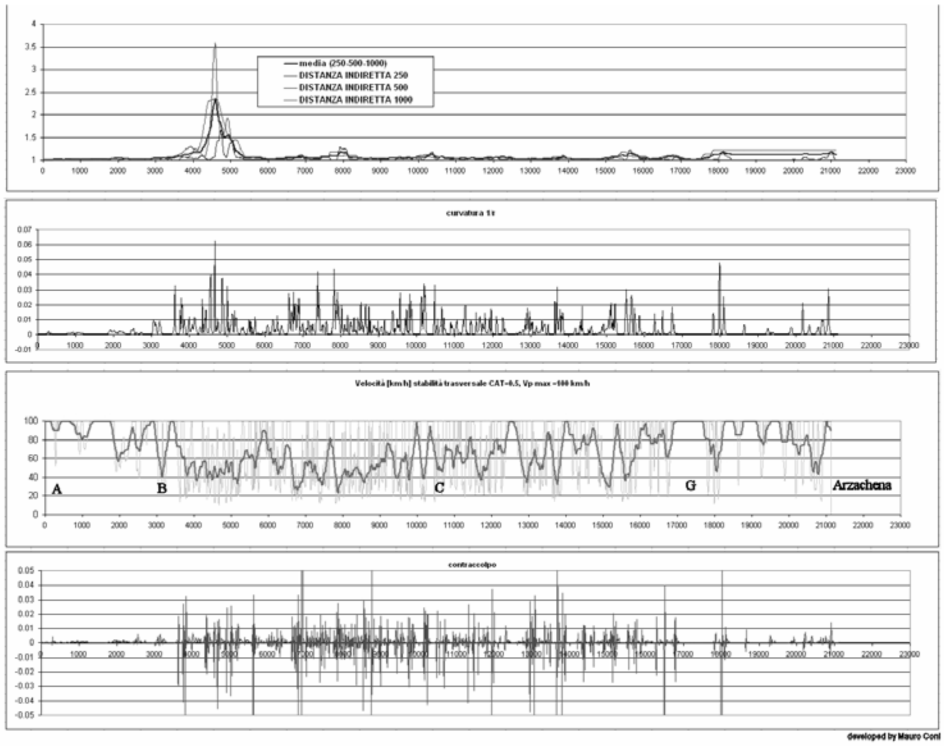

Figure 5 – Characteristics of State Road 125 – section between Olbia – the ring road interchange – Arzachena

From the analysis of the graphs it emerged that on travelling along state road 125 starting from the interchange of the Olbia ring road (section ABCG), two variable characteristics were found. In particular, the third diagram, which represents speed, shows that in the first section (AB) there is an average traffic speed with free flow of about 88 km/h. This goes down to no more than 53 km/h in unstable and poor traffic conditions. The next section (BC) presents the worst possible speed conditions, with possible speeds of about 54 km/h. Conditions improve in the next section (CG) with a speed of 67 km/h. Proceeding northwards, the last section of State Road 125 between the interchange with Provincial Road 59 (to Porto Cervo) and Arzachena presents better geometric characteristics which allow an isolated vehicle to travel at about 84 km/h.

If we observe the curvature diagram, we can see that in some stretches the values are above the maximum ([1/r]max = 0.02) which corresponds to the minimum radius. This means that the minimum radius value for the dimensioning of circular curves is not guaranteed.

Similar considerations were developed with reference to the graphs of all the roads in the network under study.

The speeds calculated and represented in the graphs are only an indicator of the infrastructural quality of the network: They are not, however, representative of the real operating conditions of the roads in relation to the vehicle loads they carry.

5. IDENTIFICATION OF CRITICALITIES

What emerges from what has been said up to now is the need to use an indicator capable of quickly evaluating critical conditions in the network. To this end, it was chosen to calculate levels of service for each section of the network so as to estimate traffic quality. The level of service was used since it defines operating conditions of a road in relation to the traffic it carries. Obviously, traffic conditions are also symptomatic of the state of an infrastructure: for example, low traffic speed is the result of heavy traffic loads, especially when large vehicles are present, but it is also the result of the difficulty of overtaking safely when visibility is poor. Furthermore, travelling speed gives an idea of travelling times; traffic density and the flow/capacity ratio can instead be considered as indicators of driving freedom, comfort, safety and cost.

In calculating levels of service, we referred to the criteria of the Highway Capacity Manual (HCM) drawn up by the Transportation Research Board.

The figure below presents a graphic representation of the levels of service calculated.

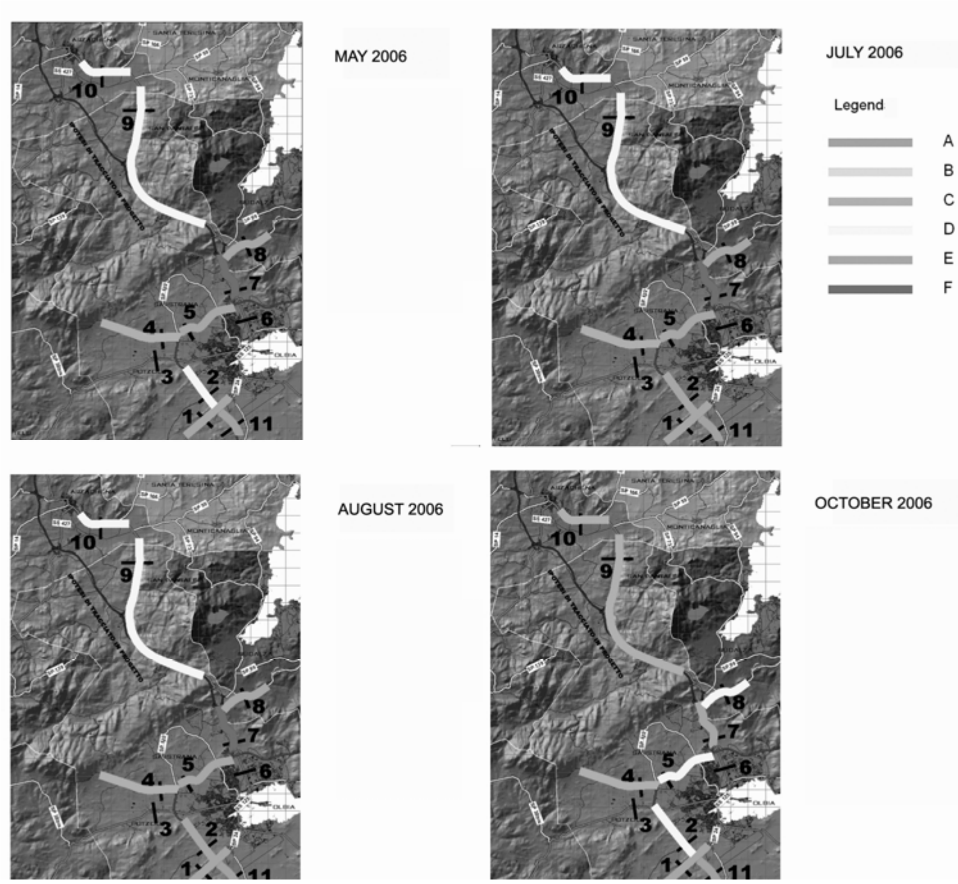

Figure 6 – Representation of levels of service in the different sections for each month of the survey

On limiting the analysis only to levels of service, the investigation revealed that the needs for infrastructures are concentrated in few, well-defined road sections that are in "poor" functional conditions:

- State Road 125 in the section exiting northward from Olbia (section 7);
- the Monti – Olbia road (section 1);
- the Olbia ring road (section 2 and section 5);
- Provincial Road 16 from Olbia to Golfo Aranci (section 8).

6. IDENTIFICATION OF POSSIBLE WORKS

For each section of the network that was analysed a comparison was made between the geometric and design characteristics and the levels of service; this made it possible to find the weak points and thus decide on the necessary works to be performed.

In particular, the final section of State Road 199 (section 1) was characterized by:

- an average speed of about 94 km/h for an isolated vehicle;
- road alignment characterized by wide curve radii, which were in all cases above minimum values;
- level of service E in all months of the survey.

In this case, the weak points of the infrastructure were connected with:

- a high percentage of heavy vehicle traffic;
- a consequent reduction in average traffic flow speed
- characteristics of the road alignment that do not provide adequate visibility for safe overtaking.

All the above considerations for this section, which belongs to the fundamental network of the region, lead to the conclusion that it should be a type B (in accordance with the D.M. 05/11/2001) road with divided lanes.

As concerns the characteristics of the Olbia ring road (sections 2 and 5), the following was found:

- an average speed of about 90 km/h for an isolated vehicle;
- an alignment characterized by wide radii of curvature;
- levels of service between E and D for the four months of the survey.

Analysis of these data reveals that traffic conditions, especially in the north, are far from suitable. The design and geometric characteristics of the infrastructure must therefore be upgraded to satisfy the noteworthy traffic flows it must handle, especially during the summer months. Thus the infrastructure needs to be upgraded in terms of cross section and radii of curvature so as to guarantee a flow of traffic along the entire section in conditions of safety and comfort. It is to be taken into consideration that the future role of this infrastructure is as an urban trunk road. In fact, the town of Olbia is undergoing a process of expansion westward and in doing so has “skipped over” the present ring road. It is thus foreseeable that the infrastructure will take on an amount of local traffic and intracommunal mobility and for this reason it is necessary to install a divided carriageway in the urban section.

State Road 127 (section 3) presents an average speed of an isolated vehicle of about 80 km/h. The alignment features wide radii of curvature with the exception of some sections where not even the minimum radius is guaranteed. Despite this, the level of service calculated for this road is at an acceptable level since it is C (in accordance with the D.M. 05/11/2001) for all months of the survey.

Survey section 4 is along the provincial road that goes from Sant’Antonio di Gallura to Olbia. It is the shortest route connecting the two provincial capitals (Olbia and Tempio).

This itinerary is characterized by:

- good operational levels in the part closest to Olbia (level of service C in all months of the survey);
- the road is tortuous in the first part in the Tempio-Olbia direction;

It can be deduced that great benefits in terms of timesaving and regional accessibility would derive from works to upgrade the roadbed and build limited variations. In this sense, the study underscores the fact that connections between the two provincial capitals must be reinforced. This will turn out to be a strategic element in the future of the new Province of Olbia-Tempio.

As concerns State Road 125, it emerged that in the first section, starting from the Olbia ring road up to the interchange with Provincial Road 94 (section 7), criticality is to be found in the reduced cross section or more precisely, in the insufficient number of lanes to handle the traffic flows on it. The analyses have shown that for this section four lanes (two in each direction) ensure a level of service at the limit of C at the end of its useful life. In the subsequent sections it emerged that in some stretches the curvature values exceed the maximum ([1/r]max = 0.02), which corresponds to the minimum radius. This means that in these stretches the radii of curvature must be corrected.

Provincial Road 16 (section 8), which goes from the intersection with State Road 125 north of Olbia to Golfo Aranci, presents an average speed for an isolated vehicle of about 70 km/h and the alignment is characterized by rather wide radii of curvature over the entire route. Comparing these data with the levels of service calculated along this road (level of service = E for the months of May July and August and D for the month of October) it emerges that traffic conditions are far from being at an acceptable level. The design characteristics of the infrastructure are evidently not suitable for the heavy traffic flows on it, especially in the summer months. The infrastructure thus requires upgrading, not so much in terms of cross section, but in terms of radii of curvature and paved shoulders to ensure good visibility for overtaking along the entire route.

State Road 131 DCN (section 11) presents an average speed for an isolated vehicle of about 95 km/h. The section is characterized by wide radii of curvature. The conditions of the road are perfectly adequate to handle traffic flows since the levels of service calculated for the different months of the survey place it at level A.

The study also highlighted the need to upgrade and improve safety on the local roads going in the direction of the holiday resorts along the coast. From this derives the hypothesis of not limiting the design only to the strong itinerary represented by State Road 125, but also to evaluate the secondary local network which forms the network of elementary relations with the former.

The objective is obviously that of sharing the load among the different parts of the road network so as to avoid overloads in a single upgraded stretch, thus emphasizing the functions performed by some urban centres and weakening the role as service centres performed by others to the detriment of the region to which it refers.

7. EVALUATION OF ALTERNATIVE PROJECTS

Following the analysis of critical points identified by superimposing the analyses on the road alignment and the analyses of levels of service, different hypotheses were advanced concerning work on the critical sections of the layout. The works proposed involved the upgrading of the road section to a road of type C1 (in accordance with the D.M. 05/11/2001) or, in some cases, where the traffic loads were rather heavy (for example in the stretch found in section 7), even a section of type B1 was suggested.

As an indicator in evaluating the efficacy of the alternatives, we used the levels of service calculated for each hypothesis projected to the twentieth year.

To exemplify, we give the values calculated for the levels of service of some of the alternatives advanced for State Road 125.

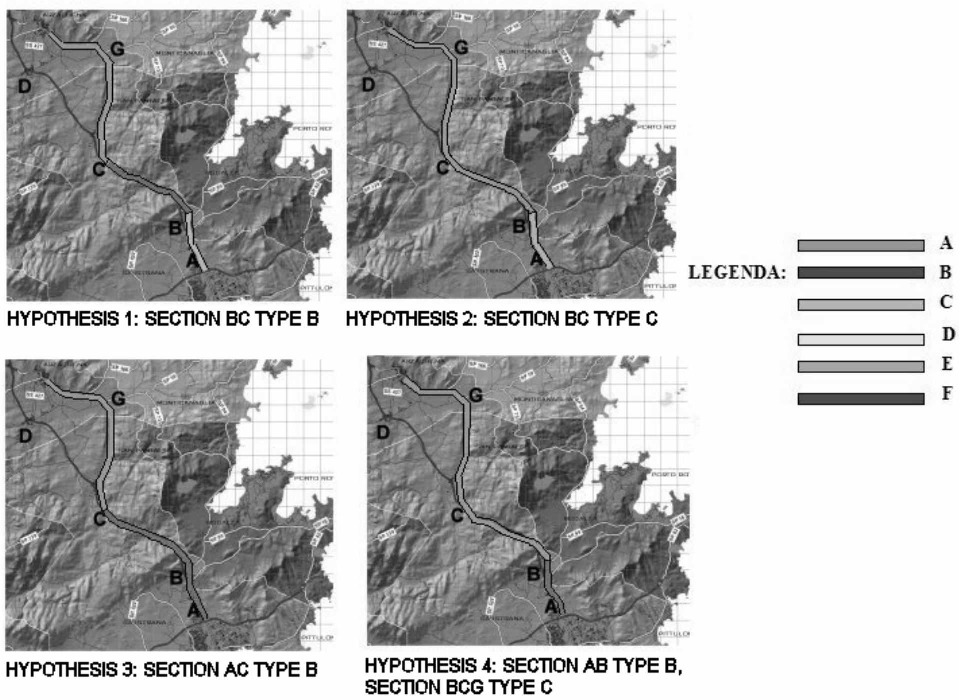

Figure 7 – Representation of the levels of service in the different hypothesis for State Road 125

The graphic representation of the levels of service obtained following implementation of the aforementioned works, gives us an indication of their effectiveness. This representation also allowed us to identify with a certain immediacy the best design solution to ensure good operation of the infrastructure.

Obviously the solution considered best was the one derived from a synthesis of the benefits produced in terms of functionality and safety, but also of construction costs, operating costs and environmental impact. Taking the latter aspects into account, for example, the best compromise for State Road 125 is represented by hypothesis 4.

Similar considerations were developed for all the roads in the network analyzed.

8. CONCLUSIONS

In this work we present the results of a research project conducted by the University of Cagliari for evaluation of the state of an infrastructural network with the aim of identifying criticalities leading to a decrease in its functionality.

The starting point was the analysis of the area served by the network, since one of the objectives of road design is regional reorganization based on the idea of maintaining the resident population.

The methodology called for the analysis of the geometric characteristics of the different sections by means of a procedure based on GIS technology and then evaluation of the state of functionality of the network in terms of levels of service, which were also used as indicators in evaluating the efficacy of the works proposed for implementation along each itinerary. In fact, the guaranteeing of adequate traffic flow conditions within the network's useful life was considered as an examination to establish whether or not the characteristics guaranteed through implementation of the works hypothesized were sufficient to upgrade the network.

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