Chapter 14
Geo-Information Technologies in Support of Environmental and Landscape Planning

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14.1 Introduction

Knowledge bases have been built to support three environment and landscape planning processes to assess and decide where and how to:

- locate environmental systems (waste disposal and processing, water supply and processing) in areas included within the EU's Objective 2 programmes for the Liguria Region;
- design strategies, zoning and rules for the plan of the Cinque Terre National Park, which prioritise high value landscape preservation; and
- establish a new layout for strategic railway and motorway infrastructures for the metropolitan area of Genoa, tackling the question of compatibility with the affected areas

The knowledge bases, built for the three planning support systems (PSS), require: the investigation of multiple phenomena to organise data, the analysis of data relationships to elaborate meaningful information and the formulation of synthetic models to represent the environmental systems involved in the planning process. Geographical information systems (GIS) projects, characterised by similar methodological procedures, were designed to process the complex knowledge, developed on the basis of a three-levels interpretation and cognitive procedure.

At the first level, official data available from public administrations and local institutions were processed on the basis of general concepts, categories of phenomena, feature classes and values consistent with the models, defined for each environmental and/or landscape planning process. At the second level, the geographical data and thematic maps were analysed. The data were processed, on the basis of morphological and topological approaches, to generate information about the geographical distribution and the simple relations between the phenomena considered

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by the models. At the third level, manifold relations between data and information were considered and analysed. The data and information, implemented at the first and the second level, were processed on the basis of the framework of the relations of the models to produce geographical representations that synthetise in an iconic way the environment and/or landscape knowledge.

The innovative aspect of this method lies in the transfer of conceptual models, used to interpret the environmental systems and to represent the landscape profiles, into the methodological procedures adopted to organise the data and to query the database. For this reason, the aspects common to all three experiences were illustrated, which are significant not only in terms of the technological instrument adopted, but above all for the way in which they were used.

In the following sections, the general outlines of the shared methodology are introduced, i.e. the theories and methods followed on the three-levels of the cognitive procedure, in order to reproduce the environmental systems on which planning operates. Subsequently, an explanation is provided of how the general methodological approach was applied in the three cases of construction of the complex knowledge supporting the environmental and landscape planning systems. The chapter concludes with some suggestions for further methodological and research development in the area.

14.2 Conceptual and Methodological Background

The knowledge building projects, to support the three planning systems, are all based upon general approaches, sharing a conceptual model to describe what the environmental system is and which cognitive procedures are required to represent it via GIS technologies. Environmental aspects are crucial in the production of knowledge; a conceptual model regarding the 'environmental system' was our previous concern.

Individuals and their communities carry out activities that establish relationships with and modify the environmental system in which they live. The new environmental systems, the landscape transformations and the new projects for railways and motorways not only represent additions, but also interrelate with and modify existing environmental systems and/or landscape profiles. In order to decide which projects and transformations should be acceptable, we should select those phenomena, elements, structures and relationships that are significant for the objectives and the assessment of the environmental and landscape planning process.

At the theoretical level of 'environmental system' we considered the environmental system accordingly as a unit of various phenomena with interrelated structures. We assumed the phenomena are composed of many elements; the elements are interrelated in structures; the elements and structures are organically connected into a complex, holistic and hierarchic environmental system: complex as it is made up of many elements, which are related to each other; holistic, as each of their elements is implicit in all the others; hierarchic, as we can represent the environment at different levels from the more general to the more detailed of defination and territorial dimensions. Each more general level implicitly contains those more determined, which, in turn, inherit the concepts and the categories of the more general (Frixione 1994; Marchetti 2002). In operational applications of the conceptual model, we could not examine the whole environmental phenomena, elements and relations (Alexander 2005; Salingaros 2000). In moving from the theoretical considerations to the operational implementation into the planning process, we should activate only those relations relevant to their purpose (Bertalanffy von 2004; Le Moigne 1995; Salingaros 2007; Waldrop 1996).

We envisaged the following environmental system: in the first case, an environmental system consisting of buildings, houses and inhabitants, which determine different types of settlement; in the second, an environmental system consisting of natural and antropic phenomena, which determine different rural organisation and landscape profiles; and in the third, environmental systems of the urban, rural and natural areas, in relation to the existing planning systems and transport network.

Before illustrating the three study cases, it is useful to summarise also the conceptual model we used to categorise the objects of reality. To data representing the objects we attributed implicit concepts and explicit properties, in order to improve the environmental systems and/or the landscape profiles. Concepts are mental representations of reality, which codify experience through categories; categorizing reality is a mental process, which considers objects as parts of a whole. The categories are made up of a series of objects whose properties are not visible (implicit or intrinsic). Because they depend on the concepts (mental pictures) they represent as well as on reasoning. Concepts are found at different hierarchical levels with different degrees of generality and abstraction (e.g. building-house-terraced house). The superordinate concepts create fewer logical inferences than the subordinate ones. A class is the series of objects with explicit properties (characteristics) attributed to them (e.g. three-storey houses, green-coloured houses). Through concepts, categories and feature classes, we associated geographical objects (data) with the phenomena constituting environmental systems. The codification of the cognitive experience through concepts enabled us not only to structure simple data, but also to carry out analyses, which produced derived information and directed reasoning which, in turn, yielded complex and synthetic knowledge.

We developed the cognitive procedure to build up knowledge about the 'environmental systems' at three levels, where the phenomena, elements and relations have been filtered through the concepts, categories and feature classes, relating to the models of environmental systems (Brachman and Levesque 1985; Retake 1995; Smith 1995; Zilli 1999). At the first level (Fig. 14.1), we associated the environmental system with concepts, categories of phenomena, classes of objects/elements and their attributes; moreover we selected belongings and hierarchical relations between the attributes. We broke down analytically the environmental system into sub-concepts: the *natural environment* subsystem, the *man-made environment* subsystem, and the *civil environment* subsystem. We considered only the physical phenomena

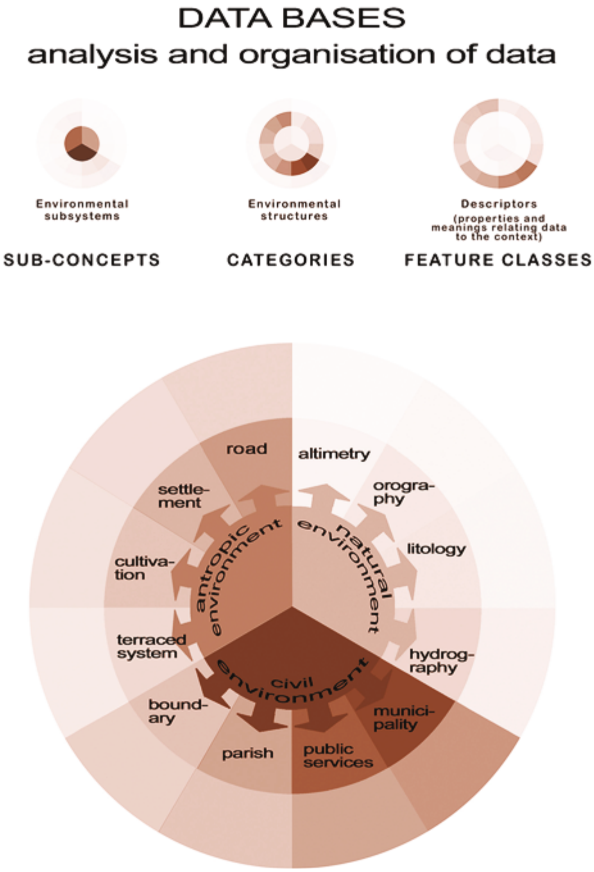

Fig. 14.1 Data-base chart

and ascribed to each one of the three sub-concepts. To the natural environment categories we associated the physical phenomena which characterise the natural features of a specific geographical context such as air, water, soil, spontaneous shrub and/or vegetation. To the man-made environment categories we associated the phenomena which have modified the natural asset of a geographical contexts such as settlements, roads and connecting infrastructures, cropping and farming. To the civil environment categories we associated the phenomena relating to the intangible and symbolic structures established by man in order to organise the society, the economy, the institutions, the culture: religious, civil and administrative poles, administrative and cultural borders, property limits, cadastre layout, symbolic buildings, for example.

We analysed the available data: ascribing each of them to one of the three subsystems (natural, anthropic and civil), assigning each to different categories and classifying each by different properties and attributes. We catalogued, selected, conceptualised, categorised and classified the data, implemented the database and drafted thematic maps (Laurini 1992; Laurini and Milleret-Raffort 1989; Oosteron

1993). The term ‘descriptors’ is used for the data representing the objects with properties and attributes, relating to the planning systems issues.

The same conceptual model produced different representations for each of the three PSS, not only because we considered different categories of phenomena, but also because of different meanings (concepts and attributes) of the same phenomena and elements. We used the same data in a different planning context with different categories, properties and meanings according to different issues. For instance, we used the same data from the Liguria Region technical map-land cover and settlement-albeit with different meanings for the Park plan and evaluation of the rail and motorway projects. In the first case, we analysed data with meanings that represent urban concentration and functions, whilst in the second case, we analysed the same data with meanings that represent landscape forms and profiles.

At the second level (Fig. 14.2), we analysed and reconnected the simple relationships between the elements (descriptors) in an attempt to reconstruct — the environment system. We described physical and spatial phenomena and their simple relations in the light of the decisions of the planning systems and analysed the morphological configurations of the geographic data and their topological relations. We carried out quantification operations in order to identify size, weight and recurrence relations and qualification operations in order to identify form, polarisation,

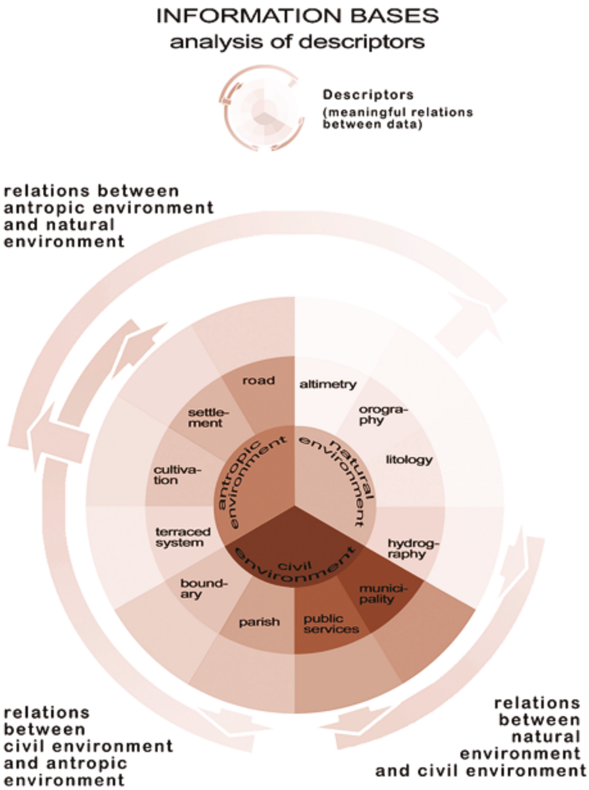

Fig. 14.2 Information-base chart

structures and reciprocal correspondence relations. We implemented the information base, representing a second level of data obtained through basic geographical data processing. We drafted maps, generated by the basic thematic maps, representing the morphological structure of the phenomena and their correspondence (Berry 1995; Bailey and Gatrell 1995; Longley and Batty 1996). ‘Descriptors’ represent not only original data, but also the data resulting from their interrelations.

At the third level (Fig. 14.3), we reconstructed the environmental system according to the conceptual models adopted. We produced a synthesis of data and information, generating models of environmental and/or landscape systems. In order to represent the simultaneous and structured occurrence of multiple phenomena, we processed data synthetically rather than analytically and adopted the selective and synthesis-oriented tree-structured logic so as to identify meaningful relationships for the context of each planning process. We subjected the data and information to multiple querying, in order to define territorial entities indicating unitary environmental systems and corresponding landscape profiles. We implemented the knowledge base, representing a third level of data, which was obtained via the synthetic, iconic and semantic processing of data and information bases. At the end, we drafted maps representing synthetically the environmental systems and the corresponding

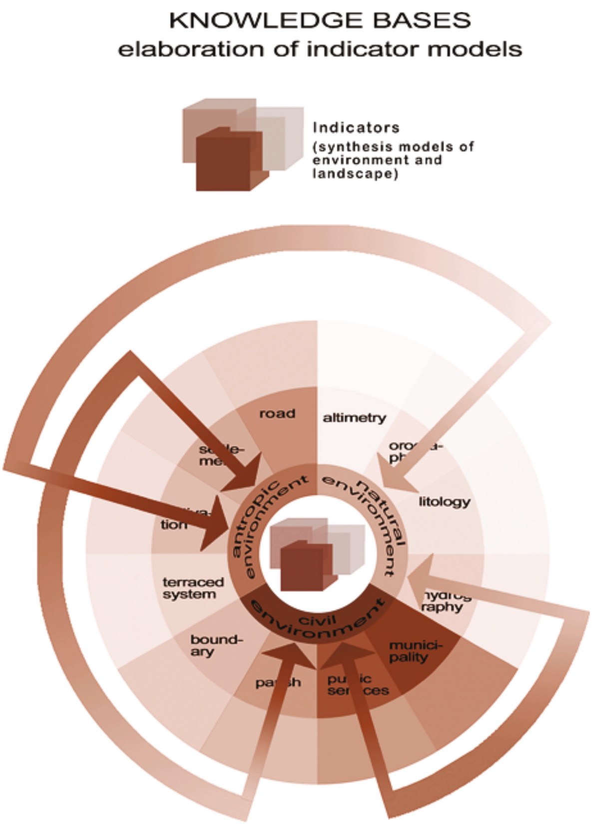

Fig. 14.3 Knowledge-base chart

landscape profile (Bessie 1999; Goodchild 1993; Morin 1993). ‘Indicators’ are the synthetic data corresponding to different environmental systems and/or landscape profiles.

14.3 Three Experiences of Methodology Application

14.3.1 The Population and Housing Database Organised on the Basis of Environmental Processes of Urban Extension

This project was realised on behalf of the Liguria Region’s Environment and Territory Department. It was implemented in those areas of the Liguria Region included within the EU’s Objective 2 programmes that represent these most urbanised of the Region. Information and knowledge produced should enrich SITAR’s data, information and communication technology (ICT) instruments and geographical information systems (GIS) projects, providing support for the Liguria Region’s environmental planning design and control. For the areas already urbanised, it supports the decisions about the planning of environmental systems such as urban waste treatment, water supply and control of pollutant emissions. For the new urbanisation, it supports the procedures evaluating the environmental impact of new residential development, the definition of zones and rules for the plans of constituent of the municipalities.

In the operational application of the conceptual model to different cases of the planning process, we consider only those phenomena, elements, categories, properties, *et cetera,* that can be linked to the tasks and objectives of the planning process and to the human activities involved in it. In this case, the human activities that should be considered are connected to producing, collecting and to processing the domestic waste and to consuming water and electric power for domestic uses. The environmental system, directly linked to these activities, is the environment of the urban and regional settlement, and the most significant phenomena that interact into the system are the dwellings and the communities that people live in.

The purpose of the project is to process the numerical and quantitative data, produced by the Italian Statistics Institute’s (ISTAT) 1991 Census, so that they can generate environmental and qualitative information and knowledge. We had to resolve the general cognitive problem to process the numeric available data, concerning the buildings and the demography, so as they produce not only quantitative knowledge, but also qualitative knowledge about the geographical distribution (morphology) of the forms and the structures of the settlements and of the way of dwelling of the communities and inhabitants.

The first operational problem was to select the data and to assign them the meaning useful to represent the form of the settlement and type of dwelling; in other words to identify the ‘descriptors’ of the phenomena considered. The second problem was to analyse the geographical distribution of the phenomena characterising the settlement form and type of dwelling; in other words to analyse the geographical distribution and consistency of the 'descriptors' and to classify them. The third problem was to identify the manifold relations between the 'descriptors' that allow one to indicate the territorial entities where the settlement environmental systems are organised and structured; in other words to produce the 'indicators' of the geographical distribution of different settlement environmental systems. The data were processed according to a three-level cognitive process (Fig. 14.4).

At the first level, the database was built by analysing, organising and geo-referencing numeric data. The original data, taken directly from the household census sheets were catalogued, aggregated and geo-referenced. Conceptualisation of the settlement environmental system refers to two sub-concepts of built-up and civil environmental sub-systems. The first is represented by the data on houses and buildings and the second by the data on the inhabitants and the families. To these concepts, categories were associated that can express useful meaning to represent the settlement form the type of dwelling and the way of living in the houses. In the case of the house concept, the categories were associated with the house structure, the use and the comfort of the property. For the building concept, the categories were associated with the structure, use and age of the building. The categories associated with the inhabitant concept were identity, cultural level and job. Finally, for the family concept, the categories were associated with structure, property of house and social condition. Then to each category values were given to the feature classes, as illustrated in Fig. 14.4. The value of each numeric datum, extracted from the household census sheets, was associated with the geographic coordinates of the centre of the corresponding census section. They represent the first level 'descriptors'.

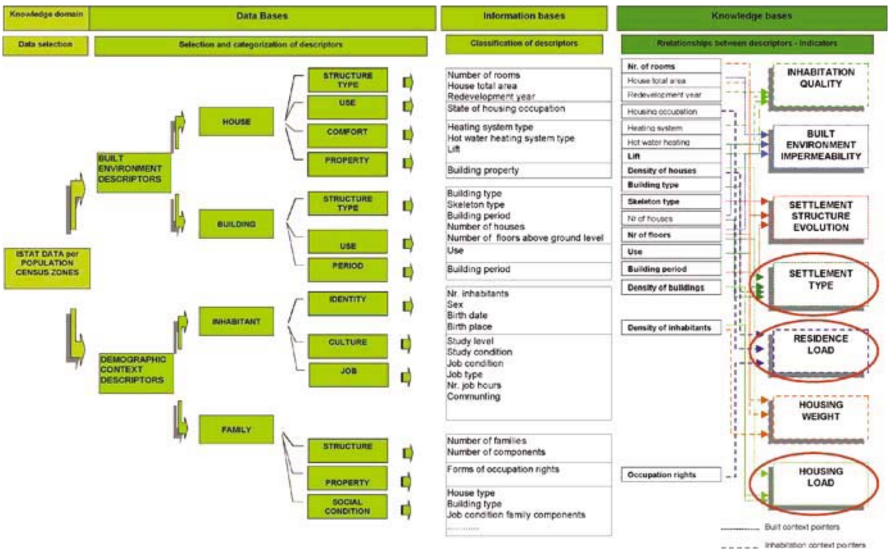

Fig. 14.4 The cognitive procedure: a methodological outline of building up knowledge

At the second level, the information base was established by the geographic processing of the first level data. Each census section is assigned a dominant value for each class of data, which represents conventionally all the present values. The 'descriptors' were assigned value classes, created *ad hoc* by calculating the parameters of the values of each class on the basis of analyses carried out on the all the values present in the Objective 2 areas. These data describe the geographical distribution of the 'descriptor' values on the census sections. Thematic maps illustrate how the descriptors are distributed in the territory of the Objective 2 areas (i.e. their morphology). At the third level, the knowledge base was constructed by means of multiple geographic processing of the first and second level data. The data were subjected to multiple querying, formulated by following a conceptual model that organised the data in such a way that it was possible to identify different environmental systems relating to the settlement, housing and dwelling. These data describe the geographical distribution of the 'indicator' values on the census sections. A breakdown was obtained of municipality territories into environmental units characterised by different types of settlement, types of dwelling and ways of living. Three such indicators were produced: 'settlement type', 'housing load', and 'residence load'.

The indicator 'Settlement type' represents the geographical distribution of various forms of settlement, distinguished from one another in terms of different densities, different aggregations of buildings and houses and different uses. It was constructed on the basis of relationships amongst the descriptors of the structure

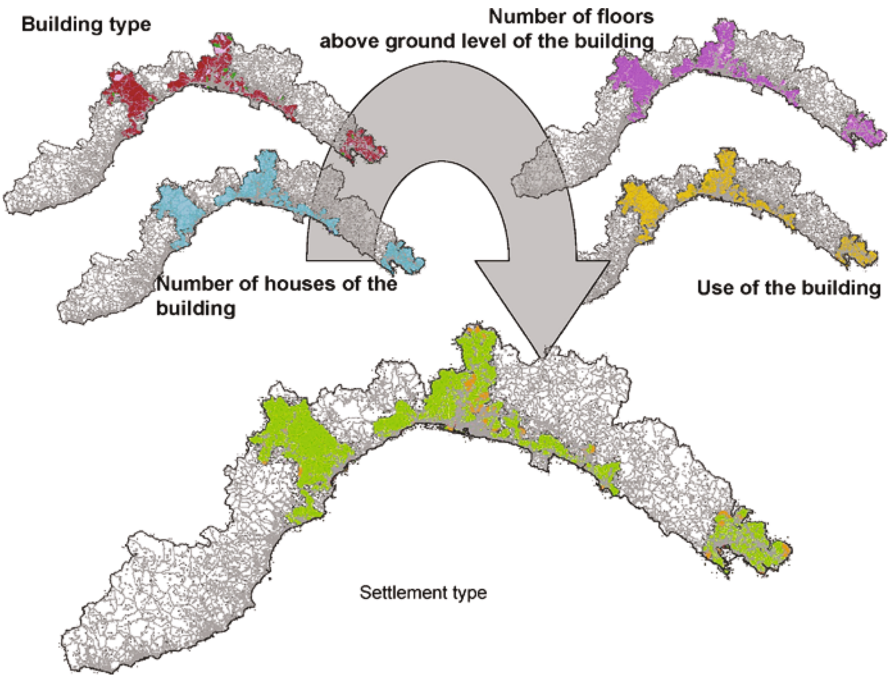

Fig. 14.5 The building up of the 'settlement type' map

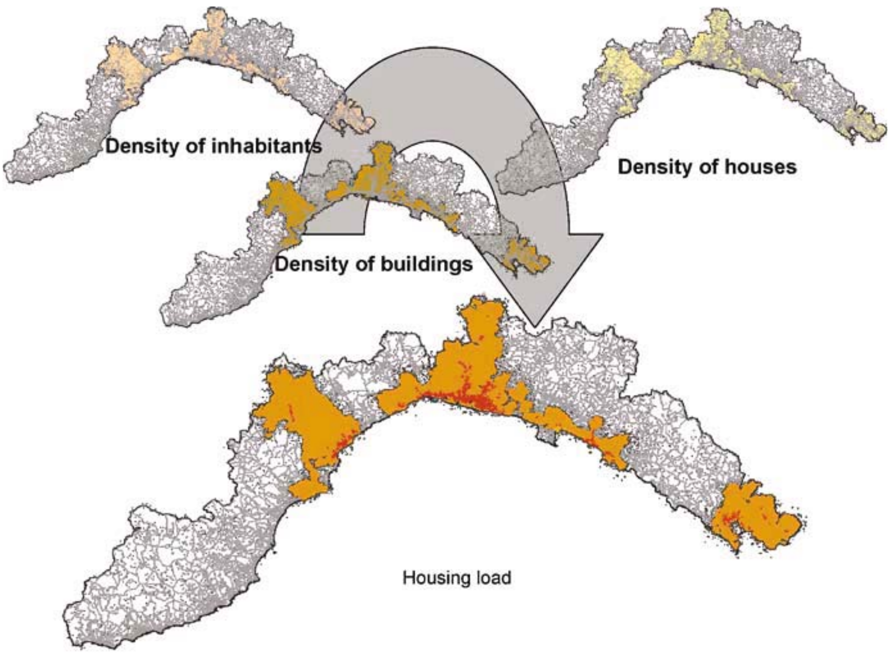

Fig. 14.6 The building up of the 'housing load' map

of buildings, of the number of houses per building, of the number of floors above ground level in the buildings and of the uses of the buildings. The indicator was then assigned values representing the relationship between the settled and unsettled spaces: 'closed' if the ratio was in favour of the first; 'semi-open' if the ratio was equal; 'open' if the ratio was in favour of the second; 'empty' if there were no settled spaces (Fig. 14.5).

The indicator 'housing load' represents geographical distribution of various types of dwelling, relating to the characteristics of the houses and of the inhabitants. It was constructed on the basis of relationships between the descriptors of the density of buildings per square kilometre, the density of houses per square kilometre and the density of inhabitants per square kilometre. The housing load was calculated exclusively with regards to settled spaces. The values are: 'high', 'medium' and 'low' (Fig. 14.6).

The indicator 'residence load' represents the geographical distribution of the various ways the inhabitants live in the houses, relating to the temporary or permanent duration of stay, to the property and to the house characteristics. It was constructed on the basis of relationships between the descriptors of the state of housing occupation, of the forms of occupation rights (i.e. ownership, tenancy) and of the density of homes per square kilometre. The residence load was calculated exclusively with regards to settled spaces. The values are: 'high', 'medium' and 'low' (Fig. 14.7).

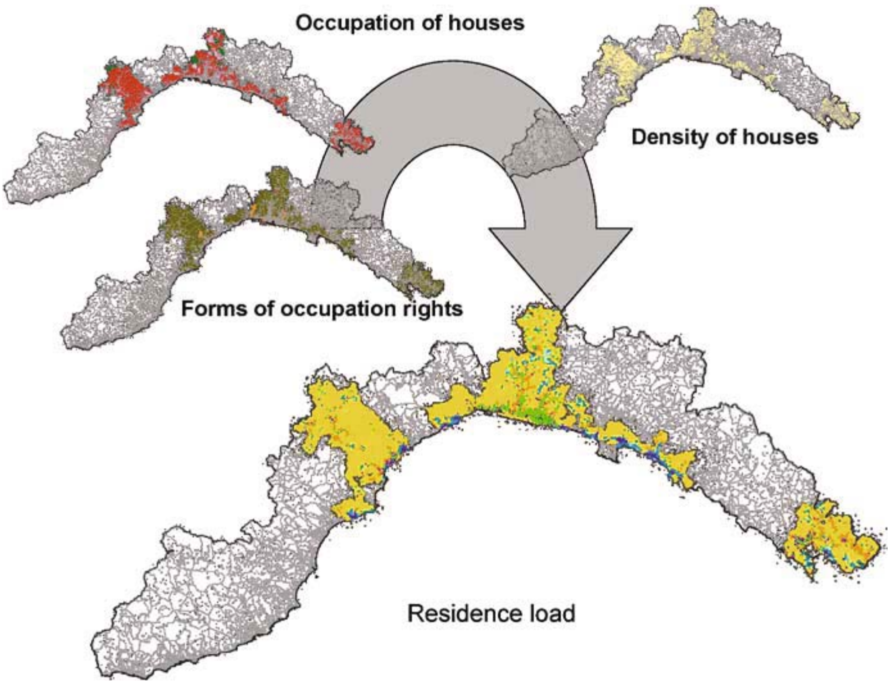

Fig. 14.7 The building up of the 'residence load' map

14.3.2 Study of Foundation Description (Descrizione fondativa) Supporting the Cinque Terre National Park Plan

This project was carried out on behalf of the Cinque Terre National Park as part of drawing up the Park Plan, requiring the official documentation of a 'Foundation Description'. The document represents the knowledge which logically and clearly justifies the choices to design the zoning maps and to establish the rules and the norms regulating the transformation of different zones of the plan. The first divides the territory into zones on the basis of a weight of natural values, whilst the second establishes those actions permitted in each zone.

The territory of the Cinque Terre was established as a National Park as a result of its natural value. However, the area's UNESCO heritage site status is also due to its man-made terraced landscape. The Park Plan, therefore, has to protect at the same time both the Cinque Terre's natural environmental system and its rural terraced landscape. Italian law establishes that the plans for the parks should divide the territory into four zones, where the possibilities of transformation increase as the value of the natural environment decreases: zone A involves all over preservation; zone B is orientated preservation; zone C is conservation areas; and zone D involves urbanised areas and coastal centres.

The Foundation Description should produce knowledge that recognises the Cinque Terre's natural environment values together with the values of its terraced landscape. In the planning process, both natural and man-built physical phenomena, elements, categories and properties were considered that could be appreciated as components of an environmental system produced as a project of the territorial architecture. The local communities have realised the project in a collective way during the past centuries, to secure their own survival and that of the coming generations. The natural conditions of the climate, soil, water, original vegetation, *et cetera,* were the resources for developing the project. The civil conditions of competence, knowledge, economy, politics, have been the structural means to develop the project. The man-made works, their spatial organisation, morphology and typology, are the visible results of the project. The natural condition, the man-made works, the civil conditions and their interrelations should be represented and evaluated by the 'Foundation Description'.

The environmental system was considered as a territorial eco-system consciously realised by human beings. The organism hosted in the eco-system is the local community and the natural and man-made phenomena interrelated is the sheltering environment. The human activities involved in the planning process are those that can modify the eco-system equilibrium such as the natural conditions of the soil, water and vegetation, and the man-made works of the rural settlement such as terraces, crops and roads. Furthermore, the institutional activities relating to the existing planning system must be considered. Conceptualisation of the environmental system considers the natural and man-made environment as a unique eco-system (interaction between man and nature) and necessarily takes into account for its protection the civil environmental system (Besio and Quadrelli 2003).

The purpose of the decision support system project was to process geographical and qualitative data to locate different territorial units, characterised by organic and unitary relations between the natural conditions and the man-made works, to evaluate their integrity and to recognise different evolving processes. Only geographic data were processed to design different zones including paper maps, raster and vector maps, technical and regional thematic maps, each produced by the Liguria Region's SITAR, thematic maps prepared by specialists, land-based and aerial photographs, and on-site surveys of terrace structures.

The first problem was to select, organise and to make uniform the data to represent the natural, man-made work and civil phenomena; in other words to build the 'first descriptors' of the phenomena. The second problem was to select the simple relations between the data, representing the meaningful interactions between nature and man; in other words to build the 'second level descriptors' corresponding to phenomena that represent typical relationships between natural and man-made phenomena. The third problem was to identify the manifold relations between the 'descriptors' that allow one to locate the ecosystems corresponding with the four zones of the plan. Moreover, also different evolving processes in the ecosystems were recognised to evaluate their integrity and risk, equilibrium or breakdown, corresponding with sub-zones of the first zones. In other words, the 'indicators' of the ecosystems and of their status were produced,

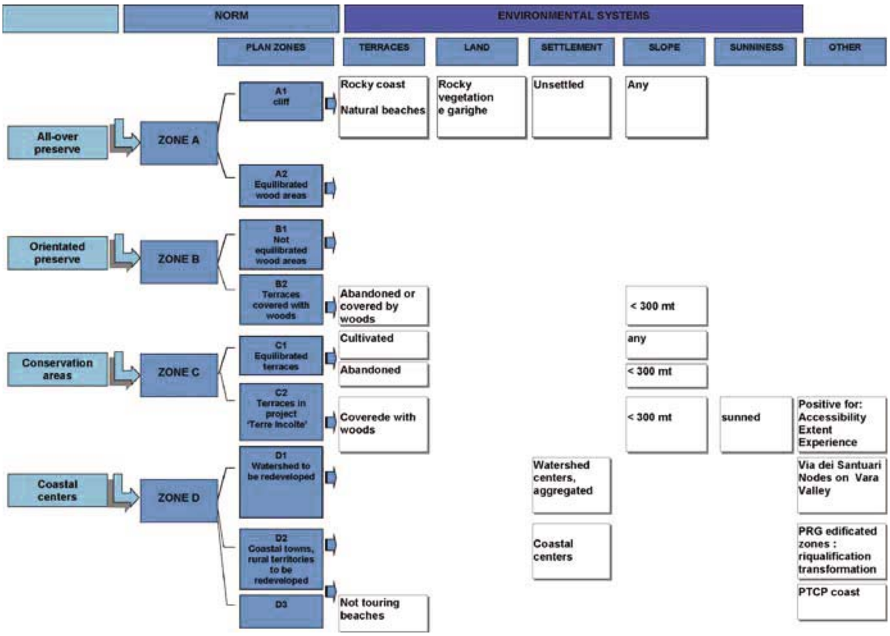

Fig. 14.8 A methodological outline of building up the zoning of the plan

corresponding also to different landscape profiles, which should support the decisions about the zoning of the plan (Fig. 14.8). Here, too, data processing followed a knowledge construction methodology developed over three progressive levels.

At the first level, selecting, standardizing, integrating, organising and implementing data were carried out in constructing the database. The concept of ecosystem (human) was split into the sub-concepts of natural environment, man-made environment and civil environment. For the natural environment, the categories that express the availability of natural resources to support human settlement were associated, such as relief, acclivity, exposure, geomorphology, lithology, natural vegetation. For the man-made environment, the categories of the rural settlement project were associated, such as rural buildings, access and mobility, soil and water arrangement (dry wall terraces and drainage channels), crops and monuments. The man-made environment was then divided into two sub-conceptual groups: the rural environment and the urban environment. To the former were assigned the categories of crop, rural settlement, inter-farm access and mobility, land and water-use structures. To the latter were assigned the categories of urban settlement, polarity and services, accessibility with the external territories, *et cetera*. To the civil environment the categories of ownership or tenancy, administrative divisions, planning regulations currently in force, *et cetera,* were assigned. The concept of instability was also introduced and broken down into two main types, natural and man-made. The first includes the categories of susceptibility to landslides, erosion, flooding, fire. The second includes the categories such as abandoned buildings, unmaintained roads, collapsed terraces. Then, to each category, feature classes values relating to the landscape profiles were assigned. Thematic maps, representing the first level 'descriptors' were produced.

At the second level, the information base was established. Using a morphological approach, the different data and their relationships were analysed, thereby generating information relating to the form and structure of the phenomena as well as to the status of equilibrium and/or conservation. For instance, the terraced areas with woodland vegetation or inaccessible rural settlements were classified as areas susceptible to risk or of instability as defined above. Derived maps were drawn which highlight the morphological configuration of each data set, the relations between different data sets and the evaluation of the status of equilibrium of the elements represented. Maps, representing a second level of 'descriptors', were produced. At the third level, a knowledge base was implemented by multiple processing of the first and second level data. They were subjected to multiple querying which produced synthetic geographical representations of environmental ecosystems and their associated landscape outlines. They represent 'indicators' of the different effectiveness of the zoning of the Park Plan (Fig. 14.9).

At the strategy and policy level of zoning, the indicators in support of the planning decisions are the natural ecosystem, the rural ecosystem and the urban ecosystem

B zones — Zoning and verify criteria

			B1	B2
zoning	NATURAL SYSTEM	geology		
		geomorphology		Collapses areas
		sunniness		adverse
		slope		elevated
		Natural vegetation	equilibrated wood areas	not equilibrated wood areas or bushes
	ANTHROPIC SYSTEM	agricolture		
		terraces	sporadic	Abandoned or ruined
		mobility	local	local
		settlement	Unsettled or rural episodico	Unsettled or rural episodico
verify	PLANNING SYSTEM	PRG/PUC	Agricultural zones (E)	Agricultural zones (E)
		PTCP	ANIMA	ANIMA, ISMA, ISCE
		SIC	SITI NATURA 2000	SITI NATURA 2000
		Risk zones		R3, R4 (D.L.180/'98)

Fig. 14.9 The query framework producing the zoning of the plan corresponding to the environmental system-landscape outlines

Fig. 14.10 Zoning map of the Cinque Terre Park Plan at the strategic level

and their landscape profiles (Fig. 14.10). At the legislative level of zoning, more detailed ‘indicators’ in support of the planning decisions are the processes of transformation in progress into the ecosystems as a result of the actions of inhabitants and tourists (Fig. 14.11).

A distinction is made between the zones with the abandonment of farming and renaturalisation of agricultural vegetation and the zones subject to pressure from tourism and urbanisation. This distinction corresponds to zones in which different norms and rules control the transformations. At the level of projects aiming for ‘recovery, landscape and environmental renewal, and sustainable development’, the rural environment system is represented in greater detail by the ‘rural settlement ecosystem’, which highlights different areas in terms of organisation and image (not considered in this chapter). The final definition of the Park Plan’s zoning was established after the ‘indicators’ representing the ecosystems were compared with the zoning of planning tools currently in force and presented for consultation with local government representatives and local residents.

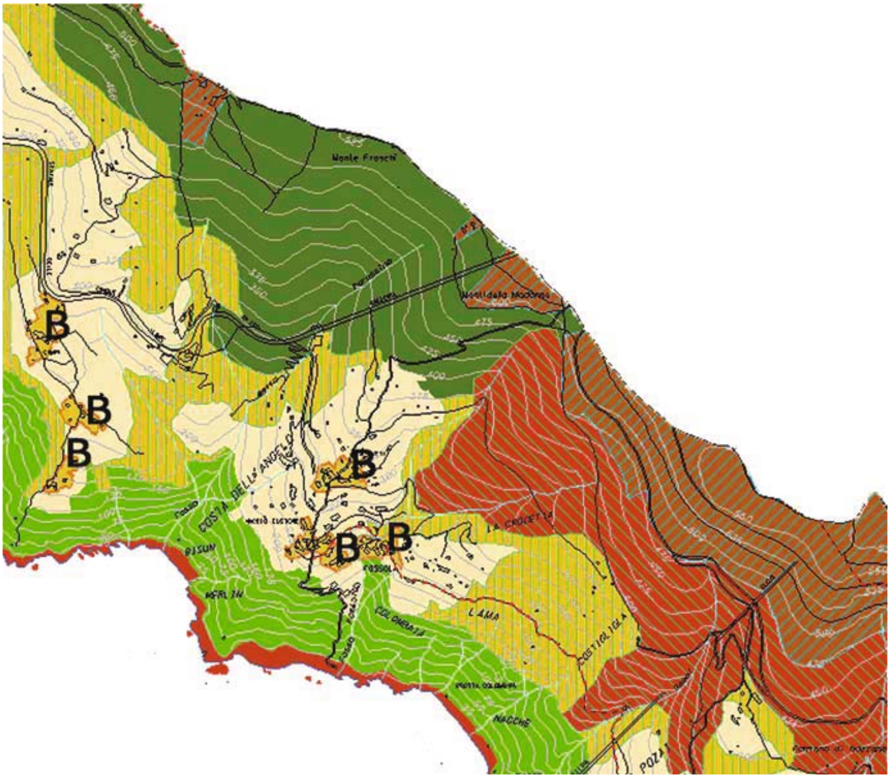

Fig. 14.11 Extract from the zoning map of the Cinque Terre Park Plan at the legislative level (See also Plate 36 in the Colour Plate Section)

14.3.3 Methods and Instruments for the Planning of Sustainable Transport Systems, Integrated with the Management of Large-Scale Areas

This project was carried out on behalf of Genoa City Council. Support was provided for the evaluation, control and realisation of new strategic rail and motorway projects for the port and city of Genoa within the framework of the EU's transport network ('Corridor 5'). It was implemented only for those territories of the Greater Genoa City Council area involved in the projects. Although many institutional bodies, from national to local level, are involved in the projects, their design is the responsibility of the companies providing rail and motorway infrastructures nationally. The local impacts of the projects should be evaluated and the sustainability of new transport links in terms of the environmental compatibility in the areas affected, the consistency with the planning system, the integration with pre-existing transport infrastructures and with urban and port area nodes should be assessed. Moreover, the project set out also to strengthen the GIS capabilities of the Genoa City Council's Territorial

Information System (SIT). An evaluation process was constructed and implemented into the GIS technologies using scenario methodologies. Partial scenarios were produced to evaluate separately the rail and motorway projects with regard to the areas affected, the planning system in force and the pre-existing transport infrastructures. The partial scenarios were integrated together in a single procedure to perform a comprehensive and a punctual evaluation of the projects (Besio *et al.* in press).

The new strategic rail and motorway links impact with the different urban and territorial areas affected: the port area connected to national and international trade; the urban area connected to the ordinary life of the neighbourhoods; the rural areas; the natural areas. The first scenario considers the environmental system corresponding to the concept of an ‘urban region’ environmental system, composed of the port, urban, rural and natural areas. The new, strategic rail and motorway projects were decided at national level outside of the local and regional decisional planning process. It was necessary therefore to assess their impact on the planning activities of the public administrations of the Municipality of Genoa, of the Province of Genoa and of the Liguria Region. Consequently, the second scenario addresses the planning system that indicates different zoning regulations for urban and rural and natural zones: zones in which no transformations are allowed; zones in which any transformations planned require particular attention; and zones in which new projects are forecast.

Although the new strategic rail and motorway projects interconnect with the preexisting network of rail and urban roads through only a few interconnection nodes, the effect on urban transport and mobility will be significant. The third scenario represents the urban network of transportation infrastructures and of traffic attraction poles, as a structure that operates at hierarchical levels: neighbourhood, urban unit and metropolitan area.

A considerable amount of heterogeneous data in terms of format (paper, raster, vector), content (generic technical maps, land-use maps, vegetation maps, woodland and forest maps, risk evaluation maps, maps illustrating the zoning of current landscape instruments, maps illustrating rail and motorway projects and major urban development projects) and origin (maps of the Genoa City Council, the Province of Genoa, the Liguria Region, the Genoa Port Authority, other maps produced directly) was used.

The most difficult problem was to integrate into a sole environmental system the ‘environmental systems’ represented by the scenarios. Conceptually, this was nearly impossible because they refer to different knowledge domains. The problem was solved by processing data with a procedure that had previously evaluated the rail and motorway layout, with each single scenario and then jointly evaluating the single evaluations. Moreover, the evaluation was done both for the stretches of land between the nodes of the rail and motorway network and for each single point of the layout. The information and knowledge generated from the scenarios was organised in a hierarchical way; from more general to more detailed. Standardizing and organising the data in a hierarchical structure such as that adopted in the Corine land-cover database successfully resolved the problem. Data processing followed a knowledge construction methodology developed over three progressive cognitive levels (Fig. 14.12).

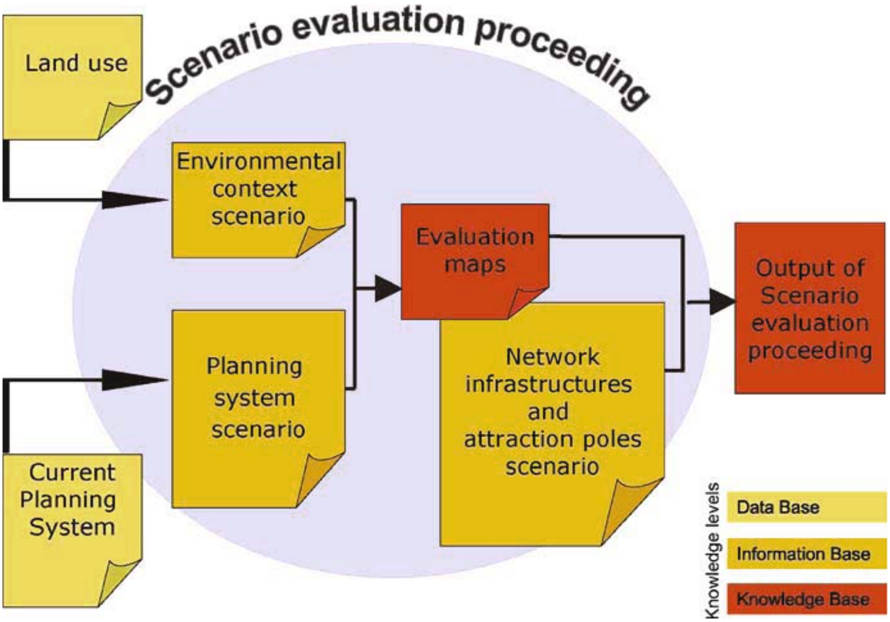

Fig. 14.12 The cognitive procedure: a methodological outline of scenario evaluation

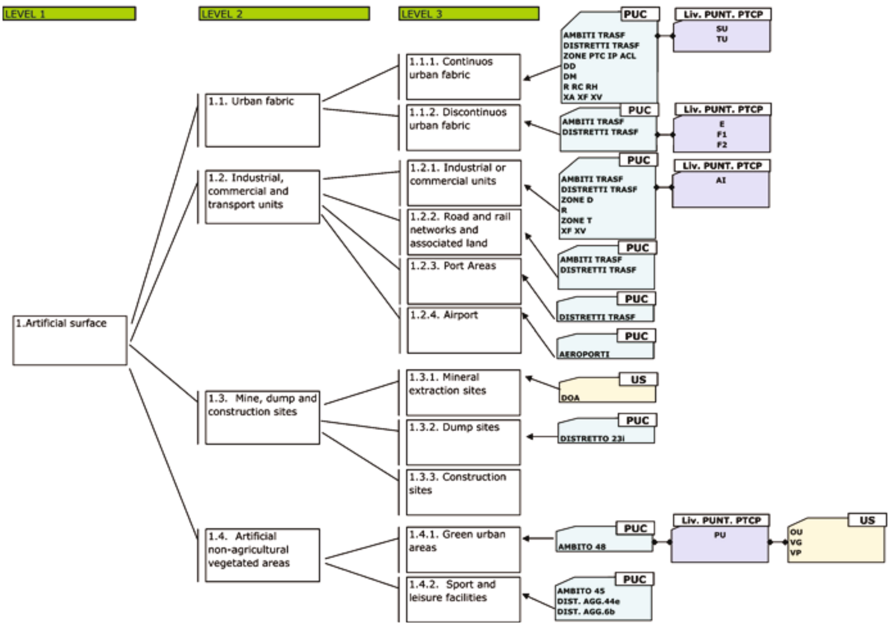

Fig. 14.13 Land-use data classification by Corine land-cover model

At the first level, the database was built up by selecting, standardising integrating and organising available data: the land-use data was used in order to produce the scenario of ‘urban region environmental system’; the planning system in force data was used in order to produce the planning system scenario; and the existing rail, motorway, roads network and the new rail and motorway links were used in order to produce the network infrastructures and attraction poles scenario. All data were organised hierarchically adopting the Corine land-cover model, which allows for evaluation both at the large-scale area and in the single points of the layout.

In regard to the first scenario, as can be seen in Fig. 14.13, at the first hierarchical level the concept of ‘urban region environmental system’ was split into the sub-concepts: port system, urban system, rural system and natural system. At the second hierarchical level, each system was assigned categories of data representing the different elements within; i.e. urban tissues, vegetation, functional use. At the third hierarchical level, each category of data was assigned different classes of values.

With regard to the second scenario, as can be seen in Fig. 14.14, the concept of ‘regulation of the territory, environment and landscape transformations’ was split into the sub-concepts of conservation of the status quo, transformation with particular attention and the likelihood of transformation projects. Moreover, there is

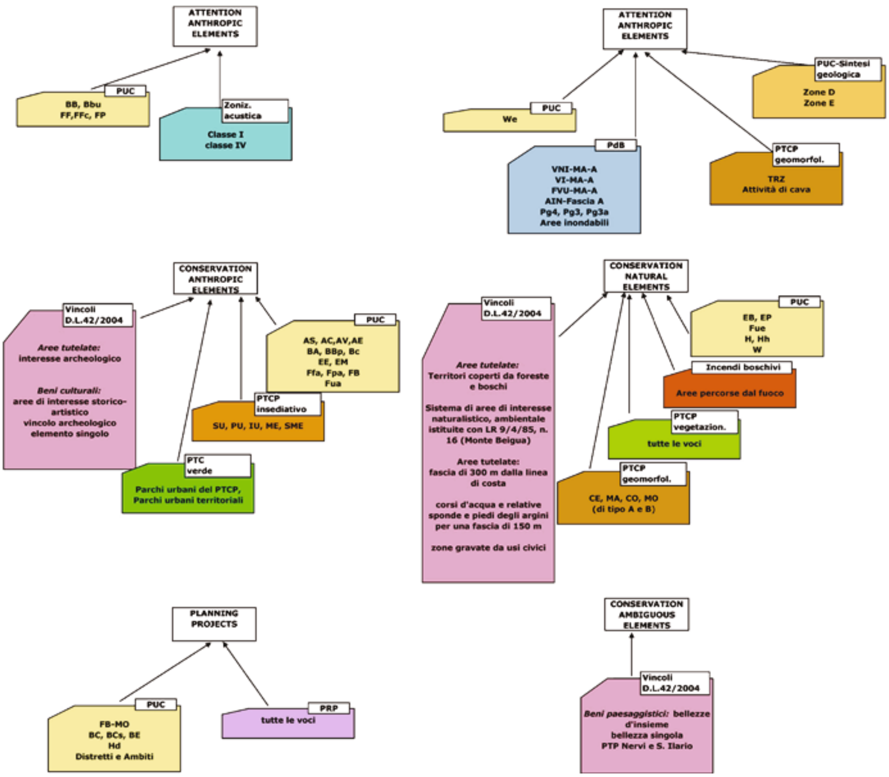

Fig. 14.14 Planning system data classification

a distinction between rules applied to natural or to anthropic elements. The sub-concepts have been applied to different categories of planning tools: landscape and hydro-geological constraints, the municipality of Genoa urban plan, the landscape regional plan, the basin provincial plan. The classes of values of zoning of each category of planning tools were assigned to the regulation concepts. In this way, the zoning and the rules of different planning tools were standardised by the same three sub-concepts: conservation, attention and project.

In the third scenario, as shown in Fig. 14.15, the different elements of the transport and mobility infrastructure network (links and nodes), pre-existing and projected, were categorised and classified hierarchically on the basis of urban functionality of neighbourhood, urban unit and metropolitan area. This first level of data corresponds to the 'descriptors' of the previous experiences of DSS. Thematic maps were produced for all the phenomena analysed.

At the second level, the procedure to evaluate the rail and motorway projects in relation to each single scenario was constructed. This level corresponds to the information base constructed in the previous experiences of DSS construction. The first scenario, evaluating compatibility of the new rail and motorway layout with the area affected, allows one to: offer an oversight of projects relating to the logistics and economic functioning of the port; define actions that limit the impact on urban

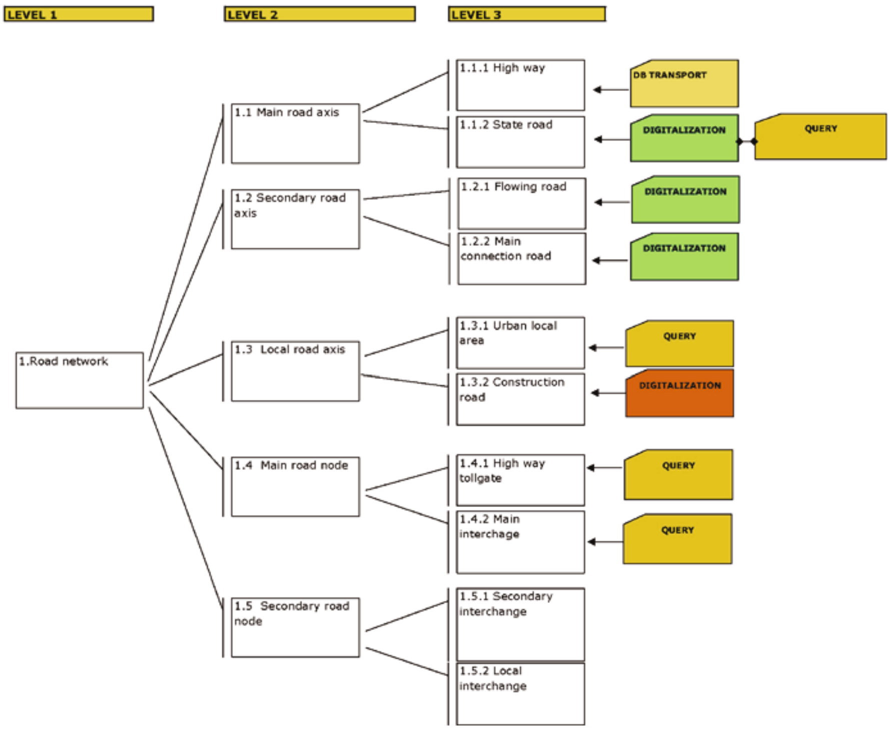

Fig. 14.15 Road network data classification

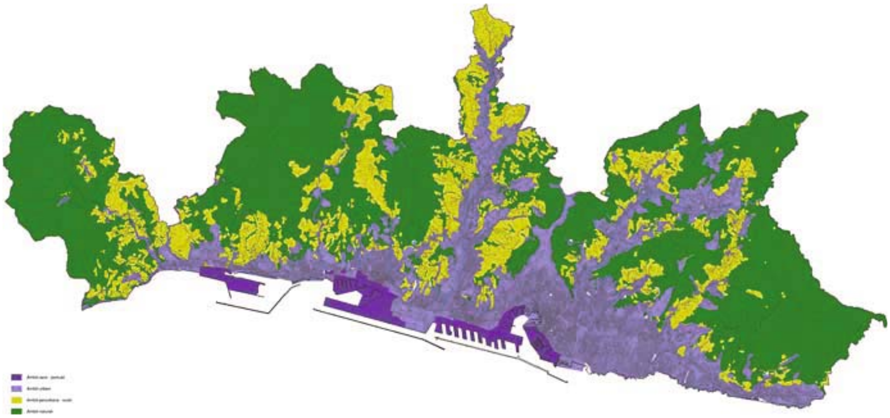

Fig. 14.16 Urban region environmental system scenario (See also Plate 37 in the Colour Plate Section)

environments; and protect the landscape and prevent hydro-geological risk on the rural and natural environment (Fig. 14.16).

The second scenario aims to compare project outlines of the new rail and motorway with the planning system in force, evaluating the congruence with its zoning,

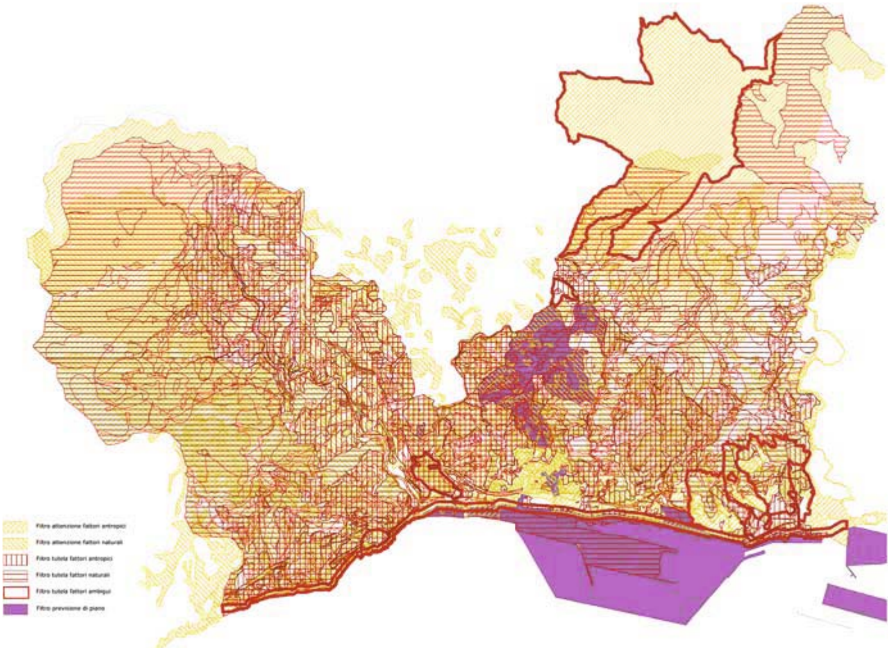

Fig. 14.17 Planning system scenario (See also Plate 38 in the Colour Plate Section)

Fig. 14.18 Network infrastructure scenario (See also Plate 39 in the Colour Plate Section)

rules and restrictions for the regulation of territorial, environmental and landscape transformations (Fig. 14.17).

The third scenario, evaluating the integration of new rail and motorway projects with existing transport networks, seeks to obtain at the same time a detailed and a global view of transport routes and nodes so as to evaluate improvements made to transport networks at national level and assess possible improvements also at local level (Fig. 14.18).

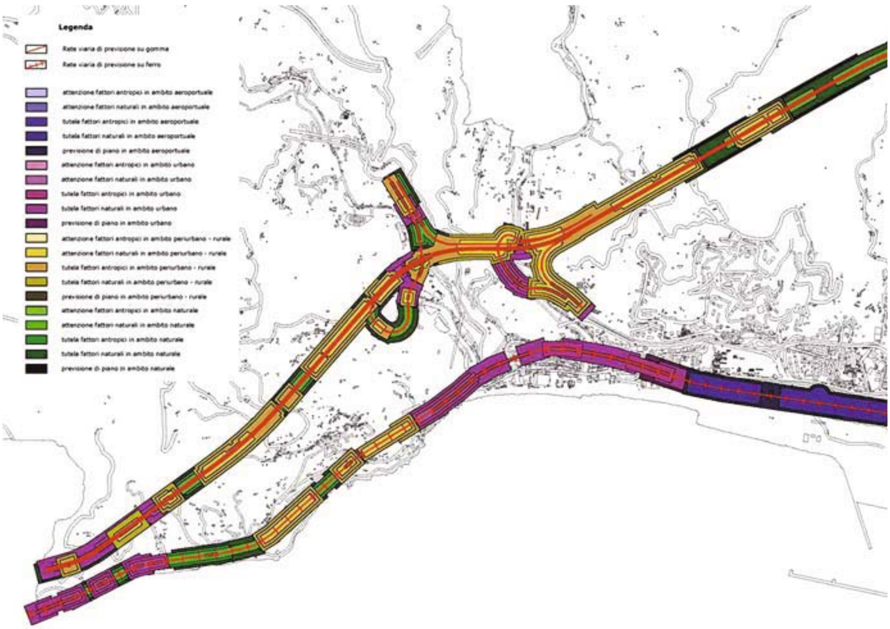

Fig. 14.19 Final scenario evaluation at the general level

Each scenario is analysed in terms of morphological configuration and of hierarchical relationships between different geographical scales. Derived maps were prepared to highlight the impact of railway and motorway projects on the scenarios. At the third level, the whole evaluation procedure was constructed to assess the rail and motorway projects with regard to the three partial scenarios as a whole. The scenarios were subjected to multiple querying, codified in the procedure that evaluated contemporaneously: compatibility with the areas affected; consistency with the planning system; and integration with the urban transportation network of the new railway and motorway projects.

The rail and motorway projects were compared to the three scenarios so as to highlight the contextual features along with an evaluation of criticality and opportunity. It is possible to visualise immediately the implications of positioning a stretch of motorway or railway on a specific urban region area, recovering the values of the three scenarios. The assessment is carried out on different scales: at the global scale, a synthetic visualisation is possible of the compatibility with the urban region crossed, of the suitability with the planning system regulation and of the integration with the pre-existing transport stretches in different affected areas (Fig. 14.19); at the local scale, it is possible to have the detailed sheets of values of indicators and descriptors (Fig. 14.20). The procedure of assessment, based on scenario methodology, corresponds to the level of the 'indicators' of the previous experiences.

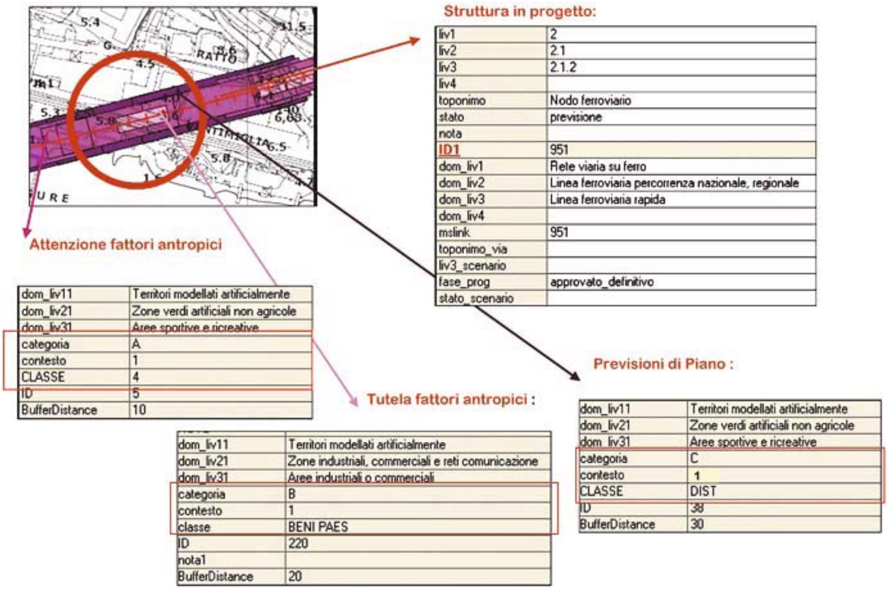

Fig. 14.20 Query of the final scenario to obtain detailed information

14.4 Conclusions and Future Directions

In conclusion, it is useful to reflect how each experience contributed to highlight a particular aspect of the knowledge construction methodology and, on the basis of the experiments, make some more general observations. In the first experiment, our aim was to identify environmental units characterised by different settlement forms and ways of dwelling. Generally, ISTAT numerical data relating to buildings and population are used to obtain quantitative statistical values which are overlaid and applied homogeneously over all municipal territories. In this case multiple numeric data sets had to be treated in combination in order to provide qualitative knowledge. In each municipality different settlement forms and types of dwelling were attributed blurred and qualitative values, produced by the interrelationships between several numeric data values. With this objective in mind, we analysed the meaning that the group of different numeric data might have with regards to settlement morphology and dwelling use. The meaning was linked not only to the choice of data, but also to the way of processing them. It was necessary to consider the logical process from the definition of the conceptual model, as far as the choice of data classes and values. We processed the data according to an ordered sequence of three levels of analysis and interpolation. Firstly, the settlement environmental system was broken down into their simple elements: houses, buildings, inhabitants, and families. Then the single relationships connecting them in a significant way regarding the settlement form and the way of dwelling were selected. Finally, the multiple relations, that locate different settlement environmental systems that represent different settlement form and the way of dwelling, were reconstructed (Besio 2001).

In the second experiment, we wanted to distinguish territorial units (zones), which correspond at the same time to environmental systems and landscape profiles. We investigated the meaning of 'environmental system' and associated 'landscape profile' in a conceptual model. We considered that only one reality exists. Consequently, if different terms of territory, environment and landscape are used to designate the same portion of land, it is not the reality that changes: each of the three terms denotes a different aspect of the reality and these three aspects are interrelated (Assunto 1980; Ghetti and Degli Alberi 1977). We assumed the 'territory' within an extensive meaning and represented it by the delimitation of geographical areas on the basis of specific functions and geographical features (i.e. municipality territories at the beginning of the process, the zoning of the plan at the end). We assumed the 'environment' within a structural, morphological and relational meaning (Giacomini and Romani 2005; McHarg 1969; Tiezzi 1992) and represented it by the manifold relationships between meaningful phenomena that assume organic and unitary structure. We assumed the 'landscape' within an aesthetic and perceptive meaning (Assunto 1975; Bell 1999; Dewey 1934; Merlau-Ponty 1945; Pareyson 1991; Council of Europe 2000) and represented it by the cartographic images conveying information regarding the environmental systems and territorial organisation forms. The territorial level is subordinate to the environmental level. The landscape level is superordinate to the environmental level. At the end of the cognitive process, the landscape level entailed the cartographic images, which define the boundaries of environmental systems and underlying territorial organisations. The theoretical-conceptual model of the 'rural settlement ecosystem', in which man-made and natural phenomena interact, has been defined. A morphological approach was adopted in order to analyse the phenomena, to interpret their meanings through the choice of the elements and their feature classes and to build up the model of the environmental system and the associated landscape profiles through the interpolation of their spatial structures (Besio and Quadrelli 2003).

In the third experiment, the produced knowledge should be useful both on an urban region scale, utilising evaluation criteria related to port logistics and urban planning policies, and at a local level, taking into account the evaluation criteria of the quality of life, of the landscape and of the hydro-geological risk of the areas affected. In order to satisfy the evaluation requisite, a scenario technique was used. In order to satisfy the inter-scale evaluation, the hierarchical structure of data was adopted so as to produce structured inter-scalar knowledge of the phenomena examined. A conceptual framework was developed which ranges from general to detailed concepts and concentrates on defining the data available. The advantage of this is to obtain models of environmental systems, albeit of different definitions, also when data is scarce and/or when it comes from different sources with different meanings and different levels of approximation.

Decisions relating to the three planning processes concern the projects of the future of territories and people. Knowledge can only be useful for environmental and landscape future projects if data and phenomena are represented synthetically. Knowledge can only be useful if it is understood by the people who are affected by it (local government authorities and residents) and therefore should be communicated in a clear and simple way. The processing of knowledge required the adoption of complex procedures, which demanded high technical skills and expertise. How ever, while developing the cognitive procedures in three different levels we tried to simulate commonsense reasoning and convey the results through simple graphics that can be easily understood by a non-expert audience (Frixione 2002; Vaccari 2002; Magnaghi 2005).

On the basis of the experiments, we can make some more general observations. GIS technologies were useful in two ways. At an operational level, as processing together manifold geographical data that should be manually impossible; as processing procedures, which are formalised and demonstrable and make planning processes more transparent. At an epistemological level, as the application of conceptual models and cognitive procedures helped to clarify the environment and landscape conceptual model and paradigms for implementing and processing the GIS projects (Besio *et al.* in press).

In all three experiments, we experienced both technical and cognitive problems yet not resolved, which could require further analyses and studies. With regards to problems of a technical nature, some elaborations of data came from outside the GIS technological process. They are essentially the operative phases of: structuring of data coming from different sources according to the same concept, categories and classes; morphological analyses and classification of the geographic data;

interpolation of various different phenomena within a single territorial unit; and of representation of cartographic results according to expressive graphic language. With regard to problems of a cognitive nature, in order to make the cognitive process seamless and more sequential, further work is required in formal ontologies necessary to acquire non-homogenous data in manner which is coherent and homogenous with the projects (Guarino 1999; Simons 1987; Teller, Lee and Roussey 2007; Varzi 2005) in spatial analyses of geographic data so as to identify morphological and semantic entities; and in topological and mereological analyses so as to mark off geographic areas in which significant interactions amongst different phenomena take place (Casati and Varzi 1996, 1999; Hillier 1999). The integration of geo-technologies with image elaboration technologies so as to produce widely understandable expressive graphic results is a typical technological problem.

The current power of geo-information technologies, together with a theoretically infinite availability of data, makes it possible to process an enormous quantity of information and knowledge. At the same time, such a capacity risks producing an information overload which can be just as problematic as an information shortage. Recent experimentation has extended the use of GIS technologies from generic multi-use geographic databases to knowledge bases structured in order to provide decision support in the planning process.

Nevertheless as to more general problems, we came across insufficient skills and competence in the area of cognitive modelling and the cognitive sciences in general. Knowledge production required the use of suitable conceptual models to interpret the phenomena subject to planning systems, as well as appropriate methodological procedures to transfer the models into processing data. Theoretical and conceptual models in the initial conceptualisation, categorisation and classification stages define the ontology of the geographic objects represented by the data. The significance of this extended role lies not in data and instruments, but in cognitive processes. This certainly represents a major drawback to extending the application of geo-information technologies to the more complex and flexible levels necessary to provide knowledge support to the planning process. To overcome this problem, closer interdisciplinary ties between experts working in the geo-technologies field and planning are needed.

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