Planning and management of mobility in natural protected areas

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SUMMARY

The attitude of the environment to tolerate the anthropic activities is limited and the concept of environmental carrying capacity reflects this limitation. On these premises it is self-evident the role of mobility management and the extension of the environmental carrying capacity concept to the flows of vehicles. From the mobility viewpoints it should be analyzed both the mobility needs of local communities and touristic flows and the infrastructural density of roads, railways and waterways. In this framework the paper describes some relevant results of an on-going research aiming to elaborate a methodology to allow the mobility in natural parks, sustainable and compatible with their institutional protection missions. On that basis, it has been developed a logic-mathematic model able to reproduce the mobility-environment relationships in various operational conditions, starting from the analysis of transport offer (operated services) and demand. The final purpose is the identification of: a) the effects of various choices in transport planning, both at long term and strategic level; b) the most effective policies of mobility management. The preliminary work was articulated in the following steps: 1) definition of protected area on the basis of ecological and socio-economic criteria and legislative constraints; 2) analysis of mobility needs in the protected areas; 3) reconstruction of the state of the art of mobility management in natural parks at European level; 4) analysis of used traffic flows measurement methods; 5) analysis of environmental impacts due to transport systems modelling (limited to air pollution and noise); 6) identification of mitigation measures to be potentially applied. The whole methodology has been firstly tested on the case study of the National Park of "Gran Sasso and Monti della Laga" and further validated on the National Park of "Gargano", both located Italy: i) the concerned area has been zoned according to the land-use peculiarities; ii) the local situations of transport infrastructure (roads and parking), services (public transport systems) and rules (traffic regulations) have been mapped with references to physical and functional attributes; iii) the mobility, both systematic and touristic, has been synthetically represented in an origin-destination matrix. By means of an assignment model it has been determined the distribution of flows and the corresponding average speeds to quantify gaseous and noise emissions. On this basis the environmental criticalities in the reference scenario have been highlighted, as well as some alternative scenarios including both operational and infrastructural measures have been identified. The comparison between the projects and the reference scenario allowed the

quantification of the effects (variation of emissions) for each scenario and a selection of the most effective management actions to be taken.

1. INTRODUCTION

1.1 History and context

Since ancient Roman times some first experiences of land protection are reported: Varrone ordered the establishment around Tarquinia of an area where deer, mouflon and hares were protected from hunting. It was a prototype of protected area, which includes the idea of safeguarding resources for a more rational use in favor of a superior collective interest. In modern times the extension of the land protection concept brings to the safeguard of the natural resources, to let them be enjoyed by future generations, mainly for conservation, education and scientific research purposes and to the different relevance assigned to these purposes corresponds the variety of modern protected area establishment and management criteria resulting in natural parks:

- in the USA (the first natural park was established in 1872 at Yellowstone) the privilege is for naturalistic-touristic aspects and the natural park is managed like a factory, where the visitor is driven to be integrated in the natural environment according to rigid rules;
- in Africa the main aspect is the safeguard from extinction the local flora and fauna;
- in Europe the concept of natural park is more complex and normally includes additional elements (e.g. population density, cultural and historical heritages), which enlarge the protection concept to a variety of assets and requires to council it with the public accessibility and the socio-economic development of the local communities.

Therefore the constraints must be imposed not to all the human activities, but only to those not compatible with consolidated local habits and traditions. The mobility is one of the primary activities, therefore in principle strictly related to local habits and traditions, nevertheless its sensibility to the modification of land-use may bring, if not correctly managed, may provoke devastating effects to the environment.

1.2 Selection and definition of protected areas

The identification of areas to be protected is normally arising from scientific studies in the concerned naturalistic sectors highlighting the peculiarities and exceptionalities possessed as far as geology, geomorphology, flora, fauna and/or landscape. Moreover, the demographic pressure should be limited, at least in the areas to be subjected to the highest levels of protection. Therefore, the final choice is normally based on a combination of ecological and socio-economic criteria, whose extensive nature is summarized in Table 1.

1.3. Legislation

The European legislation for the protection of natural patrimony is based on the following principles:

- Preservation of unrenewable genetic capital to prevent its depletion;
- Conservation of global ecological equilibrium by safeguarding flora and fauna's habitat;
- Development of ethical motivations for nature conservation.

Ecological criteria	Socio-economic criteria
Natural Diversity	Touristic potential
Natural integrity	Educational potential
Lives' dependency	Public health
Representativeness	Aesthetic value
Unicity	Local conflicts
Ecological autonomy	Economic relevance
Ecological productivity	
Vulnerability	
Extension	
Natural recoverability	
Institutional feasibility	
Accessibility	
Scientific interest	

Table 1. ecological and socio-economic criteria to select natural protected areas

Starting from basic principles fixed at International levels since 1973 (Washington Convention on international safeguard of animal and vegetal species under extinction threat) many European Directives entered in force.

The key milestone was the Directive 92/43 "Habitat" concerning the conservation of natural and semi-natural habitats of wild flora and fauna, on which basis a network of special conservation zones "Natura 2000" is established. On this basis the International Union for Conservation of Nature (IUCN), the world's oldest and largest global environmental organization, starts to work in strict connection with the EU, by fostering Commissions' initiatives in favor of:

- investments for natural protected areas in Mediterranean area, where the diversity of species is higher;
- increase of protected surfaces;
- strengthening of monitoring systems to assess the protection's effects;
- improvement of management and control systems to avoid destructive effects and decrease anthropic pressure;
- prioritization of natural protected areas on the basis of potential damages due to socio-political dynamics;
- development of sustainable tourism and other economic activities compatible with the natural vulnerability to avoid the depletion of local communities;
- support of collaboration and integration policies among EU countries.

The case studies are located in Italy, therefore a short presentation of the National legislative context includes the Law 349/1986, establishing the Ministry for Environment and providing with rules against the environmental damages and the Framework Law 394/1991 introducing the system for nature protection, which includes classification criteria for the protected areas, rules for protection and safeguard, planning and management instruments and the corresponding management bodies (Fig. 1). Therefore, the so called Plan of the Park is the key instrument to define the protected area structure and their perspectives, both in terms of safeguard and sustainable development and aims to regulate the following aspects:

- vehicular and walking accessibility;
- distribution of areas (zoning) by different uses and safeguard levels;
- constraints, land use assignment and implementation rules;
- services and equipment for social and cultural management;
- actions criteria towards fauna, flora and related habitats.

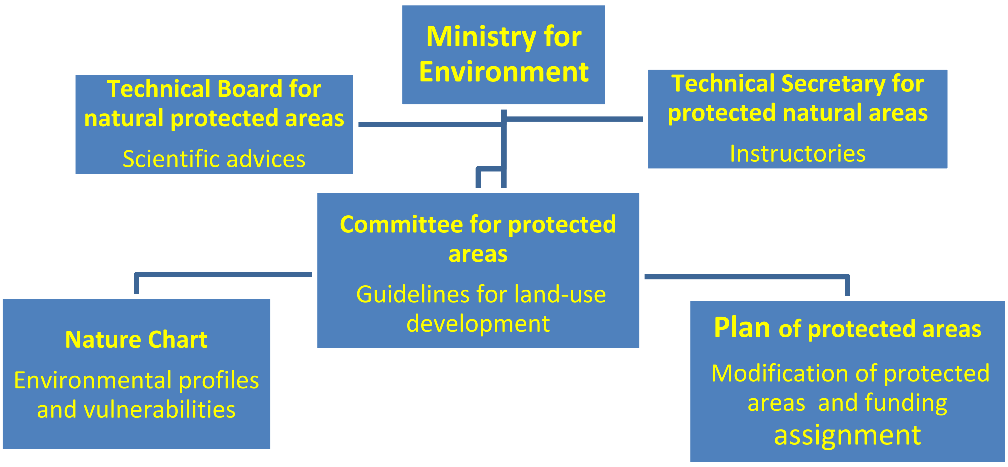

Fig. 1 - Bodies and instruments for Framework Law 394/91 implementation

The focus of the present paper deals with the first aspect, which has to be tackled on the basis of preliminary investigations dedicated to sketch the state-of-the-art of mobility according the land use zoning and activities location.

2. MOBILITY IN NATURAL PROTECTED AREAS

2.1. Mobility needs

Mobility in the natural protected areas satisfies various needs, which may be classified as follows:

- tourism, to be further differentiated according to the motivation and duration of the journeys, into holiday period, weekend journey, daily trip (picnic, etc.), excursion or alpinism, natural studies, photographic tour;
- work;

- emergency and rescue;
- regular inhabitants trips among villages and towns.

The most part of this mobility is characterized by high seasonal variability; moreover the touristic mobility may be further differentiated according to the distance between the origin of the trips and the protected area. The mobility behaviors inside the park are strongly depending upon the trip motivation, including organized groups, mainly travelling by rented buses, familiar groups, “soft” excursionists using main roads and surrounding areas, “hard” excursionists approaching more remote and physical engaging paths, etc..

2.2. Mobility management in European parks

The mobility management is a key issue to be approached in the park planning with different perspectives and multidisciplinary competences. In this respect the Pembroke-shire National Park Local Plan (UK) (Pembroke-shire Coast national Park, 1999) defined the objective to perform the required improvements of the road networks and to prevent the congestion, to reduce the atmospheric pollution, the energy consumption and the impacts on the areas surrounding the road network (e.g. by public transport systems use). The public transport plays a key role whenever the reduction of private vehicles flows is required. Again in the United Kingdom the first example of effective public transport based mobility management in a protected area was established (Yorkshire Dales National Park Committee, 1984): an integrated railway-bus scheme “Parklink” was managed by a single and collective ticketing system including the services provided inside the park. More recently similar schemes have been implemented in the UK by proposal of the National Park Authority (Dartmoor National Park Authority, 1997-1998). In Italy, the Adamello Brenta natural park (Parco Naturale Adamello Brenta, 1992) was the first to introduce a specific discipline to manage the access to the park based on the satisfaction of the mobility needs by public transport solutions, specifically addressing the architecture of vehicles satisfying sometime contradictory requirements (e.g. limited route dimensions, high panoramic visibility from inside) and the management, by prioritization, of mixed traffic. Another key policy in traffic management is the limitation of private traffic by applying a hierarchical use of basic (approaching trips) and secondary (internal trips) road networks. Particularly the functions of the secondary network are often determined starting from road geometry, heavy vehicles amount, internal mobility needs, visits management, nature protection measures and the conflicts among these peculiarities (Yorkshire Dales National Park Committee, 1984). Again, in UK the traffic restriction were applied at first in various contexts already more than 30 years ago (Curtis and Walker, 1982) on a weight limitation basis: 7.5 t along main access routes, 5 t along minor access routes and 2 t on the internal local routes network. In Spain the main focus (Parque Nacional de la Caldera de Taburiente, 1995; Parque Nacional de Teide, 1995) is on the regulation of flows in internal road network, introducing *de facto* the concept of environmental capacity of roads by limitation of the traffic affecting the sensible environmental components and introducing mitigation technologies of physical (noise) and chemical (pollution) factors. Coming back to UK, for the parking areas design criteria, it has been highlighted since long time (Yorkshire Dales National Park Committee, 1984; North Yorkshire and Cleveland Heritage Coast, 1995) that their location should be far from sensible areas, managed by real-time information systems to avoid parasite mobility, linked to them by not motorised links (mainly walking and biking paths), as well as natural barriers (e.g. vegetal fences, roads restrictions) should be introduced to avoid undesired parking.

3. TRAFFIC ANALYSIS METHODOLOGIES

The traffic analysis is a key activity to be developed before the implementation of any measure.

The typical methodologies to approach this analysis are normally involving:

- Identification of the study area by means of detailed cartography, including protected areas;
- Analysis of socio-economic activities location against protected areas;
- Analysis of geometrical and functional characteristics of transport network;
- Study area zoning according to land use and transport network morphology;
- Schematization of transport network in a graph;
- Studies on mobility demand;
- Reproduction of the present mobility framework: demand modelling and calibration.

The following steps are beyond the traffic analysis itself and represent the full application of the methodology to the study context:

- Infrastructural and operational measures identification: building up of scenarios;
- Evaluation of measures evaluation by means of simulation of scenarios.

4. RELEVANT IMPACTS ASSESSMENT

4.1. Impacts identification and relevance

The impacts potentially aggressive against the natural protected areas have been analyzed and classified in various groups synthetically described below. The atmospheric chemical pollution includes both the global effects of CO_2 (23% of the total emission worldwide are produced by transport systems) and the local effects (in brackets the worldwide contributions from transport systems) of CO (76%), NO_x (52%), HC (55%), benzene and PM (90%), Pb (50%): European and International restrictive rules on fuels are strongly fighting the emissions of combustion engines propelled vehicles. The atmospheric physical pollution corresponds to the concept of noise as mechanical perturbation of a gaseous mass resulting in local disturbing effects for human beings, animal and vegetal species (Bar, Favere and Rapin, 1980): transport vehicles of all modes are variously producing noise by different phenomena (mainly friction between wheels and rolling surfaces, engines operation and aerodynamics interaction between vehicles and atmosphere), which are normally tackled by active (source attenuation) and passive (barriers construction) measures according to zoning limits depending upon local land use (Presta and Ricci, 2003). The lithosphere is potentially attacked in its two main components: soil (erosion due to modification of morphology and dispersion of aggressive essences by vehicles) and subsoil (modification of stratigraphy, sediments, mineralogy, paleontology, hydrogeology, etc. due to transport infrastructures intrusion). Moreover, the mechanical pressure on lithosphere is producing vibrations, again resulting in disturbing normal human activities and habitats of animals and plants: the mitigation of these effects is based on structural measures on generating infrastructures and receiving buildings. The hydrosphere is potentially threated superficially (natural inundation favored by transport infrastructures and contamination of water courses) or deeply (variation of water level due to dredging, accidental and continuous contamination). The biosphere is potentially attacked by mobility effects by various impacts: soil subtraction, fragmentation and solation of biotopes (ecological corridors interruption), polluting essences dispersion. Finally, the natural landscape may be treated in its natural and anthropic components as well as in cultural and historical heritages by the intrusive presence of punctual (e.g. parking and stations) and linear (e.g. roads, railways, and ropeways) infrastructures. In the following analysis the relevance assessment of impacts has been further developed only for the most frequently aggressive factors against natural protected areas under normal operational conditions of surface transport systems: air pollution and noise.

4.2. Impacts simulation

The effectiveness of infrastructural and operational measures aimed to grant the mobility and to safeguard the natural protected areas is evaluated by means of simulation models. In particular the simulation of air pollution in the proposed methodology is developed by an original framework model based on consolidated sub-models approaching various affecting parameters (Chiquetto and Balckledge, 1998) (Fig. 2). A similar approach is used also for forecasting noise levels; the model scheme, based on consolidated sub-models (Farina and Brero, 1996), is synthetically described in fig. 3.

5. IMPACTS MITIGATION AND COMPENSATION

Measures to mitigate and/or compensate the impacts on the sensible environment typical of the protected areas have been developed with reference to air chemical pollution and noise. The measures have been selected according to their effective implementation in natural protected areas. So, for the protection against the pollution from road traffic, the analyzed measures are:

- passive infrastructural: green barriers (continuous tree alignment) capable to absorb and filter undesired particles by leafs;
- active operational: traffic control according to different disciplines (ban to vehicles not satisfying emission limits, moderation of flows, permanent or temporary

generalized ban to traffic).

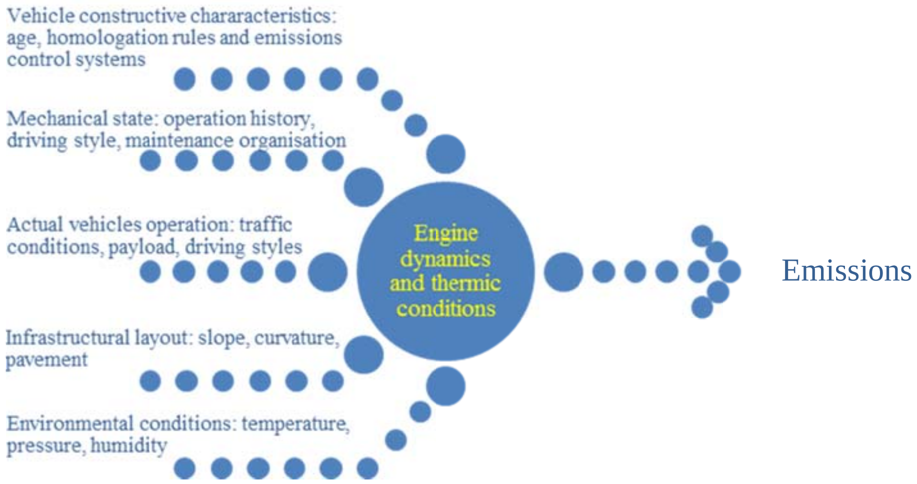

Fig. 2. Scheme of relationships among environmental factors, vehicles performance and gaseous emissions

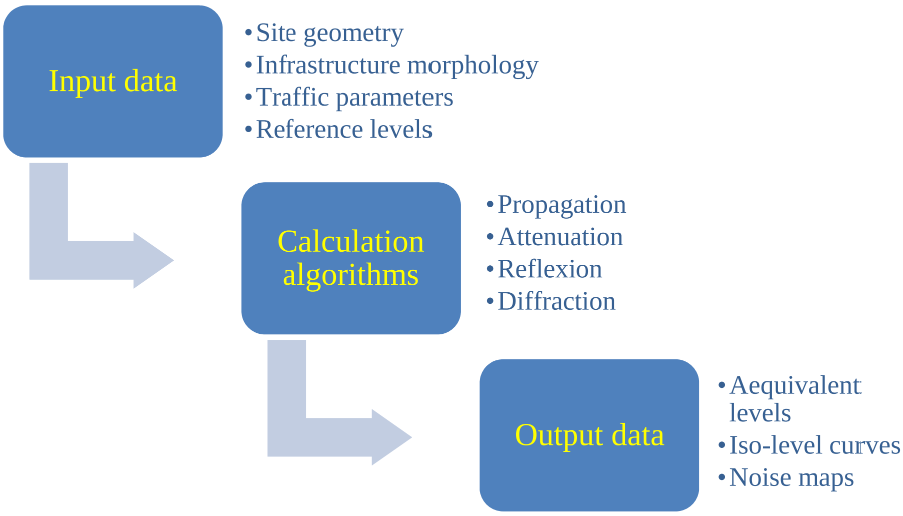

Fig. 3. General scheme of noise forecasting methods

For the protection against the pollution from rail traffic the only analyzed measure is the electric traction operation or, at least, the use of low polluting and well maintained locomotives. The compensation of pollution effects is normally performed by means of trees planted in the protected area (local compensation) or somewhere else (global compensation) or by limitation of pollution from fixed sources located nearby.

The protection against noise is possible thanks to:

- active measures on vehicles, particularly acting on making more silent engines operation and friction on rolling surfaces, or on traffic, by avoiding congestion effects and excessive speed;
- passive measures on pavements (noise absorbing), on structures (anti-vibration equipment of viaducts and tunnels), with barriers (natural and artificial), on surrounding buildings.

The only compensation measure for noise effects is the possible modification of land use, that is nearly very difficult to be applied in the natural protected areas.

6. CASE STUDY METHODOLOGY APPLICATION

6.1. Case study description

The National Park *Gran Sasso e Monti della Laga* is located in the central Italy, it was established in 1991 over a surface of about 1500 km^2 over 3 regions (Abruzzo, Lazio and Marche), 5 provinces (L'Aquila, Pescara, Teramo, Rieti and Ascoli Piceno) and 45 municipalities. The high mountains environment makes difficult the internal communications. The most relevant transport infrastructure is the A24 motorway and its long tunnel under Gran Sasso mountains with two stations laying inside the protected area. The other main roads are the National Roads SS4, SS80 and SS81 and the secondary rich network, often extended over the real needs of the low population regions. The railway links are poor both on the east (secondary not electrified west-east lines linking Teramo and Ascoli Piceno to the Adriatic coast) and west side (the secondary and not electrified north-south line Terni-Rieti-L'Aquila-Sulmona) with a limited amount of stations and a poor public transport system linking them to the most attractive Park areas. As a consequence the accessibility to the park is today based on road systems.

6.2. Transport systems network

The first activity was the acquisition and the storage of the mobility-environment systems data in a dedicated GIS database starting from a 1:50000 digital cartography. The second stage was the identification of traffic zones starting from the most detailed available zoning produced by the National statistics institute (ISTAT) and progressively aggregating them according to the local land use and the location of attractive touristic zones: the final adopted zoning includes 53 traffic zones. On this basis, the transport network has been represented by an overlaid graph including both real nodes and links of the road and rail networks and centroids representing potential mobility sources/pits internal and external to the protected area. The elements of the graphs have been characterized with their geometrical and functional features on the basis of the available data (Motorway, National roads and railways) and a dedicated on site investigation, covering all the secondary road network, performed by the compilation of sheets including the information summarized in table 2. On the basis of the resulting characteristics it has been associated to each link and node a flow curve (relationship between vehicular flow and speed).

6.3. Mobility analysis

The present mobility scenario has been defined on the basis of the procedure including the following macro-phases:

- Systematic mobility reconstruction;

- Assignment model application and calibration;
- Update of systematic mobility by means of flows measured by road management company (ANAS);
- Touristic mobility reconstruction by means of measured flows;
- Assignment of systematic and touristic mobility by means of the calibrated model;
- Application of air pollution and noise forecasting models for systematic and touristic mobility;
- The procedure is represented in fig. 4 scheme.

Information	Detected features
Investigation timeframe	Day and time
Denomination	Code and Name
Typology	Urban/Extra-urban
Length	Numerical value [m]
Functional class	7 classes (from Highway to Local)
Pavement	4 classes (from bitumen to incoherent)
Deviousness	5 classes (from straight to multi-curves)
Slope	4 classes (from <3% to >8%)
Lanes	Numerical value
Lanes width	Maximum and minimum values [m]
Shoulders width	Average value [m]
Sidewalk width	Average value [m]
Allowed directions	1 or 2
Bans	Banned vehicles categories
Speed	Maximum allowed value [km/h]
Bus stops	Numerical value
Reserved bus lane	Yes or No
Cycling path	Yes or No
Parking places on the roadway	Numerical value of total and occupied places
Parking places out of the roadway	Numerical value of total and occupied places
Traffic light phases	Cycle, Green time Straight, Right and Left [s]
Presence of side buildings	4 classes (from absent to continuous)
Height of buildings	3 classes (< 2 floors to >5 floors)
Buildings-roadway distance	Average numerical value [m]

Table 2. information collected during the on-site investigation on the secondary road network

6.4. Identification of measures

The measures were identified on the basis of a step-by-step implementation of scopes, actions and strategies (fig. 5). In particular the main identified actions for public transport system improvement and promotion are:

- Increase of accessibility and regularity;
- Introduction of special fares;
- Promotion of public transport benefits;
- Integration of the existing services;
- Extension of existing services;
- Development of innovative systems.

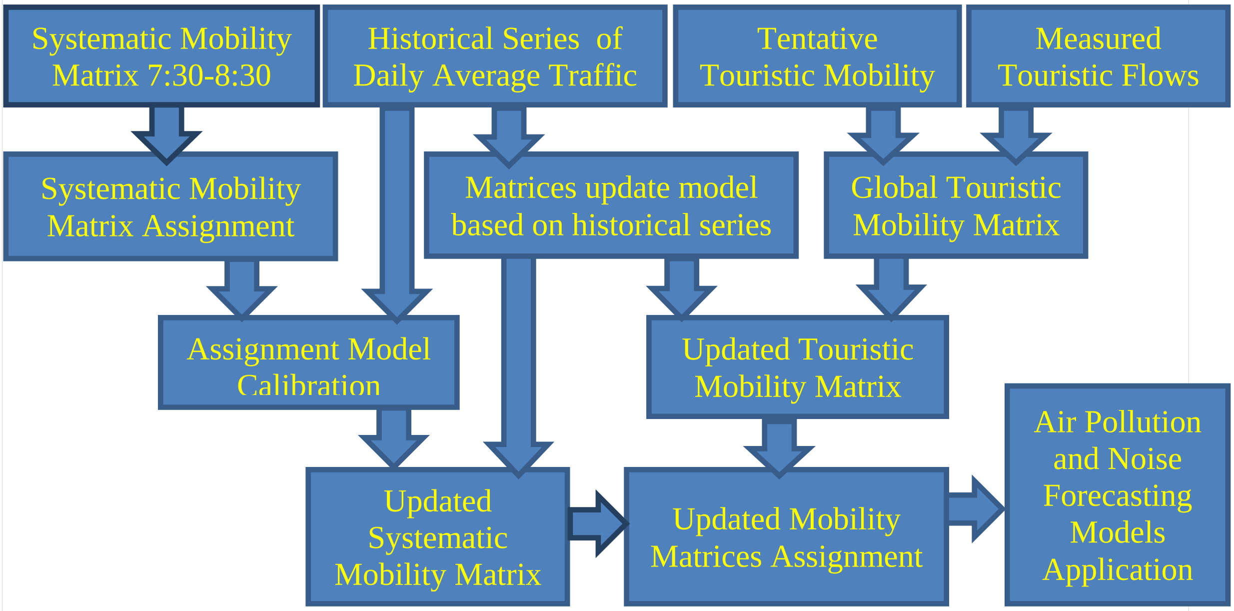

Fig. 4. Mobility scenario reconstruction procedure

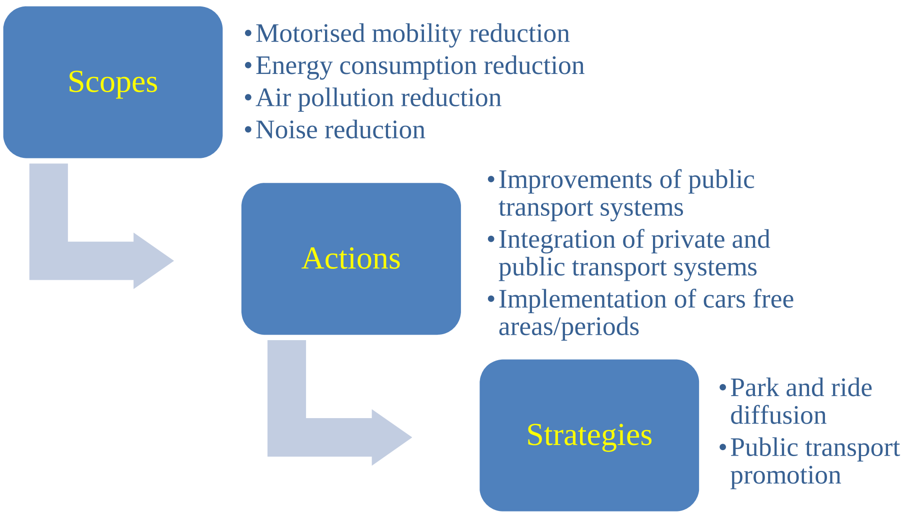

Fig. 5. Scopes, actions and strategies for measures identification

The following actions have been dedicated to the identification, on the basis of simulations results, of specific areas where private mobility is completely banned whilst the private mobility and allow full accessibility is allowed by the improved public transport services. The selected areas and the corresponding park and ride measures are synthetically described in table 3.

Area	Park and Ride scenarios	Estimated traffic redistribution
Gole del Salinello – Ceppo	Parking area (240 places) Bus service (60 places / 8 minutes)	No alternative routes
Lago di Campotosto	Parking areas (250 places) Bus services (2 x 60 places / 8 minutes)	Negligible internal touristic mobility
Campo Imperatore	Parking areas (300 places) Bus service (60 places / 12 minutes) + Cable car	12% traffic deviation on other routes
Prati di Tivo – Rifugio del Fontanino	Parking area (400 places) Walking and cycling	No alternative routes

Table 3. scenarios with park and ride implementation

6.5. Measures assessment

The effects of new scenarios have been globally estimated, by means of assignment and forecasting models, both in terms of mobility indicators (length of journeys and average speed) and gaseous emissions (CO, NOx, HC and PM). Results are summarized in table 4. The effects on noise levels have been locally relevant but not globally valuable due to the not additive effects and indicators.

Indicators	Present scenario	Implementation of new scenarios
Total journeys of private cars [km]	212,170	181,382 (- 15.5%)
Average speed [km/h]	84.9	84.5 (- 0.5%)
CO emissions [kg/km]	0.889	0.878 (- 1.2%)
NOx emissions [kg/km]	0.203	0.179 (- 11.8%)
HC emissions [kg/km]	0.119	0.105 (- 11.8%)
PM emissions [kg/km]	0.019	0.017 (- 5.9%)

Table 4. global effects on new scenarios implementation

7. CONCLUSIONS AND FURTHER RESEARCH DEVELOPMENTS

The research work synthetically exposed in this paper allows quantifying and comparing the effects of operational and infrastructural measures to reduce the impacts of the mobility on a sensible area from a strictly naturalistic viewpoint without penalization for its fruition by tourists and other accidental visitors to these protected area. Starting from the analysis of the peculiarities of the protected areas, the features of the transport network and the mobility needs, the diagnosis of the emerging criticalities led to identify the potential safeguarding measures to compose project scenarios. The process is completed by the assessment of the scenarios themselves from different perspectives. The application of the whole procedure to an Italian case study, the “Gran Sasso and Monti della Laga” natural park, allowed to identify some specific measures of mobility management, with a view to banning private traffic and to satisfy the mobility needs by non-motorized solutions or by public transport systems. The relative advantages of these solutions are relevant and could be further increased by operating public transport systems with low (or locally zero) emissions vehicles. Another application of the proposed procedure and models, although not described in the present paper, was developed with reference to the “Gargano” natural park located in the Southern Italy (Puglia region). Further developments of the research topic could include:

- Application to a more extended area, including larger and multimodal transport networks and potentially stronger flows re-distribution effects;
- Inclusion in the procedure of models approaching additional relevant impacts (e.g. those listed in §4.1).
- Introduction of dynamic, instead static, modelling of gaseous emissions taking into account instantaneous values of speed and acceleration.

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