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## ABSTRACT

Over the past decades, the implementation of several European Directives affected the European Member States normative framework influencing the traditional spatial planning process. The Directive 2001/42/EC on Strategic Environmental Assessment and the Directive 2007/2/EC on the development of INfrastructure for SPatial InfoRmation in Europe (INSPIRE) aim of improving the protection of the environment implementing the sustainable principles promulgated by the global action plan for the 21st century: Agenda 21. Nevertheless, the fruitful integration of these Directives in the planning practice is still limited. Although the SEA can be considered a structured and transparent procedure that guides the integration of environmental considerations in the planning practice, the extent of its efficacy is still unclear. Different studies summarise the shortcomings in the application of the SEA at the national and the local levels, such as the lack of informed processes for producing design alternatives, the limited influence of the public participation and inefficient monitoring programmes.

Novel methodologies and innovative technologies may offer an opportunity for dealing with these open issues in SEA. Among possible approaches, Geodesign is an emerging methodology that allows evaluating how the geographic space ("Geo-") changes due to design activities ("-design"), through an interactive framework based on six operative models. This methodology that takes into account technologies, data and actors may be considered particularly adequate for guiding the recent innovations that are affecting the Italian spatial planning system: the development of Spatial Data Infrastructures. SDI offer new opportunities and challenges to planners for supporting decision-making in sustainable spatial planning, through a wealth of interoperable spatial data and services which are for the first time, given public access. Although with the SDI the role of information and services in planning may be reconsidered toward innovation, in practice the influence of INSPIRE is still limited.

In order to address these issues, this study aims at testing Planning Support Systems for SEA in Local Land-Use Planning (LLUP). A case study regarding the Sardinian spatial governance was developed. PSS may help to reconsider the role of SDI digital data and services through interactive and dynamic geo-tools for dealing with open issues in LLUP-SEA. Indeed, PSS may enable an interactive approach to planning activities, supporting sketch planning and design, impact assessment, environmental reporting and collaborative decision-making processes. The PSS includes an indicator framework, the DPSIR, based on the concept of causal chain, which may help to organise and manage the information flow during the plan-making phases. In order to enhance its potential in spatial planning, a spatial DPSIR, sDPSIR, which integrates spatial and non-spatial data and help to add value to the SDI digital data, through its structured framework, has been built. The LLUP-SEA PSS has been tested in two different settings for investigating the influence of this innovative approach to planning practices and education. The first workshop investigated the appreciation

of professionals and researchers in applying the PSS in practice. They were able to compare the PSS tools with the actual methods for representing and analysing the territory. Furthermore, the participants tested the PSS tools for dealing with their planning tasks in LLUP-SEA procedures. The second workshop concerned an assessment of the technology in an educational setting for investigating how university planning students consider the implementation of this system in practice and for creating awareness of how this technology may help them in facing planning tasks in their future career. The results of the assessment of the two workshops demonstrated the value of PSS technology for dealing with planning activities and how the integration of PSS into practice is still in the preliminary phases. This study may be considered as a contribution to demonstrate how novel Geodesign methodologies and advanced geo-information tools may help to address a proper application of Strategic Environmental Assessment in the planning practice.

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## 1. Introduction

Over the past decades, the natural resources on which the human well-being is dependent, have become scarce and invaluable more than ever. The management of the natural components such as land, biological systems and water, is able to influence the quality of life for the present and future generations (Giljum et al, 2009). This statement is in direct relation with the concept of sustainability, which has been transposed into the European Policies for dealing with the environmental issues related to the current resource consumption processes. Indeed, the concept of sustainability can be considered a potential solution for a wide range of environmental problems at large and local spatial scales and it should be able to guide the strategic development of the territory toward a fruitful exploitation of the natural resources. Nevertheless, how to achieve the principles of sustainability seems to be unclear, which renders it a somehow utopian goal.

Over the past decades the natural resources, on which the human well-being is dependent, have become scarce and invaluable more than ever. The management of the natural components such as land, biological systems and water, may influence the quality of life for the present and future generations (Giljum et al, 2009). This statement is in direct relation with the concept of sustainability, which has been transposed into the European Policies for dealing with the environmental issues related to the current resource consumption processes. Indeed, the concept of sustainability can be considered a potential solution for a wide range of environmental problems at large and local spatial scales and it should be able to guide the strategic development of the territory toward a fruitful exploitation of the natural resources. Nevertheless, how to achieve the principles of sustainability in a fruitful way seems to be often unclear. The Earth Summit (UN Conference on Environment and Development) held in Rio de Janeiro, in 1992, fostered the adoption of a global action plan oriented to support the sustainable development into the 21st century: the Agenda 21. Agenda 21 (Agenda 21, 1992), is a document composed of four main pillars based on the (I) Social and Economic Dimensions, (II) Conservation and Management of Resources for Development, (III) Strengthening the Role of Major Groups and (IV) Means of Implementation. Campagna (2016) in particular pointed out that agenda 21 offered the opportunity to strengthen the role of “the scientific and technological community” and “information” for generating a new approach to the sustainable development in decision-making.

Recent development of European Directives generated an ideal context for investigating how the purposes of Agenda 21 may be concretely integrated into practices through innovative technologies, methodologies, data and services. Two of the most important European directives that respond to the requirement emerged in the Agenda 21 and influence the protection of the environment in the European Member

States are the Directive 2001/42/EC on Strategic Environmental Assessment (SEA) and the Directive 2007/2/EC for the development of INfrastructure for SPatial InfoRmation in Europe (INSPIRE).

The Directive 2001/42/EC on Strategic Environmental Assessment (SEA), was approved to integrate environmental considerations into plans and programmes with the aim of setting reasonable alternatives and evaluating their significant effects on the environment. The SEA has been implemented into the National normative systems of the European Community Member State. In Italy, it has been implemented through the Legislative Decree 152/2006, which applies to plans and programmes at National, Regional and Local levels. The SEA can be considered a “systematic decision support process, aiming to ensure that environmental and possibly other sustainability aspects are considered in Plans, Policies and Programmes, (PPP) making” through “structured, participative, open and transparent procedures” (Fisher, 2007). Nevertheless, the fruitful integration of SEA into planning practices does not seem to be fully guaranteed. Indeed, different studies illustrate the shortcomings in the process of application of this environmental-oriented approach into the European planning practices, such as the design of reasonable alternatives, the impact evaluations and the participation process (Tetolw and Hanush, 2012).

The European Directive 2007/20/EC, namely INSPIRE, promotes the use and reuse of spatial data for "sharing environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe". The INSPIRE Directive aims to support the creation and diffusion of Spatial Data Infrastructures (SDI) to "assist in policy-making across boundaries". SDI make spatial information and services available with the aim of supporting planners in investigating territorial phenomena and ameliorating decision-making processes. This big amount of information and services calls for adequate tools and technologies for management and analysis. In this context, Geographic Information Systems (GIS) can be considered a reliable tool for managing spatial data and supporting spatial planning practices (Flaxman, 2010). GIS make the users able to represent the territory, perform analyses and manage spatial information, supporting the comprehension of geographic space variations due to design activities. For this reason, GIS may be integrated into the SEA procedures for supporting the decision-making processes. However, their influence in planning practices is still limited, due to different shortcomings, such as the lack of user experience in setting the spatial models and tools and the capacity to support planners in facing their specific planning tasks. Indeed, although GIS can be considered as a "general-purpose system" for dealing with "a wide diversity of tasks and problems in various settings" (Geertman and Stillwell, 2004), it may not be capable of supporting planners in dealing with their specific planning activities.

Campagna and Di Cesare (2016) pointed out that emerging methodologies, such as Geodesign, may guide a suitable integration of the SEA in planning practices thanks to its design oriented approach. Geodesign is a methodological approach that allows investigating how the geographic space (“Geo-”) may be influenced

due to design activities (“-design”). The Geodesign framework, formulated by Steinitz (2012), concerns the analysis of the geographic space, the design of planning alternatives, their real time impact evaluation and the scenario comparison for feeding the decision of adequate planning solutions through participatory procedures. Geodesign offers an opportunity to integrate technological instruments and informed participation processes into planning.

The Planning Support System (PSS), defined as a systems able to "bring together the functionalities of geographical information systems (GIS), models, and visualisation, to gather, structure, analyse, and communicate information in planning" (Vonk et al, 2005), may guide the application of the Geodesign framework into LLUP-SEA processes. The PSS encompasses a range of features able to manage geographic information through the spatiotemporal dimensions, user friendly interfaces, spatial indicators frameworks, sketch planning tools and interactive dashboards. Although this emerging technology offers the opportunity to bring innovation in planning, its fruitful integration into professional practices is still limited (Campagna, 2012, Geertman and Stillwell, 2004). The PSS has been implemented in the context of the territorial spatial governance of the Sardinian Region. Sardinia is an autonomous Region with respect to the national planning system. This status allows having the primary jurisdiction of the land-use planning system, according to its constitution. The Law n. 1989/45 establishes the framework for regulating the management of the Municipal territory through the definition of contents, procedures and implementation instruments integrated into the Municipal Master Plan (MMP). One of the most important document of the MMP is the zoning plan that aims to regulate the uses of land through a set of mandatory rules and standards, in order to support the sustainable management of the resources. Indeed, the land can be considered the base on which the human activities are rooted, and therefore the way land-use changes influences the environment where we live (Vitousek, 1997). It can be argued that, relevant changes that afflict the natural environment occur at the local level, on single parcels, from public to private activities (Briassoulis, 2000). Private and public landowners act on the individual land unit in order to produce changes for satisfying their needs, generating a transformation process of the land to support a wide range of purposes.

For this reason, planning at the local level, the Local Land-Use Planning (LLUP), can be considered a procedure for dealing with the requests of the population and the local communities for goods and services, in compliance with the sustainability principles. The LLUP concerns all processes and activities that encompass the social-economic growth of the society and the soil consumption generated by the urban sprawl and land-use changes. The recent adoption of the Regional Landscape Plan (RLP) (Law n. 2004/8), which defines a set of rules and policies to protect the environment and preserve the cultural heritage, has given more importance to the role of the MMP for implementing these aims. Furthermore, the adaptment of the MMP to the RLP has to be adherent to the Strategic Environmental Assessment (SEA) process that is

a mandatory procedure which aims to integrate environmental consideration into plans and programmes. Nevertheless, the SEA does not appear fully integrated into planning practices in Sardinia. De Montis et al., (2014) argue that, although the SEA procedure aims to integrate into the plan-making phases key considerations for the environment, most of the municipalities of Sardinia "have failed to integrate SEA into their plans". Other pitfalls related to the integration process of the SEA into practices are expressed in the literature, like, for example, Pira and Isola (2011), who pointed out that the SEA, if not adequately integrated into planning practices, may not guarantee improvements of the planning process quality.

In order to demonstrate the potentiality of the PSS in supporting the integration of the Geodesign framework into planning practices, two studies have been carried out. The case studies are based on structured workshops with the aim of taking into account the participation of different actors for testing the PSS features through a range of planning activities. The workshops have been organised by the UrbanGIS Lab of the University of Cagliari in collaboration with the municipalities of Gonnese and university students. The PSS has been tested taking into account the needs of the public authorities related to the socio-economic developments of the territory and the protection of the natural capital. Furthermore, a comparison among different technologies for supporting the decision-making process and scenario comparison has been proposed during the educational workshop, in collaboration with the students of Architecture of the University of Cagliari. The workshop activities were oriented to compare the influence of different technologies, such as PSS and a common GIS software, for dealing with the same planning issues.

At the end of the workshops, the users compiled a questionnaire to provide opinions, perceptions and feedback. This information is discussed in the conclusions of the thesis with the aim of describing how the users evaluate this innovative approach to practices and how the students perceive the integration of innovative technologies into the preparation of professional curricula.

The results of the workshops offer the opportunity to discuss with regard to the open issues in spatial planning. The integration of PSS architecture into planning practices and educational context may guide the development of new approaches in spatial planning, based on the awareness of how these architectures may innovate the practices. Further case studies and practical applications may contribute to add value to the work presented in the research, guiding the development of new technologies toward suitable architecture for dealing with the intrinsic complexity of the LLUP-SEA activities.

### 1.1. Aims and research questions

In synthesis, the thesis focuses on the LLUP-SEA procedures and investigates the methodologies for supporting the participative decision-making process across the plan-making phases through the implementation of a Planning Support System (PSS) which integrate the Geodesign models.

Two case studies have been developed, involving different groups of stakeholders to implement specific tasks of a planning process.

The proposed approach aims to explore the user perceptions related to the implementation of these technologies for supporting planning activities, such as the participation processes, the design of alternatives and their impact evaluation, the scenario comparison and the environmental reporting.

The main research questions concerns different domains ranging from the inclusion degree of spatial data into planning practices to the efficiency of instruments for supporting the decision-making process. These issues may be summarised as:

- i. How to make value out of the new SDI?*
- ii. How to inform design and impact assessment in planning?*
- iii. How can the PSS support real time impact evaluation of the design proposals and the participation processes?*
- iv. How do the flexibility and complexity of the PSS influence its integration into practices?*

## **1.2. Outline of the dissertation**

The thesis consists of 5 chapters:

Chapter 1 introduces the structure of the thesis, providing an overview of the main points of the research.

Chapter 2 concerns the analysis of the context on which the thesis is based on. This section introduces the concept of sustainability and how it is integrated into planning. In turn, it focuses on the procedures and innovations that are influencing planning practices with regard to the recent European Directives, such as the Strategic Environmental Assessment procedures and the development of Spatial Data Infrastructures. Furthermore, Chapter 2 discusses the current pitfalls in the process of integration of these innovative procedures and technologies into practices.

Chapter 3 illustrates how to deal with the open issues in the SEA process and offers the opportunity to recognise the role of spatial data into planning practices. This section introduces the methodology used in the research and the technologies that allow to develop an innovative approach to planning activities. The methodology is based on the concept of Geodesign which considers how the geographic space is influenced due to design activates, through an interactive framework of six operational models. Geodesign is integrated into a Planning Support System that, through a wide range of geo-tools, such as the sketch panning and the interactive impact assessment, allows to guide planners in facing their planning tasks.

In order to demonstrate how to apply the methodologies and the technologies illustrated in Chapter 3 in practice, this section presents two different case studies. Chapter 4, represents the case studies that concern two different workshops applied to the spatial planning system of the Sardinian Region for investigating the influence of this innovative approach. Furthermore, this chapter focus on the Local Land-Use Planning procedures for managing the strategic development of the territory and how structured indicators framework may help to organise spatial data during the plan-making phases.

In conclusion, Chapter 5 summarises the results of the research, discussing the opportunities offered by the findings of the thesis for innovating current LLUP-SEA procedures and further research developments.

## 2. Sustainable development and the planning practice

### 2.1. Sustainability

The term “sustainability” encloses a wide range of definitions and concepts. It can be argued that, sustainability regards everything in the world, involving a wide range of sectors, from social to economic, from urban to environmental ([Kates et al, 2000](#)) that influence the human well-being ([MEA, 2005](#); [Flint, 2013](#)).

The early appearances of the sustainability concept are on the Report of the Brundtland Commission of the 1987: “Our common future”. It encloses the sustainable development’ definition as the *“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”* ([Brundtland, 1987](#)). In the same report, the concept of sustainability is represented as the core of three intertwined strategic sectors: Economic, Social and Environmental (Figure 1) ([Tanguay et al, 2010](#)). This union produces three different nodes: the connection between the economic and social field may generate an “Equitable” development, while the overlap between the environmental and social sectors is oriented toward the quality of life and should be “Livable”. The last dimension concerns the intersection between the environmental and the economic fields. It is represented by the “Viable” dimension which the economic growth should not be over the environmental capacity to renovate the resources ([Brundtland, 1987](#)).



Figure 1 - The three pillars of the sustainable development ([Tanguay et al, 2010](#)).



Recently, a fourth dimension has been included in the system for supporting the current dimension of the sustainability: the “Governance” ([Stoddart, 2015](#); [Czischke, 2015](#)). The urban “Governance” should take into account the needs of different groups of stakeholder (e.g. citizens, private and public organizations) in order to produce the information for supporting the community well-being (Fig. 2). Nevertheless, the stakeholders generate a wide range of demands (e.g. goods and services), making the process of urban governance a complex procedure. Citizens, commercial organizations and local authorities produce different purposes for supporting their own needs, fostering the creation of pitfalls in the decision-making processes ([Czischke, 2015](#)). The decision-making process concerns a set of human actions that influence the environment. In fact, phenomena like the urbanization may generate irreversible processes of environmental resources consumption. For this reason, the environment represents the natural capital for sustaining the life on the earth ([Liu et al, 2011](#)) and can be seen as a “resource” that need to be protected. The natural capital is strictly intertwined with the availability of natural resources for supporting the achievement of the human well being.



Figure 2 - The four dimensions of Sustainable developments

Source: Turcu, C., 2010, on the basis of Valentin & Spangenberg, 1999

Renewable and non-renewable resources, necessary to produce goods and services for human, are more than ever consumed. Currently, the assessment process of resources consumption represent a challenge for environmental scientists and planners for limiting their use to preserve the well being of future generations ([Olewiler, 2006](#)). The human population' growth, the faster requests of services and goods, which guarantee high quality of life, increases. Among them, the expansion of cities and the urbanization processes have gobbled up a big amount of rural and natural areas jeopardizing the amount and quality of environmental resources ([Wang et al, 2014](#) Kotter, 2007, [7]). This system encloses relationships between human and environmental realm that are usually expressed through land-use dimensions. ([Owens and Cowell, 2011](#)). Caldwell and Shrader-Frechette ([1993](#)) pointed out as the land "is the base upon which all human societies are built". Variations in land-uses can be characterized by changes in the social-physical condition of the human realm (e.g. large scale urbanization, agriculture). Furthermore, land use-changes can directly or indirectly influence the environment, consuming resources also cross boundaries (for instance, the decisions in a Country can produce impacts on resources, as water and air, in another Country). Sometimes, these effects can be cumulative, involving social, economic and legal (e.g. right and jurisdictions) dimensions ([Owens, 2011](#)). Indeed, the urban development is usually related to the conversion of natural areas which ownerships may be public or private. The set of policies that regulate land uses influence the rights of private landowners, aiming to preserve natural areas and limiting the urbanization processes. Landowners aim to achieve their well-being through specific actions and purposes that consuming local resources; the sum of these actions produce a range of cumulative effects on the environment that have to be considered in decision-making through specific plans, rules and policies. These phenomena led to create several threats (from local to global scale) for the environment (e.g. erosion, loss of biodiversity, climate changes, flooding) ([Caparros-Midwood et al, 2015](#)).

Land-use policies aim to mitigate the fragmentation of landscape by means of sets of rules and limits. These policies should be taken into account by the Urban Master Plan through specific methods for supporting the land-use management ([Haar, 1955](#); [Munroe et al, 2005](#)).

In the light of the above premises, the land-uses management and the sustainable developments can be considered strictly linked together. Despite the importance of the lands for the human well-being, their value is currently underestimated in the planning-processes ([Treville, 2011](#)) and it is omitted so far in spatial planning ([Berke & Conroy, 2000](#)).

The influence of the land-use changes on the sustainable development is based on the adequate use and implementation of planning tools, regulations and policies. Urban plans should be able to manage land-uses and the resources including strategies, aiming at sustainable development. Indeed, the most important plans at regional and local levels enclose implementation plans and specific rules with the aim of achieving this general objective oriented to the sustainability. One of these tools is the "Zoning". The

Zoning may help to define a range of regulations for supporting the management of the land-use changes, limiting the loss of natural areas, landscape fragmentation and uncontrolled processes of urban growth and sprawl ([Munroe, 2005](#)).

#### *2.1.1. Sustainable development, from the concept to the practice*

The concept of sustainability concerns the *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* ([Brundtland, 1987](#)). Indeed, the sustainable development aims to ensure an adequate degree of quality of the natural resources and their accessibility and availability for the future generations. This general statement needs to be translated into policies and plans for supporting concrete applications. Jepson (2001) pointed out that the concept of sustainability is strongly intertwined with the planning field. Sustainability and planning are inextricably linked in order to create a system to "protect the natural environment, meantime the economy has to be developed and the equity achieved". The role of sustainability in the strategic development of the human society is encompassed in the action plan of the United Nation, produced through the Conference on Environment and Development, held in Rio de Janeiro, Brazil, in 1992. The Agenda 21 is a global plan of action oriented to guide the sustainable development of the societies and the economies toward a sustainable use of the natural resources, focusing on the protection and conservation of the environment. The Agenda 21, such as a blueprint for sustainability in the 21<sup>st</sup> century, is composed of four main pillars:

- i. Social and Economic Dimensions;*
- ii. Conservation and Management of Resources for Development;*
- iii. Strengthening the Role of Major Groups;*
- iv. Means of Implementation.*

These four sections are organised in 40 chapters and, as Campagna (2016) pointed out, two of them are oriented to consider the contribute of the scientific and technological community and the information in decision-making for supporting the sustainable development. These general objectives are harmonised and recognised into the European Policies through the development of environmental-oriented Directives. Such Directives allow to integrate environmental considerations into plans and programmes for protecting the environment. The EIA (Directive 85/337/EEC) and the SEA (Directive 2001/42/EC) directives are two of these policies that put into effect the European Union purposes with regard to the environment, in compliance with the Agenda 21 objectives. The SEA Directive fosters the integration of environmental considerations into plans and programmes with the aim of creating an informed process for supporting the

plan-making phases (SEA Directive). The SEA is mandatory and an ongoing procedure applied at national, regional and local level (Zoppi, 2008). Indeed, the SEA has been implemented into the Italian Planning System through the Legislative Decree 152/2006 and it is intertwined with the plan-making phases at regional and local scale, in order to guide the planning process toward the sustainable development . In Sardinia the SEA is a mandatory procedure for the design of the most important document for managing the land-use planning at local level: the Municipal Master Plan. The MMP aims to guide the Local Land-Use Planning (LLUP) in order to ensure the development of society in compliance with the Regional Landscape Plan (RLP) of the Sardinia Region. Despite the adjustment process of the MMP to the RLP has to be concluded for all the municipalities, only few MMPs have been revised. The following paragraphs aim to put in evidence the current situation of the planning in Sardinia focus on the issues and pitfalls of the planning at the local level, Local Land-Use Planning, LLUP-SEA process.

## 2.2. Strategic Environmental Assessment (SEA)

Over the past two decades emerged the need of integrating environmental considerations into plans and programme. Continue human pressures on the environment and unsustainable resources' consumption require common European policies and strategies on environmental considerations.

The Strategic Environmental Assessment (SEA, Directive 2001/42/EC) and the Environmental Impact Assessment (EIA, Directive 85/337/EEC) have been developed as environmental oriented approaches with the aims of integrating environmental concerns into decision-making processes ([Abaza et al, 2004](#)). The SEA arose to guide the planning processes toward environmental-oriented procedures. The SEA was introduced into the European Policies through the Directive 2001/42/CE and should have been transposed for each European country not later than 2004. The SEA is a procedure inextricably linked to decision-making processes that integrates the sustainable development principles into Plans, Programmes and Projects (PPP) ([Fisher, 2007](#); [Geneletti, 2007](#)). The decision-making process should generate a set of alternatives in order to support the achievement of different planning goals. If the influences on the environment are not adequately considered, these alternatives, which generate land-use changes, may produce uncontrolled and undesired environmental effects.

The SEA may be considered as a structured approach which makes planners able to consider the intrinsic complexity of the development context, for evaluating the environmental changes that occur as a result of the alternatives design, such as social, economic and health impacts. Moreover, the SEA allows monitoring the effectiveness of the plans, their influence on the environment and on the other strategic fields.

Indeed, the SEA includes information about the implementation of monitoring programs for evaluating the real effects of the strategic goals on the environment. The impact analyses of the alternatives and the forecasting models allow generating a range of data that have to be compared with the results of the monitoring program. This comparison occurs for establishing the coherence of the forecasting models with the real impact of the alternatives on the environment. This evaluation process allows limiting and monitoring the uncontrolled consumption of the resources, such as land.

The monitoring program operates through a range of indicators which provides information, such as resources consumption and lands fragmentation, for supporting actions and programmes of mitigation.

The human activities influence the availability, quality and quantity of the resources that can be related to the soil/land consumption. The soil can be considered as the "*main resource that need of policy integration*" ([Treville, 2011](#)) due to its valuable properties for supporting the human well-being. The soil, or land, covers a set of strategic fields that undergo the effects of human activities. This cause-effect system encompasses an intrinsic complexity that may be not fully represented through the traditional planning methods ([Skehan and González, 2006](#)).

Innovations in planning methodologies and technologies introduce geographically referenced spatio-temporal dimensions for supporting decision-making. The integration of spatial data into practices to feed spatial analysis, may provide a range of benefits for supporting planning processes. The SEA procedure may be supported by different emerging technological and methodological sectors: the Geo-Information Technologies, the Spatial Data Infrastructure (SDI) and the Geodesign (GDF). The SDI makes available a big amount of spatial data and services in a process of continuous updating, to support planners for performing spatial analyses. Furthermore, innovations in Geospatial technologies and methodologies, such as Geodesign and PSS, have made possible to generate spatial tools and procedures for managing spatial data. The GIS could be considered as a reliable tool for managing data with a geographic component, which makes available a wealth of tools for planners in order to deal with their planning activities. As Skehan and Gonzalez (2006) argue that, the GIS in compliance with SDIs data, are able to produce an integrated framework for supporting the plan making process (Figure 3). Indeed, the GIS may support the wide range of activities related to the planning processes, such as the public participation procedures, spatial analyses, design and monitoring programmes, in order to investigate the influence of the plan choices on the environment. The next chapters investigate these aspects related to the planning procedures. The SEA may take advantage of the developments of these innovative sectors and in turn, may generate on-going procedures for supporting the sustainable development of spatial planning.

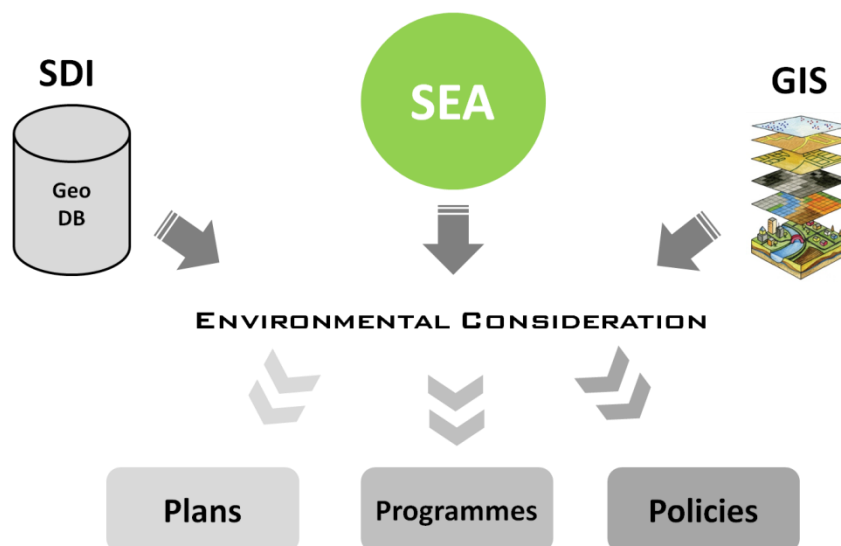


Figure 3 – GIS and SDI for supporting the SEA

Despite the efforts to integrate the SEA process into national boundaries for developing suitable planning procedures, the efficiency of the SEA approach to planning practices seems to be not fully guaranteed (Kornov and Thissen, 2000; Fisher and Gazzola, 20006; De Montis et al, 2014).

The integration of SEA into LLUP encompasses a range of issues inherent to the different phases of this process. It can be important to investigate the effectiveness of the SEA in LLUP for evaluating how this environmental assessment procedure is integrated into practices. Early attempts to evaluate how the SEA influences PPP date back to 1997. Mens en Ruimte (1997) provide an overview of the effectiveness of SEA and the degree of integration into planning practices of this environmental assessment procedure.

After that, a wide range of case studies and reports have been developed in an attempt of evaluating the SEA effectiveness in influencing PPP within the boundaries of the European State Members, such as Fischer, (1999, North West England), Chaker et al (2006, 12 States), Fischer and Gazzola, (2006, Italy), Stoeglehner, G. (2010, Austria), Carvill et al (2012, Ireland) and De Montis et al, (2014, Sardinia, Italy). Furthermore, Tetlow and Hanusch, (2012) collect the shortcomings of the application of SEA in planning practices, that can be summarised in:

- i. *Unclear influence of SEA in PPP;*
- ii. *Inadequate design of alternatives;*
- iii. *Fruitless impact evaluations;*
- iv. *Ineffective public participation processes;*
- v. *Inadequate monitoring programs.*

The aim of this chapter is to provide an overview on the SEA approach to Local Land-Use Planning (LLUP-SEA).

#### *2.2.1. The SEA for the Local Land-Use Planning*

The environment may be considered the base on which the human society has been developed. The human activities are deeply rooted on the availability of environmental resources. For this reason, the range of activities carried out to deal with the population' requests for goods and services, should be accurately planned. The integration of the environmental considerations into plans and programmes, has been fostered through the implementation of the SEA Directive into the European Policies.

The SEA has been enforced into the European normative framework through the Directive 2001/42/CE, for providing an "*high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment*" (2001/42/CE, Art. 1). As pointed out in the Strategic Environmental Assessment legal-context

page of the European Commission (EC), the plans and programmes that are mandatorily submitted to the SEA are related to a wide range of strategic sectors for the human well-being such as agriculture, forestry, fisheries, energy, industry, transport, waste/ water management, telecommunications, tourism, town and country planning or land use. The implementation process of the SEA approach into the national policies for each European country had to be concluded, not later than 2004. In the SEA guidelines, the EC pointed out as the SEA procedure should make available for the public, a report that summarize the environmental effects and the alternatives of the proposed plan or program ([SEA Directive](#)).

The first step in the SEA procedure requires that the environmental relevant authorities have to be consulted during the screening stage. After that, the scoping phase is the *"stage of the SEA process that determines the content and extent of the matters to be covered in the SEA report to be submitted to a competent authority"*. Besides, the SEA requires that a set of suitable alternatives and their assessment have to be taken into account. After that, a monitoring program has to be developed in order to mitigate unpredictable environmental effects through lenitive actions. The monitoring program is rooted on a set of indicators used in the preliminary phase (Scoping) to characterise the state of the environmental baseline. The indicators are an essential part of the SEA procedure due to their characteristic to communicate information in a simple way for supporting the monitoring program and the communication process among stakeholders ([Ezequiel and Ramos, 2011](#)). A deeper view on the indicators framework is provided in Chapter 5. Ezequiel and Ramos, ([ibidem](#)) pointed out as the indicators can be seen as a fundamental component of the SEA procedure and their importance is generally underestimated by practitioners and technicians. The Indicators are able to influence the process of assessment for the impact of plans and programmes on the environment.

The indicators may influence the collection of information: Indeed, if they are poorly selected, may cause processes of misunderstanding about phenomena and consequently a lack of fully impact assessment. Furthermore, *"the SEA obliges Member States to ensure that the environmental reports are of a sufficient quality"*. (SEA Directive).

The SEA procedure has to be transposed by all European States which are call for drawing up their own guidelines for supporting the implementation of environmental consideration for different strategic fields (e.g. land use, energy, water management), levels (Plans, Programmes and Projects) ([De Montis et al, 2014](#)) and scales (National, Regional and Local).



### 2.2.2. *The Strategic Environmental Assessment transposed into the Italian context*

The diffusion of environmental policies in the Italian normative context took place at a later stage compared to other European countries ([Lewanski, 2002](#)). The Italian Legislative Decree 152/2006 implements the SEA Directive into the national legal framework, enclosing in the second section procedures for the SEA and the Environmental Impact Assessment (EIA), since 2010. The implementation of the SEA directive in Italy regards the effects of plans and programmes on the environment at national, regional and local level.

At the regional level, the Autonomous Region of Sardinia included the implementation process of SEA directive in two laws approved in 2008 and 2012 (De Montis, 2013). The planning in Sardinian has been deeply influenced by the implementation of the Regional Landscape Plan (RLP, in Italian, Piano Paesaggistico Regionale, PPR) in the 2006, which is oriented to preserve the regional coastline area (Legislative Decree 22.01.2004, n. 42, Code of Cultural Heritage and Landscape). Sardinia is the first Region in Italy to implement a Landscape Plan.

The RLP was adopted to deal with uncontrolled exploitation of resources and urbanisation processes in the coastal area of Sardinia. The RLP coordinates the regional planning and supports the sustainable development in order to hand down the cultural, the historical and the environmental identity to future generations. In order to achieve this purpose, the RLP provides a set of rules to be implemented through the plans at local level. The most important Sardinian document, acting at the local level that acknowledges the RLP measures, is the Municipal Master Plan (MMP, in Italian, Piano Urbanistico Comunale, PUC). The process of adjustment of the MMP to the RLP has to be intertwined with the SEA procedure to be effective. The Legislative Decree 4/2008, at the article 11, encloses mandatory rules for putting into effect the MMP toward the RLP: *"the administrative measures of approval, adopted without a prior SEA, can be annulled because in violation of law"*. The law n°45/1989, and the Regional law n°8/2004, called for MMPs as a procedure oriented to manage land planning of a municipality fragmenting the territory in homogeneous areas or zones. This technique is called *zoning*. The zoning is put into effect through the implementation plans for different use of the lands. For this reason, the RLP provides a set of guidelines to make the creation of the Municipal Master Plan in compliance with regional rules and policies. The process of MMP adjustment should occur along one year. The territory and the land-uses are conditioned by a set of constraints and limits until the Master Plan will be in line with RLP rules. The Regional Law n°8/2004 establishes that each municipality in Sardinia should adjust the MMP in compliance with the RLP rules, up to one year from RLP approval. The Legislative Decree 4/2008, art. 11 states that *"the SEA procedure is an integral part of approval procedures for plans and programmes. For each plan or program approved without being subjected to SEA procedure, can be annulled due to violation of law"*. Nevertheless, few

municipalities in Sardinia have revised the Master Plan in compliance with PPR disposition while, the majority of Municipalities have put off the revision process ([De Montis et al, 2014](#)). In the next paragraph is described the MMP-making process.

### 2.2.3. *The process of Strategic Environmental Assessment*

The adjustment process of the MMPs of the Sardinian Municipalities to the RLP consists of three main phases:

- ✓ *Phase of Knowledge;*
- ✓ *Phase of Interpretation;*
- ✓ *Phase of Response.*

These main steps have to be strictly intertwined with the SEA procedure for supporting a structured and informed plan-making process. In this paragraph an overview about the framework of the LLUP-SEA process, is proposed.

The first step, called *Knowledge Phase*, is based on the “knowledge-based reorganising”. In this phase, the municipality has to collect data related to the territorial context, in compliance with the RLP requirements. This phase is important to update the knowledge-base about every physical factor of the municipality territory. The data about the municipal territory should be made available through the Regional Spatial Data Infrastructure (RSDI, or in Italian, Sistema Informativo Territoriale Regionale), established by the Sardinian Regional Government. The spatial data encloses all physical characteristic regarding the Municipality area and this big amount of information need to be updated. In fact, the Municipality, through the technicians, has to be able to access to the RSDI in order to obtain the spatial data for its own territory. A wide range of actors with different professional knowledge, such as Geologist, Naturalist, Hydrographer and Historian, meet up and merge during this phase. Indeed, these actors should be able to make available updated analyses about the territory for supporting informed plan-making process. Data updating is necessary for the three main sectors: the Environmental, the Historical and Cultural and the Settlement fields. These professionals should produce new pieces of spatial knowledge with the aim of classifying and monitoring territorial resources and phenomena, for supporting the local spatial planning (or Local Land-Use Planning, LLUP). Furthermore, this phase concerns the creation of the environmental framework on which are based the analyses, the design and monitoring programs. The new spatial information produced in this phase, shows the current state of the territory through a set of specific layers. These layers may provide a new knowledge about social, environmental and economic phenomena and, if adequately

supported by Geographic Information Systems tools, this information may be visualise, analyse and monitored, in order to support LLUP.

According to the guidelines released by the Region of Sardinia, the SEA aims to make possible the evaluation of how the plan goals affects the environment, through a collection of information about the eleven most important environmental components:

*(1) Air, (2) Water, (3) Waste management (4) Soil, (5) Flora, fauna and biodiversity, (6) Landscape, History and culture, (7) Demography and human settlement, (8) Economic sector, (9) Transport and mobility, (10) Noise pollution and (11) Energy .*

In the light of the above premises, the indicators are able to represent the information collected for each environmental component feeding back the monitoring program enclosed in the environmental report. This phase may be considered as an essential part of the SEA for integrating the environmental consideration into the plan-making.

On the one hand, this analysis is important to define how the plan deals with the environmental criticalities, fostering a set of solutions in order to mitigate current negative environmental phenomena. On the other hand, this analysis define how the plan choices may influence the environment. All phases of the adjustment process of the MMP to the RLP have to make available a set of outputs called "analysis table". These results are a mandatory requirement to verify if the MMP is in compliance with the required technical specification (e.g. data collection, format conversion) of the RLP. The Region of Sardinia receives the output of the first phase in order to verify if it is in compliance with the RLP requirements.

When the Region of Sardinia, establishes the conformity of these results, it is possible to begin the second phase: the "Interpretation phase". This phase puts in evidence the relationships among the Environment, the Historical-Cultural and Settlement systems. The interpretation phase is related to the draft of the MMP, or development plan, that encloses the analyses on which the mitigation actions and future developments are based on.

Furthermore, the development plan encloses a set of alternatives in order to compare and evaluate different planning solutions, including environmental considerations into socio-economical strategies. The outputs of the interpretation phase, have to be approved by the Region of Sardinia in order to prepare the third phase, namely the *response phase*.

The response phase aims to put into effect the MMP through a set of rules and implementation plans. In this phase the zoning plan, which indicates the fragmentation of the municipal territory, is prepared. The LLUP-SEA process has to be combined with a non-technical summary and an environmental report, describing the environmental effects of the plan objectives and a set of alternatives. In fact, according to the SEA Directive (Art. 10), the SEA Environmental Report must enclose the monitoring program in order to

evaluate the effects of the planning actions on the environment through a set of indicators. For this reason, the SEA should be integrated into decision making process as an on-going process, promoting procedures such as the identification of alternatives, the participation processes and impact evaluation planning goals, calling for lenitive actions and limiting irreversible environmental processes ([Glasson, 2013](#)). Despite the wide spread diffusion in planning practices of the SEA procedure, the efficiency of this environmental oriented approach is still limited. The next paragraph summarises a range of pitfalls related to the implementation of the SEA procedure in planning.

#### *2.2.4. Issues, pitfalls and innovation potential in SEA-LLUP*

The efficiency of the SEA procedure is rooted on the relationships of this environmental-oriented approach with PPP. Nevertheless, from a critical point of view, these relationships are usually poorly established ([Kornov and Thissen, 2000](#)).

In Italy, the integration of the SEA process in practices encloses both good examples of application and some pitfalls. Mainly, the South of Italy, and in particular the Sardinia Region, depicts a situation of complexity in the implementation process of the SEA (De Montis et al, 2014). Fisher and Gazzola, (2006), pointed out as, the Italian planning is just oriented to consider the historical and urban point of views more than the whole intrinsic complexity of the biophysical environment. The result of these analyses brings into attention how the Italian decision-making processes are poorly oriented to consider the environmental issues, causing a low degree of comprehension about these phenomena.

Further pitfalls can be related to the poor iterations among stakeholders involved in the process, influencing the role of the public participation in the decision making processes. (Fisher and Gazzola, 2006). The big amount of information taken into account in the LLUP-SEA process may produce a high level of complexity for informing the decision-making process, generating uncontrolled effects on the environment and economic consequences for supporting mitigation actions.

For this reason, the Geographic Information System may be seen as a suitable tool for supporting the LLUP-SEA processes. Treville ([2011](#)) pointed out as the GIS tools "need to be an essential part" of the SEA procedure due to their potentiality to consider the multilayer information and perform analyses to produce outputs related to the environmental effects caused by plan goals. These analyses may take into account cumulative effects that, without the support of GIS tools, may be considered too complex for the traditional planning approaches. Furthermore, the availability and accessibility of spatial data for supporting planning phase through a GIS is needed. In turn, services and data offered by SDIs, are becoming more and more important for supporting spatial planning toward the sustainable development

It can be argued that *"poor SEA reflects poor planning processes and vice versa"* (Treville, *ibidem*), and further developments and research are needed for sustaining the spatial planning procedures toward the

sustainable developments. In order to deal with the range of pitfalls that are influencing the spatial planning, especially at the local level, a Planning Support System for supporting the LLUP-SEA has been developed. In the next paragraphs, a deeper view of this innovative architecture, is proposed.

## 2.3. Spatial Data Infrastructure

### 2.3.1. SDI: recent advances

Spatial Information Technologies (SIT) and Geographic Information Systems (GIS) consider the physical position of objects and related spatial characteristics through digital maps and representations ([Fox et al, 2006](#)). The Spatial Information provides insight into European policies for a wide range of urban and environmental fields of the European geographic space, such as transport, energy, agriculture, regional and local developments ([Onsrud, 2007](#)). Spatial Information, due to their characteristic, may be considered as a fundamental component of the Infrastructures of spatial data ([Parker, 2002](#)). Indeed, the Spatial data infrastructure (SDI) is an infrastructure that enclose spatial data into a technological interoperable framework, connecting users, policies and tools and supporting the creation, diffusion and use of geospatial information (Toth et al, 2012, Li et al, 2008; [Campagna and Matta, 2014](#), SEA Directive). In fact, the United Nation promotes the development of SDIs as an essential element “*for increasing system coherence in the use and exchange of geospatial data and information for UN activities*” in order to sustain more efficiency policies, goals and global needs. ([UNGIWG 2005](#)). Recently, several initiatives that foster the accessibility and use of Geospatial Information for a wide range of users, have been developed. One of these, called GEOSS (Global Earth Observation System of Systems) produced by the Group on Earth Observations (GEO), aims to make available, through a global and flexible network of contents, the GEOSS portal, up-to-date and user friendly information supporting planners and decision makers. (Goodchild et al., 2012). The main goal of GEOSS is to provide a decision-support tool for “nine areas of critical importance to people and society” in order to deal with environmental, social and economic issues. As Boerboom ([2010](#)) pointed out, the infrastructures of spatial data are usually defined as an essential element for the integration of spatial information into decision-making, fostering a general point of view where the SDIs become a support tool for decision-making processes. However, several economic issues are rooted on the management of SDIs ([Trapp et al, 2015](#)). Indeed, the investments made to make available reliable spatial data, should be justified by an economic return in terms of achievement of the environmental, social and economic goals. The institutions and agencies of the European Union employs geographic information for their purposes becoming both producers and users of spatial data. The development of SDIs occurred through two generation. The first one, was mainly oriented to produce and collect data for completion of databases from national mapping agency while, the second generation is more represented by stockholders community toward involvement of actors and participation and process oriented. In order to support formulating and monitoring of European policies, the [Directive 2007/2/EC](#) of the Council and the European Parliament, provides the legal framework to constitute Infrastructures for Spatial Information ([INSPIRE](#)). The Inspire Directive, promotes the wide spread diffusion of spatial data infrastructures among the

European Countries with the aim of defining and supporting European policies. In turn, the spatial data may produce a range of economic benefits related to their accessibility, quality and availability. In the light of the above premises, the SDIs are becoming an important element for the understanding, monitoring and assessment of human-environmental interactions.

### 2.3.2. *The INSPIRE Directive*

The constant growth of the world population (UN, 2015) is intertwined with a wide range of urban planning problems and environmental issues which are becoming more than ever crucial challenges for planners and decision makers to achieve an adequate degree of human well-being in compliance with the environmental sustainability ([Bishop, 2000](#)). Practices and policies have been developed for dealing with planning problems related to the cities expansion. These planning activities have fostered the evolution and integration in the planning practices of spatial science ([Dodson, 2008](#)). The comprehension and analysis of urban-environmental phenomena could be related to the quality and quantity of the information available ([Qureshi, 2009](#)). Indeed, planners rely on the availability of appropriate information in order to deal with urban issues. For this reason, the importance of Spatial Data Infrastructures in Urban Planning is becoming more than ever the core of decision making processes ([Qureshi, 2009](#)).

The term Spatial Data Infrastructure encloses the concept of *"framework able to make available for using and sharing geographic data based on policies, people, technologies and data"*. Indeed the Spatial Data Infrastructure may be seen as the centralization of efforts to make available referenced spatial information and services for supporting the accretion of knowledge regards geographical features. In turn the importance of SDIs for supporting decision-making processes, is put in evidence for social, economic and environmental sectors through the development of spatial data infrastructures at National level (NSDI) ([Bishop, 2000](#), [Craglia, 2004](#)). As Chan ([2001](#)) argued that, despite the wide range of definitions for sustaining the comprehension of the SDI characteristics, this fragmentation have generated a poor understanding regard its evolution towards users and technological systems. Furthermore, the widespread diffusion of GIS technologies have promoted the importance of geographical data from SDIs, for the spatial analysis ([O'Sullivan, 2003](#)).

A Memorandum about the "Infrastructure for Spatial Information in Europe" was published in April of 2002 to support cooperation initiatives for developing INSPIRE achievement. The main objective of this cooperation is based on the creation of a legal framework to make available reliable sources for supporting the European Policies. The developments generated during the time frame 2002 – 2007, made the bases for the creation of the INSPIRE Directive. The INSPIRE ([2007/2/EC](#)), is an European Commission Directive entered into force on the 15th May 2007. The early definition of SDI in the late Eighties, was related to

foster use and re-use of digital spatial data. The INSPIRE is the acronym for the **IN**frastructure for **SP**atial **InfoR**mation in **E**urope and its principles are rooted on diffusion, sharing, availability, accessibility and updating of spatial information regarding the European territory. INSPIRE establishes the adoption and diffusion of Infrastructures for Spatial Information across European Member States to support formulating and monitoring of European Policies ([Bernard, 2005](#)).

Despite, the first aim of the INSPIRE Directive was initially oriented to focus the attention on the environmental policy needs, other sectors, such as Agriculture and Transport, have been gradually integrated. The INSPIRE Directive aims to ensure the quality and validity of spatial data, making available these components for services ([Litwin, 2011](#)). Furthermore, the INSPIRE is based on six element: (i) Metadata, (ii) Key Spatial data themes and services, (iii) Network services and technologies, (iv) Agreements on sharing and access, (v) coordination and monitoring mechanisms and (vi) process and procedures. Despite the relevant efforts to put into effect this innovative and technological approach, the process of application in practices encompasses a range of pitfalls. ([Craglia, 2007](#); Campagna, 2014). Vanderhaegen and Muro ([2009](#)) argue that, despite the wide range of spatial data produced by different organization and agencies ([Qureshi, 2009](#)), incomplete databases and incompatible dataset can be seen as relevant obstacles of this process. The Directive encloses a range of implementing rules (IRs) to be applied for specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting), in order to guarantee the usability and compatibility of spatial data infrastructures in a Community and transboundary context ([Craglia, 2009](#)).

INSPIRE is structured in three annexes which an high-level categorization of the real world. The spatial objects are represented through 34 Spatial Data Themes. The figure 4 represents the current structure of these themes. Each theme takes into account a set of spatial data components or sub-themes aiming to deal with the sustainable development goals of EU and the multi-purpose for eGovernemnt actions.





Figure 4 - The Annexes of the SDI

A fundamental step in the adoption program of the Directive for all European Member States, was the 15th May 2009. At this stage each State should have harmonized the Directive into the National Legislation creating their own Spatial Data Infrastructure.

When the Directive coming into effect, the diffusion of Spatial Data Infrastructures (SDIs) has been transposed into regional and sub-national dimension related to the diversity of the Member States.

This implementation process led to develop well structured infrastructures in most of the European Member States although much progress is still to be made ([Craglia, 2009](#)).

In fact, the development of SDIs is a process related to support decision-making addressing a wide range of issues pertaining to use of environmental resources and urban growth management ([Feeney, 2001](#); [Boerboom, 2010](#)). The diffusion and accessibility of spatial information is a procedure made available through Geo-Portals that allow users to use services for spatial data as searching, viewing and downloading (Campagna, 2014).

Geoportal is a gateway based on management and access of Geospatial Information (Catalog Geoportal) or on-line and dynamic services (Application Geoportal) ([Maguire, 2005](#)). The Geoportal allows users to make operations through lightweight web-client or desktop GIS-Client access to internet connection. Geoportal can be seen as the core of the SDI system due to its characteristic related to e-commerce and administration capabilities. The Geoportals contribute to simplify access to Geo-Information for public and private stakeholders, making easier sharing, avoiding duplicate and providing advances GIS functions. Furthermore, if Geoportals are supported by GIS applications, can become powerful tools for a wide range of processes, included planning procedures. The widespread diffusion of the Geoportals and the increasing accessibility to higher quality of information, can support the transparency in government activities,

fostering democratic participation processes and an efficiency way to reduce costs for data collection (i.e. avoiding duplicates). Indeed, it can be argued that the SDIs can support and improve the decision-making processes ([Maguire, 2005](#), [Boerboom, 2010](#)).

The SDIs may provide further benefits as economic return on the investment for the Geospatial Information diffusion. This process involves costs for collecting, maintaining and updating of spatial and costs for building the infrastructures. ([Silva, 2011](#)). Despite the benefits provided by the use of spatial data for a wide range of sectors, (from environment to economic) and the papers that have been centered on the socioeconomic impact of SDI ([Campagna and Craglia, 2012](#)), the assessment of their economic return is a current challenge ([Trapp et al, 2015](#)). In turn, other aspects should be considered in order to make an exhaustive economic consideration on the impacts of SDIs, taking into account no-economic fields (quality of life, environmental safeguards, qualitative benefits) ([Campagna and Craglia, 2012](#)) and high-wage jobs in the world ([FGDC, 2013](#)). In the same report ([FGDC, ibidem](#)) a global value of Geospatial Technology and Information (GTI) is provided, emphasizing the continued growth of the GI sectors from different economic point of views. Craglia and Campagna ([2009](#)) pointed out as the SDI value is achieved at regional and/or local more than global and/or national levels. In fact, focus on the Italian context, Regions as Lombardy, Tuscany and Sardinia, carried out legislative frameworks to integrate Regional SDI as knowledge to support local spatial planning and governance. The practice of spatial planning is intertwined with environmental changes and resources consumption ([Holtslag-Broekhof, 2012](#)) in order to promote sustainable principles. For this reason, the concept of sustainability in spatial planning is becoming a core issue for current spatial planners. The sustainable dimension for developments is represented by the overlapping of three dimensions:

*Environmental, Social and Economic* (as depicted in Fig. 5). ([Tanguay et al. 2010](#))



Figure 5 - Environmental, Social and Economic fields

In turn, most of the INSPIRE Data themes become essential elements to feed Regional Spatial Data Infrastructure, fostering the knowledge base to support regional and local planning. Indeed, in order to design land-use and zoning plans, planners and decision makers take into account a wide range of spatial information. These spatial information are useful to sustain the development of such plans in different phases. The spatial information can be used to foster the comprehension of ongoing spatial phenomena, city organization and impacts of plans purposes and goals ([Holtslag-Broekhof, 2012](#)). Indeed, decision makers may achieve an high quality of the decision process and deal with issues related to spatial planning, land use planning and the creation of zoning plans through an integrated use of spatial information ([Koenig et al, 2009](#)).

### 2.3.3. The SDI in Italy and Sardinia.

The Italian Government model is based on three levels: National public authorities, Region and Local (about 8100 municipalities). The Public Authorities, in order to fulfil their tasks, activities and analyses, collect, produce, reproduce and disseminate data. These data encloses a strategic value for public and private sector but are not always homogeneous and interoperable. The “Intesa Stato-Regioni-Enti Locali per i Sistemi Informativi Territoriali (Intesa-GIS, 26/09/1996)” is a protocol involving central, regional and local administrations, aiming to integrate the national topographic geo-database and ortho-imagery coverage. The *Intesa* aims to achieve three main goals, enclosing the production of common technical specifications,

data in compliant with the technical specifications and activities aiming to publish or make available the GI through the production of cartographic catalogues. The third objective was promoted through the creation of a National Digital Mapping Portal (NDMP) and a network infrastructures in order to satisfy the need for every end-point (users) ([Vandenbroucke, 2011](#)). According to the Law n.68 of the 2/2/1960, the official producers of medium to small-scale GI (e.g. 1:25000, 1:50000) are the Cadastral Agency, the Navy Hydrographical Institute (IIM), the Italian Military Geographical Institute (IGM), the Air Force Geotopographical Information Centre (CIGA), the National Technical Services (STN) and, also the National Statistical Institute (ISTAT) is involved in GI data diffusion (i.e. census unit). In turn, Regions, Provinces and Municipalities are producers of Large –scale topographic mapping (e.g. 1:10000, 1:5000) for their territories. Indeed, the aim of 1996 GIS Agreement was to make available a tool for good Governace at different spatial scales, from national to local. The outcome of the GIS agreement was the Italian Spatial Data Infrastructure, called “Sistema Cartografico di Riferimento” (SCR).

With the implementation of the INSPIRE Directive, some initiatives have been developed, in an increasingly cooperation process among Regions at National level ([Vandenbroucke, 2011](#)). Indeed, in Italy, several Regions (e.g. Lombardia, Sardegna and Piemonte) have built their own Spatial Data Infrastructure (Regional SDI, RSDI) in order to make available geographical information for supporting the decision making processes.

One of this, that is in the major interest for the research purposes, is the SITR-IDT of Sardinia Region, resolution of 11 June 2002, which structure is composed by two interacting element: the Information System and the Spatial Data infrastructure. The official geographic data of the Sardinia Region have been made effective through the project of Regional Authority for Municipalities, Finances and Urban Planning, called SITR-IDT, started in 2005 and finished by the end of 2009. The Territorial Information System of Sardinia (SITR) is a federated architecture unitary system based on the sharing and interoperability. The aim of the SITR is to collect and sharing data for the Sardinia Region, related to different fields: geographic, historical, urban and environmental ([Vandenbroucke, 2011](#)). On the other hand, this Regional SDI should be able to sustain territorial policies of the Regional Government. Indeed, the Regional Spatial Data Infrastructure is a database containing a wealth of interoperable services, official geographical data and web application. The SITR is easily accessible for both public administrations and web users, including simple citizens, and making available all services. In fact, the information and services of the SITR are available for agencies and practitioners to perform analyses and support their activities, and for citizen (or common users) that, thanks to dedicated services, may be able to understand a range of information about the local and/or regional territory. The RSDI encloses more than 300 layers (data layer, service layer, an integration layer and a user layer) for public use and their accessibility has been made possible through the interoperability OGC (Open Geospatial Consortium) services WMS (Web Map Services) and WFS (Web

Feature Services) or downloading and viewing. Other standards have been adopted as: ISO 19115 ("*ISO 19115:2003 defines the schema required for describing geographic information and services*", [\[4\]](#)) and 19139 and INSPIRE Implementing Rules. The Sardinia RSDI encloses relationships with the Inspire spatial data themes and, in turn, the SRSDI spatial data themes are in compliance with the technical rules for the National Spatial Data Repository (Ministry Decree 10.11.2011) and are classified according to the ISO 19115. (Fig. 6). The spatial data have been made available and freely accessible by means of the most common GIS applications for planners and/or users (citizens, technicians). The data are accessible through a range of services oriented to satisfy the user needs. Nevertheless, the accessibility for services is not fully guarantee for everyone. Indeed, some services are specifically addressed for professionals or for other SDIs or for common web-users. *Three main typologies of users can be defined for the SITR-IDT*. The first one are the *Public Administrations* that may have their own thematic SDI to perform specific analysis (distribution of air pollution data on the territory), or not have their own SDI (i.e. Municipalities). The Municipalities aim to use data from SITR-IDT to perform analysis for their purposes, using certificated geographic data (e.g during the knowledge phase of the adjustment process of the MMP to the RLP). The second group is represented by *professionals* and *practitioners* that access to standard network services as WMS and WFS, defining analysis based on official territorial data of Sardinia Region. The third group is composed by *citizens and private persons*, that use the functionality of SITR-IDT for different purposes toward the improvement of knowledge about their local/regional territory. ([Manigas et al, 2010](#)).

Despite the increasingly diffusion of SDIs across European Countries as support for decision making processes at different scales, their value in spatial planning is still limited ([Boerboom, 2010](#)). Several researchers pointed out as the design of SDI is unable to achieve the fully satisfaction of planners and practitioners (Qureshi, 2008) and as the complete implementation of the INSPIRE purposes may support decision-makers and planners to achieve planning goals ([Dessers, 2013](#)).

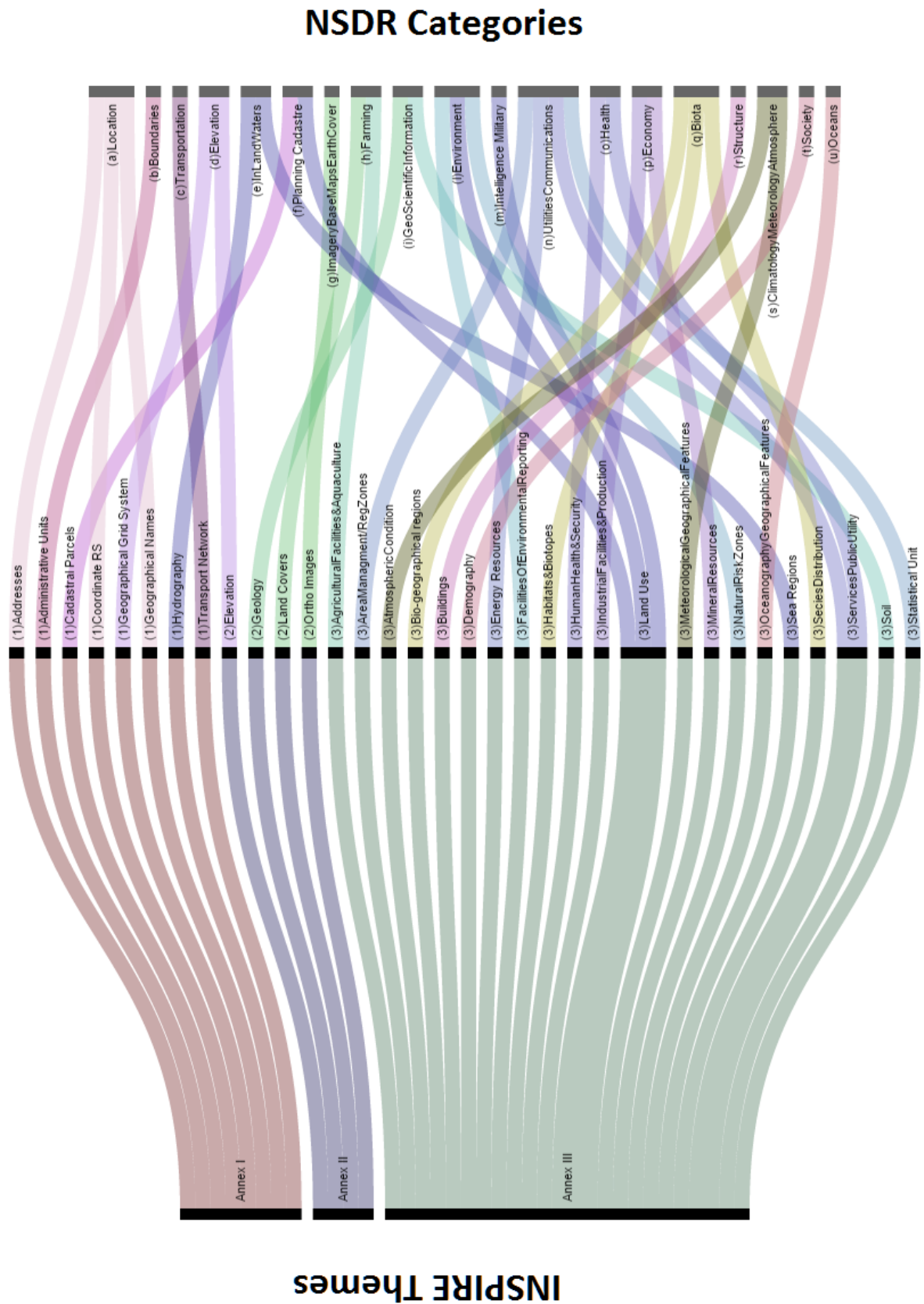


Figure 6 - The relationships between the INSPIRE and the SRSDI spatial data themes

## 2.4. Conclusions

Despite the consistent efforts to integrate the principles of sustainability into planning practices through structured and environment-oriented procedures, the results of this process are still limited and unclear.

These shortcomings may be encompassed in the lack of a clear approach to the application of SEA in spatial planning, with regard of principles, methods and tools (Campagna 2014).

Emerging methodologies and innovative technologies, such as Geodesign and Planning Support Systems, may guide a fruitful integration of such environment-oriented procedures into spatial planning (Campagna and Di Cesare, 2016).

Geodesign may be considered an iterative methodological approach oriented to evaluate through digital technologies and geospatial modelling the influence of the design activities on the geographic space for feeding a smart decision-making process (Flaxman, 2010; McElvaney, 2013, Steinitz, 2012). This methodological approach may offer an opportunity to both fill the gap between the purposes of the SEA policy principles and how they are currently implemented into practices and foster the integration into the Italian spatial planning governance of innovative technical platforms, such as the Spatial Data Infrastructure (SDI). The next sections aim to offer an exhaustive view of methodologies and methodologies applied in the research for dealing with these pitfalls. Furthermore, the application of Geodesign and PSS refers to the case study of the Sardinia Region, with regard to the process of adaptment of the MMP to the RLP.

The results of the case studies may suggest a possible integration of this approach at National and European scale in order to address open issues in spatial planning.

### 3. Novel approaches and technologies for the contemporary planning practice

The proposed methodological approach deals with the issues concerning the adjustment process of the MMP to the RLP, investigating how the spatial data can support this procedure. The methodology is based on a framework that takes into account how the geographic space may change due to the design proposals. The GeoDesign framework proposed by Steinitz (2012) is based on six levels of inquiries and six models in order to support the planning processes. This interactive framework is able to take advantages from the information about the territory, enclosing participation processes. In fact, different groups of people (i.e. technicians and citizens) can integrate their knowledge into the planning process with the aim of supporting the decision making phase.

The GeoDesign framework (GDF), through the first three models, makes value of the information for representing the studied area, supporting the spatial analysis and the evaluation of the current situation. Moreover, in the second part of the framework, through the last three models, the design proposals will be put into effect, in order to assess their environmental impact for supporting the decision-making toward the most suitable solution.

The models can be integrated into the planning practices in many ways. The Geodesign matches the geotechnologies and the spatial information aiming at support the decision-making process. The GDF is able to inform the planning process through analysis, participation, design, impact assessment and scenarios comparison. For this reason, the tools oriented to manage geographic information should be considered as a support for the Geodesign activities.

The Geographic Information System (GIS) and Planning Support System (PSS) are design-oriented systems and, could be considered as reliable tools for integrating the GDF into the planning practices. The PSS integrates the GIS tools in the architecture, through dynamic models and user friendly interfaces, which make available a flexible structure intertwined with the complexity of the planning process. The research aims to define a PSS architecture oriented to integrate the GDF framework models for supporting the LLUP-SEA procedure.



### 3.1. Methodologies: Geodesign

Since 1993 ([Kunzmann, 1993](#)), until the recent definitions (i.e. [Steinitz, 2012](#)), the term of Geodesign has increasingly become popular among spatial planners and Geographic Information Science scholars. It can be argued that a wide range of definition regarding Geodesign can be found in literature ([Goodchild, 2010](#), [Ervin, 2011](#); [Miller, 2012](#), [Steinitz, 2012](#)) [1]. Geodesign can be defined in short, as an approach centered on planning and design and oriented to inform decision-making by means of collaborative processes rooted on geographic analysis. ([Campagna, 2014](#)-1). Looking back to the 1969, Ian McHarg in his book "Design with Nature" describes a system oriented to support knowledge processes for a place, based on analysis of a wide range of layers, such as history, hydrology and topography. The McHarg's system paves the way for the concept on which the Geographic Information System and Geodesign are rooted (Raumer, 2011). In recent years, the diffusion of Spatial Data Infrastructures (SDIs) across European Countries is contributing to foster the growth of Digital Earth (Craglia et al., 2012) through the use of authoritative and volunteered geographic information for supporting decision-making. In turn, regional spatial planning laws intertwined with Strategic Environmental Assessment, (e.g. Tuscany, Sardinia, Lombardy) are addressing local land use plans toward regional SDIs in order to represent plans in digital format. Despite of these innovative approaches that contribute to increase the quality of decision-making processes, the planning practices based on spatial data and analysis are still far to fully exploit their potential. Thus, Geodesign may be considered as a approach capable to take into account planning issues in order to foster innovation in urban and regional planning. In fact, Steinitz ([2012](#)) proposed a framework for the Geodesign based on six models and three iterations with the aim of developing an interactive structure. The Geodesign framework can be applied to Local Land-Use Planning - SEA (for instance through a Planning Support Systems) ([Campagna and Matta, 2014](#)) for supporting spatial planning practices.

#### 3.1.1. *Geodesign: an innovative approach oriented to planning and design*

The GeoDesign is deeply rooted on the concept which the human activities influence the natural environment. Since human developed a society to live, the impacts of our choices, or design, have been taken into account to evaluate the effects on the geographic space. As Miller ([2012](#)) pointed out, each activity or design that affect or change the environment may be related to the Geodesign concept.

Urban phenomena, as the city expansion and the population growth, the increasingly request of well-being and the scarcity of resources, influence the choices for planners. In fact, European Policies have been implemented and harmonized across European Countries at national and regional level in order to deal with these issues. Furthermore, planning processes are influenced to digital representation of geographic

information and spatial analysis to inform decision-makers about spatio-temporal phenomena and to evaluate the effects of the plan choices. These intertwined components are addressing planning processes toward complex multiple tasks that call for high competence and technical skills for planners and practitioners.

The Geodesign approach aims to fill the gap among the range of different disciplines that are influencing the current planning practices, defining a framework able to make in compliance spatial planning and Geographic Information Science (Campagna, 2014). Indeed, Geodesign bridges the gap between geographic knowledge and geo-technologies in a framework oriented to inform decision-making processes through services as analysis, projection and forecasting, design of alternatives and relative impacts and assessment (Steinitz, 2012). The framework proposed by Steinitz may be related to a general system that combine a big amount of information from different sources. This system allows to design future alternatives for evaluating, on the one hand, their impacts on the natural environment and, on the other hand, their influence on the human society. The alternatives generated into the framework can be evaluated in order to guide the choice toward the most suitable solution (Figure 7 ).

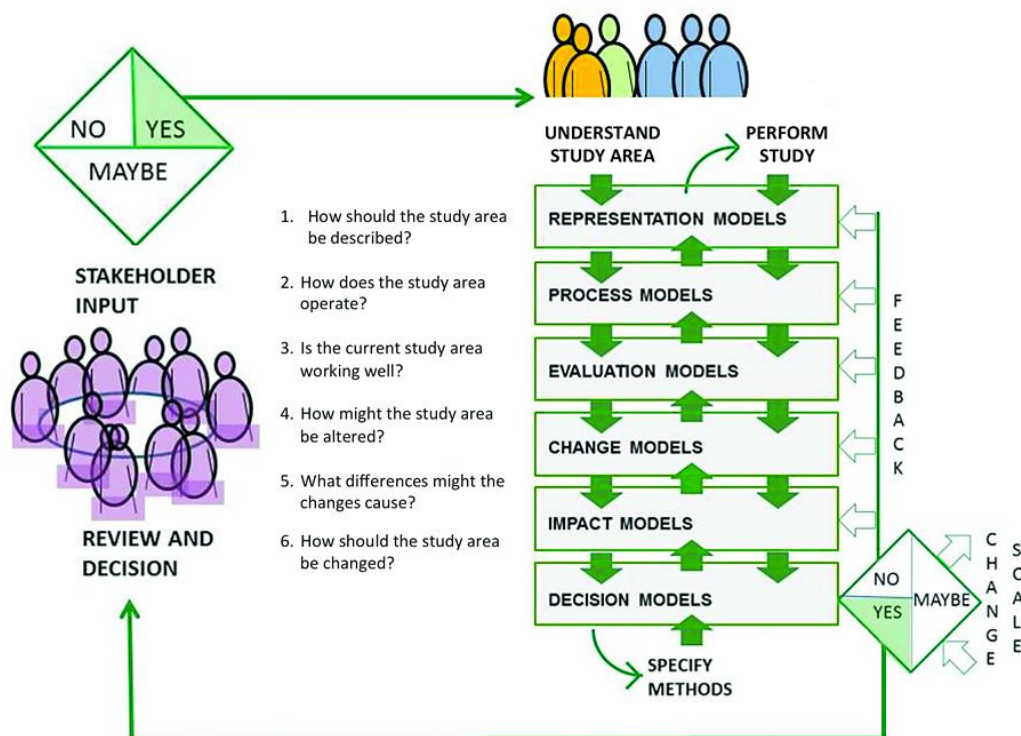


Figure 7 - The Geodesign Framework (Source, Changing Geography by Design, Steinitz, 2012)

The Steinitz's framework allows generating, evaluating and testing the alternatives through a stepwise structure based on sequential models and producing information to support informed plan processes during the three iterations. For each step in the framework, a level of inquiries is required in order to

address the output of the specific model to be the correct input for the next. According to Steinitz, the "*Geodesign changes geography by design*". This general definition becomes the base concept for the framework. Indeed, the "design" is not dependent of an unique way but exist a plethora of methods to deal with it. Steinitz (ibidem) pointed out as the framework proposed, should be based on six levels of inquiries, on which design processes are deeply rooted on. These questions are:

1. *How should the study area be described in content, space and time?*
2. *How does the study area function?*
3. *Is the current study area working well?*
4. *How might the study area be altered?*
5. *What differences might the change cause?*
6. *How should the study area be changed?*

Geodesign may deal with large and complex problems, often related to different geographical scales. Geodesign intends to take into account complex phenomena in order to support knowledge processes in compliance with people, disciplines and methods. These Geodesign processes are oriented to the collaboration among group of people that assemble the Geodesign Team.

The Geodesign Team is composed by four essential group of people representing: people of the place, design professionals, natural and social scientist and technologists ([Steinitz, 2012](#)). These groups of people allow to integrate different types of knowledge into the framework, feeding the collaboration in the Geodesign practice. The *natural and social scientists* as geographer, ecologist and economists, the *design professionals* as planners and urban designers and *their technologists*, represent the first three groups of the Geodesign team. The people of the place represents that group that change depending on the geographical study area, addressing local knowledge as input for the study and reviewing the final decision toward the most suitable.

Another relevant aspect regards the scale on which the Geodesign should be applied. Indeed, different scales are related to different aspects, concepts and outputs. At the global level, the main goals are related to public health and global environmental phenomena. The output aims to produce general rules and treaties on which develop national laws. The regional level is oriented to provide knowledge about phenomena that take into account different cultures, social context politicians. The output is related to find consensus between who perform the Geodesign practice and politicians that should make decisions. At the local level, the relationships with stakeholders changes. Indeed, the Geodesign practices are oriented to satisfy public (municipality) or private (business) requests. At this scale level, the local knowledge and the people of the place may be considered the core of the Geodesign practice. Also, is possible to produce

innovative ideas to support planning and design. In conclusion, the design across geographical scales produces different outputs, taking into account different levels of information or layers, intertwined with different group of people and knowledge.

In order to give value to the Geodesign purposes, the framework proposed by Steinitz (2012) intertwines models and questions in a flexible structure that is not based on a unique linear process but on an iterative loops and feedbacks.

Each level of inquiry may be implemented in a model with the aim of answering to the specific question. The first of the three iterations in the framework, should provide knowledge for the study area. Indeed, it is called **Understand Study Area**. The first question, *“How should the study area be described in content, space and time?”* is connected to first model of the Geodesign framework. Indeed, the **Representation Model (RM)** aims to provide knowledge about the study area in order to make in evidence every component, field or sector that characterize the complexity of the territory. The RM should be able to answer some other questions regarding boundaries of the study area and its physical, social and economic spatio (Geographical)-temporal (Historical) characteristics. Furthermore, the RM should take into account possible plans and design for the study area and, if they are accessible, the digital databases. Lee et al (2014) pointed out as the RM is a collection of spatial information, digital maps and features with the aim of addressing analysis regard how the territory operates. Indeed, the output of the RM feeds data input for the next model: the **Process Model (PM)**. The PM answers to the question *“How does the study area operate?”*, enclosing in the model that processes are relevant for the Geodesign studies. Decision makers and people of the place should be able to integrate in the process their opinion and concerns about the study area with the aim of supporting the decision making. Furthermore the PM, should provide knowledge about physical, ecological and human processes and their relationships in order to support the comprehension of how the territory operates through phenomena (endogenous or exogenous) intertwined each other. After this step, the next question is *“Is the current study area working well?”*. The **Evaluation Model (EM)** is able to answer this question. The EM takes into account the people of the place and their knowledge and perception about the study area. Indeed, the people of the place are able to define which aspect work well or not, fostering the evaluation processes through cultural knowledge. But people of the place integrate different cultural aspects and group of people, making a vision of the urban development from different point of views. The Geodesign team, should be able to consider conflicts generated in the public opinion regarding project changes and address the design toward a suitable methodology of study. The EM should produce an output that provide knowledge on attractiveness and vulnerability of the study area explaining why or why not. In turn, it can enclose current environmental problems and various perspectives from different groups of people. The fourth model in the framework, called **Change Model (CM)**, should be based on the output of the EM aiming to answer the question: *“How might the study area*

*be altered?*". The alterations of the study area can be rooted on different causes. Changes may be generated by past projection toward present, with relative benefits and problems, a situation that need to be solved or a new issue that is not connected with models based on the past. This context may be related to a high degree of complexity that may imply different ways of design. The CM should be able to answer a range of issues regarding changes foreseen for the region and if they are oriented toward growth or decline (or both), development or conservation (or both) and if the pressure for changes are endogenous or exogenous. The CM generate a set of alternatives that may be evaluated in order to establish their social, economic and environmental impact. Indeed, the **Impact Model (IM)** aims to answer to the question: *"What difference might the changes cause?"*. In this step the Geodesign team represent an important part of the Geodesign procedure relating to the evaluation of the assessment that may be used to base for legislation, legal proceeding or as an informal way in a discussion. The comprehension generated in this phase should be the base on which choose the method during the second framework iteration and how carried out the studies. The IM should be able to produce an output answering to the way on which these foreseen changes can be seen as a benefits or threats and if they are irreversible or not. The last model in the Geodesign framework is called **Decision Model (DM)**. The DM aims to define the major stockholders involved in the decision making process, if they are public and private, their conflicts and the most important consequences of changes. Indeed, the assessment of decisions may be related to different decision-making models relating to a range of private and public level. The six models of the Geodesign framework, and relative levels of inquiries, allow to develop a range of scenarios that represent different hypothetical future solutions for the study area. The scenarios may be seen as the outputs of the (Geo)design procedure where planning processes take advantages from GIS potentiality intertwined with the flexible framework of Geodesign. The GIS capabilities have been recognized as increasingly important for planning practices in the last decade. Flaxman (2010) pointed out as *"Geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts"* aiming to highlight as GIS can be considered as a tool to make innovation in planning processes. In turn, Jack Dangermond (2010) argued as the sketch tool and layers comparison can be seen as (a part of) important instruments to support Geodesign activities. The Geodesign activity should led to develop a set of scenarios, enclosing a range of alternatives (usually generated through the change model). Steinitz (2012) define a scenario as a *"hypothetical future of the geographical context of the study"*. The scenarios may be generated through technological systems able to take into account a wide range of geographic information and give value to the design. Indeed, GIS and PSS have been made to the centre of discussion in Geodesign, like systems oriented to support the design (Yang, 2014). Indeed, one of the goals of the research is to investigate how the Geodesign framework may be integrated in the PSS for supporting planners to face the LLUP-SEA process.

### 3.2. Technologies: Planning Support System

The constant growth of Information and Communication Technologies (ICT) and the integration of innovative methods and tools into planning is creating new opportunities for planners, citizens and technicians to deal with the environmental transformations of the territory. Furthermore, the availability and open access to a wide range of spatial data and the diffusion of Geographic Information Systems (GISs) may sustain the concrete evolution of the planning practices ([8], [9]). This exploitation of technology and information that drives the transformation of traditional planning steps into spatial planning tasks leads to the creation of information systems able to integrate spatial tools, to manage spatial information and to improve the communication processes among stakeholders ([Goodspeed, 2012](#)), namely the Planning Support Systems (PSSs).

A lot of research in Planning Support Systems has been carried out in the last three decades, resulting in a wide range of concepts and models. The general concept of Planning Support Systems was originally introduced by Britton Harris ([1989](#)) as "*an architecture for coupling a range of computer based method and models into an integrated system for supporting the planning functions*". Harris ([ibidem](#)) defined the PSS in greater detail as: "*a user-friendly microcomputer-based planning system, which integrates GIS, sketch tools and spatial models*". This definition takes into account techniques with which planners can design or sketch planning solutions, that themselves become data input for spatial models, feeding spatial analysis.

The most famous support systems include *CommunityViz*, *WhatIf?* and *Index*, all developed in the United States, respectively by Placeways™, What if?™ and Criterion Planners™. However, even though these instruments are used in research and their proficiency has been demonstrated by many, they are still poorly integrated into practices ([Stillwell, 1999](#); [Geertman, 2004](#), [Couclelis, 2005](#); [Campagna, 2012](#)).

#### 3.2.1. The definition and the diffusion of the PSS in professional practices

The widespread diffusion of GIS-based software and the increasingly growth of microcomputer technology in the last twenty years, have transformed the manner on which represent, analyse and communicate spatial information ([Vonk, 2007](#), [Goodchild, 2010](#)).

In the early 90th, research and studies focus on the spatial characteristics of data used by public administration in planning and urban processes. Information was strictly linked with spatial components fostering the centralisation of public administration technologies around a Geographic Information System ([Campagna, 2004](#)). The GIS can be defined as a system able to take into account spatial information for analysing, showing and producing data for understanding geographical phenomena ([Maguire, 1991](#)). These innovative technologies are contributing to advances in planning procedures, promoting the comprehension of phenomena on different geographical scales and impact assessments of human activities

supporting decision-making. Furthermore, another set of instruments is able to take into account spatial information for supporting spatial analysis through the application of a single or a range of functions in a stand-alone process or integrated in a GIS environment. These groups of tools may be considered "something less than a GIS" (Campagna et al, 2006), supporting specific models, analysis or planning tasks for urban management and decision-making, but can be banded together (GIS and Geo-tools) under the general term of Spatial Information Technology (SIT). In fact, the fast growth of human society demands for innovation in technology fields for supporting planning processes. As Zhao (2009) pointed out, the use of GIS for planning :*"has become an inevitable choice for the regional urban planning departments to realize the office automation, the management modernization and the policy-making scientification"*. Campagna, (2004) emphasizes the wide range of scientific publications in the 90<sup>th</sup> regarding the implementation of Geographic Information Technologies into a range of planning fields related to urban design, land use, environmental and socio-economical planning. Indeed, planning is a discipline concerning multiple complex tasks performed by planners and technicians oriented to satisfy human needs in compliance with the sustainability principles. Despite a single technology may not fill the intrinsic complexity of planning processes, a GIS-based assortment of technologies can be integrated in a specific architecture in order to sustain planners to carry out planning procedures (Brail, 2001; Campagna, 2004).

Nevertheless, implementing Geo-tools in planning processes is a complex procedure for planners due to poor GIS-science professional training, which is becoming increasingly intertwined with the urban planning field (Innes, 1993; Campagna, 2004; Simao, 2009). After almost three decades, the second definition of Harris (1989) provides an actual representation of a possible solution to couple geo-tools with user friendly interfaces supporting planners' needs. In fact, a generic PSS architecture consists in a wide range of geo-tools integrated into the Geographic Information System (GIS) software (Goodspeed, 2012) that can be applied on different spatial scales and geographic contexts to support the planning procedures. The PSS, in order to be considered as a reliable support tool for practitioners and planners, should be able to integrate the most suitable geo-tools for supporting the various tasks in the planning procedures (Campagna, 2006). Campagna and Matta (2014) pointed out that the concept of Information WorkSpace (IWS) referring to the management (collection and organization) of data from a wide range of sources for specific users or tasks, introduced by Langendorf (2001), may be considered as a background for incorporating the Spatial Data Infrastructures notion into the Planning Support System (PSS) architecture. In fact, the widespread diffusion of spatial data for supporting informed process in decision-making are filling the gap between traditional planning procedures and innovative advances in the ICT field.

The concept of PSS is evolving over a wide range of applications in research fields worldwide. Klosterman (1999), provides a definition of PSS as an architecture which "combines GIS (and non-GIS) data, computer based models, and advanced visualization techniques into integrated systems to support core planning

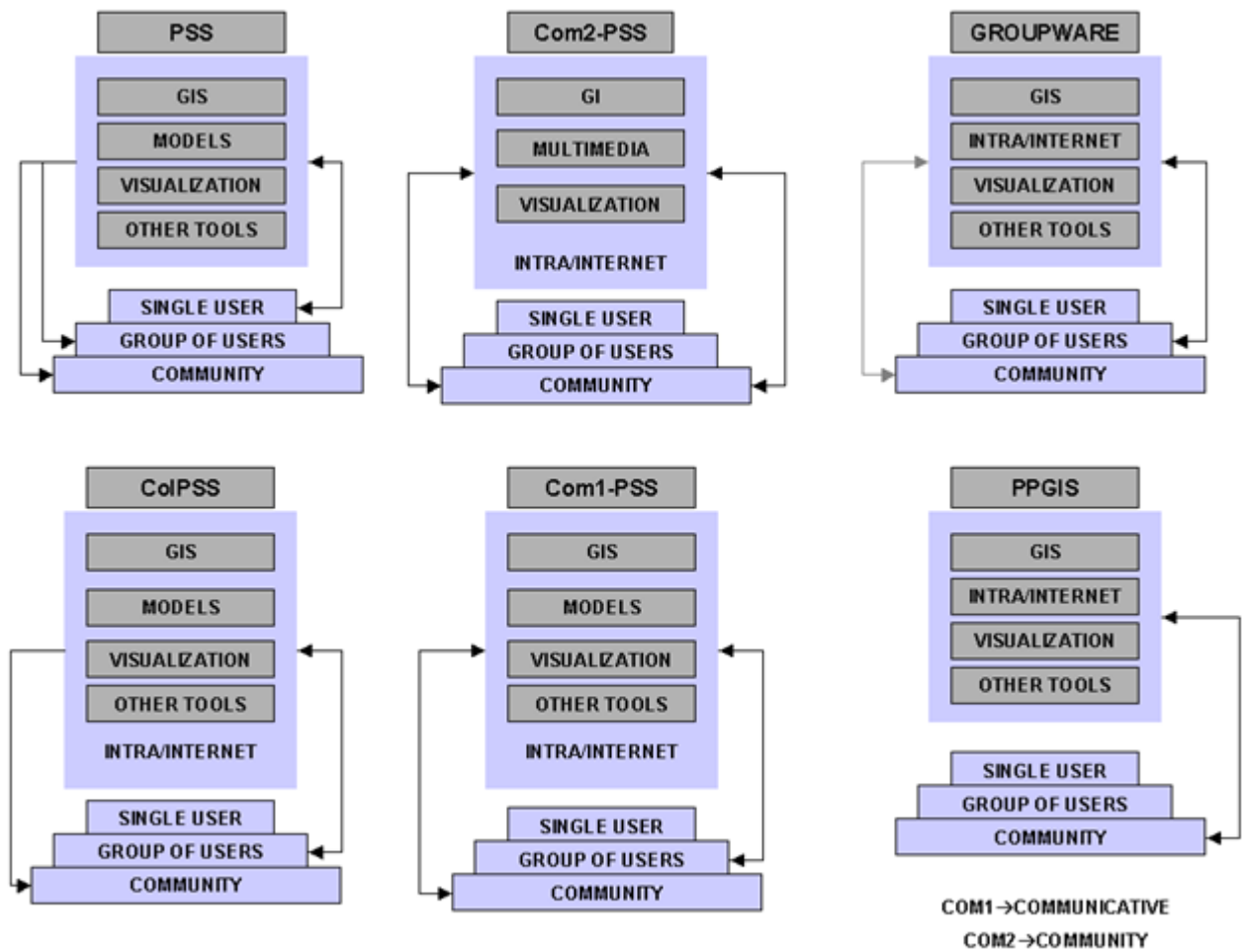


functions such as plan preparation and evaluation". More recently, Geertman and Stillwell in [2003](#) and in their reviewed definition ([2012](#)), represent a PSS as subset of geoinformation-based instruments that incorporate a suite of components (theories, data, information, knowledge, methods, tools, etc.) that collectively support all or part of a unique planning task. These definitions are evidently suited to the most successful GIS-based PSS prototypes developed in the last two decades in the USA, including Klosterman's "WHAT IF?", "CommunityViz" created by Placeways LLC and "INDEX" developed by Criterion Planners.

Despite efforts to develop innovative architectures for higher flexibility and more user-friendly interfaces, the inclusion process of PSS into professional practices seems to be far from over ([Vonk, 2003](#); [Vonk, 2005](#); [Campagna 2004](#)). In fact, critiques have been related to poor flexibility (Campagna, 2006), incompatibility of geo-tools in practices and high degree of complexity making their use difficult. The process of geo-tool adoption in practices encloses a range of pitfalls pointed out in a number of research studies carried out in the last decade, which are oriented towards taking into account human, organizational and institutional factors ([Vonk, 2005](#)) beyond the technical ones. The scarce use of PSS in practices produces a cause-effect loop where the poor implementation of planning support technologies generates a lack of knowledge for planners regarding the instrument's potential, causing in turn further underuse of PSS ([Vonk, 2006](#)). Geertman and Stilwell ([2009](#)), referring to the framework of Vonk ([2006](#)), focus their attention to bottlenecks of PSS inclusion in professional practices. Vonk and Geertman ([2007](#)) explain the reason of limited diffusion of PSS to their technology-oriented architecture rather than to planning processes. In turn, Campagna ([2012](#)), pointed out that an efficient implementation of PSS in practice may be achieved bringing planning processes into focus in order to make the architecture more flexible.

Nowadays the widespread diffusion of technological systems is influencing the way on which the planning processes may be performed. Campagna ([2004](#)) wrote: "If this is not a technological issue, will it be a socio-cultural problem?". Indeed, one of the major challenges for developers and planners is to take into account technological developments and produce a flexible PSS able to adapt to the huge number of planning processes and procedures. Campagna ([2004](#)) proposed a PSS taxonomy (figure 8) based on different planning processes and the tools and methods integrated in the systems.





Campagna M, Deplano G, 2004

Figure 8 - The PSS taxonomy (Campagna, 2004)

According to Campagna (2004), the different groups of users, namely single users, group of users and community, enclose respectively expert users like planners, a group of stakeholders and, the last one, citizens that collaborate in the participative plan-making process. Campagna (ibidem) describes the different conceptual models illustrated in the taxonomy. The models range from a systemic approach in planning (PSS), to the inclusion of the local community in the planning process (Com2PSS), and from a model opened to specific groups of people (Collaborative PSS), (Klosterman, 1999), to PPGIS that aims to ensure the inclusion of the needs of disadvantaged communities into the planning procedure. The last one is the Com1PSS, that encloses a range of tools able to share the knowledge related to the plan-making process.

Figure 9 shows a generic PSS architecture composed by different sets of functions. The most external part refers to specific features like real time analysis, sketch planning, automating reporting, design of alternatives and scenario comparison. These features are able to support the decision making process from different points of view and in different ways and they will be put into effect through different case studies

for supporting the LLUP-SEA procedure. Several successful examples may be related to "What If?" ([Klosterman, 1999](#)), "Index" ([Allen, 2001](#)) and "CommunityViz" ([Kwartler and Bernard, 2001](#)). CommunityViz has been used to reach the goals of the research into the LLUP-SEA in Sardinia.



Figure 9 - A general PSS architecture

The internal cycle refers to the technological components that support the functions of the PSS. The modelling component helps the planner to define spatial models, rendering the system dynamic. Spatial models are now more than ever important for representing the space and supporting spatial analysis in informing the planning processes. The territory may be represented in different ways and for different purposes. It may be related to the definition of different homogeneous areas or zones for supporting the comprehension of the impacts based on land-use changes. In fact, the constant growth of ICT technologies is fostering the detachment of the planning procedure from a traditional point of view (based on static hand-draw maps) toward spatio-temporal dimensions ([Wegener, 2001](#)). The models are able to represent the space for communicating the complexity of the territorial phenomena. Wegener (*ibidem*), pointed out that the spatial planning models have been influenced by a wide range of disciplines, from the economic (housing market) to geographical (population dynamics) fields. Other fields are related to the social, transport and integrated modelling, fostering the spatial relationships among these different strategic fields. The various fields that have been related each other through the spatial modelling are able to improve the comprehension of the territorial phenomena. Beside, the connections rooted on the new technology developments have fostered the formation of new pitfalls and issues. The GIS, the second component, may be able to deal with these issues through the implementation of different geo-tools for

supporting spatial analysis. Indeed, Geertman and Stillwell ([2009](#)) pointed out the "*PSS are generally regarded as systems in which technologies dedicated to the planning profession are brought together*". The third component, the geo-visualization, can support the communication of the information related to the representation of the territory and the results of the spatial analysis. The PSS makes the planner able to visualise and communicate the results of the decision-making process, the impacts of these choices and the solutions to deal with these planning problems. Indeed, the last component aims to foster the use of the PSS through the user interface. Geertman and Stillwell ([2009](#)) argues as the diffusion of these systems in planning processes is still limited due to their intrinsic complexity. Indeed, the implementation of the PSS in the practices can be considered limited to research applications or "experimental trials". For instance, Campagna, ([2012](#)) argues as the professional curricula of planners and technicians are not in compliance with the technical skill required for using these instruments. The user interfaces enable the planners to put into effect the architecture of the PSS for supporting their work across the various steps of the planning process, from the representation of the study area to the impacts of the alternatives. The user interfaces have an important role for supporting the use of complex technologies for the users. The design of the user interface should be oriented to guarantee the use of the instrument at different levels, from the common user (citizen) to the expert (planners or practitioners). Despite the pitfalls for the implementation of the PSSs in planning practices, their importance has been documented in literature ([Batty, 2007](#)).

A literature overview offers an important point of view about the potential of PSS that is able to provide complex spatial information in a simple way fostering participation and communicative processes ([Batty, 2007](#), [Campagna, 2012](#)). In order to take into account these consideration, the Langendorf perspective ([2001](#)) depicted an Information Workspace as the collection and Organization of data and information from multiple resources for a particular (group of) person or task(s). This concept encloses an important relationship between PSS and spatial database. These database are infrastructures of spatial data that are in compliance with the Directive 2007/2/EC, called INSPIRE, currently under implementation. The implementation of the INSPIRE Directive is fostering the diffusion and development of Spatial Data Infrastructures (SDI) in Europe. The consequent diffusion and availability of common Spatial Database at National and Local level promotes an instruments of spatial planning support in an integrated way. The presence of common regional regulation on spatial planning affects the contents and format of the required knowledge to be expressed in the plan document as well as in the SEA environmental report. ([Campagna, 2014](#)).

### 3.2.2. A professional PSS: CommunityViz

The PSS used to put into effect the aims of the research is CommunityViz. CommunityViz is a Com1-PSS ([Campagna, 2004](#)) and it can be defined as "a set of planning tools that integrates 2-D mapping information, 3-D visualization, and policy simulation technologies that can be applied to the planning and design issues of specific communities" ([Kwartler and Bernard, 2001](#)). Indeed, as Kwartler and Bernard (*ibidem*) pointed out, CommunityViz makes the planners, technicians and citizens (the users in general) able to analyse the social, environmental and economic impacts and effects of policies, proposals and goals. Indeed, CommunityViz the main internet page that male available the CommunityViz extension (<http://placeways.com/communityviz/index.html>) defines CommunityViz as "GIS-based decision support software for regional and local planners". Walker and Daniels (2011) pointed out as, CommunityViz can be sees as a reliable tool for supporting the decision making process. CommunityViz is structured on ESRI's ArcView GIS and it is based on a series of modules for supporting the planning practices. CommunityViz® is a GIS-based software developed by the Orton Family Foundation and is distributed by Placeways, LLC. One of the most important CommunityViz components to deal with the aims of this research is the scenario constructor. This module allows the users to create land-uses based scenarios and perform a range of analysis for evaluating the effects of different alternatives on the strategic fields. The scenario constructor is able to take into account different type of data, from vectors to raster, with the aim of managing the layers to produce a dynamic information. This information may be changed by the user for simulating how the choices proposed may influence the other features. The first simulation process may be linked with the Land Suitability Analysis (LSA) that make the user able to take into account different information layers through the Suitability Wizard tool. Indeed, the LSA is be based on the factors weight, set up by the user. Every factor considered for the suitability analysis may be changed on the fly through a panel containing every parameter. These variations of the factors weight cause a change in the map that show the most suitable area related to the goal. The list of parameters and their weights will be included in the final report made available by the PSS.

Indeed, the impact evaluation component is able to considers the performance of different planning alternatives. The alternatives and the way on which them influence the environment and the socio-economic system, may be evaluated through a set of (custom or predefined) indicators defined by the users. The indicators may be built through a dedicated environment into the software, where is possible to create specific formulas for indicators calculation. The indicators are able to make in comparison different states of the scenario, from the initial state (alternative 0) to the implementation of the alternatives that generate different scenarios. Benchmark, thresholds, indexes and alerts make dynamic and interactive the indicator (Figure 10).

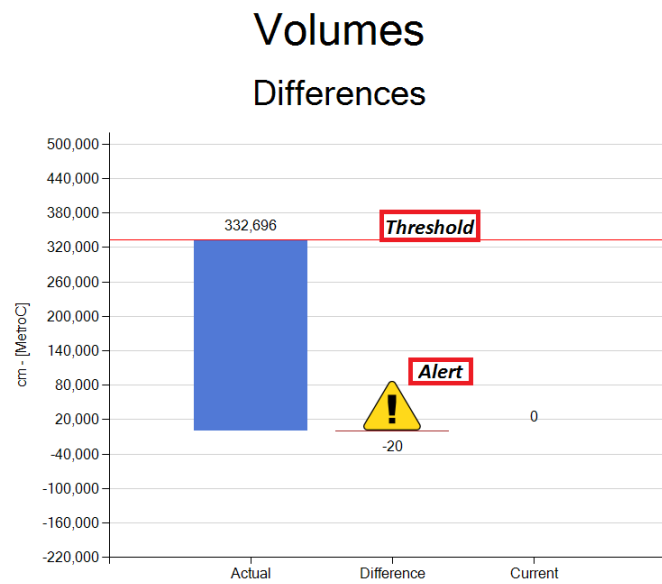


Figure 10 - Indicator structure

The indicators operate taking into account the attribute values of the information layers. An indicators may simply represent the value of a single area (or a sum of them), a combination of attribute values (e.g. the maximum volume feasible for specific area) for a pyramidal structure of information, from simple to composite indicators. When the scenario is edited, the value of the indicator change for supporting a real time comprehension of the alternatives impact. In turn, the indicator may be fed by external values as variables and assumptions with the aim of creating a structured information taking into account policies, urban standards, legal constraints and every type of information not available as attribute in a layer. The PSS is able to make these endogenous assumptions dynamic, allowing a real time scenario evaluation with regard to a wide range of information related to different sources. The sketching tool allows the user to propose land-use variations for supporting policies and planning goals with the aim of evaluating the effect of these changes. The user is able to choose which feature to modify, through the design of a new area or reshaping the existence on the fly. In turn, when the polygon will be closed, the indicators formulas will automatically rerun and their values will be updated. This interactive system of impact assessment of alternative implementation is able to support a real time communication among stakeholders regarding the effect of their choices. The PSS, through its interactive architecture, may be able to improve the communication during the decision making and the transparency for the choice of the most suitable solution for the specific issue. Indeed, CommunityViz can be considered a reliable tool for supporting the process of decision-making through the wide range of spatial analysis and models that made available ([Kazak et al, 2014](#)). Chapter 8 illustrates how the PSS has been applied for supporting the implementation of Geodesign methodologies to the LLUP-SEA in the context of Sardinia. The case studies will be based on a

range of steps related to the decision making process, demonstrating how the PSS may be able to support the plan making phases.

### 3.2.3. Integrating the GeoDesign into the planning practices: Geoplanner

In the light of the above premises, the PSS may be considered a suitable tool for implementing the GeoDesign framework into the planning practices. Indeed, the growing attention on the web applications for supporting planning processes is intertwined with the development of new methodologies. The Geoplanner Web-App may be seen as an example of this statement. *“GeoPlanner supports a complete planning workflow from project creation to report generation”* [10]. Indeed, Geoplanner is a web app able to implement the Geodesign across planning processes. Geoplanner for ArcGIS, is based on seven interactive steps (Figure 11).

## GeoPlanner and the GeoDesign Workflow

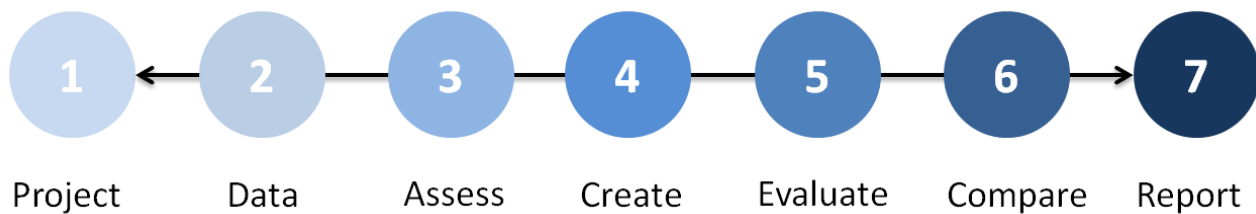


Figure 11 - The Geoplanner interface

These steps are related to the GeoDesign framework. After the first step (Project) that allows to set up a project (1), the "DATA" (2) represents the initial phase for intertwining the GDF and the Web App. Indeed, through this model is possible to add data to the project for creating an overlay of information layers with the aim of making available a wide range of spatial data for supporting territorial knowledge processes (Representation Model) (Figure 12).



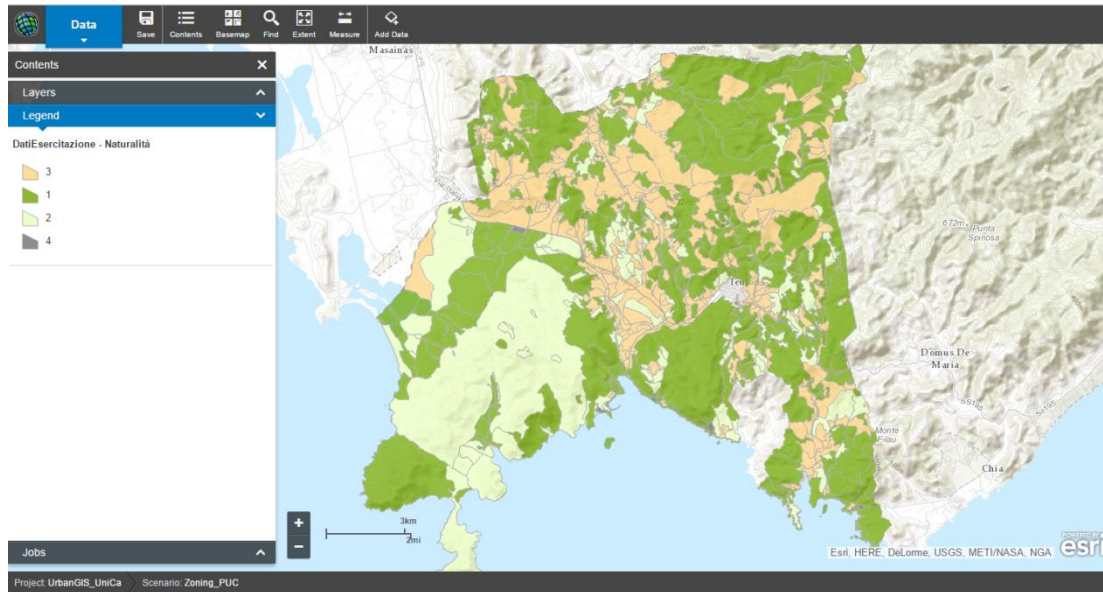


Figure 12 – Geopanner, Data model

The assess phase (3) allows to evaluate, through a range of geo-tools (i.e. Buffer, Overlay), the current situation for identifying phenomena and processes. The "assess" is based on the Process and Evaluation Models of the Geodesign framework, making the planner able to analyse the territory with the aim of creating an informed process on which establish the decision-making process (Figure 13).

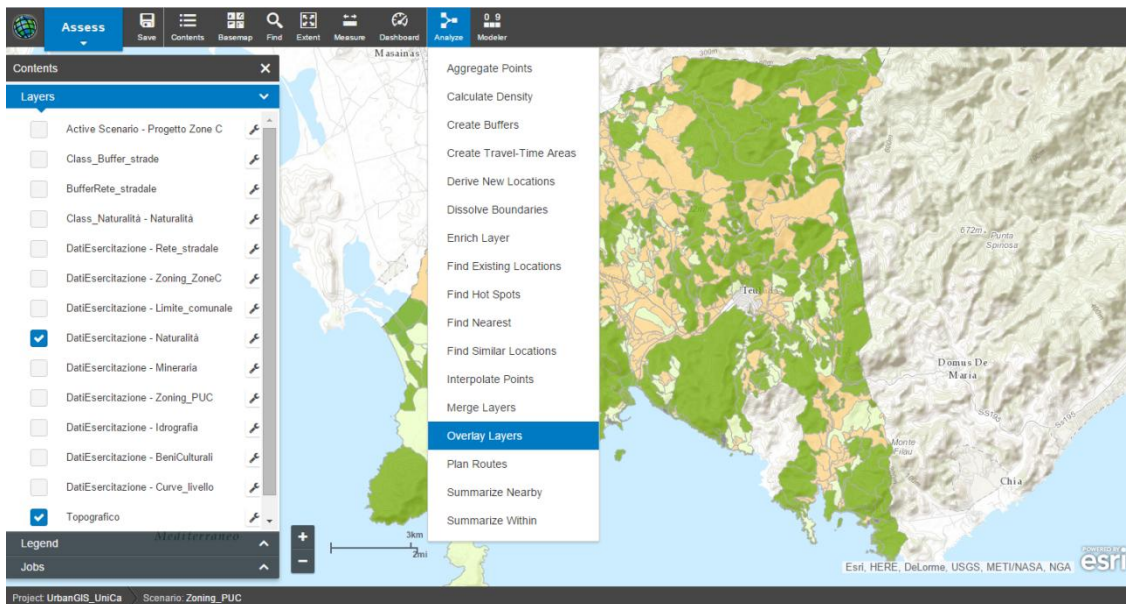


Figure 13 - Geopanner, Assess Model

Through the Assess step is possible to combine a wide range of factors (i.e. slope, aspect, population) to evaluate the site' suitability [1]. This phase can be related to the classic Land Suitability Analysis (LSA) oriented to establish the level of suitability of the land for a specific purpose. At this stage is possible to

apply changes (4), modify areas (e.g. zoning), lines (e.g. roads) and points (e.g. Historical Goods), or creating new ones (Change Model). Geoplanner through the “Create” phase makes the user able to put into effect a set of decisions with the aim of evaluating in real time the influence of these changes on the environment (Impact Model). Indeed, GeoPlanner may help to “make better GeoDesign decision” [1], fostering the management of the planning process and improving the collaboration among Geodesign team members. The last two steps guide the planners to evaluate and compare different scenarios and alternatives with the aim of considering of the best solution for the territory (Decision Model) (Figure 14)

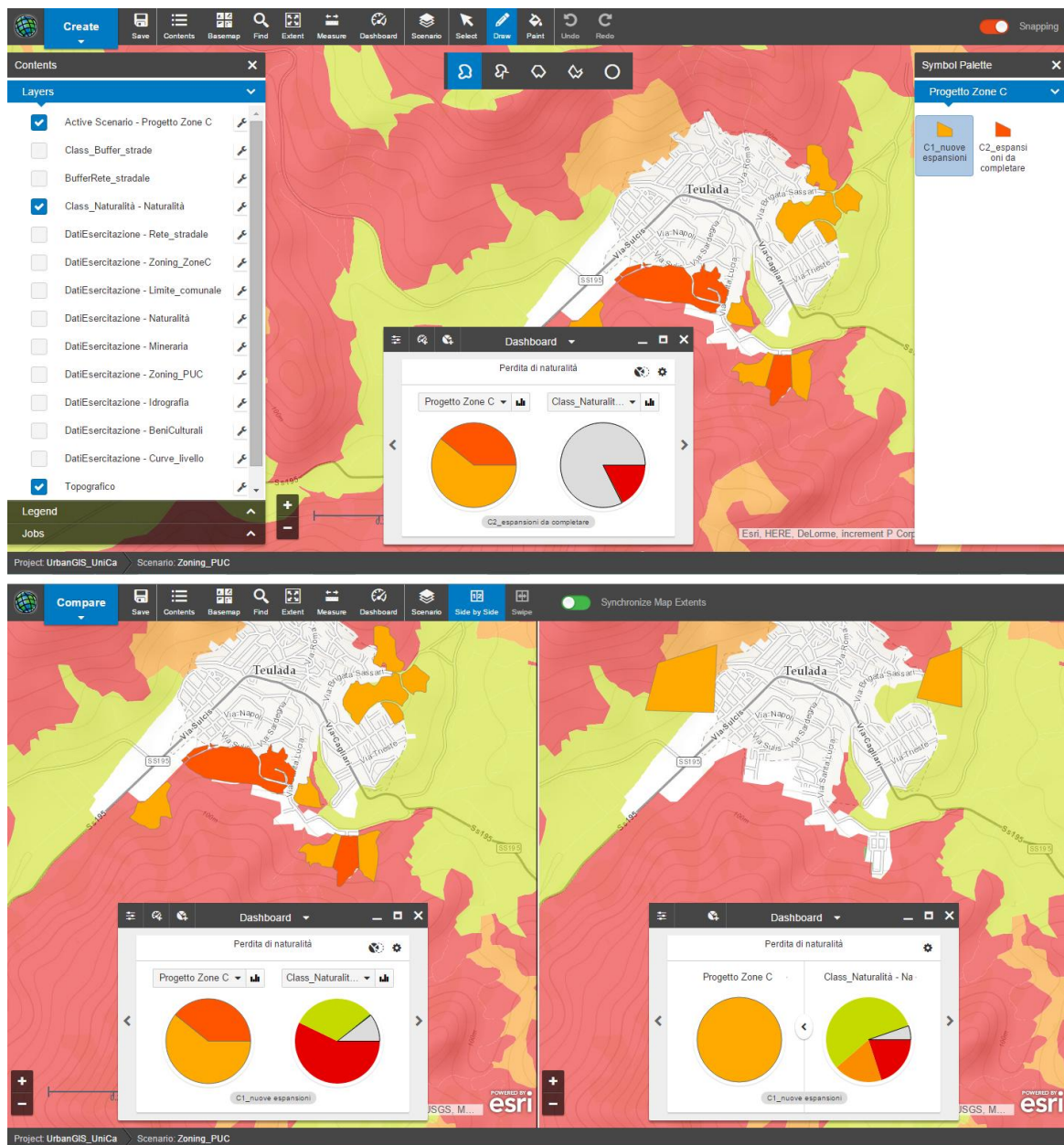


Figure 14 - Geoplanner, Create and Compare Models



Geoplanner may be able to support the participation processes thanks to its flexible and interactive structure. First of all, Geoplanner is able to create group of users that work to the same model for evaluating their purposes and objectives. This interactive system help to compare the different users scenario with the aim of producing an evaluation among the alternatives. The results of this comparison may guide a discussion among the users that, through the web-tools nested in the system, are able to modify their alternatives or to create a new one. The potentiality of the GeoPlanner web-app has been tested in a workshop organized by the UrbanGIS Lab of the University of Cagliari for academic student during the academic course of "Urban Planning" for engineers and architects.

### 3.3. Conclusions

The PSS offer the opportunity to develop an innovative approach to planning practice. These systems may guide planners for dealing with the complexity of the planning tasks. Furthermore, emerging methodologies, such as Geodesign, may address a fruitful integration of SEA into LLUP. In order to investigate the efficacy of PSS for supporting the plan-making phases, two different case studies have been carried out. The case studies concern two different workshops, based on a structured sequence of activities. The first one concern the process of adaptment of the MMP to the RLP and how the users perceive the integration of innovative technologies and methodologies for supporting planning practice. The second one was performed in collaboration with the students of Architecture of the University of Cagliari, in order to evaluate the comparison between different system for dealing with the same planning tasks and how the students evaluate the implementation of these systems and methodologies in planning and in the educational field. Furthermore, this workshop may help to develop the awareness for the future planners on the influence of PSS and Geodesign into LLUP-SEA.

## 4. Case Studies

This chapter illustrates the implementation of the methodological approach in order to deal with the pitfalls and issues illustrated in Chapter 2. The first case study, concerns the municipality of Teulada and aims to illustrate how the PSS works and how it has been applied for supporting the LLUP-SEA process. Furthermore, the case study concerns the support that the spatial indicators framework (sDPSIR) provides during the plan-making phases. The Teulada case study puts in evidence how the DPSIR and the PSS features are in compliance with the Geodesign framework and how this innovative system may enhance the participation processes. The Teulada case study helps to guide further investigations in the integration process of the methodology and the technology into LLUP-SEA procedure.

The second case study regards the application of the PSS through a structured workshop into practice, which has been performed in collaboration of the Municipality of Gonnese. The purpose of the workshop is to fill the gap between the research and the planning practice, testing the features of the PSS through a case study. Moreover, the workshop gives the opportunity to test the potentiality of the PSS in collaboration with different actors, such as technicians and researchers. The case study is oriented to consider the experience of technicians and professionals in order to evaluate how the PSS may be integrated into planning practices. A series of questionnaires have been proposed during the workshop to the participants, in order to collect their professional opinions with regard to the influence of the PSS in practices.

The third case study is oriented to test a web-based PSS, based on the Geodesign framework, through an academic workshop organised for university students. Indeed, the workshop was organized to test two different approaches to LLUP-SEA procedures. First of all, the students have to deal with a structured problem related to a common planning issue by using two different technologies. The first one oriented to test how a common GIS software (ArcGIS) may deal with planning issues and produce results. The second technology concerns the use of a web-based application in order to deal with the same planning issue. The results of these approaches are compared and evaluated with the aim of collecting the students feedbacks through a questionnaire. The findings of this investigation help to demonstrate how innovations in Geo Information technologies may foster a different approach to planning practices.

Furthermore, this section introduces two new concepts in the structure of the thesis.

The first one, focus on the current planning technique for managing the fragmentation of the territory: The Zoning. The Zoning is one of the most important document of the Municipal Master Plan that helps to manage the territorial transformation, addressing the land-use changes toward a suitable process of resource consumption.

The second concept concerns the indicators selection. Indeed, the indicators used in the decision-making process may help to organise the information in order to communicate information, create a baseline of knowledge of the development context, evaluate the impact of the alternatives, compare different scenarios and monitoring the effects on the environment. Different studies and research demonstrate both how the influence of these activities in practice is still limited and how the integration of a structured indicators framework may help to address open issues in spatial planning.

#### **4.1. Geodesign and PSS in LUP-SEA**

The GIS makes the users able to manage geographic data, fostering the analysis, comparison and communication of the spatial information through a wide range of geo-tools. A layer can be defined as a "mechanism used to display geographic datasets" [5] and can be represented through point, line and polygon. The layers are information that provide an overview on the geographic space and can be overlapped to build the relationships among different strategic sectors. In turn, the layers enclose a range of characteristics associated to the information, represented by attributes. These attributes can be defined by numbers or text, providing editable data. The capability of changing the attributes makes the users able to propose variations of the geographical space, evaluating and comparing these choices. Indeed, the changes can be related to areas (zoning, land use, houses), points (monumental trees, points of interest, historical monuments) or lines (roads network, rivers, sewer). The accessibility to a multitude of layers promoted by INSPIRE, should support the process of spatial analyses and enhance the seeking of suitable solutions for planning problems. Spatial problems call for optimal solutions in a spatial environment. The design process of suitable solutions is usually known as spatial optimization. ([Goodchild, 2010](#)). The spatial optimization can be related to the transition from one feature to another (i.e. from point to line) or toward the creation of a new feature. This process makes able stakeholders to visualize geographic information in a map that, as Goodchild ([ibidem](#)) pointed out, is an essential part of Geodesign practice. In turn, GIS is able to address traditional planning and design practices, such as static to dynamic procedures. This innovative approach allows making GIS the core of spatial decision-making ([Batty, 2013](#)). Despite the GIS capabilities to show a big amount of information in a map, the wide range of attributes that are often associated to a single layer may generate a high degree of complexity to be managed. In turn, the comprehension of

phenomena depends on a wide range of factors that are intertwined each other, represented by different feature classes and analysed through a series of geo-tools on different steps. This complex process may be seen as out of the boundaries of classic GIS software. Indeed, design problems are usually directed toward a range of simplifications that may generate a lack of comprehension about the phenomena and a poor base of information in decision-making processes.

Geodesign is a framework able to integrate the potentiality of GIS system for renovating planning procedure, fostering a sustainable resources consumption ([Goodchild, 2010](#)). Indeed, the Geodesign aims to support informed design solutions and collaborative and participative processes, enclosing a wide range of figures, such as public to private stakeholders. The Geodesign framework can be integrated in an innovative technology in order to deal with pitfalls in planning practices bringing the gap between GI science and traditional planning procedures.

The Planning Support Systems may be considered as a suitable tool, offering a flexible architecture able to couples GIS (and non-GIS) data, operational models and geo-visualization tools ([Klostermann, 1999](#)) and implementing an Information Workspace to collect and organise information from multiple sources for a particular (group of) person or task(s) ([Langendorf, 2001](#)). This general definition of PSS allows considering different shortcomings in planning practices, such as the role of spatial data and geo-tools in practice. The research aims to carry out an integrated system based on the Geodesign framework that operates through the PSS architecture. This architecture has been proposed in order to deal with planning issues with regard to the current planning system in Sardinia.

## 4.2. The Land Use Planning

The intensive use of the Earth's resources calls for detailed investigation of the natural' capital consumption ([Revesz et al, 2008](#); [Chichilnisky and Heal, 2013](#)). The sustainable management of the resources consumption processes, may be seen as one of the major challenges of this century ([Muilerman, 2001](#); [Gjoksi, 2011](#), [3]). This process is related to increasing requests of lands for urban growth. Indeed, the land is an earth's component that undergoes effects of the human activities, becoming even more scarce and valuable. The lands are the foundation of human activities and represent the base on which the human society is rooted on ([Wang et al, 2014](#)). Despite the count of square kilometres categorized as "land" on the earth surface, not every land is suitable for human living, reducing the effective space where the human society can be developed. The lands make available every kind of resource to sustain the human demand for goods and services. The quality, the quantity, the typologies and the availability of resources are more than ever intertwined with the human well-being generally and with the human activities, specifically.

Indeed, the human activities aim to produce goods and services for sustaining the human society in a process of increasing resources consumption and pressure on the land.

The land may have different characteristics and/or natural components, enclosing urban surfaces, basins, forestry, agricultural areas, rivers and mountains ([Sombroek and Sims, 1995](#)) and are usually represented by a range of usages that the human activities may change in different ways. These changes may be generated by direct (e.g. climate change, resource consumption) or indirect drivers (e.g. demographic, economic) on different geographic (from local to global or vice versa) and temporal scales (from short to long-term) ([MEA, 2005](#); [Lambin et al, 2001](#)). This system of intertwined phenomena, may produce reversible or irreversible effects on lands, generating a range of environmental impacts that may undermine the availability of resources for the future generations. For instance, the city expansion and the standards related to the quality of life, more than ever should be based on sustainable consumption processes of the environmental resources, in order to mitigate uncontrolled phenomena of urbanization ([Lambin et al, 2001](#)). The constant pressure due to human activities causes changes regarding the use of lands and influences the biophysical attributes of the Earth's surface: the land covers.

The most important land-use changes usually occur at local level on single parcels, causing variations and consumption processes with regard of the land covers ([Briassoulis, 2000](#)). Every action operates singularly on the parcel but their cumulative effect may produce large phenomena of land-use changes, such as industrialization and tourism development. The land-use changes are more than ever studied with the aim of providing reliable models on which based sustainable decision for the human demands. The most important land-use changes and resource consumption processes occur at the local level. In this context, the role of the planner should be oriented to support a sustainable land-use changes, in order to preserve the value of land for the future generation. One of the current challenge for planners is to find an adequate balance between the constant demand of services and goods for supporting human well-being and the maintaining of the environmental characteristics (i.e. ecological functions) of the lands ([Kaiser, 1995](#)). Kaiser (*ibidem*) pointed out as the planning of the land-uses should be related to systems for predicting the effects of human activities on the environmental resources. These effects may be positive (i.e. if the activities are suitable for maintaining the natural environment and services) or negative (i.e. the pressure of the activities on the environment cause irreversible changes). The planners are called for giving value of a wide range of information in order to improve the comprehension of the current economic developments for supporting human society growth and their environmental impacts, in compliance with the sustainable development principles ([Godshalk, 2004](#); [WCED, 1987](#)). Governments (from the national to the local level) should be able to make decisions regarding the land-uses in order to provide an adequate organisation of the geographic space ([De Wit and Verheye, 2003](#)). Land-use planning may be considered as the core of such planning practices, oriented to identify a set of alternatives for the land-use changes in a region, in order to

evaluate reasonable solutions ([FAO, 1993](#)). The land-use planning may inform the plan-making phases, regarding the consequences of land-use changes, guiding the decision-makers toward the most suitable land-use options.

Local community may be seen as an essential element for supporting informed processes in plan-making ([FAO, 1993](#), [Steinitz, 2012](#)), for this reason the plan should take into account local communities goals and priorities. At the same time, different stakeholders' perspectives may drive irrational and uncontrolled changes in land-uses, fostering an unsustainable process of resource consumption ([Zaslavsky, 1999](#)). In order to deal with the range of issues that arise from private and public land owners, the land-use plans are put into effect through a set of subordinated plans or regulations. These implementation plans are embedded in the main document of the spatial planning, in order to provide specific rules for the local development. One of the most important documents with regard of the land-use management, integrated into the urban plan, is the zoning ([Zaslavsky, 1999](#)). If the environmental information is orchestrated by planners for supporting informed planning practices, the efficacy of land-use planning for managing the land-use changes may be improved ([Kaiser, 1995](#)). The land-use planning should take into account a big amount of information, from the environmental components that characterize the study area, to the policies and laws that influence the local community life. This information is represented through thematic and choropleth maps, indicating the spatial relationships among environmental and/or urban features. Nowadays, the constant growth of the Information and Communication Technologies (ICTs) makes available a wealth of spatial tools and services for supporting spatial analysis (Campagna and Matta, 2014). Indeed, spatial information may be represented, analysed and managed through the Geographic Information Systems (GISs). The GIS takes into account information with a proper geographic coordinate system, in order to make available, through a user friendly interface, geo-tools and services for supporting planning practices. Furthermore, the wide spread diffusion in the European Countries of Spatial Data Infrastructures (SDI) is offering to planners an unprecedented wealth of data and services for sustaining their activities ([Campagna et al, 2014](#)). In order to increase the availability and usability of information, the SDI encloses a wide range of spatial data, representing the European territory at different spatial scales. The national SDI should embed spatial information related to phenomena at national level, such as demographic structure and main transport infrastructures. Instead, the regional SDI makes available a deeper view of the geographic space, at regional level. In the Italian context, the SDI of the Sardinia Region, namely the SISTR-IDT, plays a major role for the availability of data and services for practitioners, citizens and stakeholders (Manigas et al., 2010). Despite this richness of information at regional scale, it is the local level that offers the deepest comprehension of the territory. As a matter of fact, the zoning may be considered the document that operates at local level identifying specific regulations for each territorial homogeneous area. The zoning aims to avoid mixing of incompatible land-uses providing specific rules for

each type of zone ([WB, 2014](#)). The zones usually represent industrial, commercial, residential and green areas of a specific municipality. The GIS-based software and the accessibility to spatial data may foster knowledge-based planning processes required to carry on sustainable development strategies ([ESRI, 2007](#)). The next paragraphs discuss different aspects of the zoning, such as the evolution of the concept and the process of integration both into practices and into the ICT sector.



#### 4.2.1. *The concept of Zoning*

Since the early of 20th century, the expansion of cities from a standpoint of physical, social and economic growth, has been related to the well-being of the citizens ([Haar, 1955](#); [Burgess, 2008](#)). Industrialisation processes intertwined with the growth of demand for increasing the well-being, characterized the movement of people from the countryside to cities. Indeed, the city offers a wide range of services related to health, economic and social sector that are not common in rural areas (Melesse, 2005). This migration process causes rapid and often, uncontrolled urban growth phenomenon ([Bhatta, 2010](#)). The physical expansion of cities gobbled up a big amount of agricultural and natural area in an uncontrolled process of territorial transformation. The effects of this process, encompass a range of pitfalls, such as the decreasing of land availability for food production, environmental and social problems, such as erosion, desertification and land fragmentation. The land-uses and land-covers have been changed according to the economic growth of human society and with regard of the request of land for the industry development. Uncontrolled land-uses changes may occur due to a lack of planning actions, affecting the environmental conditions on different spatial scales. The constant and rapid growth of industrialisation' phenomenon, generates complex and dynamic processes of transformation of the territory. ([Antrop, 2004](#)). The comprehension of the relationships between the human and the environmental realm are becoming an important element to guide the comprehension of the influence of the human society on land-use and cover changes. The most important land-use changes occur at local level and are intertwined with socio-economic factors, such as the population growth and the industrialization process ([Falcucci et al, 2007](#)), generating global phenomena, such as the loss of natural characteristics ([Sanderson et al, 2002](#)). The land-use changes, if uncontrolled, may cause the loss of biodiversity, natural and landscape values, climate changes and environmental irreversible processes, influencing the Earth's health and the human well-being. Regional and local bodies are responsible for adopting laws and regulations to support the low-impact of development strategies on the environment and preserve environmental resources and socio-economic conditions ([Nolon, 2008](#)). In order to put into effect this statement, the planning activities have become an essential step to support the sustainable development. The comprehensive plans enclose physical and socio-economic long-term purposes, representing the key concepts for future development plans. The Regional government usually produces rules and laws in order to manage the territory and limit an inappropriate use of the resources. This general statements promulgated at Regional level should be taken into account in the subordinate local plans, in order to put into effect the regional directives for managing the local territory. The plans that concern future developments of the regional land are represented by the "Municipal Master Plans" that operate at local level. The Municipal Master Plan (MMP) brings to pass the general statements of the Comprehensive Plan through several instruments. The Zoning represents one of

these techniques and may be considered as an appropriate method standing over the land use management ([Haar, 1955](#)). The zoning ordinance deals with a range of planning issues, regulating the resources management and the uses of lands ([Munroe, 2005](#)). The Zoning operates with the aim of avoiding inadequate mixed of land-uses ([WB, 2014](#)), regulating the property rights of private land-owners that through their activities may produce pressures on the land generating unsuitable changes of land-uses ([Raymond, 2001](#)).

#### *4.2.2. The application of Zoning*

The concept of “zoning” implies a territory’ fragmentation in different areas or zones. The zoning subdivision may be enclosed in a document containing maps and documents. This “plan” is called Zoning and it is one of the most important document of the Municipal Master Plan (MMP). The map(s) depict the fragmentation of the territory, represented by different zones affected by specific regulation ([Ellickson, 1973](#)). Thus, for each zone a set of rules is made available, in order to create the basis for the sustainable land-use changes. ([Jepson, 2014](#)).

The Zoning regulates the use of land, both defining the specific function of each zone, such as residential, commercial, services and industrial, and influences the land-owners activities ([Zaslavsky, 1999](#)). Furthermore, other beneficiaries (e.g. occasional users, citizens or communities) may be influenced by the Zoning (for instance in the case on which the zone is addressed toward the public utility). The zoning operates through the soil composition of the territory, orchestrating public and private right and the change of the land-uses in order to preserve the natural capital. Indeed, the land can be considered as a non-renewable resource able to guarantee the vital functions of the human society and, the use and consumption of this valuable resource, have to be monitored and regulated ([Treville, 2011](#)). For this reason the zoning may become an important tool for dealing with these issues.

However, the zoning does not just provide a division of a territory in zones but may be related to other important actions, such as the definition of a set of standards for supporting the strategic development of the territory. Indeed, these factors are usually implicit in the zoning ordinance, as necessary services to guarantee adequate standard of life for each zone, or land-use, from green areas, parking location and public spaces, to the definition of building height, volumes and restorative measures, limiting the resource consumption.

The efficiency of the zoning as tool for supporting the sustainable developments, can be related to a wide spatial scale and may concern the consumption of the Mediterranean Basin resources. As Falcucci ([2007](#)) pointed out, the Mediterranean Basin represents one of the most anthropised place in the world. The human presence, from coastal zones to the mountains, generates changes in the environmental

components, such as forestry, biology diversity and the marine environment, influencing the conservation of the natural species and components of the Mediterranean basin. This continue human pressure exerted on the Mediterranean environment calls for conservation measures to limit the loss of landscape ad natural values. The strategy for the conservation and protection of the environment should be related to the most socio-political and economic processes that are taking place across the Mediterranean basin, particularly in that areas located in the coastal zones where the human presence is strongest than any other areas ([Falcucci et al, 2007](#)).

One of the European countries that have an important coastal development is the Italian peninsula. The Italian peninsula is located in the Mediterranean sea and it has been the core for the developments of many populations. Nevertheless, the Italian environment has been strongly influenced by human activities in the last 60<sup>th</sup> years. Falcucci ([ibidem](#)) pointed out as the land-use changes occurred in Italy in the last 40<sup>th</sup> years concern the variations of the population density. The land-uses/covers changes concern almost 50% (in the time-frame 1960-1990) and almost 20% (in the time-frame 1990-2000). The land-use change have been related to an increment of artificial area toward coastal zones intertwined with the loss of pastures and transformation of the forestry and agricultural areas. The maps and values that are used to deal with the issues in land-use change, may be supported by the CORINE Land Covers values.

#### 4.2.3. The Corine Land Cover as tool for supporting decision making.

The Corine Land Cover (CLC) is a project developed by the European Council in the 1990 through the European Environmental Agency (EEA). The CLC has been set up with the aim of making available for the European States Members a range of environmental information. This information have been created and spread to foster the environmental protection across the European territory. The EEA purposes is to intertwine the environmental information related to CLC and a set of environmental indicators in order to support the creation of adequate European Environmental Policies and evaluate their impacts.

In turn, the CLC may be seen as a planner's tool providing reliable environmental information for supporting spatial analysis, the visualization of the interest areas and development of land use management. ([ETC, 1999](#)). The CLC makes available comparable environmental information for the whole European territory thanks to a nomenclature based on three levels. The table 1 shows as, the first level represents different types of land cover into a limited range of standard European classes.

Level 1	Level 2	Level 3
<b>1. Artificial Surfaces</b>	<i>1.1. Urban fabric</i>	1.1.1. Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	<i>1.2. Industrial, commercial and transport units</i>	1.2.1. Port areas
		1.2.2. Airports
<b>2. Agricultural Areas</b>	<i>2.1. Arable land</i>	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
	<i>2.2. Permanent crops</i>	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plant.
<b>3. Forest and Semi-natural Areas</b>	<i>3.1. Forests</i>	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
	<i>3.2. Scrub and/or herbaceous</i>	3.2.1. Natural grasslands vegetation
		3.2.2. Moors and heathland

<b>4. Wetlands</b>	<i>4.1. Inland wetlands</i>	4.1.1. Inland marshes
		4.1.2. Peat bogs
	<i>4.2. Maritime wetlands</i>	4.2.1. Salt marshes
		4.2.2. Salines
<b>5. Waterbodies</b>	<i>5.1. Inland waters</i>	5.1.1. Water courses
		5.1.2. Water bodies
		5.2.1. Coastal lagoons
	<i>5.2. Marine waters</i>	5.2.2. Estuaries
		5.2.3. Sea and ocean

Table a – A part of Corine Land Cover nomenclature, source EEA

In the second and third level of the CLC nomenclature, a deeper view of the territory is illustrated (Tab. a) aiming to detailed description of the territory for feeding the knowledge of the territory.

Monitoring programs and assessments for environmental impacts of governments development objectives, are becoming more important with the implementation of European Directive in planning practices. For instance, the CLC information may support the integration of environmental consideration in European policies (Buttner, 2004). In turn, the CLC is considered by decision makers as a reliable planning tool for supporting spatial analysis and environmental assessments (ETC, 1999). The Corine Land Cover maps may be integrated into the Spatial Data Infrastructures fostering the harmonization of values regarding the land-uses and support the wide spread diffusion of a common knowledge across European Territory. The current challenges for decision-makers are based on the comprehension of the territory in order to support informed planning processes and sustainable use of resources. For this reason the use of GIS software for supporting the management of spatial data promotes the integration of new methodologies and tools for spatial analyses into policies and decision-making processes (Goodchild and Haining, 2004).

The GIS-tools make the planner/decision-maker able to take into account spatial data from different sources (e.g. Regional SDI, local dataset) for different strategic fields (e.g. economic, environment) and define spatial analysis for supporting decision-making. For instance, the overlay technique operates on a range of spatial entities in order to develop combination and comparison of spatial maps. The combination of environmental data and methodologies foster the creation of informed process for supporting spatial planning. Indeed, the zoning is built to provide information for land-uses purposes that should be intertwined with environmental information to "inform the plan" about the environmental impacts of decision-making. The zoning is one of the most used planning-technique for the implementation of overarches policies at local level. The diffusion of this tool in Italy took place in the second half of 800<sup>th</sup> and

until nowadays that the zoning has been implemented in the spatial planning through geo-tools and infrastructures of spatial data.

#### 4.2.4. *The use of zoning in the Italian planning practices*

The concept of zoning was introduced in the Italian planning system in the last decade of 1800<sup>th</sup>. Indeed, the early traces of zoning may be found in the Plan of Florence (1865), Naples and Milan (1885) and other Italian Plans in the early of 900<sup>th</sup>.

The term “zone” becomes popular in the second world war period and it is officially introduced in planning through the National Urban Law (17 Agosto 1942 n. 1150, art 7). The same law defines several typologies of plan on which the PRG (Piano Regolatore Generale – General Regulatory Plan) is able to identify dedicated areas to the city growth. These areas are related to the physical expansion of the city, gobbling up agricultural area in a transformation process to urban growth and services. The Law of 6 Agosto 1967 n. 765, in the article n. 17 and the Ministerial Decree 1444/1968 defines the concept of homogeneous territorial zones, providing specific set of rules for each areas of the territory of municipality.

The homogeneous zones described in the Law are:

*Zone A (City centre), Zone B (Zone totally or partially built – different form Zone A), Zone C (Areas for new residences), Zone D (New industrial areas), Zone E (Agricultural areas), Zone F (General services).* The other articles are related to standards for public areas, parking and public green (Art. 3, 4, 5), building density (Art. 7) and height limits (Art. 8). These limits are put into effect through the zoning, in order to control and manage the physic expansion of the city. Treville ([2011](#)) pointed out the process of urbanization in Italy is more than ever uncontrolled and not ever related to the population growth. For this reason, the plans that provide rules for managing the land-use changes and limiting the resource consumption are becoming more than ever important in spatial planning. Nowadays the plan for supporting the urban planning in Italy is the Municipal Master Plan (MMP). The MMP is created with the aim of managing the growth of the municipality, defining future urban organization and a homogeneous zones composition of the municipal territory. The land-use policies are based on the rules and regulation enclosed in the zoning. ([Zoppi and Lai, 2008](#)). The zoning is able to influence the local community and the development of the territory through the implementation of a set of rules.

The Region of Sardinia has adopted the D.M. 1444/1968 through the D.A. n° 2266/U/1983 called “*Decreto Floris*”.

The section n°3 of the Decree provides a list of homogeneous zones for the Sardinia Municipalities:

- **Zone A:** Old Town Centre;  
The *Zone A* represents parts of the city having structures, buildings and bordering areas with high historical, artistic and traditional values.
- **Zone B:** Residential Completion;  
The *Zone B* represents totally o partially built-up areas.
- **Zone C:** Residential Expansion;  
The *Zone C* are that areas designated for new residential expansions.
- **Zone D:** Arts and Crafts, Industrial and Commercial areas;  
These areas represent parts of the territory on which is possible to make new industrial and commercial activities.
- **Zone E:** Agricultural Area;  
The *Zone E* are that areas suitable for agricultural, pastoral and fishing uses in order to increase the value of the products.
- **Zone F:** Touristic Area;  
These areas are designed for touristic purposes, having mainly seasonal characteristics.
- **Zone G:** General Services;  
Areas oriented to public or private general services, such as sports facility, schools and markets.
- **Zone H:** Safeguard.
- **Zone S:** Public spaces reserved for parking, public activities and public green.

The *Zone H* are areas that can not be classified into the precedent fields. These zones represent particular archaeological, landscape and natural values.

The other articles of the Floris Decree, make available regulation for building density, buildings height and public services in order to deal with an adequate organization of the urban space. Indeed, the zoning rules represent the roots on which are based land-use policies and the sustainable developments of the urban growth. The zoning may represent one of the planning tools able to deal with sustainability issues for supporting planning practices ([Jepson, 2014](#)).

The adjustment process of the MMP to the RLP, (as described in Chapter 2, paragraph 2.4.) is based on three steps: the *knowledge phase* (1), the *interpretation phase* (2) and the *response phase* (3). The knowledge phase encloses the updating step regarding the current mix of land-uses and zones for the municipal territory in order to support an adequate informed process during the plan-making stage. The documents, such as maps and reports produced in this phase, have to be in compliance with the RLP

regulations, and should be made available for the public access (through Geo-portal and Regional and/or Local Spatial Data Infrastructures). The Zoning Plan may be considered as a spatial tool for supporting the sustainable development in Local Land-Use Planning and Strategic Environmental Assessment (LLUP-SEA) processes. The Zoning Plan may be supported by GIS software in order to feed spatial analysis as a dynamic layer in an overlay process of information. The Zoning Plan is able to provide a range of information about the current mix of land-uses, addressing future choices to land-use changes for new residential areas, industrial sites, infrastructures and services. The Figure 15 shows as the zoning plan appears through the use of spatial data in a GIS environment. The Zoning provides information related to the spatial characteristics, standards and rules. These pieces of information constitute a layer that feeds the spatial models to represent the territory (or study area), the spatial analyses, the design of alternatives and their comparison.

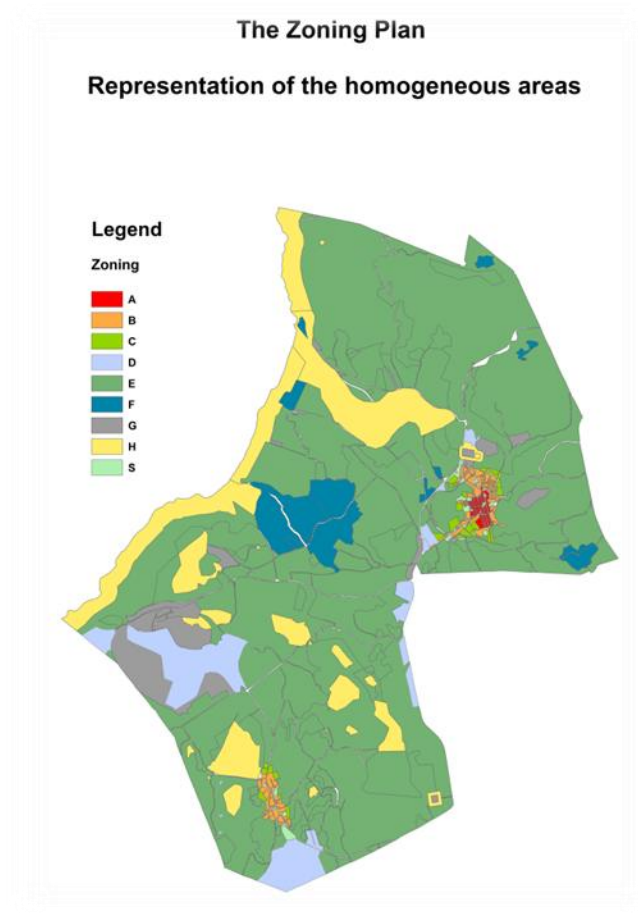


Figure 15 – How the zoning appears through the use of spatial data.



The spatial information needs to be represented through a set of specific indicators in order to improve the communication process of values e measures. In fact, the indicators are able to provide and represent the information about phenomena in a simple way for supporting the decision-making procedures (UN, 2001). Chapter 5 illustrates how the research has been carried out, integrating an indicator framework into a spatial environment in an attempt to consider the value of the spatial data (Chapter 3). In turn, this system has been further integrated into the architecture of a Planning Support System (it is discussed in chapter 6) for supporting the implementation of the GeoDesign framework (Chapter 6) into planning practices. For instance, the figure 16 shows as the map produced through the PSS, represents the results of a single spatial analysis (in this case the representation of the territorial fragmentation, the zoning), supported by a set of indicator. These indicators represent the area of three different homogeneous area, such as A, B and C, in order to communicate the value and, if the zoning is modified, how this information change in real time.

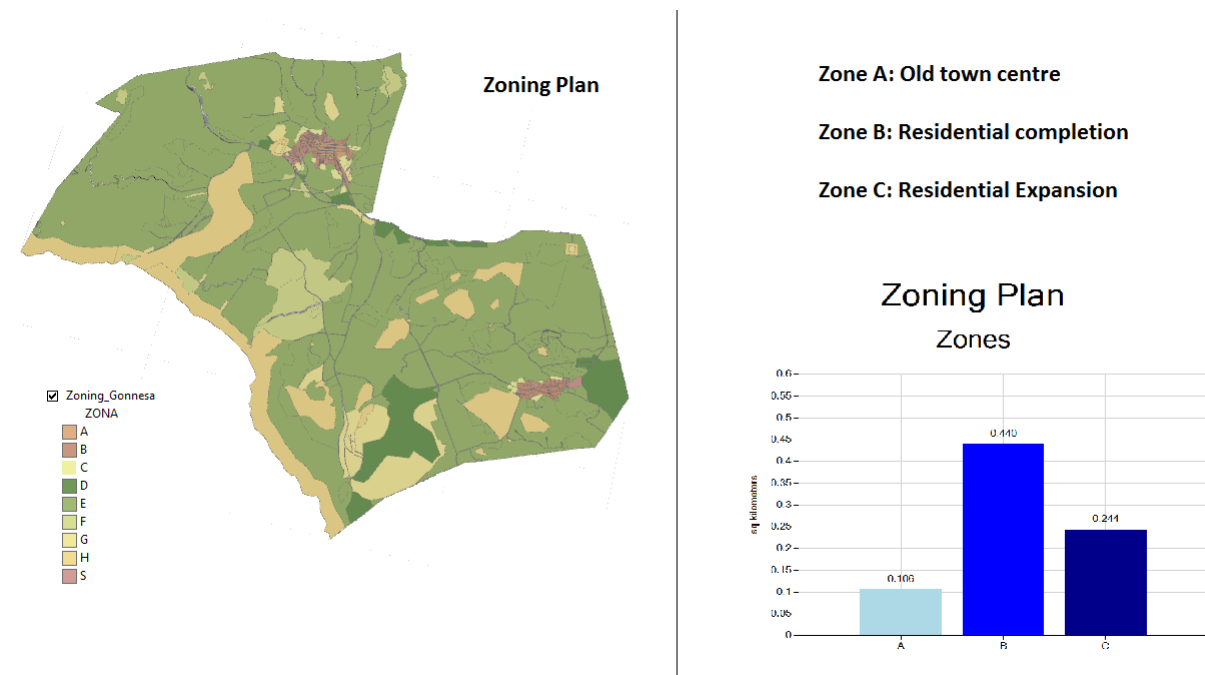


Figure 16 - Zoning and spatial indicators.

### 4.3. The indicators

The general meaning of the term "indicator" founds the roots on the Medieval Latin "indicātor", equivalent to Latin indicā(re) to indicate, and it is related to the concept of: "communication of information about measurable values or measurements". An indicator communicates values and measurements of a specific value (or combination of them) in a simple way. In turn, an indicator can represent high level of complexity beyond simple information, providing quantifiable insight to support comprehension of the real world ([Hammond et al, 1995](#)). The output of an indicator can be depicted through different forms (i.e. colours, signs, numbers and symbols) with the aim of communicating the results in a clearly and efficiently way. [Smeets and Weterings](#) (1999), pointed out as the communication and simplicity are concepts strictly intertwined each other: "*Communication demand simplicity and indicators always simplify a complex reality*". In turn, [Meadows](#) (1998) describes how the indicators may cause pitfalls and malfunctions for describing a system if they are poorly chosen. Furthermore, Meadows (*ibidem*), argues how this process of indicators selection assumes an important role in the reliability of the results obtained. The number of indicators that human needs to represent worldwide phenomena is enormous and it depends on what we have to communicate.

For instance, human activities that sustain the well-being, produce an impact on the environment, consuming resources and living habitats. This process, based on relationships between human realm (i.e. societal and economic factors) and the natural environment (natural resources, landscape), may be evaluated and monitored through indicators. The indicators may represent the core elements of many scientific fields, providing results to support the interpretation of complex relationships between factors that compose specific systems. [Pissorius](#) (2013), provides an overview and evaluation of the use of indicators in five scientific disciplines (Sustainability, Society, Economy, Environment, Ecological) pointing out the attention on the key indicators and their relationship to support the comprehension of complex phenomena. Environmental indicators usually supply insight on environmental issues, providing information to support monitoring action and related policies and solutions ([Smeets and Wetering, 1999](#)). However, the set of indicators used to represent the relationships between environmental and human realm is currently in progress. This large number of indicators may provide streams of information not easily correlated with the comprehension of human activities and their effects on environment. Theoretical and analytic frameworks can be used to orient the capability of the indicators to provide information toward the spatial planning requirements. Indeed, an indicator framework can correlate input and output of single indicators with internal and external variables and factors, enclosing cause-effect processes ([Mainguet, 2006](#)). The most important indicator frameworks used at international and national level, are based on the concept of causal chain, where the output of each component of the framework feed the

other in a loop ([Smeets and Wetering, 1999](#)). The causal chain concept became the base model on which some of the most famous indicator frameworks (currently in use) found their theoretical roots.

#### 4.3.1. Indicator Frameworks

An indicator framework based on the causal chain theory, may help to organize the cause-effect relationships among indicators, in order to provide reliable information about interdependences between human societies and the natural environment ([Niemeijer and de Groot, 2008](#)). This concept arises from the stress-response framework developed by Rapport and Friend in the 1979. This framework is based on the concept on which, the pressures on the environment (or the STRESS), cause changes in the environmental state and, in turn the environment "react" through (eco)system responses.

The OECD (Organisation for Economic Co-operation and Development) in the 1991, made suitable for its purposes the STRESS framework, where the pressures have been linked with the human activities and the responses provided only from the society. Indeed, the STRESS framework was remolded obtaining the current PSR (Pressure-State-Response) model, adopted by the OECD, ([Gabrielsen and Bosh, 2003](#)). The relationships among the PSR components are set on the causal chain concept. Indeed, this framework represents how the Pressures exerted by the human activities on the natural components, produce changes on the State of the environmental quality. In turn, the societal Responses found their roots on the perception of the environmental state, fostering the production of general sectorial policies that feed back the pressure component in a loop ([OECD, 1993](#)). The PSR framework has been applied worldwide to evaluate the progress of the environmental state on which human activities exert pressures. For instance, the PSR was performed in China to study the health of the Ulansuhai lake ([Xufeng et al, 2014](#)) or the assessment of island ecosystem ([Xiao and Yang, 2007](#)), and marine environment ([Fock et al, 2011](#)). A list of case studies performed through the PSR are available in the work of Smith et al ([2014](#)), taking into account also other two frameworks (DSR and DPSIR) that will be discussed in the next paragraph of this thesis. The PSR was also integrated by the OECD organization for using in the environmental reporting starting from the 1991. However, every sustainable issue had been translated in an indicator of the PSR framework, contributing to exponentially increase the number of the indicators.

This process led to produce an unmanageable amount of information reducing the performance of socio economic goals related to the sustainable principles ([Ewert et al. 2006](#)). Despite this range of pitfalls related to the application of the PSR framework, further indicator frameworks were developed based on the concept of this causal chain. The [Glossary of Environment Statistics](#) (1997) encloses the definition of the DSR framework as a "*framework for indicators for sustainable development adapted from the Pressure State Response framework*". The DSR framework has been adopted by the UNCSO in order to categorize its 134 SDIs. The DSR framework allows to categorize the indicators through the three components of the

framework in a causal chain loop. The **D**riving forces enclose human activities that may have negative or positive impacts on the environment. The **S**tates component depict the current system state (i.e. percentage of different land uses or social factors) and, in turn the **R**esponses represent the societal reaction to changes in the State component. According to the [guidelines and methodologies for sustainable development](#) (2001) the PSR is currently used in environmental set of indicators associated with impacts of human activities, more than the DSR framework that appear not well-suitable for addressing the pitfalls rooted in the cause-effect relationships among indicators.

As discussed above, the PSR and the DSR frameworks show a range of pitfalls related to the transparency of the process and phenomena comprehension. A third framework was developed for addressing these limits into a more appropriate indicators selections. The DPSIR framework was developed by the EEA (Environmental Protection Agency) and had been adopted with the aim of describing environmental phenomena. The DPSIR encloses the relationships among the factors that constitute the framework ([Smeets and Wetering, 1999](#)). The five components of the framework, should help for supporting the comprehension of phenomena and fill the gap between the real world and its representation. From a general point of view, the framework allows to define a structure for supporting territorial representation and analysis. Indeed, the initial phase aim to highlight the causes that generate the problems (the second phase). The third phase is based on the responses that arose from the previous informed process, feeding back the causes and problems in a loop. The DPSIR is currently used to stimulate the societal responses related to the environmental problems, in order to preserve the resources for the future generation, according to the sustainable principles ([Carr et al., 2007](#)).

#### *4.3.2. The DPSIR framework*

The concept of "causal chain" has been described in philosophy as a flow of sequential events in which any one event in the chain become the "cause" of next. The DPSIR encloses the concept of causal chain in an indicator framework supporting comprehension of human - environment relationships. Societal developments are related to socio-economic growth, which may have positive or negative influence on the environmental state. These changes in the environmental state may be related to the resources and biodiversity with the aim of depicting the impacts on the ecosystem and/or materials. This chain (should) produce(s) a societal response to these endogenous solicitations, feeding back the societal developments, changes in the environmental state and a range of impacts. This loop represents a general view of "how the DPSIR works". Indeed, the five components allow to organize indicators in a structure where both results and linkages among factors are intertwined each other.

#### 4.3.2.1. The five components

This paragraph aims to illustrate how the DSPIR is structured and how it works. The framework is based on five components: D - P - S - I - R. The first component in the framework is the Driving Force (**D**). This component take into account the human activities that are carried out for developing of the human well-being. The human activities influence the environment worldwide, but this pressure is more evident on local level than national or global levels. Indeed, the human well-being is based on the availability of resources that are consumed by a plenty of different activities. The Millennium Ecosystem Assessment (MEA) in its monumental report ([MEA, 2005](#)) provides two different and intertwined types of drivers: *direct* and *indirect* driving forces. According to MEA ([ibidem](#)) the indirect drivers are represented by demographic, economic and socio-political factors affecting indirectly the resources and the ecosystems. In turn, indirect drivers may affect drivers that directly affect resources and ecosystems as changes in local land uses/covers, use of technologies and harvest of resources consumption. Leemans ([2003](#)), provides a different point of view in the organization of Drivers that affect the decision making processes at the local level. Indeed, the previous classification of direct and indirect drivers has been enclosed in further categorization based on *endogenous* and *exogenous* driving forces. The endogenous local drivers are usually managed during the decision making process and may be organized in direct (i.e. change in local land use and cover), and indirect (i.e. technology adaption) drivers of changes. In turn the exogenous local drivers may be uncontrolled during the decision-making process, including direct (i.e. ecosystem characteristics and pollutant concentrations), and indirect (i.e. prices and market) drivers of change ([Leemans, 2003](#)). The driving forces are usually categorized as "needs" that people fulfill through developments of an increasing number of activities, undermining the capacity of territory to regenerate resources. The driving forces may influence the availability, quality and quantity of the resources also putting into effect mitigation actions for limiting the effects

This process allows to depict as human activities are able to produce Pressures (**P**) on the environment. The pressures may be related to the emissions of substances, use of resources and lands to satisfy human needs ([Gabrielsen and Bosh, 2003](#)). According to Kristensen ([2004](#)), indicators representing the pressures may be based on three main groups regarding resource consumption, emission of pollutants and changes in land use. Emissions of CO<sub>2</sub>, waste production, use of resources for construction and the use of lands for transport network and shelter may be considered as examples of pressures. The pressure represents the second element in the causal chain that, according to the initial definition, becomes the cause of next chain element. Indeed, the pressures exerted by human activities provoke changes in the environmental State (**S**). These changes represent how the quality of the environment, and in particular the quality of the resources on which the services are based, has been influenced. The Indicators related to the state component, are able to depict the concentration of pollutants, the levels of particular factors that influence

the human well-being and the percentage of resources available. As discussed in the previous paragraph, the first three components in this causal chain framework allow to depict the "causes" generating the "problem". (Figure 17) Indeed, according to the framework, the Driving Force - Pressure - State components represent the base on which the impact studies of the human activities may be rooted. The changes in the state component are integrated in the impact component (**I**) producing assessments of the environmental quality, economic evaluations and how the changes influence the human well-being. The impacts provide insight into the decision-making process and how the changes in the environmental states, may be related to the economic, social and ecosystems fields. The impact component is the fourth element in the causal chain, representing the problem on which the societal responses should be rooted. Indeed, the Responses (**R**) may be performed by decision makers or society, in order to provide solutions about the problems or impacts generated in the precedent phase. The Responses arise to

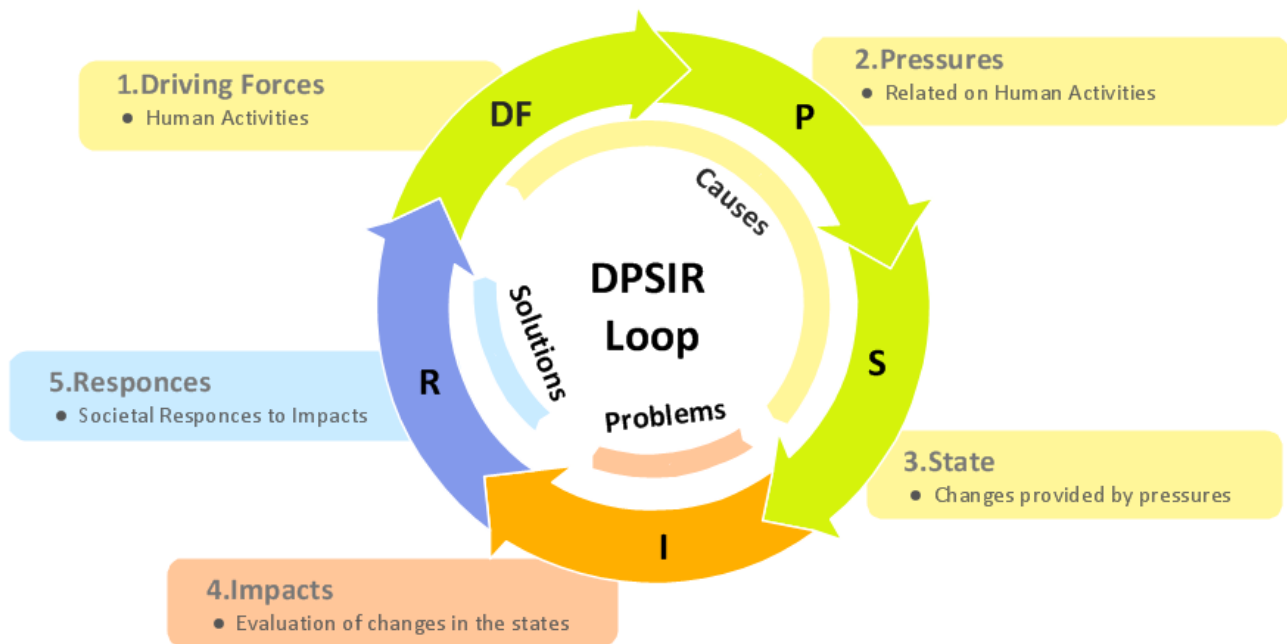


Figure 17 - The general structure of the DPSIR framework

deal with a wide-range of issues related to impacts and, in turn feeding back each component of the causal chain for supporting a loop that generates new policies and rules. A simple example related to this loop, may be represented by responses that influence the sector of transport, from private to public (**DF**), regulating about emission of pollutants (**P**) and the levels of concentration in the air (**S**) ([Kristensen, 2004](#)). The DPSIR framework has been applied toward a wide range of case studies worldwide ([Atkins, 2011](#); [Smith, 2014](#)) with the aim of demonstrating how maintain a certain degree of resource quality and in turn, support the human well-being.

The wide spread diffusion of the ICT toward the planning practices, calls for the implementation of the classic planning instruments in an innovative technological architecture ([Pinto et al, 2013](#)). The next paragraph illustrate the implementation of the DPSIR framework in a spatial environment where the components will be related to spatial information that are able to change dynamically across the space and time through GIS applications. The DPSIR based on spatial information is called: spatial DPSIR (sDPSIR) ([Campagna and Matta, 2014](#)).

#### 4.3.3. *Toward new perspectives: the “spatial” DPSIR*

In the light of the above premises, nowadays the massive use of technologies has changed the way on which the information is represented. In fact, in the last 20<sup>th</sup> the wide spread diffusion of geographic information systems has allowed to manage a big amount of data regarding objects based on geographic components. This structure of data depicts the spatial information. The term “*Spatial Information*” is based on the concept of “*identification of geographic location of objects having features and boundaries on Earth*”. Objects are the fundamental parts for sustaining the phenomena comprehension and their characteristics and relationships need to be represented and managed through Geographic Information Systems. The GIS is a system able to manage and represent spatial information for supporting the decision-making processes. In fact, a current challenge for planners and technicians is to give value of spatial information through GIS for supporting their work. As mentioned in the previous paragraph, human activities influence the environment consuming resources and stressing the ecosystems. These processes usually enclose a high degree of complexity, involving a big amount of correlated factors. They should be related to dynamic components, such as space and time that may change the information (how the information is represented and how it changes across the space and time). The spatiotemporal variation of information represents a more realistic point of view of the phenomena and need to be managed through advanced technological system for supporting the comprehensions of it and communication processes. For this reason, advancements in ICT call for new methodologies and tools for managing and representing spatial information.

As Campagna and Matta (2014) argue, the use of spatial indicators in spatial planning for supporting the comprehension of environmental phenomena, is a current issue. Spatial indicators may be well characterized in space and time in order to make dynamic their outputs. Indeed, the results can enclose dynamic data representing phenomena related to time (from past to present), influencing further spatial analysis and supporting reproducibility and comparability of the results. The DPSIR framework may be integrated in GIS environment in order to support the phenomena comprehension. The DPSIR transposed in a spatial environment, the spatial DPSIR (sDPSIR), is able to support a suitable communication, through

the indicators chain, about the relationships between human and environmental sectors. ([Campagna, 2013](#); [Apitz, 2007](#)). The section 4.4. illustrates a case study related to the Municipality of Teulada. The case study is based on the implementation of the sDPSIR for supporting the communication of information during the LLUP-SEA process ([Campagna and Matta, 2014](#)).



#### 4.4. A PSS for supporting the spatial governance in Sardinia

The Regional Planning system in Sardinia is influenced by the Regional Landscape Plan (RLP) that has been adopted in 2006 for the first time. The RLP aims to implement protection rules toward cultural heritage and landscape (LD 42/2004) at local level. The integration of protection rules from regional to local level is rooted on the process of adjustment of the Municipal Master Plan (MMP), (in Italian, Piano Urbanistico Comunale, PUC) to RLP. Moreover, this process have to be related to the development of the SEA in a intertwined procedure of plan construction. The RLP includes a range of well defined requirements oriented to level out the information produced during the phases of adjustments of every municipality of their Local Land-Use Plan (LLUP) procedure ([De Montis et al \(a\), 2014](#)). Furthermore, the spatial governance in Sardinia is innovated by the Regional SDI (RSDI) since the early 2000. The RSDI spatial data themes in compliance with the technical rules for the National Spatial Data Repository (Ministry Decree 10.11.2011) are classified according to the ISO 19115 as showed in figure 6. The RSDI makes available more than 300 layers and services that can be accessed through web platform or Web Features Services (WFS) in compliance with INSPIRE Directive. The spatial data are becoming crucial in supporting both decision-making processes from global to local scales and for organizations and individuals. ([Trapp et al, 2014](#)). Nevertheless, the process of integration of spatial information into practices seems to be far from over. The wide range of spatial information and services offered by the RSDI and the application of Geodesign, may offer an unprecedented opportunity to innovate spatial planning in Sardinia ([Campagna and Matta, 2014](#)). Furthermore, the PSS based on the GDF, may help to reconsider the role of spatial data in planning practices and deal with the pitfalls in LLUP-SEA.

##### 4.4.1. *The application of an integrated PSS into a LLUP-SEA procedure*

The PSS encloses a range of “characteristics” that may support the SEA-LLUP procedures. These characteristics can be summarized in:

- i. **Land Suitability Analysis (LSA)** that foster the design of alternatives;
- ii. **Sketch Planning** that makes the user able to sketch in a screen in order to interact in real time with the design of alternatives.
- iii. **Interactive Impact Assessment (IIA)** that is based on a specific indicators framework for calculating dynamic indicators.
- iv. **Dashboard** allows visualising in real time the performance of indicators.
- v. **Automatic Reporting (AR)** makes available predefined templates enclosing indicators, maps and every kind of information to be included in the **Environmental Report (ER)** as required by the SEA guidelines.

Indeed, the IIA is based on the implementation of an indicators framework, the DPSIR. The DPSIR framework has been directed toward spatial information in order to define an analysis system based on the interactions among the environmental and human systems (Smeets and Weterings, 1999). The DPSIR is a framework that enclose five components in a loop: the Driving Forces (**DF**) or human needs, cause Pressures (**P**) on the environment, generating changes in the State (**S**). This changes may be evaluated through the Impact (**I**) component that produce Responses (**R**), feeding back each component in a loop. The DPSIR framework can be seen as a support to decision-making and should be in compliance to the GDF models ([Campagna and Matta, 2014](#)) The relationship between DPSIR and GDF are illustrated in figure 18. The image demonstrates how the DPSIR framework and the GDF may be intertwined. The first DPSIR loop completes the first three models of the Geodesign framework defining the current development system, in order to integrate suitable solutions in decision-making processes. In turn, the responses to current phenomena, foster the development of suitable planning solutions and alternatives. This activity complete the first DPSIR loop, feeding back the other DPSIR components in the second loop and providing data for the change model in the GDF. The second DPSIR loop supports the change, impact and decision models, completing the GDF. The implementation of the DPSIR in a spatial environment considers the importance of spatial indicators in spatial planning. Indeed, representation, design activities and communication of information are based on spatial information that need to be represented in space and time. For this reason, the implementation of the conceptual DPSIR model in GIS generates a spatial version of the DPSIR: the spatial DPSIR (**sDPSIR**). In the next paragraph is possible to explore an application of the *sDPSIR* in a Sardinian municipality through a GDF-based PSS architecture.

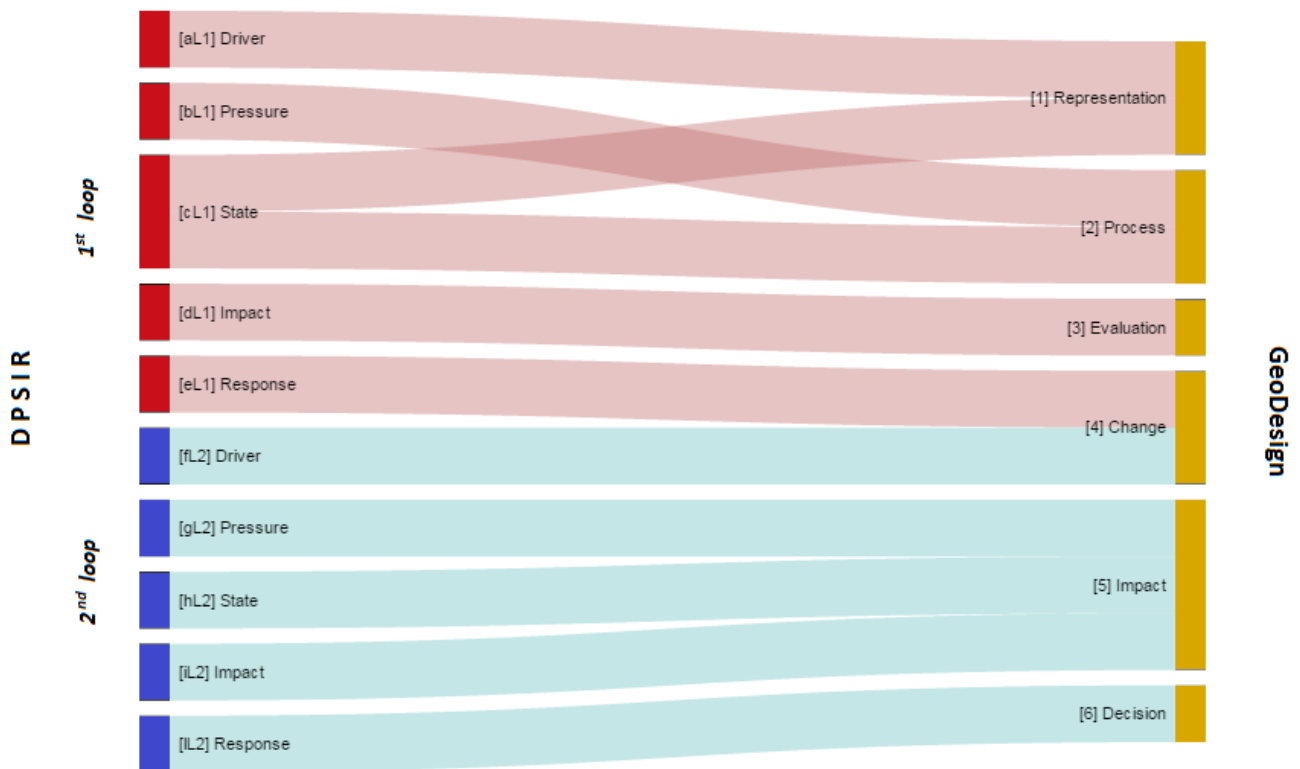


Figure 18 - The relationship between the DPSIR and the GDF

#### 4.4.2. A sDPSIR application into LLUP-SEA

The LLUP in Sardinia is compliance with the Italian national regulatory framework and the Regional Planning Law n. 45/1989 (RLP) that foster the location of protected areas and new development zones, such as a new residential area.

The growing attention toward the environmental issues fosters the diffusion of development measures oriented to satisfy the sustainable principles. The implementation of Strategic Environmental Assessment procedure into planning processes for supporting land-use plans should be supported by tools able to take into account spatial information. Indeed, the design of the alternatives, impact assessments and environmental reporting, are complex activities in the SEA-LLUP process and should be sustained by reliable indicators framework. The framework may foster the comprehension, diffusion and assessment of information about territorial phenomena in space and time. For this reason, the DPSIR framework may be seen as a nested tool in the PSS architecture, able to support the implementation of the GDF. Indeed, the early information are related to the current situation (Representation Model), taking into account Drivers or human activities that afflict the environment, exerting Pressures that change the State (Process Model). The assessment of the output of this first step through the Impact component (Evaluation Model), makes

available the information on which alternatives or responses, should be based (Change model). The case study presented in this paragraph is centred on the second part of the GDF. Indeed, the model takes into account the spatial information related to the study area in order to represent the territory. The representation model provides the base on which develop scenarios enclosing different alternatives (change model).

Indeed, during the decision-making phase (Change Model), is possible to design a set of alternatives that may be evaluated in real-time. The quantitative and qualitative results may be established on-the-fly with the aim of providing real-time information for feeding the plan-making process ([Campagna and Matta, 2014](#)). The table b shows how the first part of the DPSIR framework is applied to the case study of Teulada. The image (figure 19) illustrates how the sDPSIR is able to provide a structure to assign the spatial information toward the framework to support decision-making. Indeed, for each component has been assigned the spatial layers in a feedback loop, generating causal relationships.

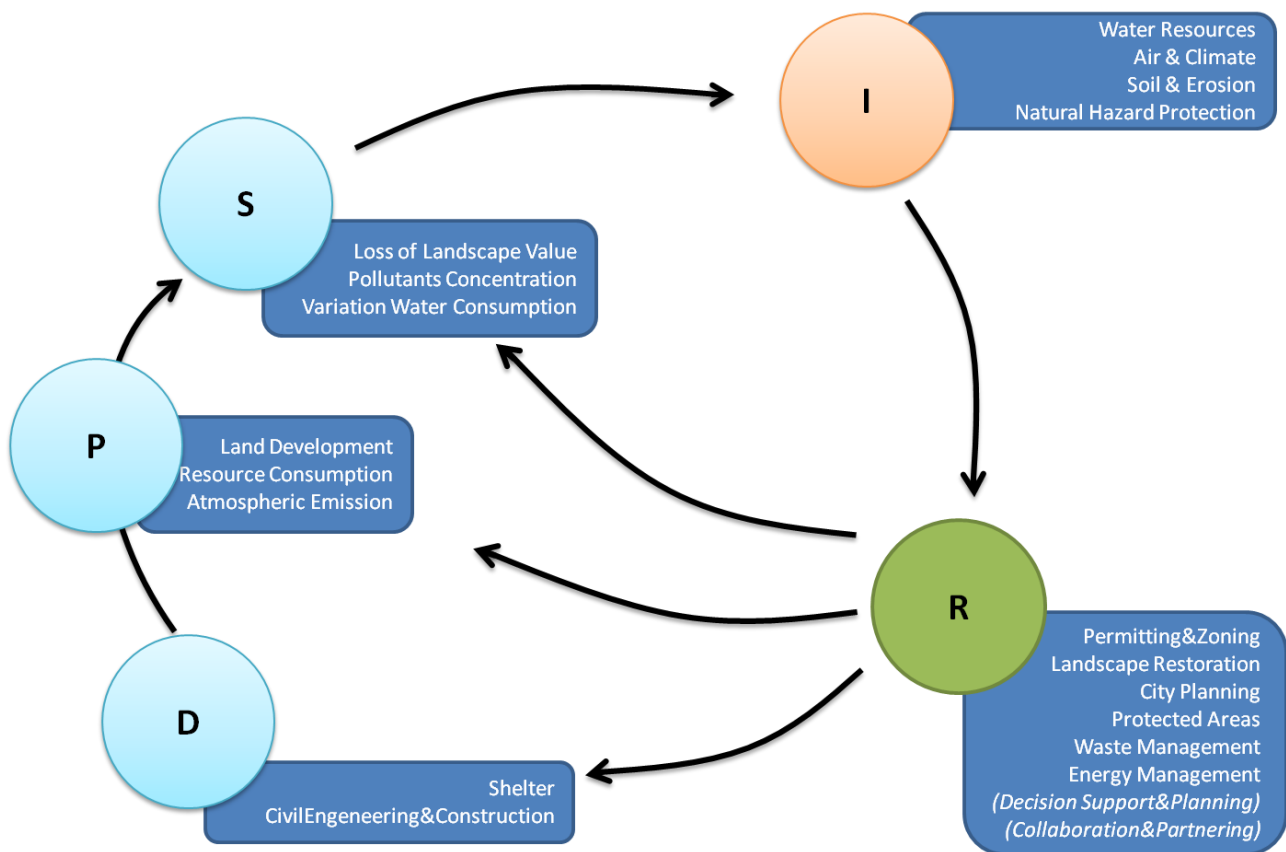


Figure 19 - Adaptation of the general EPA DPSIR model to the SEA-LLUP case study at the concepts level

A deeper view of the application of this framework is represented in the table b. The table takes into account only the first part of the chain (D - P - S components) and it is composed by 5 columns: the first

three are related to the general Environmental Protection Agency (EPA) DPSIR framework (Chapter 5), while, the last two represent the result of SEA-LLUP process.

**The study area:** Teulada is a municipality of the South-West Sardinia that has a population of almost 3700 inhabitants and cover 245,6 km<sup>2</sup>. The RSDI makes available the spatial data of Teulada territory, on which are performed the models of the Geodesign and the spatial analyses.

### DRIVERS

<b>Sub categories</b>	<b>Concept</b>	<b>Sub Concept</b>	<b>Plan Option</b>	<b>Unit</b>
Human needs	Shelter	Housing	Residential Area	km <sup>2</sup>
Infrastructure	Civil Engineering	Land-Based C.E.	Roads	km

### PRESSURES

Landscape Change	Land development	Reduction Natural Area	Loss of Landscape Value	% - km <sup>2</sup>
Landscape Change	Land development	Reduction Natural Area	Land Use Change	% - km <sup>2</sup>
Consumption	Resources Consumption	Water Consumption	Water Consumption	m <sup>3</sup> /inh * Y
Discharge	Atmospheric Emission	Traffic Emission	Pollutants	g/km

### STATES

Biological State	Living Habitat	Natural Area	Loss of Landscape Value	Δ % - km <sup>2</sup>
Biological State	Living Habitat	Area	Land Use Change	Δ % - km <sup>2</sup>
Abiotic State	Physical Variables	Water	Gross Water Consumption	Δ cm/Y
Abiotic State	Chemical Variables	CO <sub>2</sub>	Gross Pollutants Emission	Δ% - g/km

Table b- Adaptation of the general EPA DPSIR framework (<http://www.epa.gov/ged/tutorial/>) to the SEA-LLUP sDPSIR.

The RM, represented in the figure 20, has been depicted through an overlay of layers: the current zoning plan of the General Regulatory Plan (in italian "Piano Regolatore Generale", PRG), the land-use, the roads infrastructures and hydrograph.

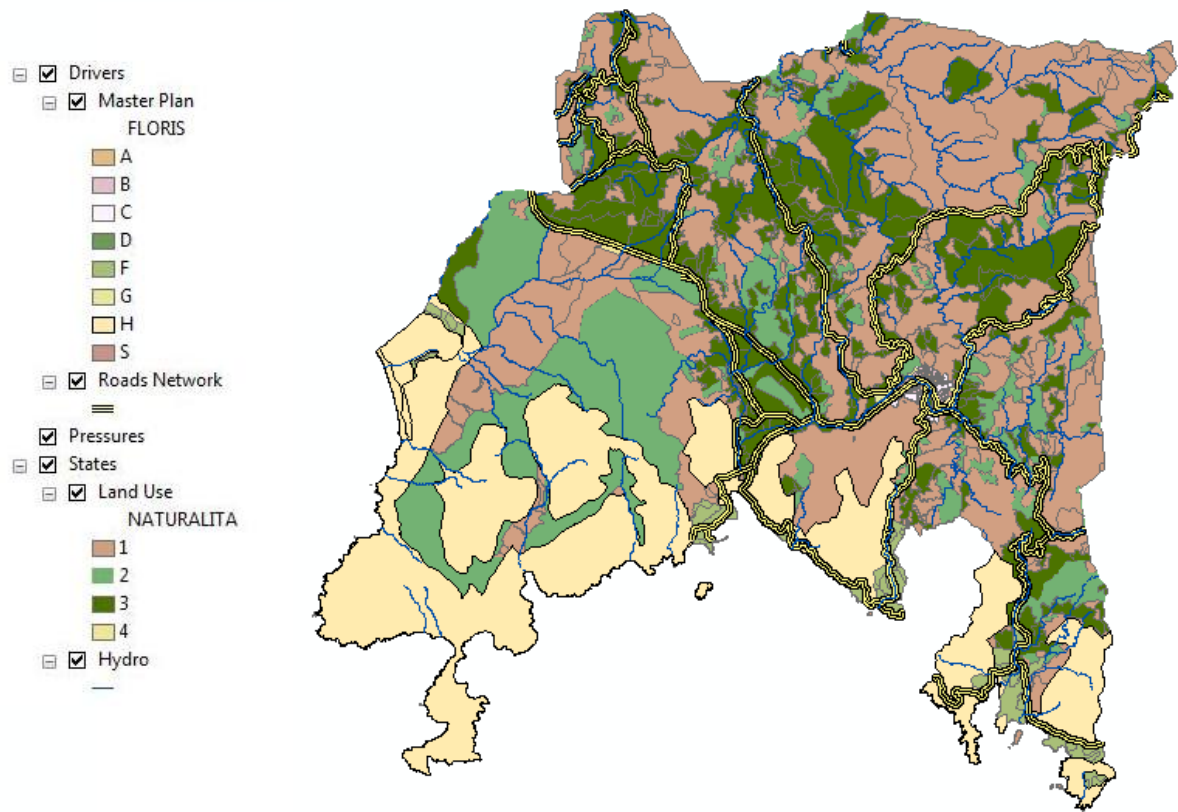


Figure 20 - The Representation Model for the Teulada municipality and the DPSIR

The GIS is able to support the relationship between the nested decision tool (DPSIR) and the GDF. Nevertheless, the GIS may not be capable to display and summarize the information related to the study area. The Planning Support System makes available a wealth of tools that support analysis, representation of data and their variation. As illustrated in the figure. 21, a range of spatial information has been selected in order to support the comprehension of phenomena (e.g. social, environmental), the information process for the plan-making phases and the communication among stakeholders. The range of data represented can be static and if adequately supported by suitable tools, can dynamically change.

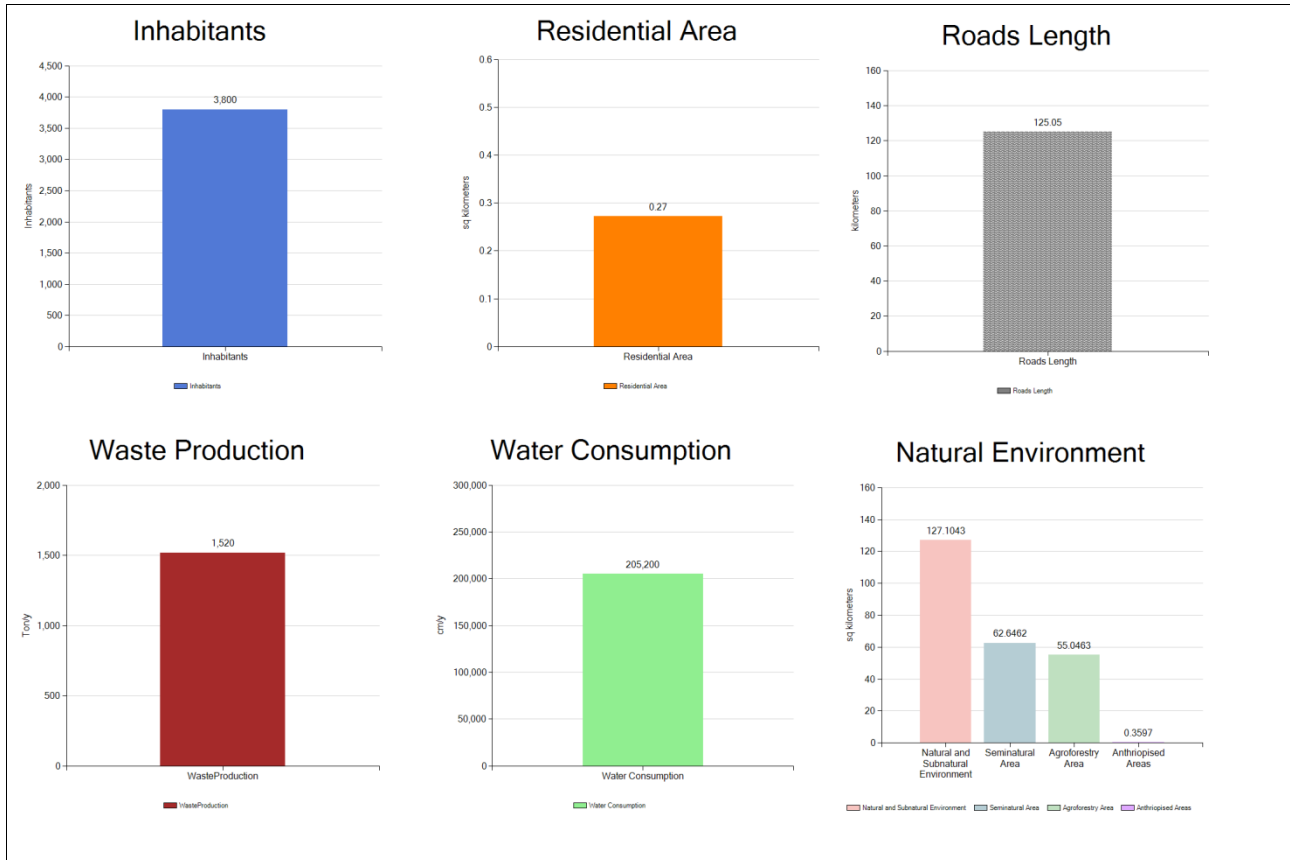


Figure 21 - Indicators dashboard - Representation Model

Plan alternatives and strategic goals may produce a range of pressures on the environment, causing change of the states.

The wide range of information that can be taken into account could make the causal chain extremely complex. The intrinsic complexity of this process may lead to a lack of phenomena comprehension and misunderstanding regard the impacts of the alternatives. In order to demonstrate how the PSS architecture may be useful to support the communication, the comprehension and the comparison of the design proposals, a new residential zone has been located into the urban area. Once the knowledge has been created, it may be used to inform the design of possible solutions or alternatives in compliance with the change model, which are then assessed through impact models and eventually chosen with the decision models.

The potentiality of the PSS makes the planners able to deal with these issues trough several nested tools, such as the Sketch Planning, the Interactive Impact Assessment (IIA) and the Dashboard. The new residential area has been designed changing the dimension of two different plan proposals in order to consider how the architecture is able to produce a real-time information during the decision-making process. For this preliminary phase, the main goal is to make in evidence how the first part of the DPSIR

framework (D-P-S components) intertwined with the GDF and implemented in the PSS architecture, may support informed SEA - LLUP procedure and the communication processes.

The figure 22 shows how using a digital pen is possible to design a new residential area in a screen. Almost in real time, it is possible to visualise in a dashboard the results regard the impacts of the alternatives through different scenario(s).

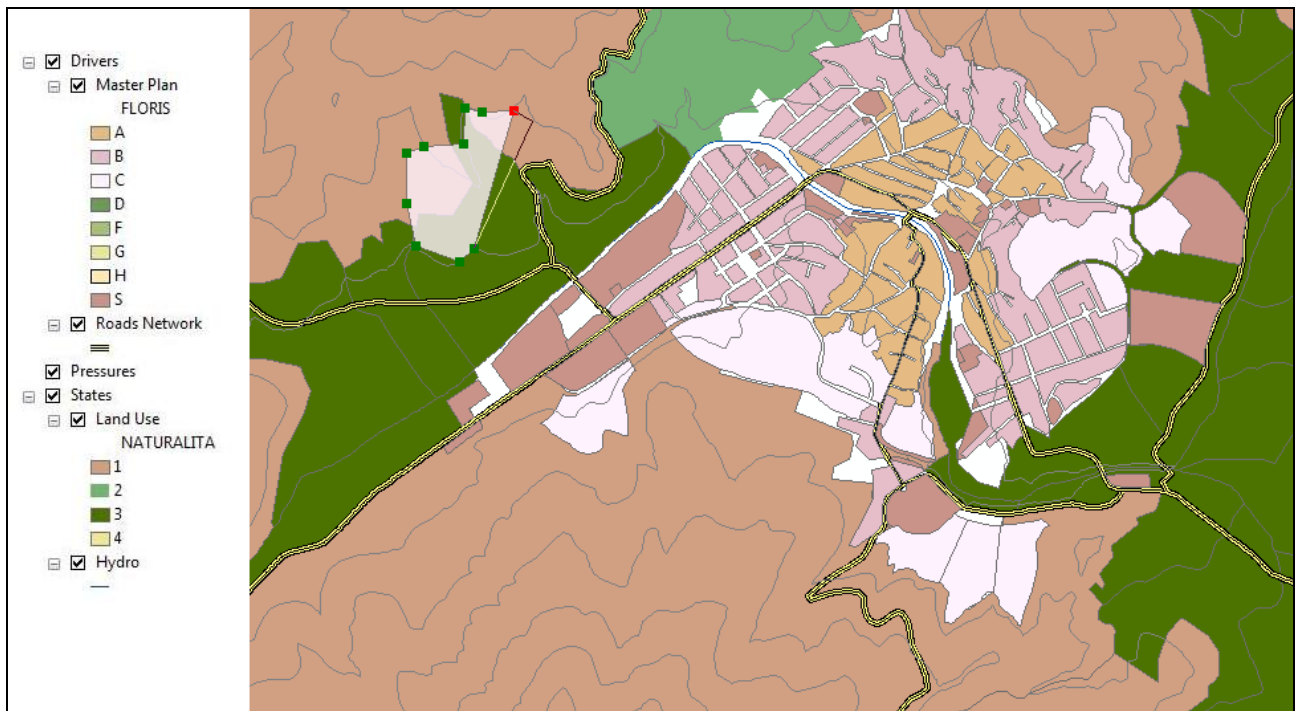


Figure 22 - The sketch planning tool

The design, such as a new residential area, creates or edits the drivers that produce pressures and variations of the environmental states (sDPSIR framework).

In turn, through the IIA is possible to calculate a set of indicators related to the impacts. Indeed, a new residential area may produce environmental impacts, such as the loss of natural landscape, resources consumption, population growth and their relative needs and pressures, such as the water consumption and waste production. The results of the causal indicator chain may be illustrated in a dashboard compared with the initial situation (figure 21).

The sketch planning makes the planners or, more generally, the users able to sketch in a screen thanks to a digital pen. Indeed, this innovative tool "allows on-screen hand-drawing using a digital pen and to immediately calculate the impacts of different solutions by interactive impact assessment models" (Campagna et al, 2014).

The figure 23 depicts as the PSS architecture is related to the GDF and in turn, how it is able to support the stakeholders interaction. Different proposal can be defined and designed on the fly, according to a wide



range of information based on socio-economic and environmental sectors. This process produces a real-time assessment of plan options and proposals, supporting planning collaboration and interactions among stakeholders.

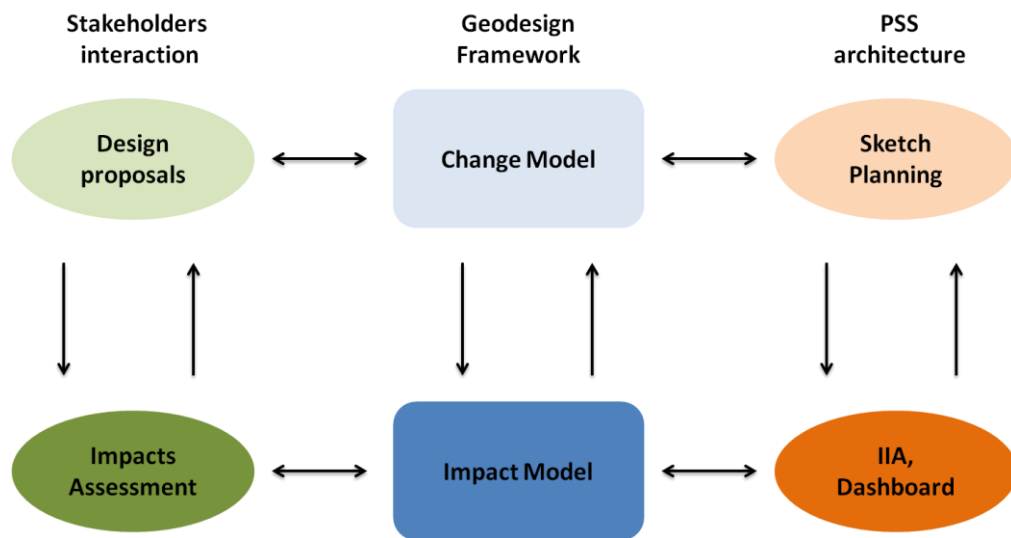


Figure 23 - The relationship between the PSS and the GDF

Furthermore, in a context such as Sardinia where geo-information technologies are barely used in the local planning practice, this prototype shows how value can be added to the availability of the Regional Spatial Data Infrastructure to support sustainable spatial governance in the region. (Campagna and Matta, 2014). In turn, as mentioned in chapter 3, the availability and updating of spatial data may provide a range of economical benefits. Despite the cost to maintain and update the databases and web platforms, the spatial data are a central role for the understanding, monitoring and assessment of environmental, social and economic sectors (Trapp et al, 2014).

The spatial information offers the opportunity to perform spatial analyses to support the design and the impacts evaluation of different alternatives based on strategic goal. The PSS may be applied to other municipalities in the region, and it may be easily adapted to other regional contexts in Italy.

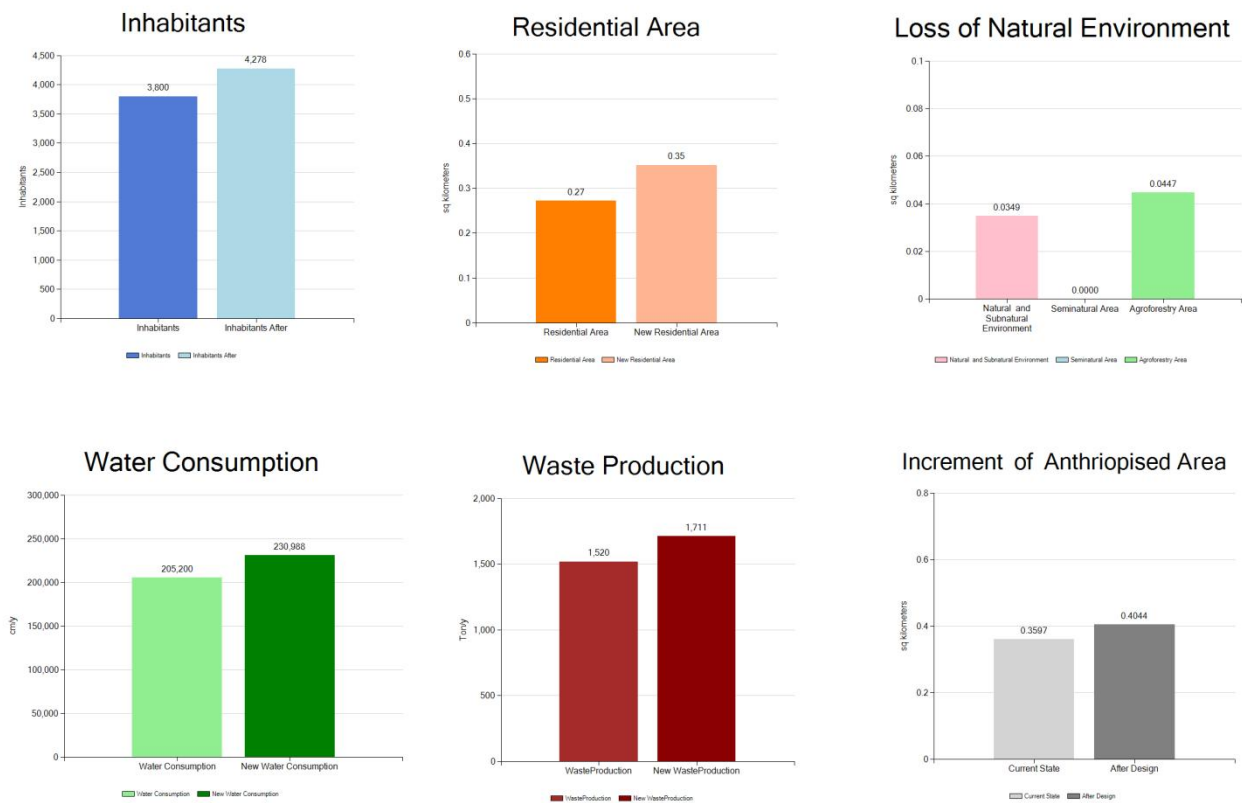


Figure 24 - Spatial indicators related to the Teulada case study

In order to demonstrate how the PSS architecture may support the spatial governance in Sardinia, two case study have been carried out.

The first one, thanks to the help of the Engineer Matteo Serra in the context of his Master Degree thesis, is developed in the Municipality of Gonnese in the South West of the Sardinia Region. The Second one, thanks to the help of the Architect Chiara Cocco, concerns the comparison between two different planning approach throughout different technologies for dealing with the same planning issue.

## 4.5. The Gonnese Case Study

The case study has been carried out by the UrbanGIS Lab (<http://people.unica.it/urbangis/staff-eng/>) in collaboration with the local authority of Gonnese. A workshop was organized in order to test the potentiality of the PSS for the LLUP-SEA of the Gonnese Municipality. The workshop is structured through a range of steps related to the plan-making phases. The aim of this work experience is to investigate the value of using the PSS for supporting the process of adaptment of the Municipal Master Plan (MMP) to the Regional Landscape Plane (RLP). The case study of Gonnese is oriented to locate a new touristic zone (F Zone) in compliance with the needs of the local authority for the socio-economic development of the municipality. At the beginning, it was proposed to the participants of the workshop, such as technicians and researchers, to identify the most suitable area for a touristic purpose. After that, it was proposed to design a new F zone, evaluate the impacts of such choices and compare different alternatives. The workshop was performed in compliance with the COST TU 1002 guidelines for the organization of the workshop in supporting local planning.

### 4.5.1. The general structure of the Workshop

The workshop was organized in compliance with the theories and methods of the 'experiential learning' by Kolb and Fry (1975) (Figure 25).

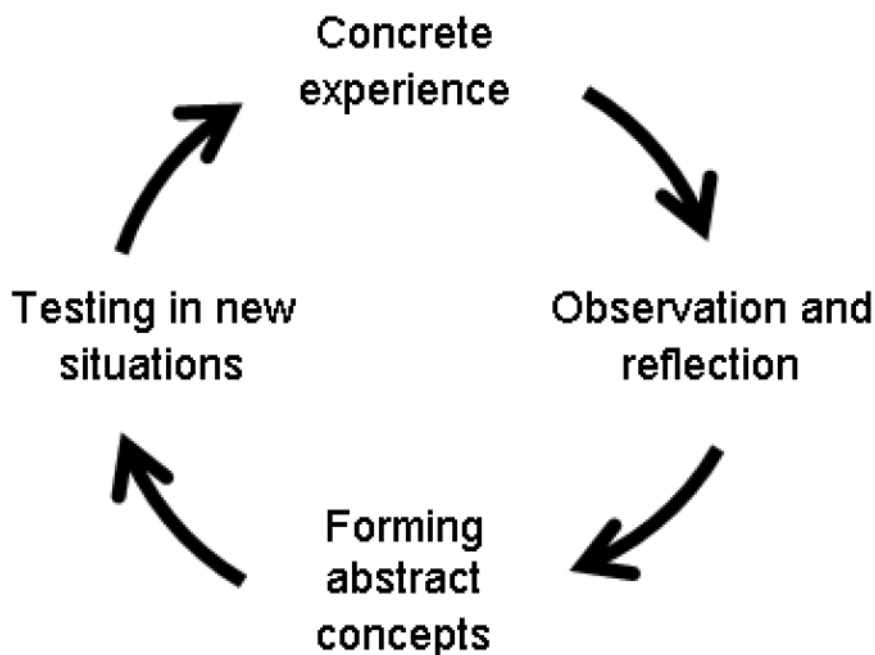


Figure 25 - The experiential learning cycle

The experiential learning cycle is an interactive loop where the actors are able to "form abstract concepts" based on "observation and reflection on concrete experience". These abstract concepts are then "tested in new situations" for adapting existing practices as "concrete experiences". Brömmelstroet et al (2014), pointed out that, the experiential learning cycle can be considered as a support framework for planning research and practices. On the one hand, the researchers focus the attention on the concrete experiences and, on the other hand, the practitioners need to take into account more reflective activities in order to 'form abstract concepts'.

Nevertheless, it was impossible for a single workshop session, to set a range of specific exercises and activities for both users and tools. For this reason, has been set a single experience cycle on which every single user, was able to observe and interact in every step of the workshop.

The workshop is based on a replicable structure that can be used and compared in other case study. For this reason the workshop has been structured through a preliminary session of interviews with the users (Workshop Users - WUs) in order to take into account their opinions and purposes. The structure is in compliance with the model performed by Goudappel Coffeng and it is based on 4 main phases. The model has been adapted for the Gonnesa case study as depicted in figure 26.

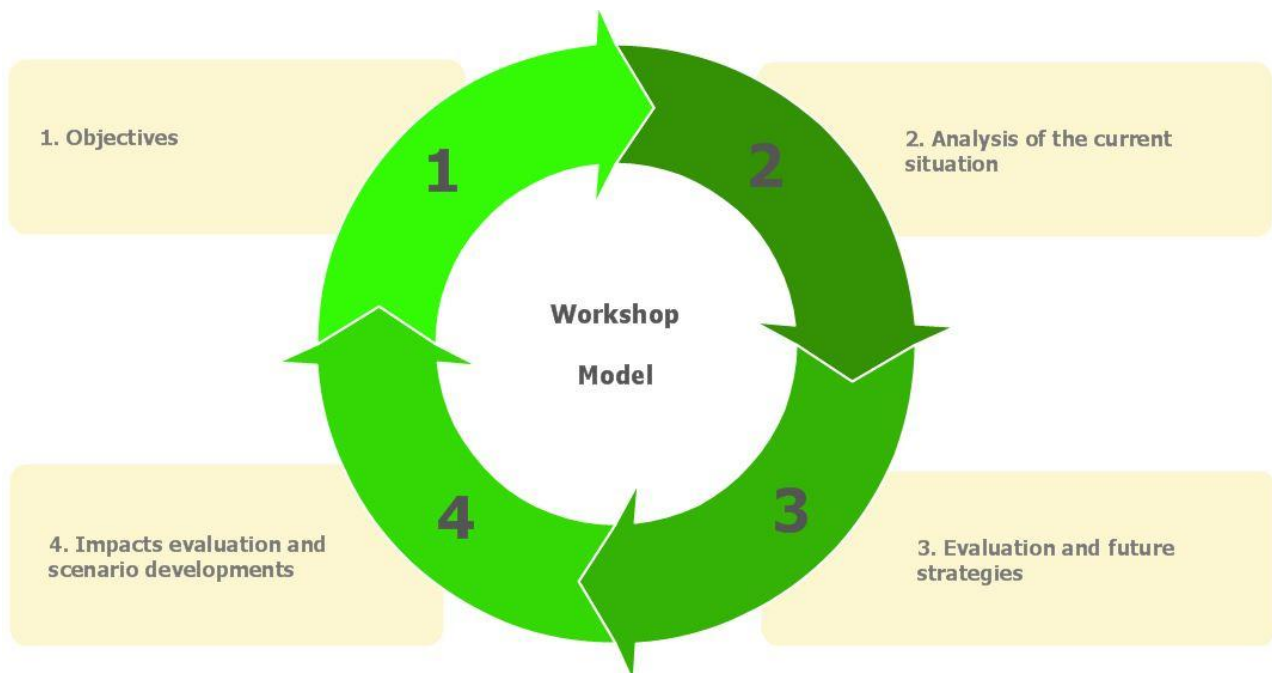


Figure 26 - The four phases of the Workshop

**Pre-Step:** The interviews have been carried out with the aim of taking into account specific issues related to the current planning context. In this phase the WUs were call for producing a range of considerations about the indicators, local planning goals and further questions. The preliminary phase of interviews feeds the step one: the Objectives.

**Step 1:** In this phase, the PSS has been set for dealing with the planning issues with the aim of producing suitable solutions and setting the information. The planning questions have to be translated in data and indicators in order to be managed through the PSS. For instance, the location, design and impact evaluation of a new homogeneous area in the municipal territory may be performed through a range of spatial data, indicators and standards, with the aim of communicating the influence of such activities on the geographic space.

**Step 2:** The second step is based on the representation of the territory. The territory may be depicted in many ways through different tools (i.e. maps and tables) with the purpose of communicating the characteristics of the study area and how the current phenomena influence the territory. The representation of the territory is important to create processes of communication to public and stakeholders. The representation is able to communicate new information, setting knowledge-based processes and relationships among different sources of information.

**Step 3:** In the third step is possible to produce the knowledge with regard to the capacity of the territory of dealing with new land-uses, in order to feed the design of the alternatives.

**Step 4:** The last phase is oriented to evaluate and compare different scenarios, based on the design of the alternatives, in order to guide the decision-makers toward the most suitable planning solution(s).

This general approach to the workshop, is intertwined with a range of steps dedicated to the data collection. As Brömmelstroet et al (2014) pointed out, the phase of the data collection should be performed through several steps (Figure 27):

1. *Pre-workshop survey;*
2. *Post-workshop survey;*
3. *Semi-structured focus group;*
4. *Working group panel assessment.*

The first step aims to establish a flow of information between every WU and the Workshop Staff (WS) in order to take into account the "*current state of practice in the use and understanding of accessibility*"

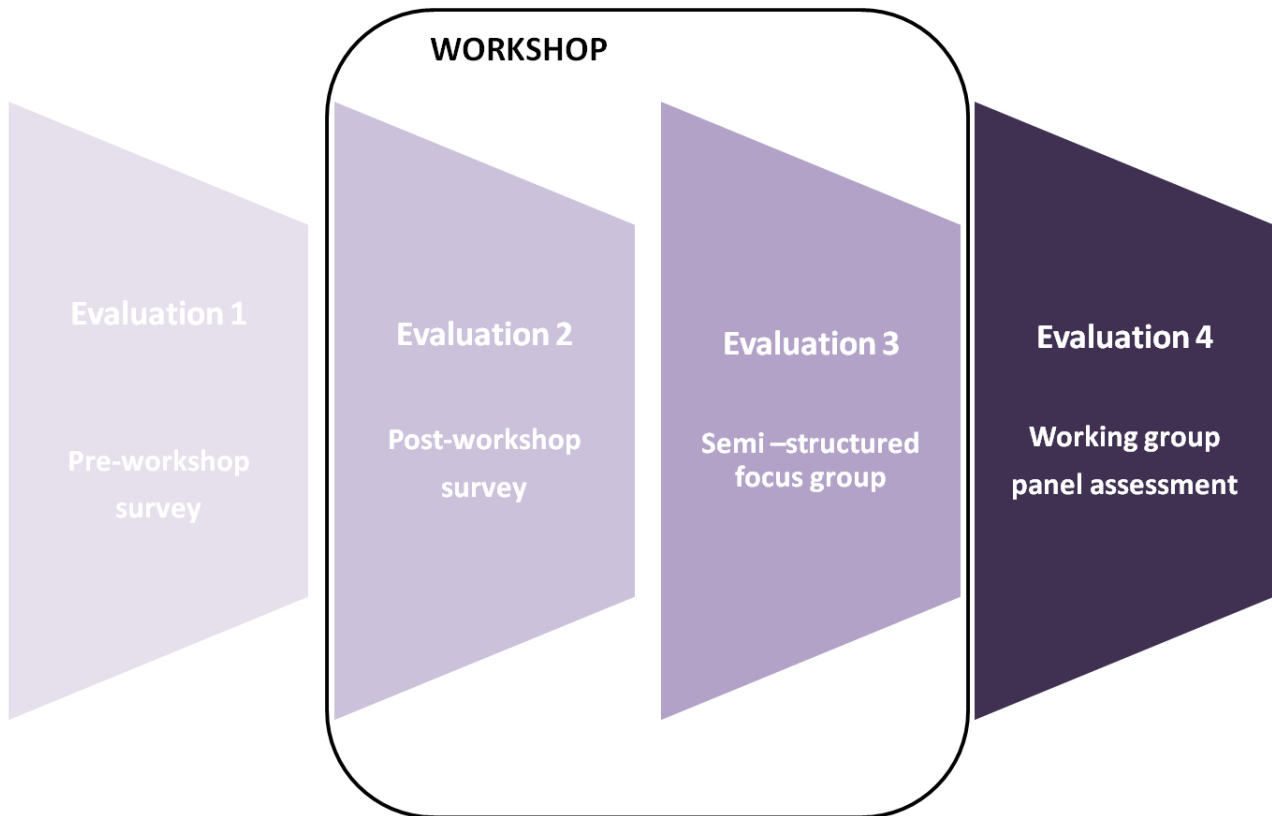


Figure 27 - The Workshop Steps

*tools/models"* ([Brömmelstroet et al, 2014](#)). The second and the third step, have been performed during the workshop phases in order to give value of the WUs assessment about the use of the geo-tools. The fourth phase is based on a panel where WUs and WSs discuss about the previous phases with the aim of considering the pitfalls of this approach in supporting plan-making activities. This phase may improve the communication between the researchers and the stakeholders. The fifth phase is merely dedicated to the WS in providing their opinions about the level of satisfaction for the workshop organisations. The next paragraphs show how the workshop has been organized by the UrbanGIS Lab in compliance with that guidelines.

#### 4.5.2. *The Workshop (I) of Gonnese*

The workshop is structured in order to take into account a wide range of components, such as the organization, contents, methodologies and tools. A limited number of users have been invited in order to make the participative process suitable for the time available. The actors involved in the process are technicians, local administrators, engineers and researchers. In order to guarantee the privacy, the actors were identified through an informal code. The workshop has been carried out in Gonnese, at the s'Olivariu

park, through the four steps of the theoretical model proposed in the previous paragraph. The preliminary interviews (Step 1) with the actors involved in the workshop, guide the activities toward the planning goal of the municipality for defining a new touristic area (F Zone). After that, **Prof. Campagna** illustrates the theoretical framework of the Geodesign with a particular focus on the pitfalls in the SEA application, providing the information to WUs to actively participate to all workshop phases. The first phase of the workshop has been conducted by the Ing. Matteo Serra through a PSS-Representation Model-Web Based (PSS\_RPM\_WEB) in order to make available the comparison between the current method to show and share the information of the Gonnese territory and this innovative technology (Step 2). In this phase have been performed the first two models of the Geodesign framework (Figure 28).

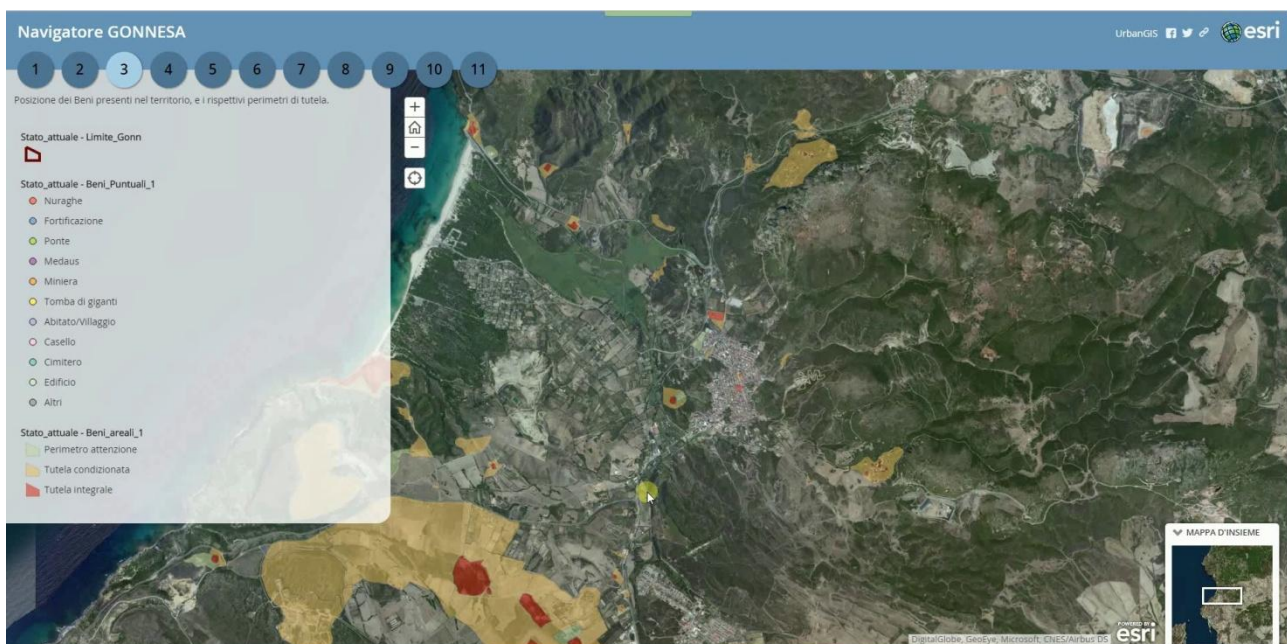


Figure 28 – The Story Map

The representation model and the process model are represented in the story map through an interactive technology that make the users able to compare different spatial information, perform a range of spatial analyses and create informed processes to sustain the decision-making phase (Figure 29). This phase puts in evidence how the spatial data may be used to improve the informed process at the base of the decision-making. In fact, the PSS is able to support a different and more suitable use of the spatial data, offering an advanced technological support to perform real time analysis and improve the communication process among stakeholders. This web system is easy to set and may help to innovate the way of sharing information of the territory, improving the accessibility for the public.



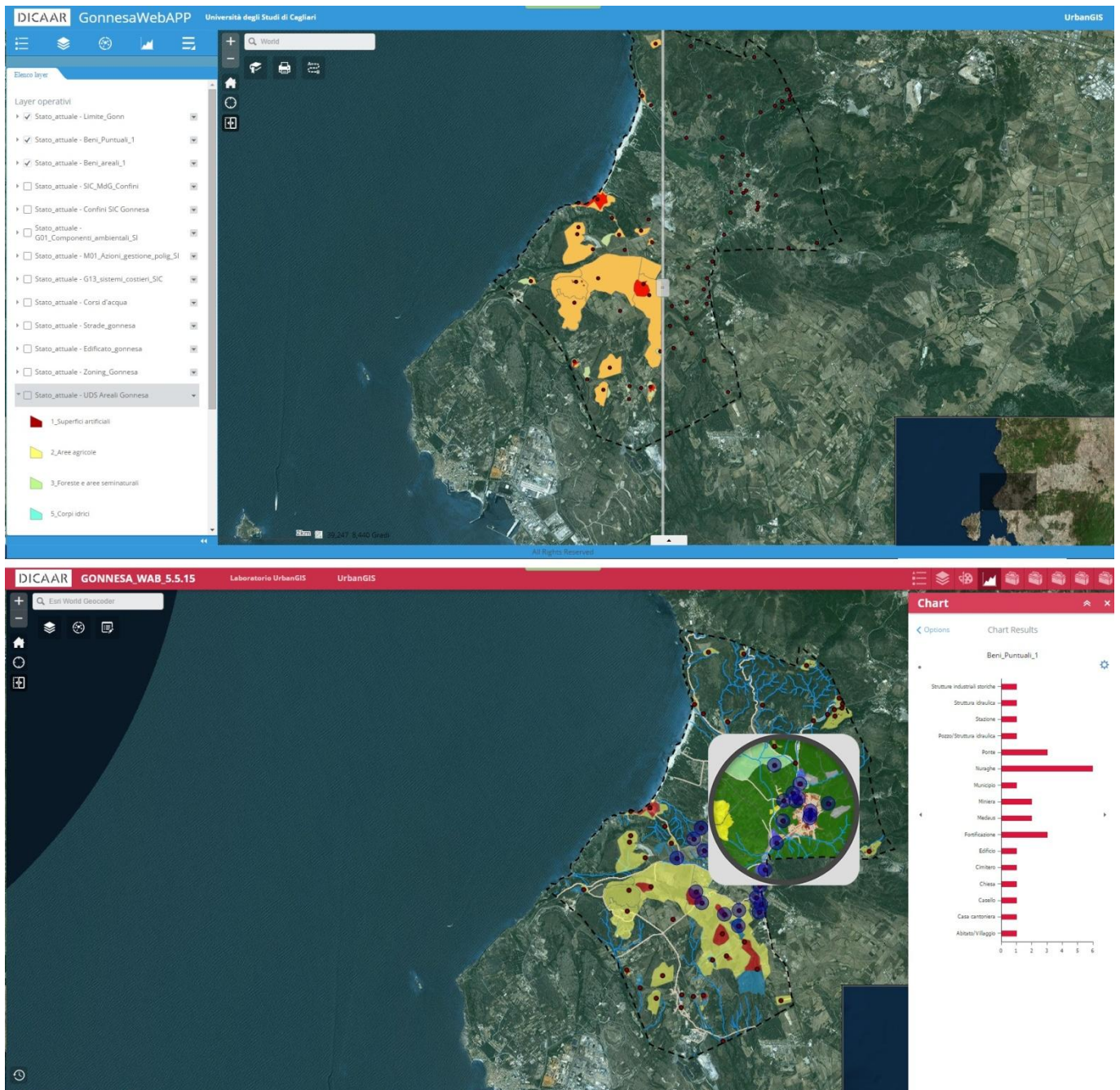


Figure 29 - The Web App



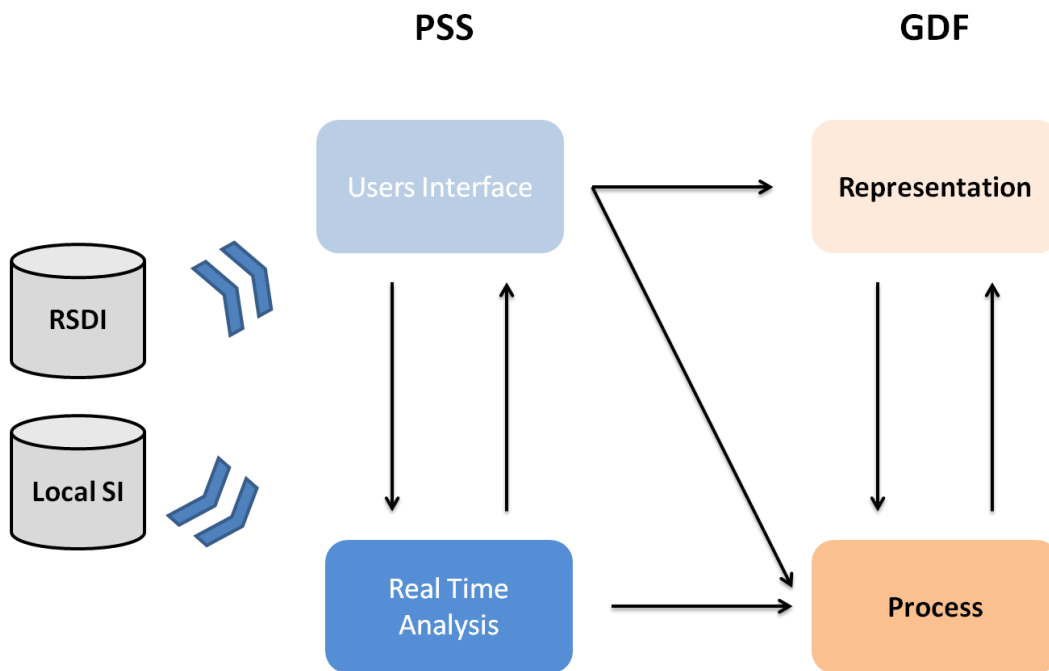


Figure 30 - The general system that make in compliance spatial data, PSS and GDF

The third phase (Step 3) is based on the outputs generated during the previous steps in order to deal with the planning goal on which the workshop activities are based. Indeed, the third step is oriented to identify adequate geographic spaces in the municipal territory to locate a new touristic zone. For this reason, the Land Suitability Analysis (LSA) may be considered as a reliable tool for supporting this planning task. In this case, the LSA can be considered the first step of the design activities, and the figure 31 shows how the PSS features may be related to the GDF during the plan-making process.

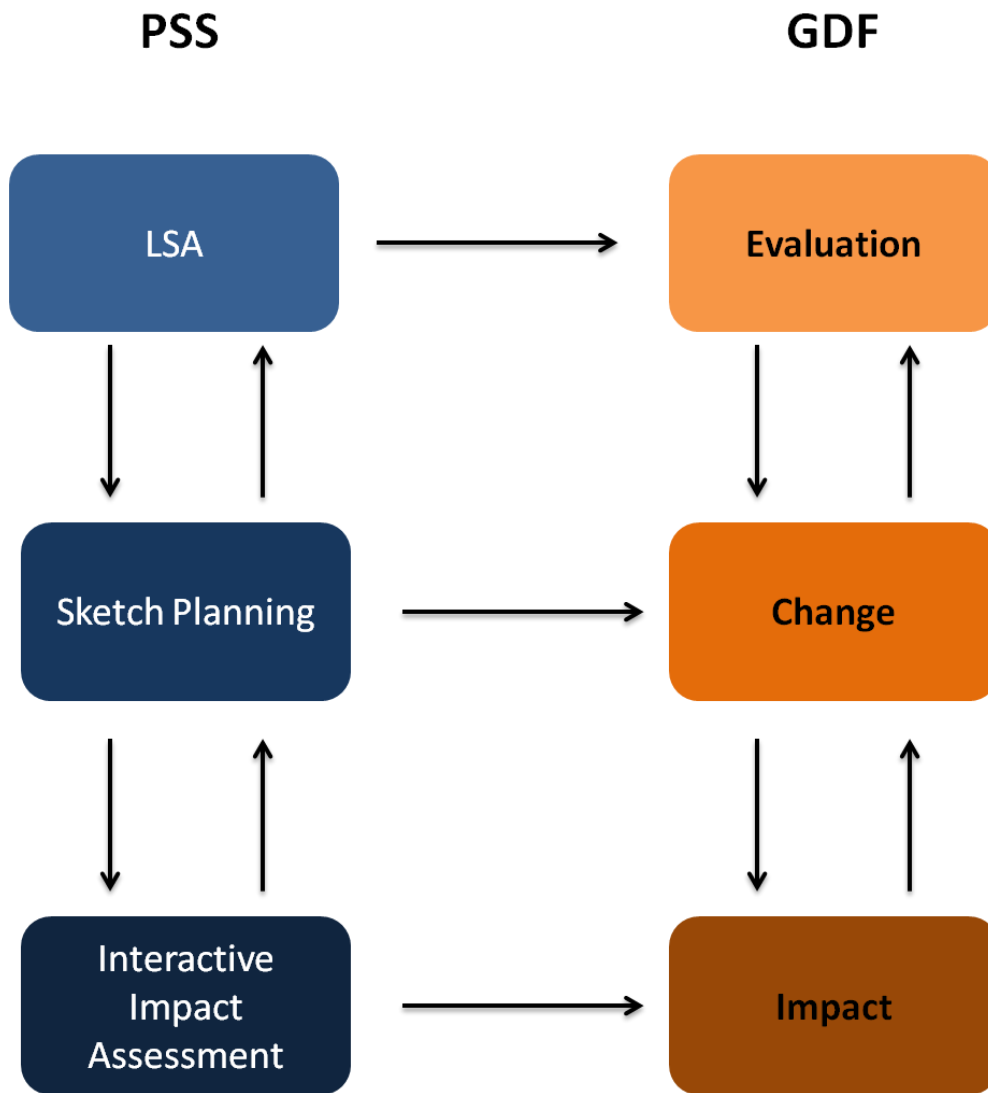


Figure 31 - The PSS and GDF, the second part

The LSA is a GIS-based procedure on which a range of parameters can be modified on the fly in order to illustrate the suitability degree in a map. The suitability map shows a range of areas based on a suitability degree, from suitable to unsuitable, on which is possible to produce further analyses and design ([Jafari and Zaredar, 2010](#), FAO, 1976). In the case of Gonnesa, a new F Zone was required and a set of information and parameters was taken into account in order to achieve this planning goal. These parameters depict environmental, social and economic sectors and the variations of specific value(s) are related to real-time changes in the map. This phase is linked to the Evaluation Model of the Geodesign framework. Indeed, the evaluation based on an informed process, arose from the knowledge provided by the first two models (Representation and Process), and makes possible to identify the current issues for the municipal territory. The parameters have to be related to the layers, such as roads network, zoning plan, corine land cover, hydrography and services. These parameters have to be classified to make them comparable. For instance,

the distance of the main roads network is incomparable with the presence of a Site of Community Importance (SIC) and the maximum volume feasible for different areas. The LSA makes the planner able to classify a range of parameters through a spatial multicriteria methodology ([Jafari and Zaredar, 2010](#)). This method has been applied for the Gonnese case study and illustrated during the workshop. The list of parameters taken into account, is illustrated in the Table C. The parameters are divided in two main classes: **Criteria** and **Factors**. The criteria, or constraints, are related to the set of rules and normative at local level (standards) and regional level for the landscape and environmental protection (RLP or Hydrogeological Risk Plan, HRP, in Italian Piano di Assetto Idrogeologico, PAI). The constraints can be considered like limits for the process of evaluation. For instance, the maximum feasible volume or the full preservation related to historical goods represent different type of constraints to be applied in the LSA.

The factors can be represented through the spatial distribution of a specific attribute (e.g. slope, distance from other features) and have been selected by the group of researchers and technicians for the workshop purposes. The PSS is able to make dynamic the LSA parameters in order to apply real-time changes in the map, representing the variations of the parameters values.

Constraints			Factors		
Name		Source	Name		Source
Homogeneous Area	A	MMP	Distance	Coast Line > 300 m	RLP
	B			Disused mining areas	
	C			Rivers	
	G			Levels of HRP 3 - 4	
	H			SIC	Region
	S			Roads Network	MMP
Full protection area	Historical goods	Houses			
Buffer zone	Rivers	H Zone			
	Coast Line	Historical Goods			
Disused mining areas					
High risk for flooding	Hi3			HRP	
	Hi4				
High risk for landslides	Hg3				
	Hg4				

Table C - Parameters of the LSA

The figure 32 shows as the constraints and factors have been represented and managed through the PSS and integrated into the LSA. The constraints and the factors can be interactively modified with the aim of representing how the suitability degree of the areas may change.

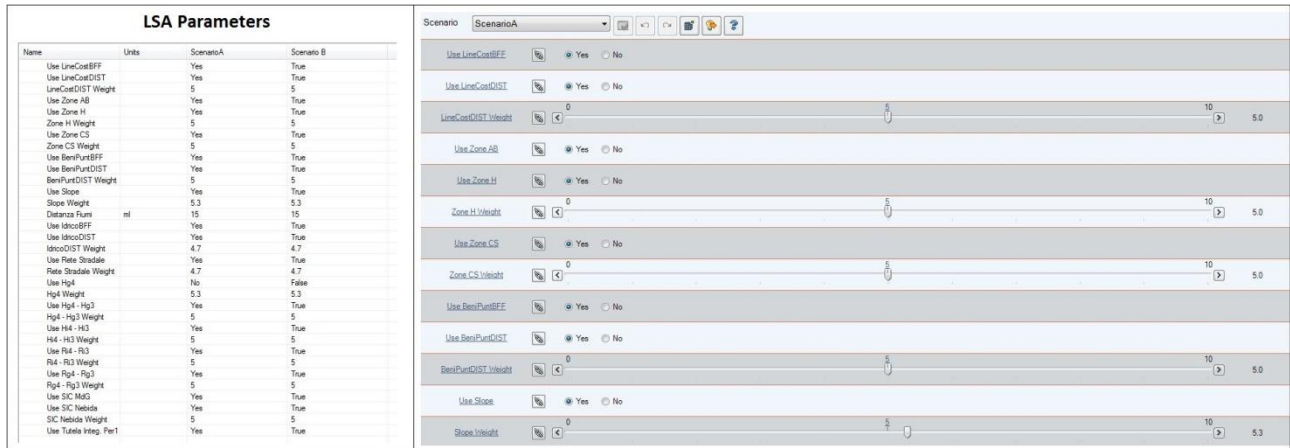


Figure 32 - Parameters and factors of the LSA

A specific area may change from suitable toward unsuitable or vice versa and this variation is real-time represented in a map, as showed in the figure 33.

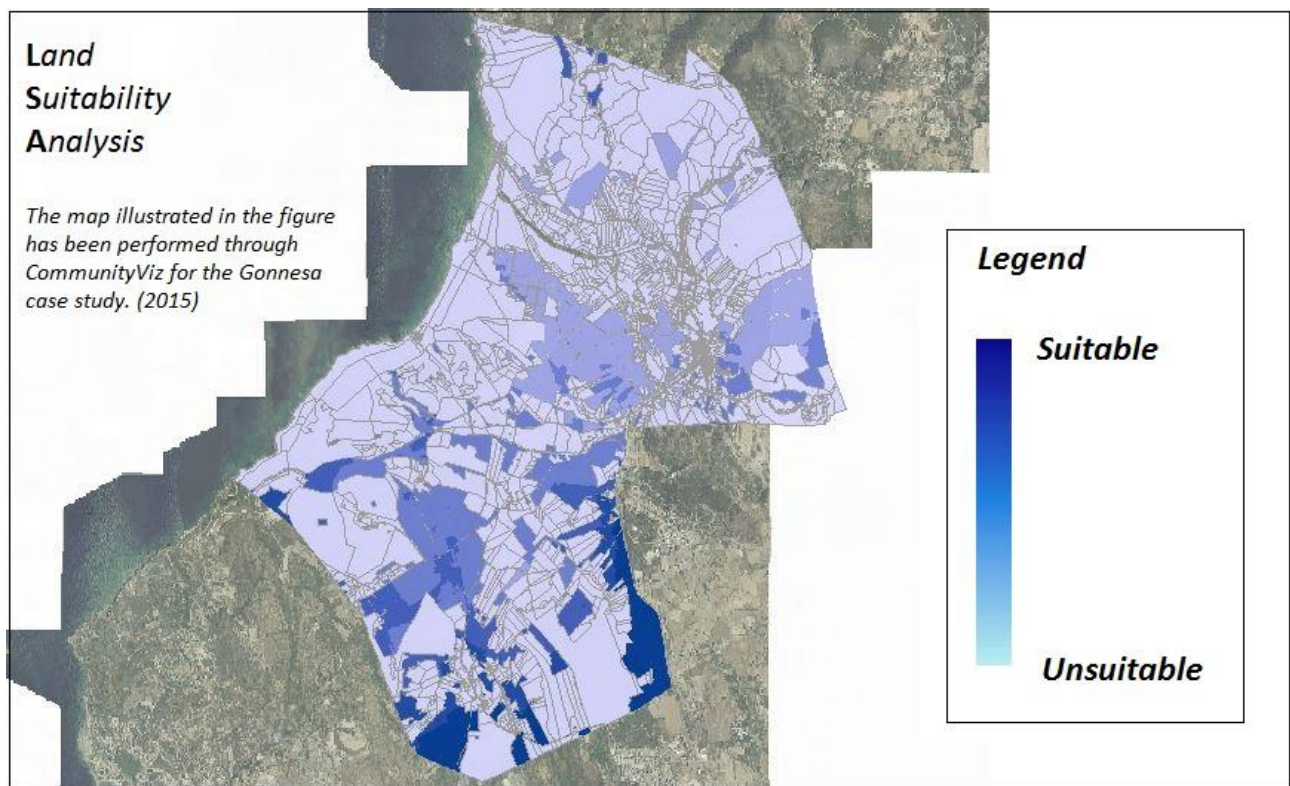


Figure 33 - A suitability Map

The Land Suitability Analysis has been performed through the support of CommunityViz (the figures 32, 33 and 34 refer to the user interface of CommunityViz) that, through a user friendly interface makes the parameter' values dynamic. When the user complete the variation of the parameters value, the model represents these variations through a choropleth map. For the Gonnese case study, two different solutions have been developed with the aim of feeding the design of the alternatives and the creation of two scenarios. These scenarios and the relative parameters value, may be compared in order to illustrate the differences between such alternatives. The scenarios were oriented to satisfy two general planning goals: the environmental protection and the society development. The parameters were changed in order to achieve these two different goals and show to stakeholders the differences in the results. The scenarios comparison phase, developed during the workshop, fed a discussion among the WU and WS. The discussion is based on the value of the parameters and why and how they are related to the changes in the map. This approach supports a real time evaluation of the solutions proposed, improving the discussion among the stakeholders. The figure 34 shows the LSA scenario comparison proposed for the workshop of Gonnese.

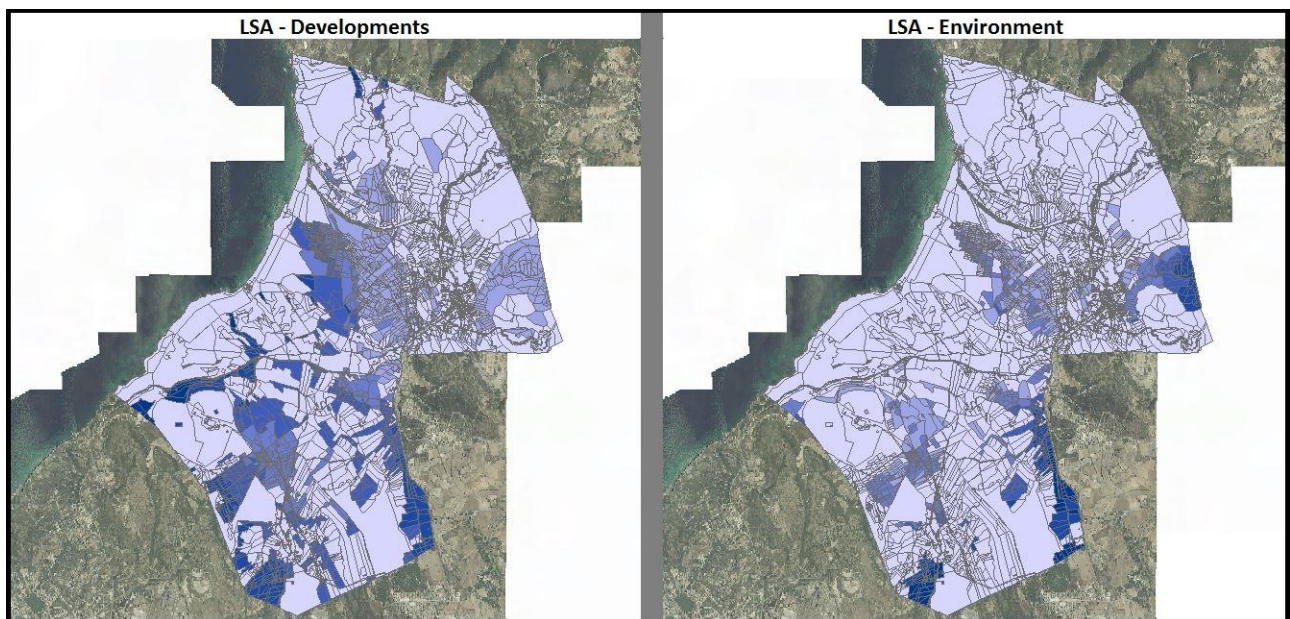


Figure 34 - the LSA scenarios comparison

**FOURTH PHASE** The fourth workshop phase takes into account the data and information defined in the previous step. Indeed, the scenarios produced through the LSA are able to inform the design of the alternatives in compliance with the SEA procedure. This phase is characterised by the application of the PSS for supporting the change model and the impact model of the GDF (Matta and Serra, 2016). The aim of this phase is to interact with the WUs to create a discussion based on the impacts of the proposed alternatives. The impacts have been represented through a range of indicators related to different strategic fields. Every

change related to a specific attribute of a spatial layer is real-time represented through indicators. The range of indicators used to represent the impact model concern three main dimension (table D):

1. Measures;
2. Environment;
3. Economy.

Measures	Environment	Economy
Inhabitants (n°)	Loss of natural landscape (sqm)	Agricultural Land Value (€)
Volume (cm)	Water consumption (cm/Y)	New homogeneous area value (€)
Area (sqm)	Pollutants (mg/cm)	Planning fees (€)

**Table D - The three dimension**

The measures (1) are represented by indicators, such as the number of inhabitants or the volume feasible for a specific area. The Environment (2) is related to other data, such as the loss of natural landscape (square meters [sqm], or %) and the production of pollutants. The last field, the economy (3), is oriented to communicate the economic suitability of the alternatives. For instance, the design of a new F zone may be influenced by the realisation of a new roads for connecting to the main roads network. Indeed, the most important indicators used to discuss about the suitability of a specific solution were related to the economic sector. The indicators used to manage the information were based on the sDPSIR causal chain. A set of 30 indicators have been selected:

1. Area	[ha]
2. Volume for each homogeneous area	[cm]
3. Maximum volume feasible	[cm]
4. Inhabitants Estimation	[n°]
5. Inhabitants New Area	[n°]
6. Standard of Water Consumption	[cm/inh * Y]
7. Standard of Waste Production	[Ton/inh * Y]
8. Standard of Energy Consumption	[kWh/inh * Y]
9. Standard of CO <sub>2</sub> Production	[Ton/inh * Y]
10. CO <sub>2</sub> Production	[Ton/ Y]
11. Energy Consumption	[kWh/ Y]
12. Waste Production	[Ton/ Y]



13. Water Consumption	[cm/ Y]
14. Loss of Natural Landscape	[sqkm]
15. Loss of Natural Landscape	[%]
16. Loss of land capability	[%]
17. Distance from the main road network	[km]
18. Cost of the New Road	[€]
19. Standards cost for the primary urbanization services	[€/cm]
20. Primary Urbanization Services	[€]
21. Value of the Agricultural Land	[€]
22. Value of the Homogeneous Area	[€]

A second group of indicators has been joined for managing different spatial information with regard to the design of a new road.

23. Standards cost for the road construction (for categories)	[€/lm]
24. Standards cost for the roads services (for categories)	[€/lm]
25. Preliminary cost of the new road (estimation)	[€]
26. Cost for road categories	[€]
27. Cost for road services	[€]
28. Cost for the new road	[€]
29. Loss of natural value	[sqkm]
30. Loss of natural value	[%]

The figure 35 shows as the DPSIR may provide a reliable organisation of the information. This scheme represents just the main group of indicators. Indeed, other information, indicators and parameters that constitute the basis on which more complex data have been created, are not taken into account in this graph. The PSS makes the users able to show and calculate a wide range of information standing behind the main group of indicators. Several of these, regard distances, unit numbers, areas, percentages, sum and every types of measurements that the user needs to perform the spatial analyses. These indicators have been taken into account for the Interactive Impact Assessment (IIA). When a condition in the map changes, an indicator can show this variation for a specific spatial attribute. Indeed, the IIA encloses the results of the variations performed in the change model through the sketch planning tool.

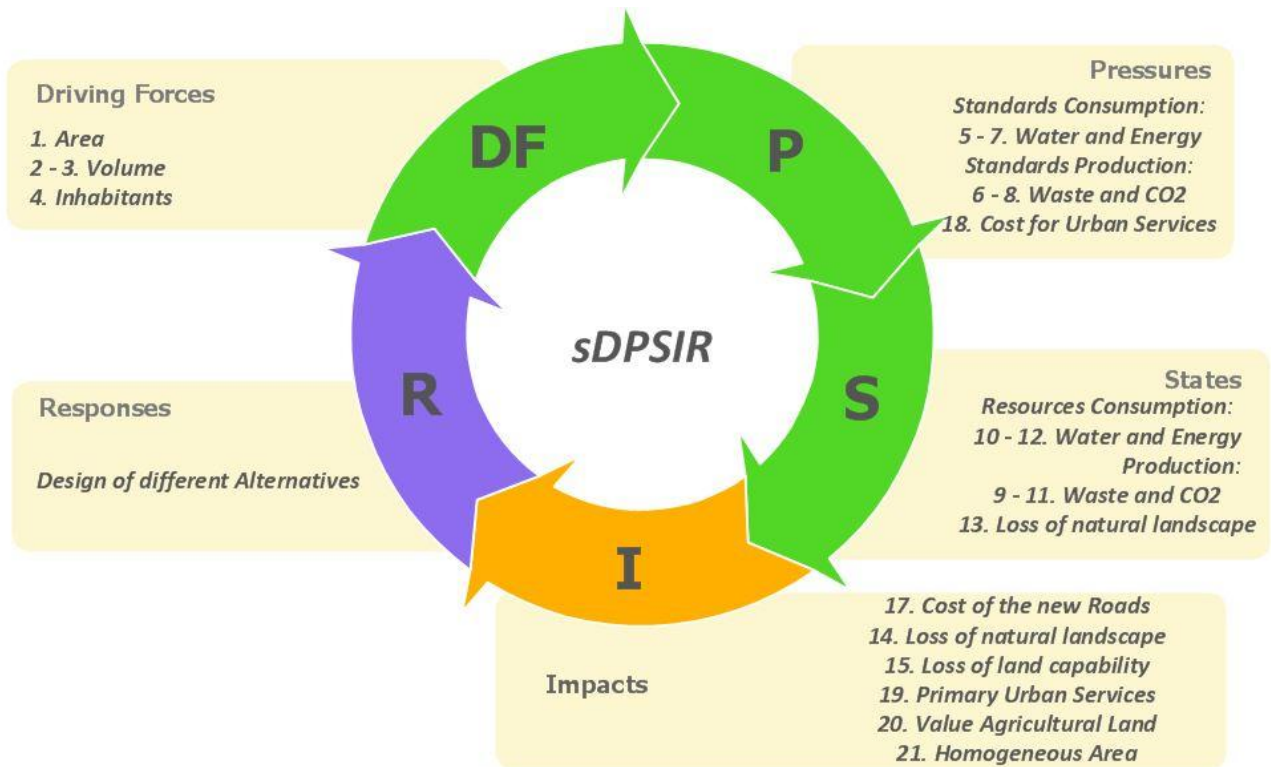


Figure 35 - The indicators related to the DPSIR framework

The two proposed scenarios concern the results of the LSA. The figures 36, 37 and 38 represent the two scenarios used to demonstrate how the PSS has been set for the fourth phase. The PSS architecture made the Ws able to illustrate how the LSA may inform the plan and how the alternatives may be designed and evaluated in real time.

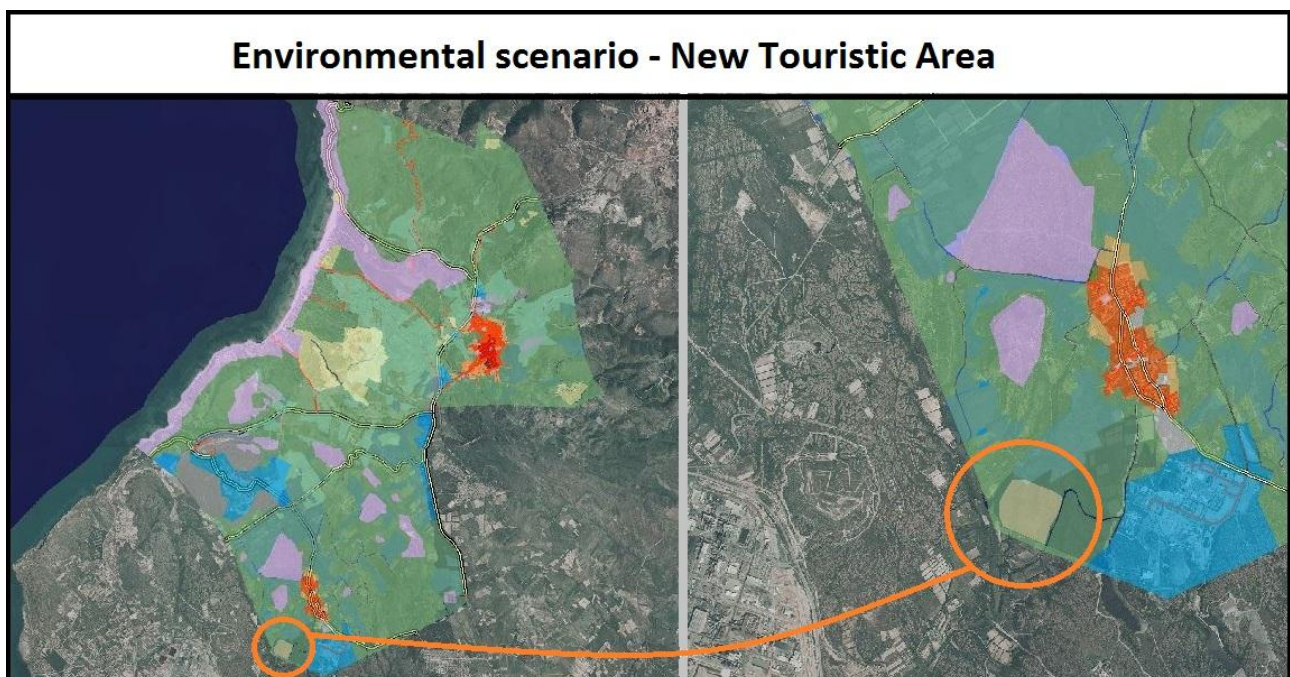


Figure 36 - The Environmental scenario



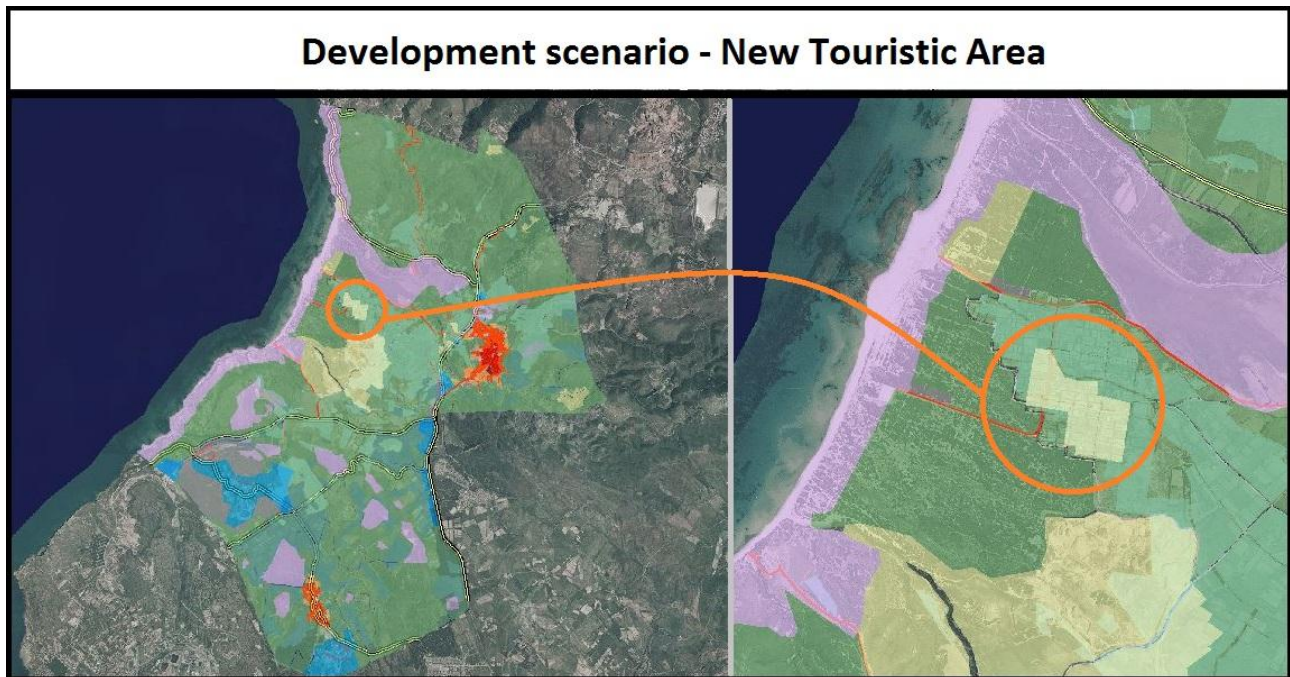


Figure 37 - The development scenario

The alternatives produced by the UrbanGIS Lab for the WUs, have been analysed through the set of indicators illustrated above. The figures 38 and 39 represent the impacts of the different solutions adopted to deal with the design of a new touristic area. These impacts may be compared with the current territorial situation (alternative zero) to consider the variation that occur for the strategic fields. Many of these comparisons, among both the alternatives and the current situation, are made possible through thresholds, alerts and constraints, represented in the same indicators, such as the figure 13. This approach to the real-time impact evaluation produced in the scenarios comparison, generated a discussion among WUs and WSs on how the design influences the development context, such as the environment and the economic sectors. The WUs proposed a range of design variations for each alternative in order to achieve the goal. Indeed, the WS put into effect the variations on the fly, with the aim of providing the real-time impacts of the proposed actions. The changes and the modifications to the alternatives generated and performed during the discussion, demonstrated as the communication process among stakeholders may be improved. A third scenario was created for sketching a new alternative based on the discussion among WUs with regard to other aspects not covered by the previous alternatives. Indeed, further alternatives were proposed by WUs based on their knowledge about the municipal territory in order to assess the real time impacts of their purposes.

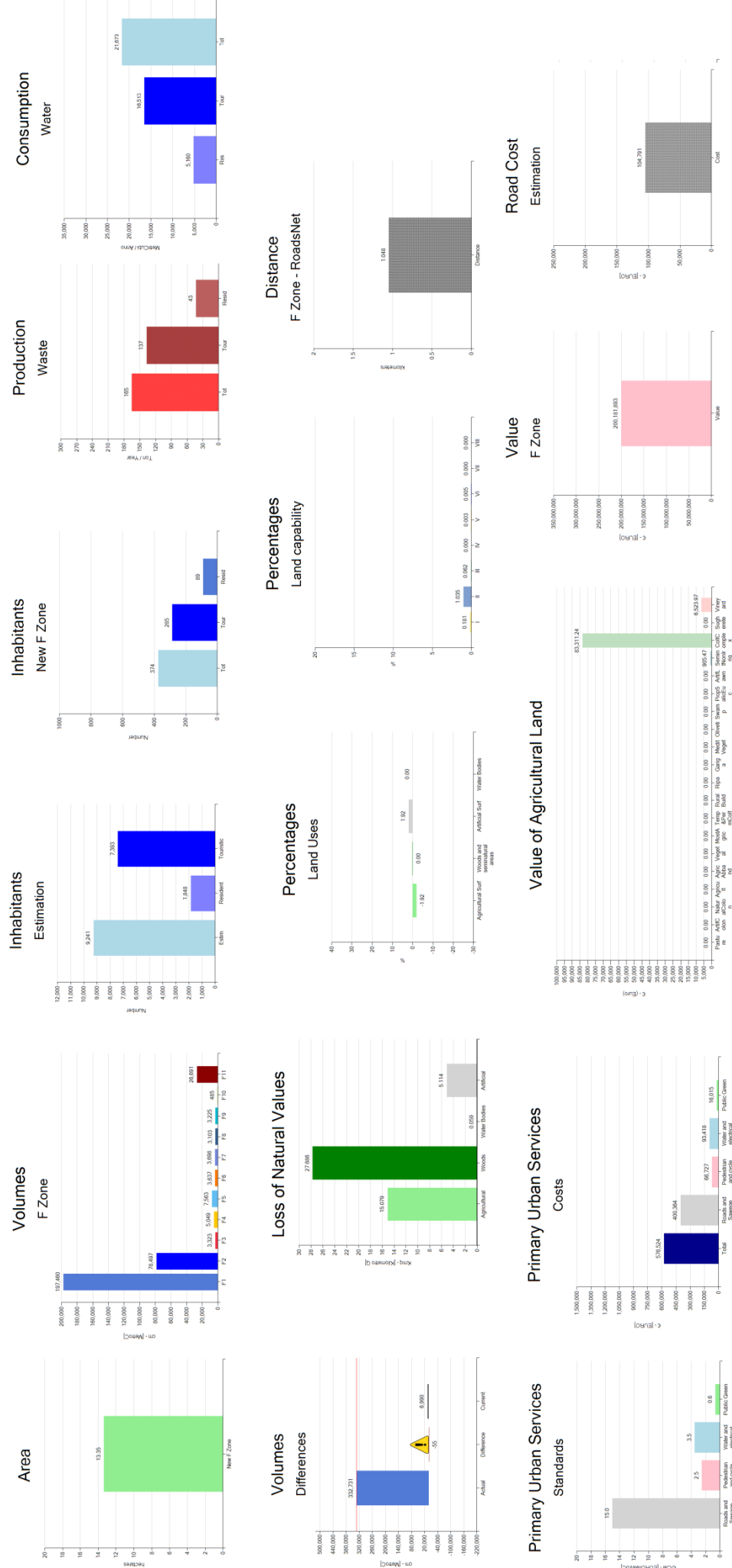
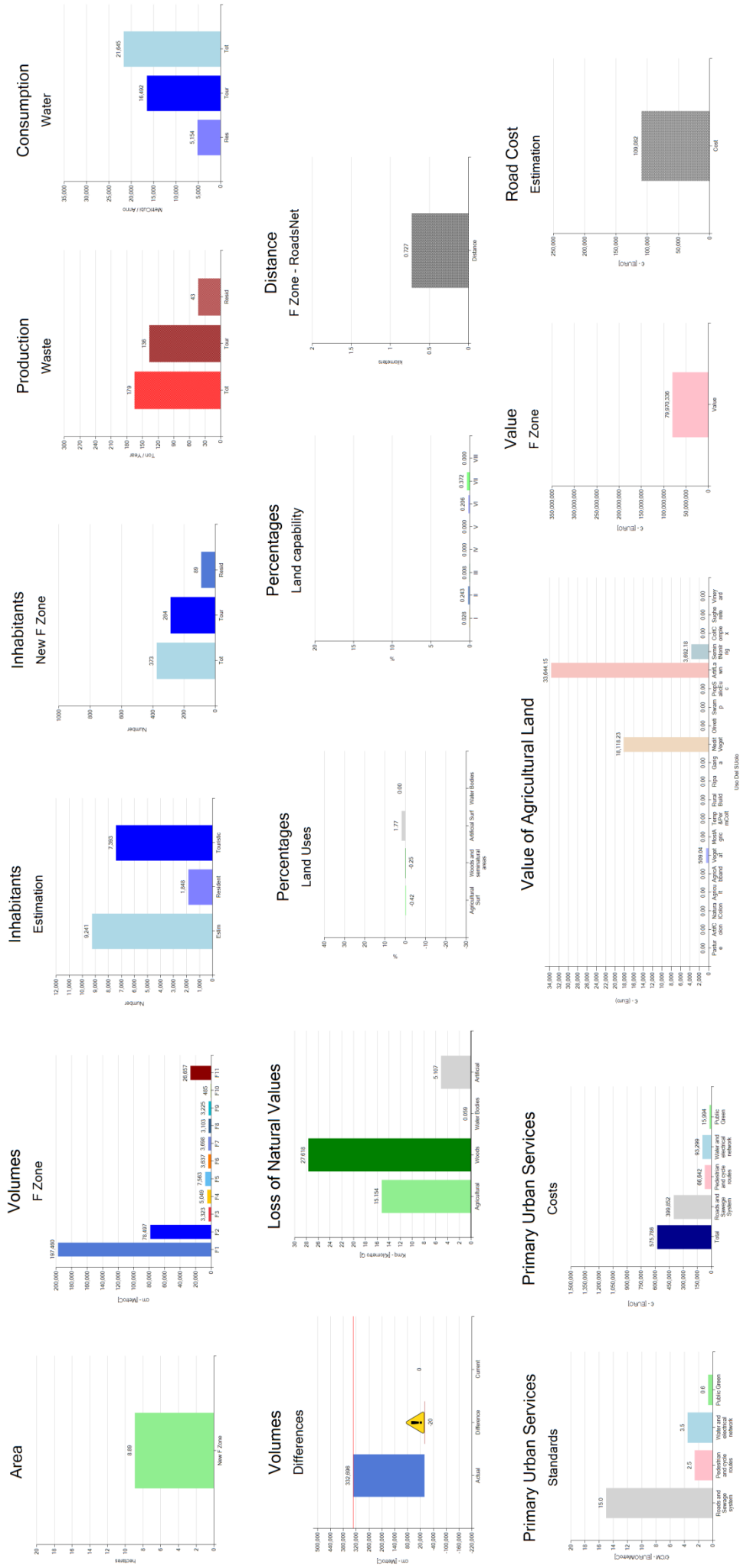
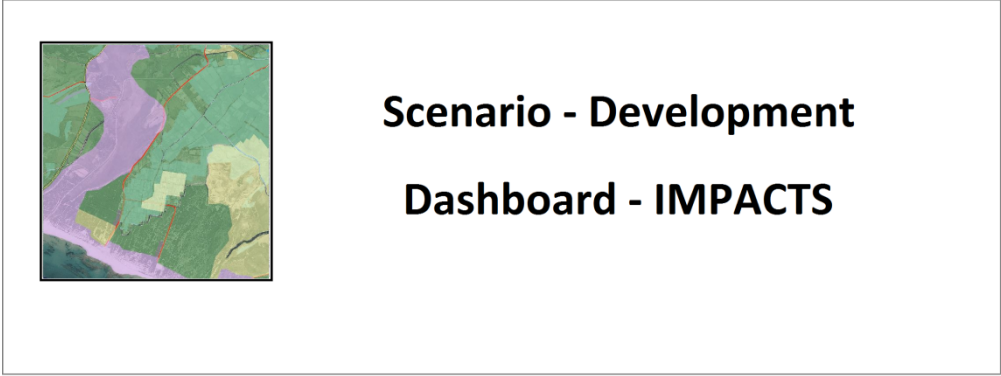
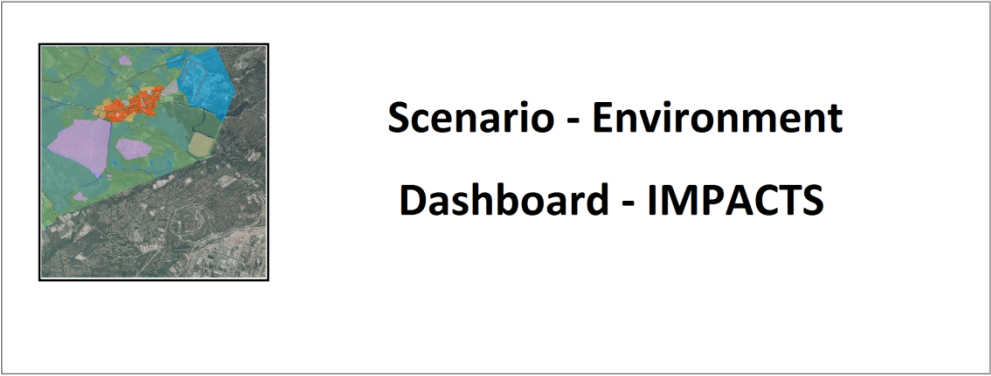


Figure 38 - Impact - scenario environment

Figura 39 - Impact - scenario development

#### 4.5.3. *The assessment of the local planners*

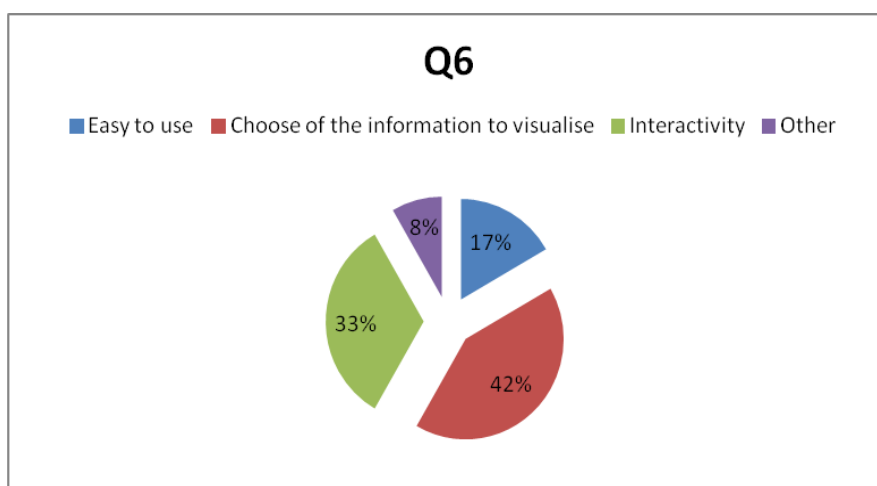
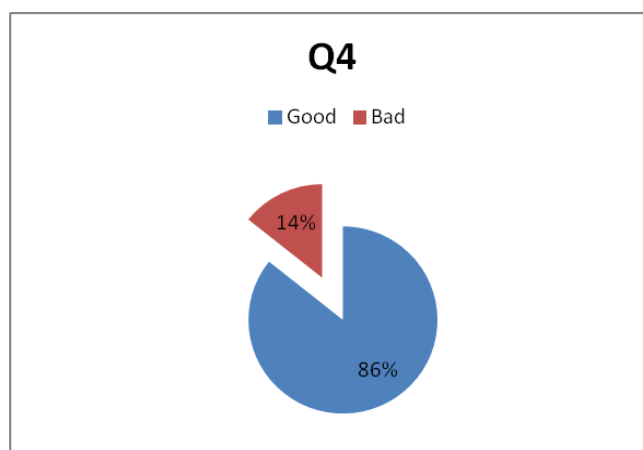
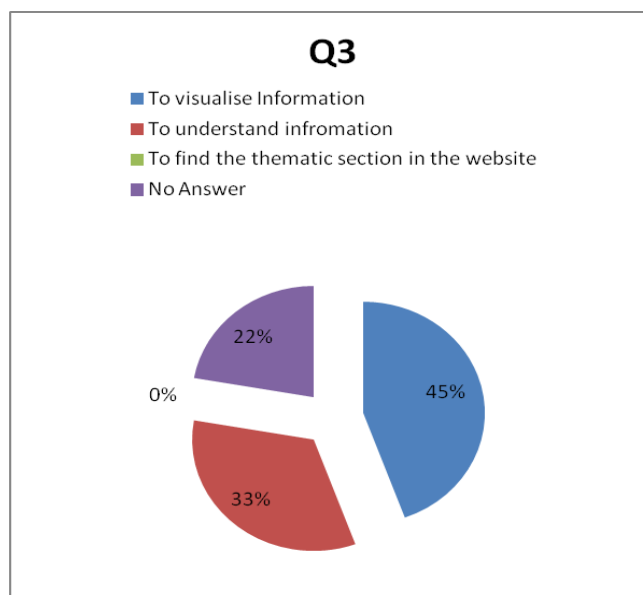
As mentioned in the previous paragraph, at the end of each workshop phase, an anonymous questionnaire has been proposed to the WUs with the aim of collecting their opinions and considerations. This approach, according to the experiencing cycle of Kolbe and Fry (1975), intends to fill the gap between the research and the practices. Indeed, the practitioners and technicians were called for giving value of their experience through the PSS architecture. This interaction may be able to put into effect the relationships between researchers and technicians for bridging the current gap and improve the implementation of innovations in planning practices. The results of the questionnaires of each phase are presented.

##### **Questionnaire 1**

The first questionnaire is oriented to analyse how the WUs assess the support provided by the PSS for creating an informed process across the first three GDF models. Indeed, in this phase the territory was represented (Representation Model) and analysed (Process Model) through innovative web applications with the aim of creating an informed process to sustain the design of future development strategies (Evaluation Model). Serra pointed out as, the first questionnaire concerns the way of different methods to represent and share the information about the municipal territory. The story map and the techniques proposed by the UrbanGIS Lab in the first phase of the Workshop has been considered as reliable methods for supporting the representation and analysis of the territorial spatial data. Indeed, the analysis of the WUs answers, composed by a choice among a range of alternatives, such as yes/no or a list, and open discussion, confirm the current complexity to find (55%) and to visualize (45%) the information in the Municipal website (**Q3**). Furthermore, the integration of the rules and normative into the web application may further improve the communication between public authorities and citizens. The innovative web app proposed to deal with the current issues for sharing and visualizing the spatial information, have been appreciated by the WUs (86%) (**Q4**). The web app may help to simplify the accessibility to information, encompassing a high level of interactivity. One of the questions is to identify the most important characteristics of the web app compared with the current services made available by the website. The answers illustrate how the opportunity of choosing the information for representing the territory (42%) and the interactivity (33%) are considered important innovations (**Q6**). Furthermore, the WUs define the web app as a reliable tool for illustrating and sharing spatial information for the public, such as citizens and local population (100%).

In conclusion, the WUs consider the web app an important innovations for dealing with different current shortcoming in planning, such as the accessibility to the information and the analyses of spatial data. The integration of this technology into the local website may enhance the process of communication between the

public authorities and citizens and support the participation process of the public to the decision-making processes.



## Questionnaire 2

The second questionnaire is oriented to consider the WUs opinions regard the impact model. The WUs were call for evaluating the influence of the impact model in practices, though the PSS architecture. In turn, the evaluation regard the LSA (Evaluation Model), and the different scenarios proposed to design (Change Model) and evaluate (Impact Model) the different alternatives.

The results of the questionnaire illustrate how the WUs are satisfied about of how the impact model may support practices (100%), defining this model interactive (50%), practical and intuitive (20%) and complex (10%) (**Q2**). Indeed, the PSS architecture is structured for supporting the different planning tasks of the planners, through different tools. These tools demonstrate how to create a reliable connection among the plan-making phases through an information flow. This innovation helps planners to minimise the time for discussing the integration of different strategic objectives in the geographic phases, supporting the process of design of reasonable alternatives.

After that, the WUs made their opinions regard the indicators. On the one hand, they are satisfied of the indicators selection (86%). One the other hand, they suggested the integration of other indicators into the model, oriented to satisfy specific economic requirements, such as the economic Impacts of design of services, building and urban development. Indeed, the sketch tool and the IIA guide the WUs to discuss of their opinions regard the planning options, evaluating in real—time the influence of the design activities.

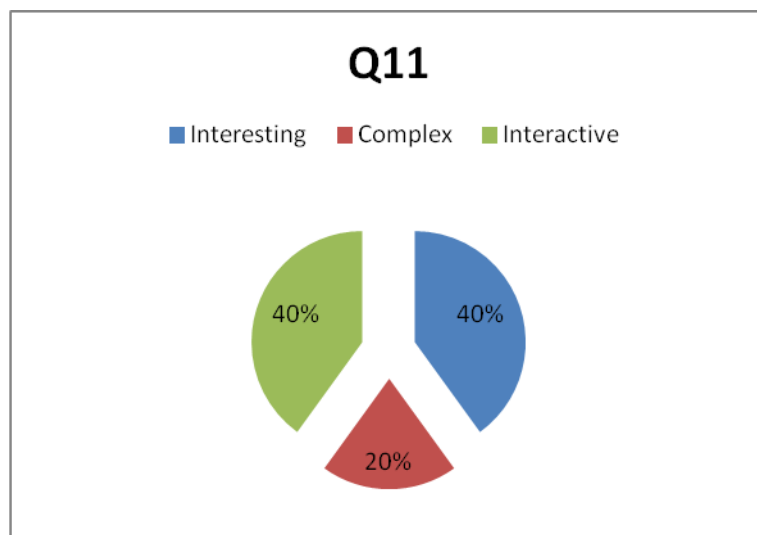
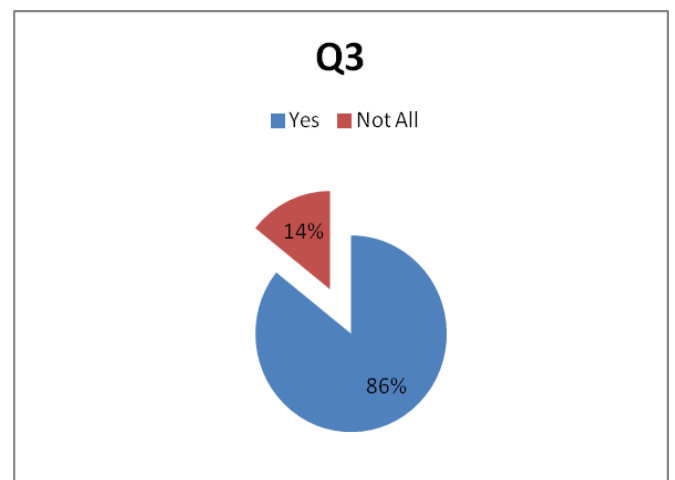
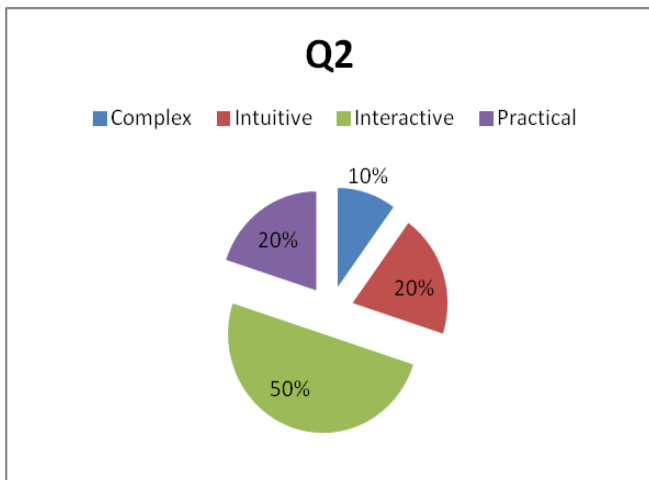
Furthermore, the WUs confirm that this approach, based on innovative technologies and methodologies, may help to fulfil their planning task (86%) (**Q3**)and deal with the planning issues (100%). Indeed, this approach may innovate the current planning practices (100%) supporting the integration of the PSS into planning. Despite the last two answers, oriented to define this approach “reliable” and “innovative”, the intrinsic complexity of the models may discourage planners to use this technology for fulfilling their planning tasks. Indeed, the WUs discuss about both the procedure for creating the models and the complexity of this technology. Indeed, the PSS architecture requires an adequate specialised knowledge for setting the relationships among data to perform analyses, illustrate the result and represent the outputs in the maps.

The last questions take into account the opinions of the WUs regard their experience during the workshop. Despite the workshop is “interesting” and “interactive” (40%) (**Q11**), the complexity in managing data and creating models may limit the diffusion of these innovations in practices.

In addition, the Workshop experience suggests some avenues to be explored. The GDF-based PSS architecture may support planners both to fulfil their planning tasks in LLUP-SEA procedure and fill the gap between the requirements of environmental oriented procedure, such as SEA, and current planning practices. Despite this

architecture offers an unprecedented opportunity to innovate spatial planning, the integration of PSS into practices seems to be far from over. Indeed, the ability of planners in managing this technology may influence the diffusion of PSS in planning.

For this reason, the flexibility become an important element for an adequate integration of PSS into practices. If, on the one hand, user friendly interfaces and wizards may reduce the experience required to manage this technology, on the other hand, these components may reduce the flexibility of the PSS, influencing the capacity to be adherent to the planning process.





## 4.6. The assessment of the planning students

The third case study is based on a workshop organised by the UrbanGIS Lab during the academic course of “Urban Planning” of the University of Cagliari. This workshop gives students critical information on the numerous requirements for dealing with planning tasks. The workshop has been organised to investigate the performance of a web-based application which structure refers to the GeoDesign framework. This web-technology, namely Geoplanner, has been compared to the common GIS software (ArcGIS) with the aim of evaluating different technological approaches to the proposed planning issues. The main goal of the workshop is to investigate how academic students evaluate the instruments for dealing with a specific planning task. The academic students can be considered both not expert users, due to their poor experience for using advanced geo-tools, and informed users, that are currently studying planning theory and applying planning techniques. This approach to the education context, may foster the creation of academic curricula for the future planning practitioners, dealing with the problems of the lack of experience for managing advanced technologies in planning practices. The workshop investigates three main important questions:

1. *How do the students evaluate the tools for supporting the plan-making phases?*
2. *How do the students assess the integration of the web-based tools for supporting the participation during the decision-making process and for communicating the results of the analysis?*
3. *How do the students consider the application of these innovative tools (e.g. Geoplanner) for academic courses on planning?*
4. *How do the students perceive the differences between the common GIS software (ArcGIS) and collaborative web-based software?*

The academic workshop is based on the same structure proposed for the Gonnese workshop. Indeed, it has been defined according to the ‘experiential learning’ by Kolb and Fry (1975) (Figure 25). The university students were able to use both GeoPlanner and ArcGIS to perform analysis, create maps and sketch in a screen for dealing with the design of a new residential area in the municipal territory of Teulada. The case study has been composed by two sessions during the academic course of “Urban Planning” at the University of Cagliari. In the next paragraphs are illustrated the results of the workshop.

#### 4.6.1. *The workshop (II)*

The case study takes into account the perceptions of the students with regard to the architectures used to deal with the planning issues proposed by the UrbanGIS Lab. The case study is oriented to analyse the territory, design the alternatives, evaluate the impacts and compare the scenarios for supporting the plan-making phases. Furthermore, the workshop allows comparing the technologies. The first one oriented to support the design and discussion, such as Geoplanner, defined as a "collaborative instruments", and ArcGIS, oriented to "*collect and manage data, create professional maps, perform traditional and advanced spatial analysis*" ([11]). For Geoplanner, a group of users has been qualified to access to the database created ad hoc by the UrbanGIS Lab about the territory of Teulada. Every user was able to access a specific scenario through a dedicated web access-point. The spatial data integrated into Geoplanner, made the user able to analyse, represent and modify the scenario. Each scenario represents a specific design performed by each user, enclosing the dashboard with the pie indicators and the key performance indicators (figure 40) that represent the impact of the alternative. These activities were performed during the workshop, as illustrated in the next paragraphs.

##### **1. Preliminary phase**

First of all, a group of data has been selected with the aim of representing the main characteristic of the municipality for both generating a sufficient knowledge of the territory and supporting the design activities. Indeed, the proposed planning issue is related to the location of a new residential area, according to the hypothesis of the population growth. The new residential area is designed in compliance with a range of urban standards (e. g. territorial index cm/sqm) and environmental constraints.

The first software used in the workshop was ArcGIS. After that, Geoplanner has been applied for dealing with the same planning issue.

The students can compare the two approaches based on the technologies proposed by the UrbanGIS Lab. In turn, at the end of the workshop, the students provided their opinions regard the activities, through a questionnaire. The questionnaire takes into account different phases of the workshop, considering how these technologies may support planners for dealing with their planning tasks. The questions were framed and aligned for the purpose of the workshop in order to capture all issues of concern.

For each model of the GDF, an activity has been performed with the aim of making the students able to compare these different technological approaches. These activities refer to the representation of information, the design of the alternatives, the evaluation of impacts and the capability to support the participation process. The students may work alone or in group, with the aim of testing different solution to the problems. On the one hand, they can evaluate how the technicians may be supported by these innovative architectures



for fulfilling their planning tasks. On the other hand, the students investigate how a collaborative instrument (Geoplanner) may support the process of participation to the plan-making phases. Indeed, Geoplanner can be defined as a "collaborative tool", able to "support a complete planning workflow from project creation to report generation" and "share items including web maps, feature layers, and data exports" ([10]). Therefore, the UrbanGIS Lab created a range of specific workshop activities, demonstrating to the students how these innovative architectures can be used for supporting:

- *The plan-making phases*
- *the collaboration among stakeholders*
- *the design of alternatives*
- *the decision-making procedure*
- *the impact assessment*
- *the reporting phase.*

The next paragraphs illustrate the results of the questionnaire for each question.

## **2. *An investigation of the students experience***

### **2.1. *How do the students evaluate the tools for supporting the plan-making phases?***

The comparison between ArcGIS and Geoplanner is based on a range of planning activities . First of all, the students were able to acquire the information to evaluate the technological differences between these architectures. Indeed, the first phase and the second phase of the workshop, related to the application of ArcGIS and Geoplanner respectively, are based on a range of specific exercises for evaluating the influence of a range nested geo-tools in practices.

The first two questions, related to ArcGIS and Geoplanner, investigate how the spatial data are represented, (maps), can be modified (editing and draw), managed and analysed (i.e. buffer and overlay) and how the results and the analyses may be represented and "communicated" to the users, such as dashboard, indicators and tables. The same data used to represent the territory, have been managed and analysed through the architectures for evaluating the differences.

After that, a range of analyses have been performed for improving the comprehension about the territory, dealing with the question: How does it work?

Despite ArcGIS is currently considered more suitable than Geoplanner for dealing with spatial analyses, the way on which the latter is able to represent the results of the analysis is considered one of the most important

features for supporting the plan-making phases. Indeed, Geoplanner provides the real-time results of the analyses through spatial indicators and dynamic dashboards (Fig. 40).



Figure 40 – The user interface of Geoplanner

Furthermore, the students consider Geoplanner able to compare the scenarios in a more efficiency way than ArcGIS. The capacity of comparing the alternatives on the fly, within the support of dynamic dashboards and spatial indicators makes Geoplanner an innovative approach to the scenario analysis and to the participation processes. As illustrated in the figures 41 and 42, the comparison between the scenarios operates through a single interface where is possible to represent different user alternatives and the alternative "0" (current state). As illustrated previously, each user is able to work through his own dedicated access point editing the geographic space and create a proper scenario. Each scenario is available for other users to compare the results and evaluate the impact of the alternatives with the aim of supporting the most suitable solution in a transparent and participative process, compliance with the SEA purposes.

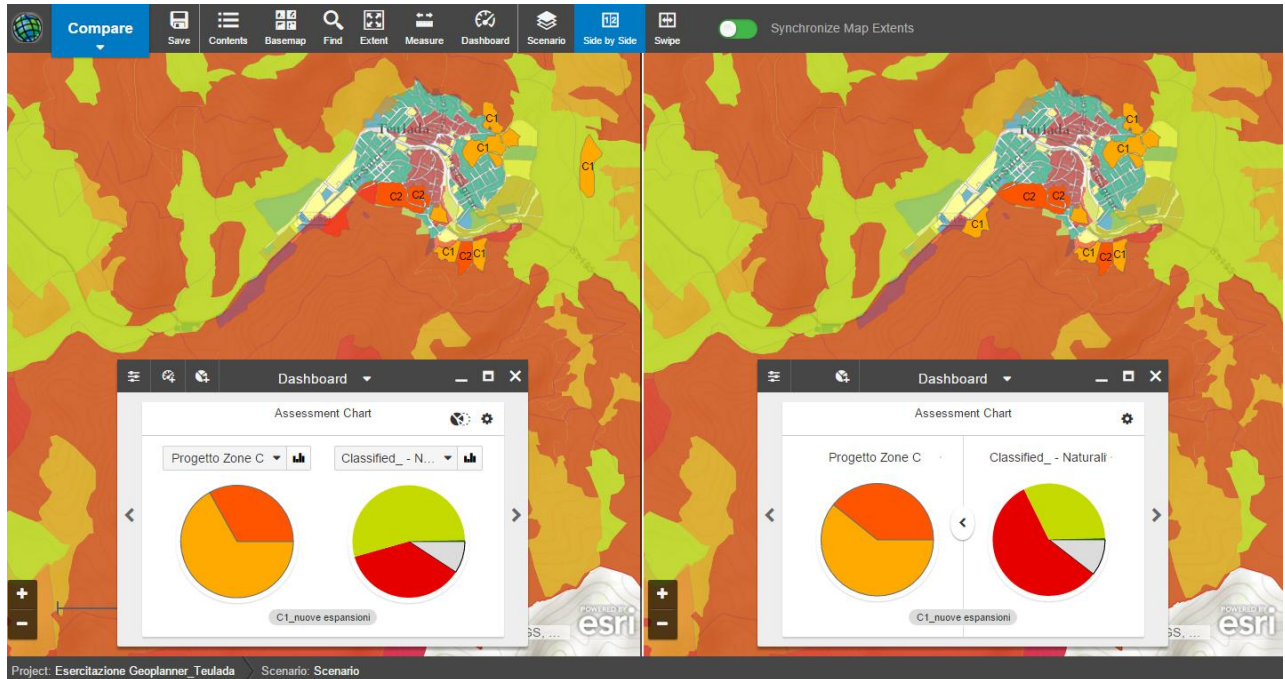


Figure 41 – The scenario comparison – Maps and dashboards

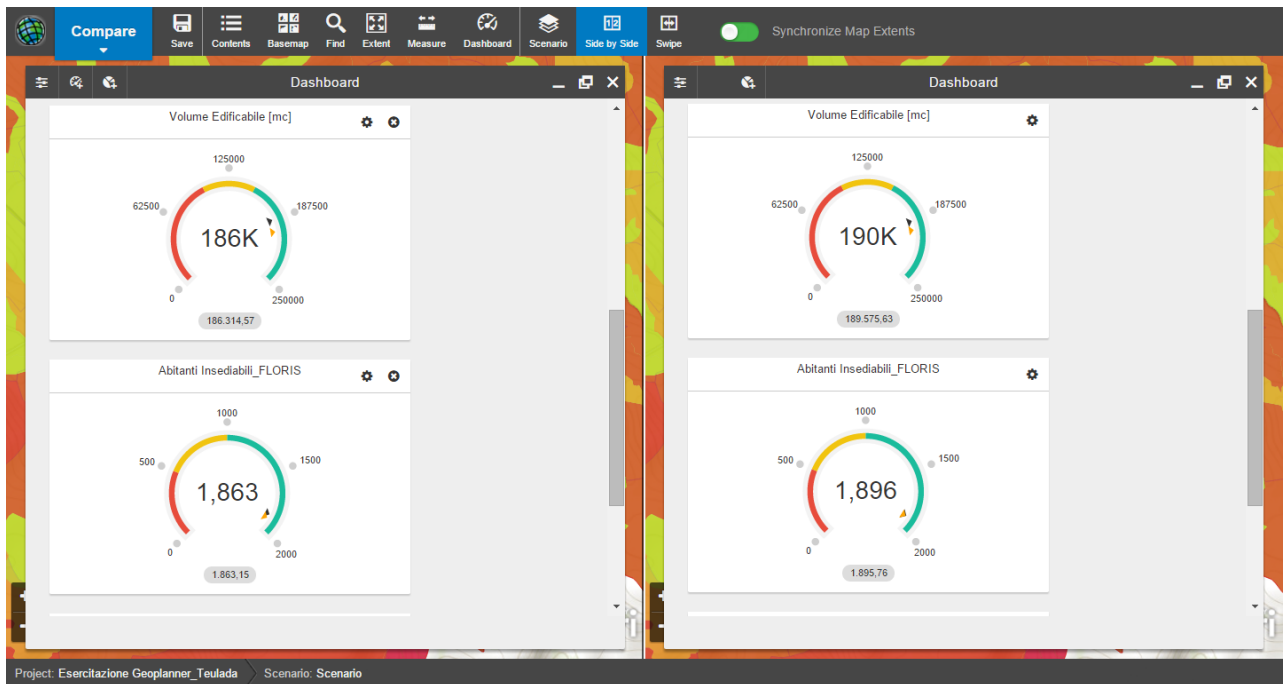


Figure 42 – The scenario comparison – Dashboards

The second question concerns:

***2.2. How do the students assess the integration of the web-based tools for supporting the participation during the decision-making process and for communicating the results of the analysis?***

The second question aims to investigate the influence of innovative technologies for supporting the European Policies purposes. As illustrated in the chapter dedicated to SEA Directive (Chapter 2), the planning procedures have been oriented toward transparent and participative impact assessment-based processes. In turn, Geoplanner is oriented to support a collaborative planning procedure and the participation processes in compliance with the SEA goals. Indeed, the students, during the sketching phase (editing), produced their own alternative, evaluating on the fly the impact on the environment. This phase has been supported by a discussion with the UrbanGIS Lab staff for evaluating these variation and supporting a suitable real-time editing phase. After that, the scenarios comparison contributes to feed the participation process. Indeed, the comparison among the alternatives and the current territorial situation, generates a discussion about the solutions adopted by the users. Each design choice has been discussed by the user with the aim of producing a reasonable alternative. According to the results of the questionnaire, the discussions supported by dynamic dashboard and spatial indicators, may guide the students to consider Geoplanner as an efficient tool for supporting a concrete integration of the participation process into planning practices. Despite ArcGIS has been considered as the tool having the more important set of nested tools for dealing with the complex analysis related to the planning procedures, the user friendly architecture of Geoplanner has been defined as an opportunity for innovating planning practices, dealing with several issues in planning.

***2.3. How do the students consider the application of these innovative tools (e.g. Geoplanner) for academic courses on planning?***

Likewise, the students perceive the integration of innovations, such as Geoplanner, into academic courses as an important step to generate an adequate comprehension of these architectures. Indeed, more than 70% of the students are interested to analyse these innovations in a process of academic learning toward the planning practices. The students appreciate the way on which Geoplanner is able to perform and communicate the analysis results, the user friendly interface and the capability of putting into effect the planning theory. On the other hand, the comparison between professional GIS software (e.g. ArcGIS) and collaborative web-based application in an academic environment may support the growing attention for filling the gap between planning practices and research.

This approach to planning in an educational context based on workshop and practical activities, may foster the students awareness of learning how the development of innovative technologies may support their future

activities in planning. Indeed, one of the shortcoming in the process of integration of PSS into planning practices concern the poor experience of planners to manage technologies, data and methods for dealing with their planning tasks. This workshop may offer an opportunity to consider how undergraduate students may take advantage of learning new approaches to spatial planning, based on technologies and methods, and for training students in dealing with future planning issues and bringing innovation in practices.

***2.4. How do the students perceive the differences between the common GIS software (ArcGIS) and collaborative web-based software?***

The last question is oriented to considers the main differences perceived by the academic students during the application of ArcGIS and Geoplanner for dealing with the planning issues. A focus on the specific differences between the tools is available in the next paragraph where the questions are analysed through the questionnaire. These questions aim to provide a general point of view with regard of the differences between these technologies. The structure illustrated in the figure 43 aims to classify the main feature used to dealing with the issue proposed by the UrbanGIS Lab.

Indeed, ArcGIS is considered more suitable than Geoplanner both to perform the representation of the territory (maps and data) and to manage and analyse big amount of spatial data for supporting the sketching phase (Editing). For this reason, although the academic students consider ArcGIS more complex to set and to use than Geoplanner, ArcGIS thanks to its architecture may be more suitable than Geoplanner to deal with the intrinsic complexity of the planning procedures. Despite the ability of ArcGIS to provide a wide range of solutions for supporting spatial analyses, Geoplanner through its architecture may guide planners to deal with different issues in LLUP-SEA procedure, such as the evaluation of impacts and the participation process. Indeed, Geoplanner has been considered by academic students as a suitable tool for sketching design solutions, communicate in real time the impact of the alternatives, supporting the participation processes.

Indeed, the user friendly interface allows sketching design proposals in the map and evaluate in real-time the impact of these alternatives on the environment. This interactive and dynamic process of design and evaluation, promotes the discussion among stakeholders with regard of the influence of such proposals on the strategic development of the territory in compliance with the protection of the environment.



Figure 43 – The comparison between ArcGIS and GeoPlanner

Furthermore, Geoplanner is able to communicate to different group of people, such as citizens and politicians, through dynamic dashboard and spatial indicators, the results of complex analyses shortly and in a simple way, fostering the dynamicity of the model. This capacity may support and improve the participation processes of stakeholders to the planning procedures, taking into account the knowledge of different group of people (as illustrated in the Geodesign chapter) representing the Geodesign team ("People of the place, design professionals, natural and social scientist and technologists", Steinitz, 2012).

Despite this approach promises to support planners for fulfilling their tasks in planning procedures, further efforts should be made for making the architecture more flexible. Indeed, once the architecture has been set, it is impossible to enrich the database used to calculate, design and evaluate the alternatives. In the light of these premises, despite Geoplanner seems to bring dynamicity in practices, the full integration into planning procedures is still limited. Nevertheless, Geoplanner may contribute to guide the development of these architectures toward more suitable technological structures for supporting the different activities required during the plan-making phases.

The next paragraph provides a deeper view on the questionnaire, giving value of the academic students experience.

#### 4.6.2. Findings of the questionnaire

The questionnaire puts in evidence how the students evaluate the main characteristic of both the PSS architecture and the GIS software. Indeed, two specific questions led the students to investigate their experiences using these tools for dealing with the same planning issue. The first two questions aim to provide information about the perception of the students with regard of the single tools and which component has been evaluated as the most significant for representing the potentiality of these architectures. The management and analysis of data, such as the representation, buffer and overlay, have been considered as the most important features of ArcGIS (53%) (**Q1**). In turn, the representation of findings and the communication of the information (i.e. final maps and dashboards) have been highlighted as the most significant Geoplanner functions (47%) (**Q2**). According to these answers, ArcGIS can be considered most suitable in the preliminary design phases, which the spatial data have to be represented, managed and analysed. In turn, the students put in evidence how Geoplanner fits better to the second phase of the plan-making process, intertwined with the design of alternatives and the impact assessment. According to the Geodesign framework, it can be argued that ArcGIS may be suitable to deal with the first part of the framework, enclosing the first four models, from the representation of the spatial information to the design of alternatives. On the other hand, Geoplanner might be able to deal with the second part of the framework, considering a most suitable approach toward the design of the alternatives, the impact evaluation and the decision-making phase.

The second part of the questionnaire takes into account of the students experience using ArcGIS and Geoplanner in order to evaluate the comparison between these tools for dealing with the planning tasks.

The students answered to questions related to the representation of the information, the management and analysis of data and the design of alternatives, considering ArcGIS more suitable than Geoplanner.

Focus the attention on the design of the alternatives, despite ArcGIS helps planners to operate the design better than Geoplanner (respectively 53% to 47%) (**Q5**), the students opinions show how Geoplanner may provide a different approach to this phase.

Indeed, the user-friendly interface of Geoplanner may help to guide planners for designing reasonable alternatives. This web architecture guide the design of the alternatives in real time, supported by a set of dynamic indicators that illustrate how the information change due to the design activities. Although this architecture provide a new approach to the design phase, the capacity to calculate and illustrate the impact of the alternatives is still limited.

According to these results, Geoplanner may innovate the application of the second part of the GDF, (change, impact and decision models), into practices.

Geoplanner is able to represent how the information dynamically change during the design process, improving both the flexibility of the architecture and the phase of discussion with regard of the design of the alternatives.



Indeed, the students were able to change in real time their own scenarios and, thanks to the capacity of Geoplanner to illustrate the dynamic variation, they discussed about their purposes with the workshop staffs. The real-time interaction between user (students) and expert (UrbanGIS staff) suggests how the participation process may be improved. Indeed, the students consider Geoplanner as a suitable instrument for supporting the participation processes among stakeholders, citizens, professionals, technicians and other group of people, in compliance with the definition of SEA, such as a participative and transparent impact assessment based process.

The, question number 8 is related to the adaptment of the MMP to the RLP. More than 75% of the students defined Geoplanner as a reliable tool for supporting this planning procedure. On the other hand, also ArcGIS has been evaluated as a reliable tool for dealing with the adaptment of the MMP to the RLP (93%). The differences between these evaluations concern how the students perceived these tools for supporting the activities of this process: despite ArcGIS is able to be adapted to the whole process for dealing with each activity, Geoplanner thanks to the user-friendly interface, dynamic indicators and calculate models, may guide planners for dealing with specific tasks of the planning procedure.

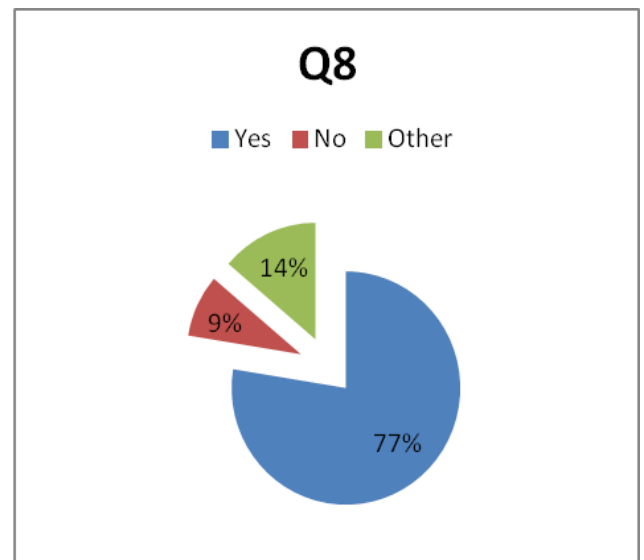
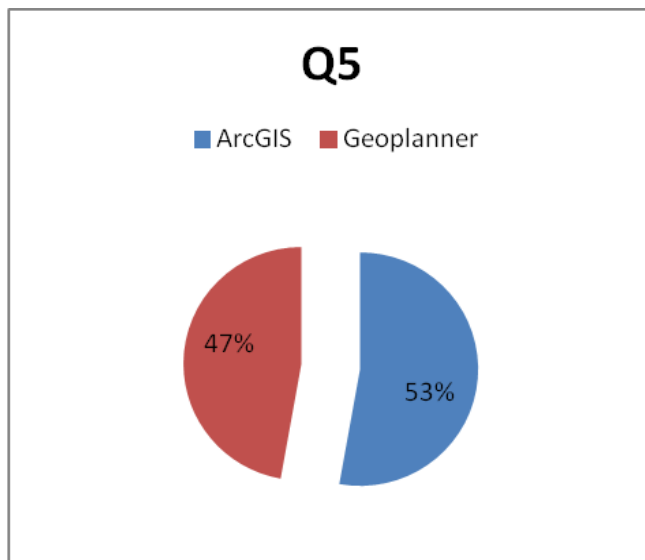
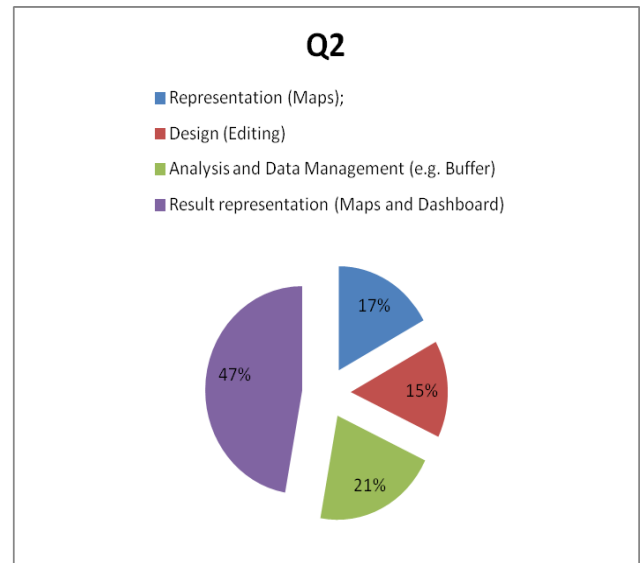
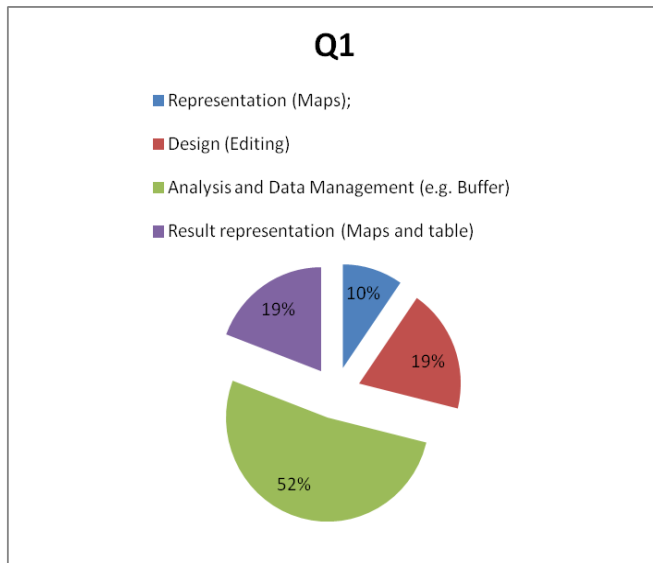
The last part of the questionnaire was oriented to provide information to the UrbanGIS Lab about the level of appreciation of the web-based PSS. For instance, the question 10 considers the users opinion with regard to integrate this innovative technology into the web-page of the Region and/or municipalities. The 98% of the answers is oriented to change the communication of information and the management of data of the institutional web-page, making available in the website a web-based PSS.

Likewise, the findings of the Gonnese workshop questionnaires confirm how the participants appreciate the integration of this technology into the the web-systems of the public administrations. Beside, this process may support the integration of innovations in planning practices supporting the planners for dealing with their tasks. Furthermore, this technology may improve the accessibility to the information for non-expert users, such as citizens. The 95% of the users consider the web-based PSS able to deal with the issues related to the comprehension and research of information for non-expert users, improving the communication of the information between the citizens and professionals, such as public administrations and technicians.

The final considerations consider the process of innovation in planning practices, the comparison among different technologies for supporting the plan-making phases and how the users perceive the introduction of these technologies in planning for sharing, analysing and representing the information.



The results of the questionnaire depict a general agreement about the integration of these technologies in planning practices. The participants consider the PSS as an opportunity for innovating the approach to planning practices. The PSS may support planners for dealing with the planning activities, fostering the participation processes during the plan-making phases. Although the process of evaluation of how this architecture influence planning practices can be considered at the early stages, this practical application may guide further considerations for improving the process of integration of PSS into plan-making phases.



## 5. Discussions and Conclusions

This chapter aims to provide the results of the research and further considerations regarding the integration of the GeoDesign framework and PSS into the planning practice. The SEA-LUP PSS was implemented at the local scale during the adaptation of the MMP to the RLP. The thesis aims at contributing to improving the comprehension regarding the influence that the PSS may have in decision-making processes.

Furthermore, the study takes into account the role of Spatial Data Infrastructure for generating informed processes with regards to the geographic space procedures for supporting planning.

The LLUP-SEA can be considered as a stepwise and sequential series of activities. These activities are carried out by planners in order to fulfil the planning goals in compliance with the RLS regulations. The PSS is composed by a range of dynamic and interactive geo-tools that can support the wide range of activities carried out by planners. In order to test the potentiality of the SEA-LUP PSS for supporting the Local Planning Practices, two workshops were organised.

The first one was run in a real world setting involving the Public Administration of the Municipality of Gonnese and the second one was run in educational settings involving a group of students from the Faculty of Architecture of the University of Cagliari.

The workshop structure of the Gonnese case study encompasses a wide range of actors, such as technicians and researchers with the aim of considering their experience in planning practices to test the PSS tools. The six models of the Geodesign framework were implemented during the steps of the Workshop through the PSS.

The workshop structure of the Students case study is based on a sequence of activities for testing the performance of two different tools, both dealing with the same planning question. Furthermore, the workshop allows comparing these tools through the GDF models for evaluating how they may help planners to execute the planning tasks during the plan-making phases.

For each workshop, a specific design issue has been defined, generating a range of interactive planning activities for testing different geo-tools.

The conclusions illustrate how the actors evaluate this innovative approach applied to the workshops phases, registering their opinion through structured questionnaires.

Hence the results of the workshop offer an opportunity to guide a discussion with regard to the research questions:

- i. How to make value out of the new SDI?*
- ii. How to inform design and impact assessment?*
- iii. How can the PSS support real-time impact evaluation of the design proposals and the participation processes?*
- iv. How does the flexibility and complexity of the PSS influence its integration into practices?*

This was done both in practice and education settings. In the following paragraphs the main answers to the above questions.

### **5.1. How to make value out of the new SDI?**

The first question concerns both the still limited contribution of SDI to planning practices and the limited use of spatial data by planners to feed informed planning processes. Indeed, the workshops demonstrated how the spatial data can be used to support the diffusion of information about the geographic space and to advance current practices.

This first step of the workshop supports the development of the first part of the GeoDesign framework (Representation and Process models).

Indeed, the SEA-LUP PSS enables users to access a suitable representation of the geographic space through maps and indicators. This approach is innovative with respect to the traditional ways of representing the territory and sharing information, usually based on digitalised static (the data of the maps can not be changed) and “silent” maps (only visible information in the maps). The user is given a user-friendly mean to improve the comprehension with regard to the environmental characteristics, interacting with the spatial data represented in the maps. The map can easily be changed in order to illustrate the information required for describing the development context. The user can choose on the fly the information that needs to be visualised, representing single layers or multiple selections at different spatial scales. In addition, the flexibility of the tool helps to organise the information to perform spatial analyses, thanks to the availability of the web-app module which allows managing the spatial data through user-friendly interfaces.

Spatial data is provided by the RSDI and is further enriched through the information produced by the municipality to deal with the requests of the Regional authorities for the adaptation of the MMP to the RLP. The PSS features used to integrate the first models of the Geodesign Framework are considered by the Workshop users as reliable tools for supporting the innovation processes in planning practices.

The Process Model has been implemented through a range of geo-tools for performing spatial analyses. These tools consider both the layer used to represent the geographic space and further external information. These analyses may offer an opportunity to improve the comprehension of the territorial phenomena for addressing the design of the alternative and achieving the planning goals.

The two workshops employed different types of tools for dealing with the process model. The web-based PSS and the collaborative PSS architecture (Geolpanner), take into account only the spatial information preliminarily integrated into the model. The PSS used in the second part of the workshop of Gonnese is more flexible and allows integrating into the architecture other information to perform further analyses. Moreover, these PSS allow showing in real time the results of these analyses, improving both the comprehension of the territory and the discussion among stakeholders with regard to the current territorial phenomena. The PSS may offer a new perspective on spatial data use in planning, not only for creating maps but for a dynamic and innovative integration in planning practices, such as spatial analyses, real-time design and evaluation of alternatives, scenario comparison and environmental reporting.

The same spatial data have been used to feed the suitability analysis model (Evaluation Models), the design of the alternatives and the impact evaluation (Change and Impact models) and the decision-making process based on the scenario analysis (Decision Model).

Indeed, the output of the Process Model generates the base for developing the evaluation model. For instance, we can consider the example of investigating the historical and cultural heritage of a specific territory for locating a new touristic area. In this case, the representation model may illustrate the concentration of historical sites and artefacts in a specific zone and the process model may provide the number of historical goods, typology and distance to the roads network for the public access. The evaluation model concerns the use of this information to provide a planning solution for managing the historical heritage.

This way, it is possible to evaluate a range of solutions for adding value to the historical goods for the integration into touristic areas. Different approaches could be considered for achieving the planning goals, based on the use of spatial data through the support of PSS architectures. Once the suitable areas for achieving the planning goals are established, it is possible to design different alternatives. This activity is performed through the sketch planning tool of the PSS architecture and it is related to the Change Model. This geo-tool considers the output of the evaluation model for designing the alternatives. The user may design different planning solutions in a screen, generating several alternatives to fulfil the planning goal. The design is evaluated in real time through a range of spatial indicators encompassed in a dashboard. These indicators represent the Impact Model and are strictly connected with the design process. These tools foster the discussion among the actors involved in the process with regard of the results of the design activity. It is possible to apply real-time variations to the design alternatives, evaluating how they may influence the environment.

The research contributes to demonstrate that, despite the potential of the SDI, the contribution of the spatial data for supporting spatial planning processes is still limited. Nevertheless, thanks to the implementation of innovative technologies and methodologies into practices, such as PSS, web applications and Geodesign, supported by user friendly interfaces, the spatial data may provide a wide range of benefits to practitioners. The architectures that help to manage, represent and analyse the spatial data need to be managed with advanced expertise. Indeed, the process of modelling and integration of spatial data into the architecture may encompass different levels of complexity. The preparation of models, tools and dashboards may limit the diffusion of these innovations in planning, due both to the level of knowledge required by technicians and planners to manage these systems and the capacity to evaluate an appropriate economic return.

## **5.2. How to inform the design and impact assessment in planning?**

The Geodesign framework has been implemented into the LLLUP-SEA process through different innovative instruments and models. The main features of the PSS have been tested during the workshop phases to deal with the planning issues. Starting at the preliminary phases of the adaptation of the MMP to the RLP, GeoDesign may supports the process of Strategic Environmental Assessment.

The SEA is a procedure that fosters the comprehension of the geographic space for investigating the environmental issues. It is supported by a set of environmental indicators that represent the environmental components. These indicators generate the knowledge for evaluating the environmental trends and the current state of the development context. This information has to be considered since the preliminary phases of the plan-making process to feed the suitable design of the alternatives. The first part of the GDF, representation and process models, helps to organise this big amount of information, that is represented and analysed through the PSS. Indeed, the information used to deal with the creation of the baseline knowledge is influenced by a wide range of data. The PSS helps to manage this information flow in order to establish the relationship among data to perform spatial analyses and share the results through the indicators. The spatial indicators framework, nested in the architecture, may be fed both to the spatial data used to represent the geographic space and the external information, such as tables and models. The operations of modelling can be considered as an innovation in practices, due to the poor use of spatial models for supporting the analyses of the geographic space in current LLUP-SEA processes. Furthermore, the user-friendly interface fosters the communication of these results, integrating indicators, thresholds, limits and maps into dynamic dashboards. This approach has been tested during the first workshop phases for comparing the current way of managing, analysing and sharing the environmental information and the LLUP-SEA PSS. The Workshop Users (WUs) confirm that this approach helps managing the big amount of information, sharing the results in a suitable way

and operating variation to the spatial model. This information can be enriched even further, fostering the prediction of impacts generated by the design of the alternatives. Once the most relevant environmental issues are identified, the procedure of LLUP-SEA guides the identification of planning options for achieving the strategic goals. In this phase, the PSS generates an innovative approach to the process of identification of adequate solutions, making available advanced tools, such as the Land Suitability Analysis (LSA), for the management and analysis of the knowledge baseline created in the preliminary LLUP-SEA steps.

The suitability analysis is able to support the discussion among the actors of the LLUP-SEA process. This interactive geo-tool, related to the evaluation model, makes the users able to modify on the fly the parameters that influence the output. This geo-tool for identifying suitable planning strategies represents an important innovation in practices that merge the real-time assessment of strategic goal and the participation process, improving the suitability of the results and supporting the design of the alternatives.

Several studies report that the influence of the SEA on Plans and Programmes is still limited and how the decision-making process is not fully supported. For this reason, the LLUP-SEA PSS allows dealing with these issues, fostering an informed decision-making process since the preliminary planning phases. The environmental information generated through the representation and process models, becomes the base for defining strategic goals, weaknesses and opportunities of the study area, generating the design of alternatives and supporting the monitoring of the impacts on the environment of the planning goals. This procedure allows informing the design of reasonable alternatives, dealing with the weakness of the SEA and innovating the process of Land-Use Planning.

Furthermore, the results of the workshops demonstrate how the PSS is able to integrate the engagement of stakeholders into a fruitful discussion for defining the strategies to deal with both the environmental threats and the development of socio-economic goals.

The set of maps, indicators, tables and data created during these phases, through the PPS architecture, can be included in the final environmental report, improving the transparency of the process and supporting the communication and comprehension of how the strategic decisions have been made by decision-makers.

### **5.3. How can the PSS support real time impact evaluation of the design proposals and the participation processes ?**

The decision-making process takes into account the factors that influence strategic sectors, such as the environment and socio-economic fields. The decisions are influenced by the information produced in the preliminary steps of the plan-making phases, conditioning the design and the evaluation process of the alternatives. The analysis of the development context, if not adequately supported by a structured process,

may generate a lack of comprehension of the territorial phenomena. Such poor baseline of knowledge may direct the design of the alternatives toward inadequate planning solutions, generating uncontrolled environment effects and the development of unsuitable options. Furthermore, the impact evaluation of the alternatives may be unclear or ineffective, influencing the way on which the strategic goals impact both on the environment and on the human well-being. Indeed, Tetlow, and Hanusch (2012) pointed out that the development and evaluation of reasonable alternatives as a part of the SEA process in practice, could be of dubious effectiveness. The lack of reasonable alternatives in plan-making processes can be considered as one of the most important pitfalls in LLUP-SEA.

Focusing on the Sardinian planning context, the analysis of different case studies carried on by Campagna e Di Cesare (2016), shows how the design of the alternatives is barely considered in LLUP and just a small number of alternatives are generated during plan-making.

The PSS may support planners in dealing with these activities through different tools, such as the sketch planning and the Interactive Impact Assessment, with regard to the Change Model and the Impact Model of the GDF. Furthermore, these tools were used during the workshop of Gonnese for evaluating how they can support planners during the simulation of strategic goals. The WUs were able to sketch in a screen different alternatives, based on the analyses of the development context. At the same time, the PSS makes available a range of indicators and alerts for identifying the impact of the alternatives on both the environment and other strategic sectors. Nevertheless, the indicators included in the PSS are not sufficient for representing the territorial context and inform the process for developing strategic goals. For this reason, further indicators were developed for filling the gap between the requirement of the LUP-SEA to create a suitable processes of evaluation and the current indicators selection of the PSS architecture. These indicators were developed through a dedicated programming language nested into the PSS architecture.

Real-time design and evaluation of the alternatives allows supporting the participation process in the decision-making, fostering the discussion among stakeholders about the planning solutions. In turn, this approach supports the creation of different alternatives, that can be compared with the current environmental state, in order to provide adequate information to evaluate how the alternatives may affect the current development context.

Each alternative and related environmental indicators, define a specific scenario. The sketch planning tool allows to create different scenarios that may be compared with the aim of evaluating how different alternatives may influence the zero alternative. Indeed the scenario comparison fosters the process of communication to stakeholders of how the planner operates to build informed alternatives and how they may affect the strategic fields.

Instantaneous variations of the geographic space can be performed with the aim of feeding collaborative discussion among the stakeholders. The sketch tool offers an opportunity to integrate the Change Model of

the GDF into the planning practices, making use of the informed process generated during the preliminary phase. The actors of the workshops expressed their opinions with regard to the influence of this approach to planning practices. Such feedback concerns how the LUP-SEA PSS architecture may support the practices, making use of the information flow to generate informed planning alternatives.

Furthermore, such tools may support the collaborative approach to the design of planning goals, reducing the time for the creation and evaluation of different design proposals. For instance, two scenarios may influence the same strategic sector in a different way (e.g. the design of a new touristic zone can "consume" the land in a different way depending on the geographic location).

This process of real-time evaluation allows to select which alternatives may fulfil the requirement of social and urban growth in compliance with sustainable resource consumption. Indeed, the decision-makers may feed back the sketch models for defining changes to the alternatives, creating an interactive process of evaluation and design. The variations are further evaluated through the Interactive Impact Assessment (IIA), supporting the participation of the actors to the decision-making process. Despite the participation has an important role in the decision-making process, different studies (Fisher, 2010), demonstrate that the influence of participation in planning procedures is still unclear.

The PSS allows to communicate the results of the spatial analyses through a range of indicators, maps and reports. How the information is shared with the public, takes on an important role in the communication process and may influence the participation in the plan-making phases.

Indeed, if the results of the spatial analyses and the impact assessment, are not clearly communicated to the actors through indicators and maps, the design of alternatives and the decision of suitable solutions, may cause unclear and unexpected impacts. Indeed, the evaluation of the environmental effects due to the implementation of plans and programs must be managed by the Member State through monitoring programs (Art. 10 of the SEA Directive 2001/42/EC).

Barth and Fuder, (2002) pointed out that the important role of indicators in the monitoring programs. Indeed, they argue that indicators support the comprehension of environmental phenomena, representing relationships among environmental components, weaknesses and threats, and targets with regard to the decision-making process, in a simple way.

The range of indicators used to represent this information flow, helps to communicate the current environmental state and how it may be influenced by the design activities. The PSS architectures used in the workshops encompass different ways of communicating the information. CommunityViz makes available a range of indicators and alerts for communicating the results of the analyses, through a dynamic dashboard. On the one hand, there is no limit in producing indicators for sharing information. On the other hand, it increases the level of complexity of the model, influencing the time for calculating (Processing).



Although Geoplanner makes available a smaller number of indicators than CommunityViz, it is easier to set. Despite this characteristic of Geoplanner may support an easier setting of the impact evaluation than CommunityViz, it may limit the operating range of the evaluation.

The indicators of both PSS are dynamic, showing in real-time how the information may change. Such characteristics may improve the communication of information related to the spatial analysis. These analyses may provide complex results based on multiple relationships among data, and this approach may support a clear representation of them, in a simple way.

Nevertheless, the representation and analysis of environmental phenomena may concern a wide range of components that change with regard to the geographic location. For this reason, it does not seem to be appropriate to guide the evaluation process through a "universal" indicators selection but through a framework able to take into account the intrinsic complexity of the environmental questions, such as the DPSIR (Barth and Fuder, 2002).

The indicators selection of the Gonnese workshop is based on the DPSIR framework. This indicators framework may help to guide the comprehension of environmental phenomena changing the role of indicators in the process of representation of the information. Indeed, the indicator does not just communicate a value of a specific component of environmental phenomena, but it is part of a causal chain that represents the relationships among these components. For instance, the design of a new road may cause the production of pollutants due to the transit of cars. The DPSIR allows for considering how the design of a new road (Driver) may cause the production of pollutants (Pressure) influencing the quality of the air (State). Furthermore, this "cause" may generate health and environmental questions (Impact) that help to generate suitable responses to the problem (Response). The responses feed back to the other components that are further evaluated through the indicators framework, in a loop-like mode.

This interactive process of design, impact evaluation and comparison, complete the Geodesign framework, feeding the decision model. The same spatial indicators used to define the development context, evaluate the alternatives and compare the scenarios, support the monitoring framework required by the SEA Directive for evaluating and monitoring the effects of the alternatives on the environment.

Indeed, the PSS allows generating a report enclosing all data, indicators, constraints and parameters and maps produced during the LLUP-SEA process. The structure of the report may help to communicate to the public and stakeholders both the results of the decision-making process and how such process has been fulfilled through the plan-making phases. This approach may enhance the transparency of how the decisions are made and how such decisions are influenced by the information flow generated in the preliminary steps of the plan-making phases for generating reasonable alternatives.

In conclusion, the workshops may offer an opportunity to evaluate how the LUP-SEA PSS may help to deal with current issues in LLUP-SEA procedures. Although it can be considered a concrete approach to fill the gap

between practices and research, further applications of such methodology may strengthen their integration into spatial planning. Indeed, there are different shortcomings that currently limit their full integration into practices.

The intrinsic complexity of these architectures, in their web and desktop implementations, concerns how to set the models for dealing with the planning activities. Such procedure has to be managed by experts and it may cause high economic investments, influencing the diffusion of innovations in practices. Furthermore, the flexibility of the PSS is a characteristic that seems directly related to the complexity of the architecture. This relationship may be the base on which develop a discussion regard the probable level of integration into practices for each architecture.

#### **5.4. How do the flexibility and complexity of the PSS influence its integration into practices?**

The development of Geographic Information Systems (GIS) and Planning Support System (PSS) architectures over the last few decades has influenced the activities in spatial planning. The PSS allows planners to deal with their tasks in planning practices in a more efficient way, through a range of services, such as the management of spatial data, spatiotemporal analyses, user-friendly interfaces, sketch planning, real-time impact evaluation and reporting. These components of the PSS help both to adapt the system to the planning procedure and planners to fulfil their planning tasks. The capacity of the PSS to be adapted to the planning activities may represent the “flexibility” of the architecture. Nevertheless, this modelling phase of the PSS architecture may require a high level of user experience for managing the complexity in defining suitable tools.

Different architectures may provide similar support tools to planning activities through different levels of flexibility and complexity. The workshops make a comparison among these architectures, such as ArcGIS, a common GIS software, and two PSS architectures, such as CommunityViz and Geoplanner and how they may influence the integration into practice.

Focusing on the workshops experience, the WUs provided their feedback with regard to the activities carried out for dealing with a specific planning tasks.

- **ArcGIS** has a high level of flexibility which allows dealing with the intrinsic complexity of the planning activities. Indeed, the planner may take advantage of the capability of ArcGIS to provide a huge range of instruments for performing representations and analyses. Despite the actual diffusion of ArcGIS in planning procedure, its contribute is limited to represent data and perform a small number of analyses. ArcGIS may support planners for representing the territory, performing spatial analysis, design alternatives based on informed processes, evaluate the impacts and produce environmental reports, combining spatial and non-spatial data. In spite of this flexibility, the ArcGIS software needs to

be managed by experts to fulfil the full capability of supporting planners to deal with planning tasks. Furthermore, the ability to show the analyses results is still limited due to a lack of both a dedicated user-friendly interface and a spatial indicators framework.

- **CommunityViz** is an architecture that provides a wide range of tools for supporting planners for dealing with their work during the planning activities. CommunityViz has been applied to different case studies around the world in order to test the potentiality of the tools. These case studies documented by Placeways are 28 and concern a wide range of sectors, such as Coastal Resiliency, Planning and Smart Growth, Climate Change and Scenario planning. Despite these applications in practice, the extensive use of this PSS in planning is strongly limited. CommunityViz helps users to manage the system through a range of wizards, user-friendly interfaces and a dedicated programming language. This approach supports planners to adapt the geo-tools nested in the architecture for dealing with their tasks and fulfilling the planning activities. Although CommunityViz requires less experience than ArcGIS for performing spatial analyses, its ability to be adherent to the planning procedure is limited. If, on the one hand, CommunityViz helps users to manage the services offered by the architecture, on the other hand, it is less flexible than ArcGIS.
- The third one, **Geoplanner**, is a novel web-based architecture that guides users through generating maps, spatial analyses, design activities and impact evaluations. Geoplanner is at the preliminary phases of its diffusion in planning and its capacity to support planners in making planning tasks is limited. For this reason, the application of this technology through structured case studies may help the developers in investigating the efficiency of Geoplanner in practice. Geoplanner is easy to set due to its web-interface that helps users to define analysis tools, maps and indicators. Nevertheless, Geoplanner seems to not be full adherent to all activities required during the plan-making phases due to the rigidity of its architecture. Indeed, Geoplanner may support just a few phases of the planning practices, related to the design of alternatives, impact evaluation and scenario comparison, if adequately defined at the beginning of the spatial models creation. For this reason, although the integration of Geoplanner into practices can be easier than ArcGIS and CommunityViz, it is not enough flexible for supporting the planners to fulfil their planning tasks. Figure 44 represents how these architectures may be classified according to the relationships between their complexity and flexibility. This relationship defines the degree of “usability” of each architecture for planners (Fig. 45).

It can be argued that, although the increment of the system flexibility may foster the process of integration into practices, it may reduce the capability of dealing with the complexity of all planning procedures.

A suitable development of PSS architectures may be supported by a continuous use in planning practices, guided by planners and practitioners through reports and feedback. Indeed, the research demonstrates that

planning practices may be concretely supported by PSS and how the process of integration of PSS into LLUP-SEA procedures is far from being concluded.

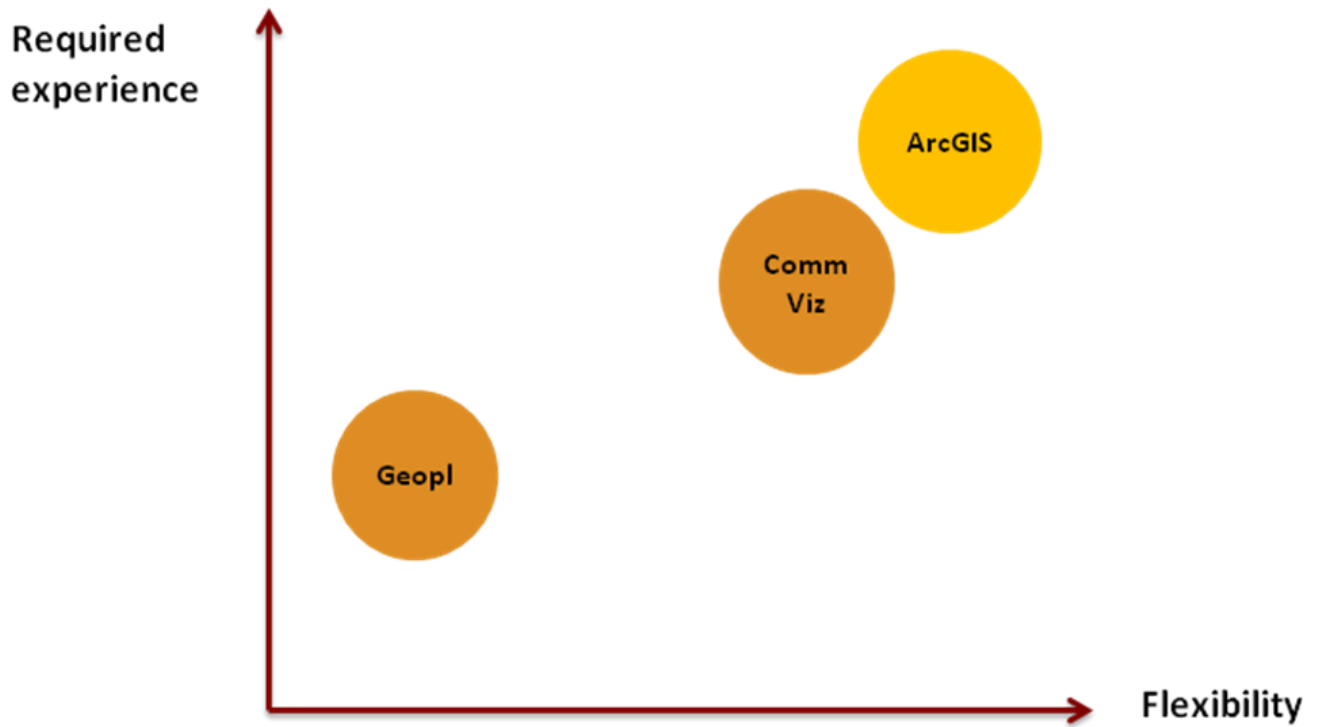


Figure 44 – Flexibility and Complexity

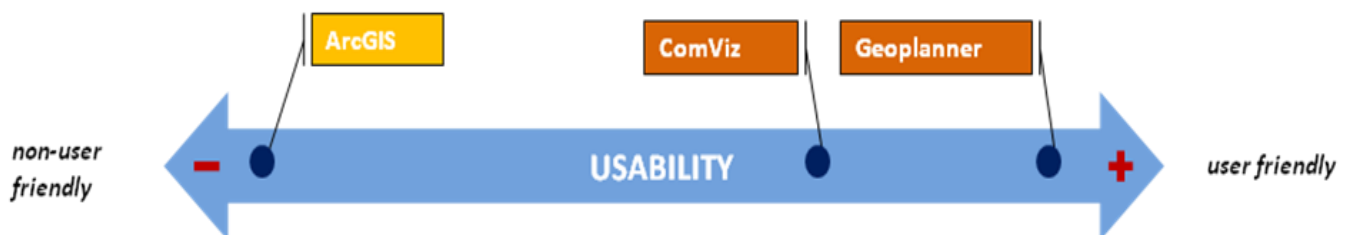


Figure 45 – Usability

## 5.5. Conclusions

The aim of the research was to investigate how a PSS may be applied to LLUP-SEA processes. The workshops illustrate an attempt of filling the gap between research and practices and would represent a suitable way for integrating both innovations in geo-information technologies and emerging methodological approaches into decision-making processes.

Over the past two decades, the production of spatial data and the diffusion through public accessible databases, have offered an opportunity for innovating the planning practices. Indeed, digital data was barely used in spatial planning due to both the onerous process to digitise information and limited technologies for the management and analysis. The simultaneous development of SEA procedures oriented to integrate environmental considerations in planning has fostered the generation of a new approach to planning practice at National, Regional and Local levels. Nevertheless the implementation of SEA procedures and spatial data into Land-Use Planning is still limited and the efficacy of these innovative drivers is unclear. This research offered an opportunity to evaluate how the availability and accessibility of spatial data may foster the development of technologies able to support the LLUP-SEA practices, such as the PSS, and how the novel Geodesign methodology may guide this process of implementation.

Although the early concept of Planning Support Systems is dated to 1989 (Harris), the lack of data and suitable technologies may have limited their development and diffusion in planning practices. The current development of SDI and the diffusion of spatial data may contribute to the development of PSS as a suitable support tools for dealing with planning tasks contributing to add value of digital information in planning.

Indeed, the results of the workshops demonstrate how the PSS may be considered a concrete support for planners to deal with current issues in LLUP-SEA procedures, merging the purposes of public administrations to guarantee the socio-economic growth of the territory with the policies requirements to integrate sustainability principles into planning practices. Indeed, the PSS may support planners for creating an informed process to the plan-making phases, the design of reasonable alternatives and the real time impact evaluations. Furthermore the case studies contribute to demonstrate how the Geodesign may support the LLUP-SEA process through its structured framework, starting from the analysis of the context for guiding the design of alternatives and their evaluation, comparing the scenarios and feeding the decision-making through an informed process.

The case studies illustrated in this dissertation take into account both the current practitioners that may take advantage of the development of PSS and the integration of spatial data into practices, and the students of spatial planning that may be considered the new professionals in the near future. This wide range of workshop participants may help to guide planners to fulfil their planning tasks meantime the new generation of planners

builds their professional curricula for dealing with the integration into practices of both innovative technologies and spatial data.

This approach to the development of tools able to add value to spatial data through practices may offer an opportunity to guide a concrete applications in spatial planning. Indeed, this research represents an attempt to deal with current issues in planning, stimulating the development of innovative tools able to support planners for fulfilling their planning tasks. Furthermore, the research demonstrates how spatial data may have an important role in planning if adequately integrated into practices through PSS.

## **5.6. Further Work**

The evaluation process of the influence of PSS and Geodesign in supporting planners for facing their planning activities is a complex one. The workshops presented in this dissertation may be considered as a preliminary approach to the issues emerged in the LLUP-SEA. Further analyses may concern different aspects of the planning procedures, such as the application of this approach for managing spatial data in creating the baseline of knowledge for feeding the plan-making phases, evaluate how this technology may influence the process of public participation into LLLUP-SEA, create adequate monitoring programmes and environmental reporting and how the transparency of the process may be influenced. These different activities concern specific phases of the plan-making process and can be analysed through dedicated workshops and then integrated into a complete process of adaptment of MMP to the RLP.

The development of an adequate PSS able to support planners for dealing with the planning activities may be influenced by the opinions of practitioners and technicians that, participating to the activities of evaluations during structured workshops, may guide the fruitful integration of these innovations in practices.

The workshops help to demonstrate how merging methodologies computer-aided, such as Geodesign, may address open issues in SEA-LLUP, calling for further applications in practice.

A LLUP-SEA PSS that integrates the models of the GDF has to be further analysed and developed in order to be in compliance with the requests of planners for dealing with their planning activities. In turn, this system may be applied to other spatial scales, such as Regional and National and European levels.

The application of a LLUP-SEA PSS at European level may help to guide a homogeneous integration of the European Directives into the European Member States in compliance with the principles of sustainability.

## Acronyms

Change Model	CM
Corine Land Cover	CLC
Decision Model	DM
Driving-State-Response	DSR
European Environment Agency	EEA
Environmental Impact Assessment	EIA
Evaluation Model	EM
Environmental Protection Agency	EPA
GeoDesign Framework	GDF
Information and Communication Technologies	ICT
Interactive Impact Assessment	IIA
INfrastructure for SPatial InfoRmation in Europe	INSPIRE
Impact Model	IM
Implementing Rule	IR
Land Suitability Analysis	LSA
Local Land Use Planning	LLUP
National Digital Mapping Portal	NDMP
Open Geospatial Consortium	OGC
Organisation for Economic Co-operation and Development	OECD
Public Administration	PA
Process Model	PM
Plans, Programmes and Policies	PPP
Piano Paesaggistico Regionale	PPR
Planning Support System	PSS
Pressure-State-Response	PSR
Regional Landscape Plan	RLP
Representation Model	RM
Sistema Cartografico di Riferimento	SCR
Spatial Data Infrastructure	SDI
Sustainable Development Indicators	SDIs
Teritorial Information System of Sardinia	SITR
Spatial DPSIR	sDPSIR
Strategic Environmental Assessment	SEA
United Nations Conference on Sustainable Development	UNCSD
Valutazione Ambientale Strategica	VAS
Web Feature Service	WFS
Web Map Service	WMS

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# **Annex I**

## **Workshop - Gonnese**

## Questionnaire 1

### *Representation and Analysis*

**1. (Q1) Current state**

Are you satisfied with the municipal website system for managing and sharing spatial information?

**2. (Q2) Current state**

How do you consider the way of seeking for information on the municipal website?

**3. (Q3) Current state**

Select the main shortcomings of this system:

- i. To find the thematic section in the website;
- ii. To visualise information;
- iii. To understand the information;
- iv. other:

**4. (Q4) Interactive Map**

How do you consider the efficiency of the representation model?

**5. (Q5) Interactive Map**

Did you know this technology?

**6. (Q6) Interactive Map**

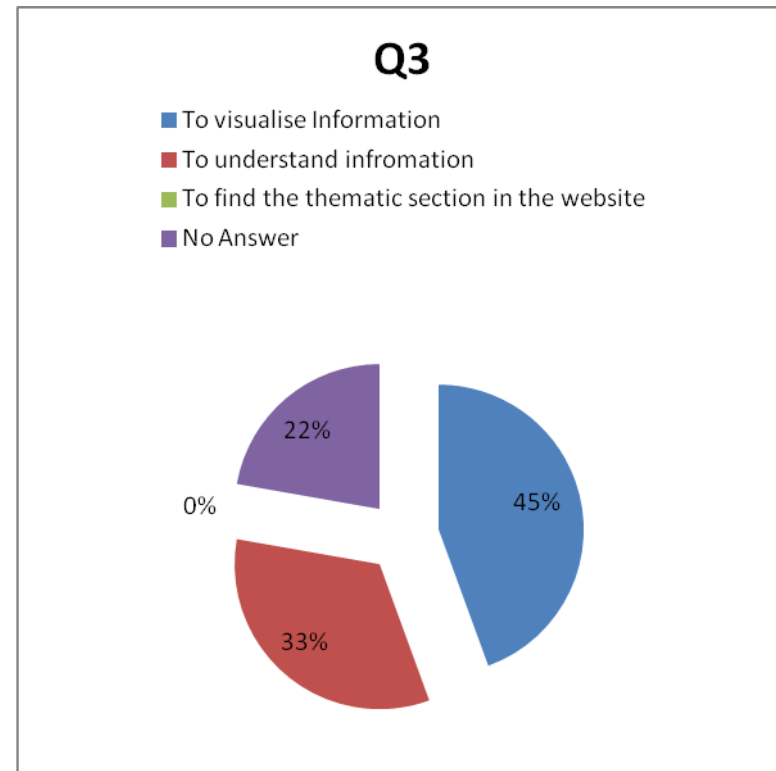
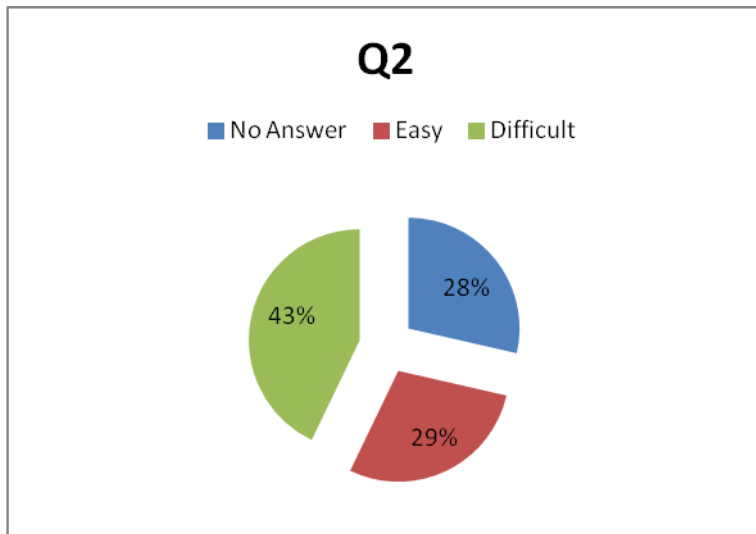
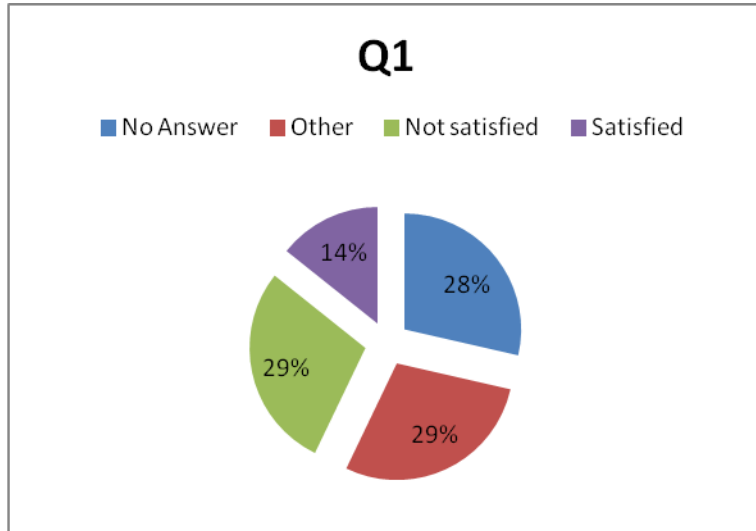
Identify the web app characteristics that you consider more relevant:

- i. Easy to use;
- ii. Choose of the information to visualize;
- iii. Interactivity
- iv. Other:

**7. (Q7) Interactive Map**

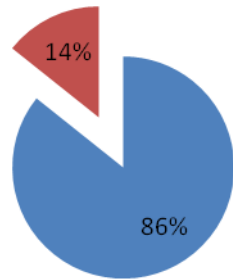
Do you consider this technology more efficient for representing spatial data for non-expert users (citizens)?

## Results



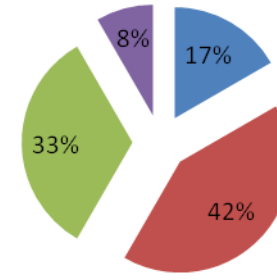
**Q4**

■ Good ■ Bad



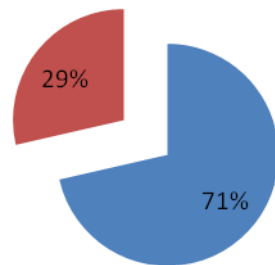
**Q6**

■ Easy to use ■ Choose of the information to visualise ■ Interactivity ■ Other



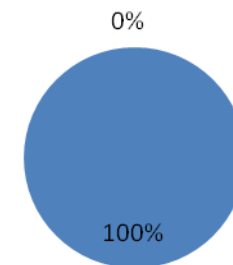
**Q5**

■ Yes ■ No



**Q7**

■ Yes ■ No



## Questionnaire 2

### *Design and Impact evaluation*

**1. (Q1) Impact Model**

Are you satisfied with the impact model?

**2. (Q2) Impact Model**

How would you characterise the impact model?

- i. Complex;
- ii. Intuitive;
- iii. Interactive;
- iv. Practical;

**3. (Q3) Impact Model**

Do you agree with the selection of indicators?

**4. (Q4) Impact Model**

Would you integrate further indicators into the impact model? If yes, could you give an example?

**5. (Q5) Impact Model**

Do you think this technology may be considered a reliable support for dealing with the proposed planning issues?

**6. (Q6) Impact Model**

Could the workshop contribute to generating an alternative to the current approach to planning problems?

**7. (Q7) Impact Model**

What do you think of the integration of this technology into practices for dealing with planning tasks?

**8. (Q8) Impact Model**

Could you analyse further your answer?

**9. (Q9) Terminology**

Do you think the terminologies used during the workshop are clear?

**10. (Q10) Terminology**

Did you learn new concepts/terms?

**11. (Q11) Terminology**

What do you think of the workshop?

- i. Interesting;
- ii. Complex;
- iii. Interactive;
- iv. Other

**12. (Q12) Terminology**

Would you like to study more extensively any of the workshop activities?

**13. (Q13) Terminology**

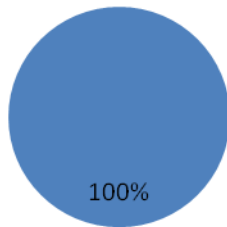
If yes, which one?

## Results

**Q1**

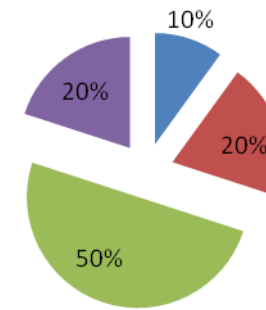
■ Very Satisfied ■ Not Satisfied ■ Other

0%



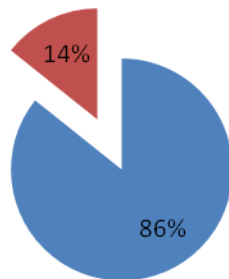
**Q2**

■ Complex ■ Intuitive ■ Interactive ■ Practical



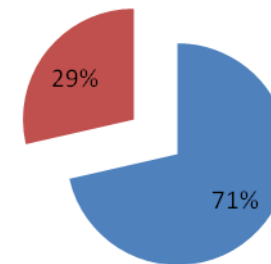
**Q3**

■ Yes ■ Not All



**Q4**

■ Yes ■ No Answer

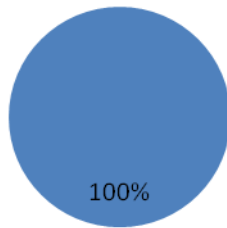




**Q5**

■ Yes ■ No ■ I do not know

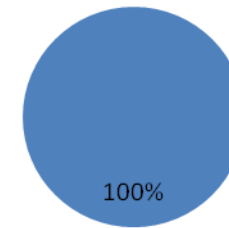
0%



**Q6**

■ Yes ■ No ■ I do not know

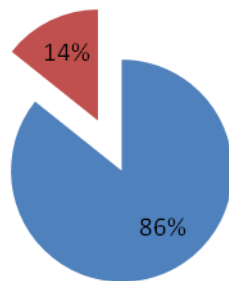
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**Q7**

■ High ■ Medium ■ Low

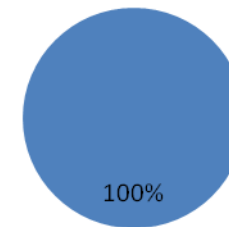
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**Q9**

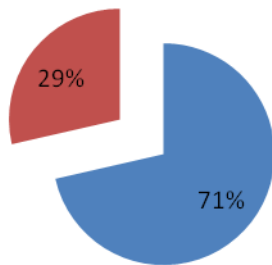
■ Yes ■ No ■ I do not know

0%



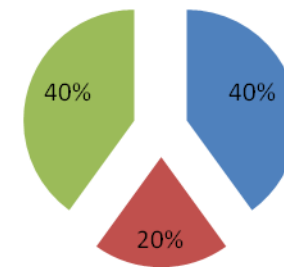
**Q10**

■ Yes ■ No



**Q11**

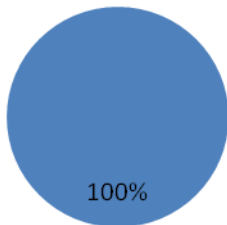
■ Interesting ■ Complex ■ Interactive



**Q12**

■ Yes ■ No ■ I do not know

0%



- **Q4** Economic Impacts of design, such as services, building and urban development.
- **Q8** No answers
- **Q13** No answer

## **ANNEX II**

### **Workshop – University Student**

## Questionnaire 1

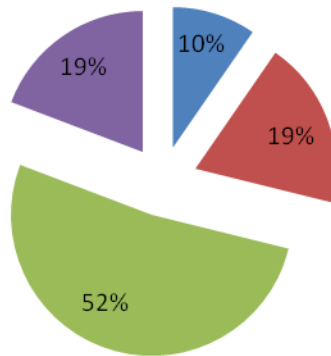
### *Innovation in Geo-information technologies for supporting planning procedures*

1. (Q1) Could you identify the most useful features in ArcGIS?
  - i. Representation (Maps);
  - ii. Design (Editing)
  - iii. Analysis and Data Management (e.g. Buffer)
  - iv. Result representation (Maps and table)
2. (Q2) Could you identify the most useful features in Geoplanner?
  - i. Representation (Maps);
  - ii. Design (Editing)
  - iii. Analysis and Data Management (e.g. Buffer)
  - iv. Result representation (Maps and Dashboard)
3. Which do you consider the best software for representing spatial information?
4. Which do you consider the best software for developing spatial analyses?
5. Which do you consider the best software for supporting the design of alternatives?
6. Which do you consider the best software for evaluating the impacts of the design activities?
7. Which do you consider the best software for supporting the participation processes in planning?
8. Do you think Geoplanner may be considered a reliable tool for MMP to RLP adjustment?
9. Do you think ArcGIS may be considered a reliable tool for MMP to RLP adjustment?
10. Do you think these technologies may be integrated into the website of the public administrations?
11. Do you think that technologies, such as Geoplanner, may simplify the seeking and comprehension of information for non expert users (citizens)?
12. Would you like to study more extensively any of the workshop activities? If yes, which one?

## Results

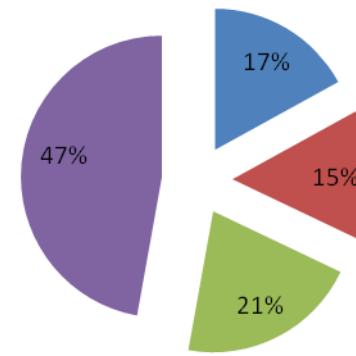
### Q1

- Representation (Maps);
- Design (Editing)
- Analysis and Data Management (e.g. Buffer)
- Result representation (Maps and table)



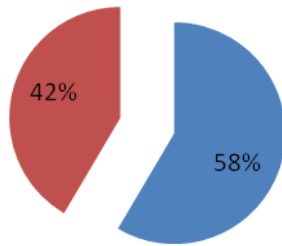
### Q2

- Representation (Maps);
- Design (Editing)
- Analysis and Data Management (e.g. Buffer)
- Result representation (Maps and Dashboard)



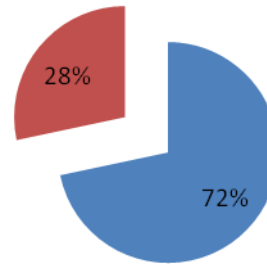
**Q3**

■ ArcGIS ■ Geoplanner



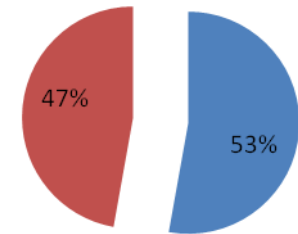
**Q4**

■ ArcGIS ■ Geoplanner



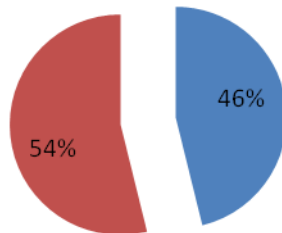
**Q5**

■ ArcGIS ■ Geoplanner



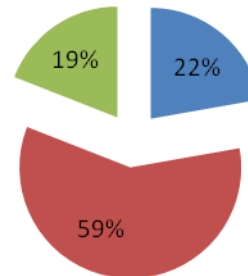
**Q6**

■ ArcGIS ■ Geoplanner



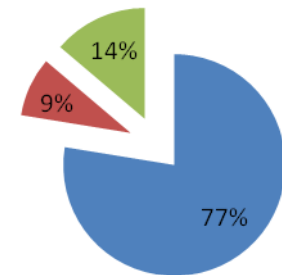
**Q7**

■ ArcGIS ■ Geoplanner ■ Other

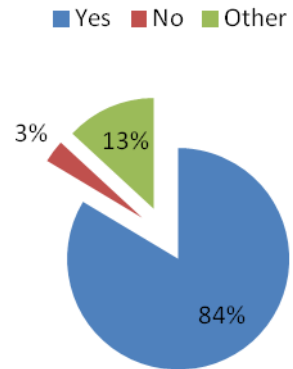


**Q8**

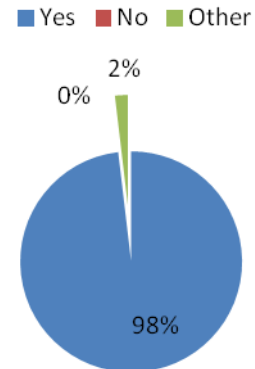
■ Yes ■ No ■ Other



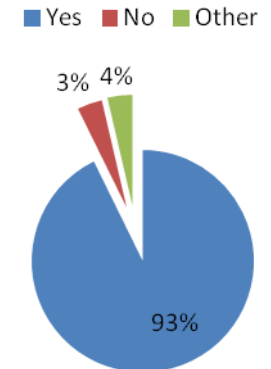
**Q9**



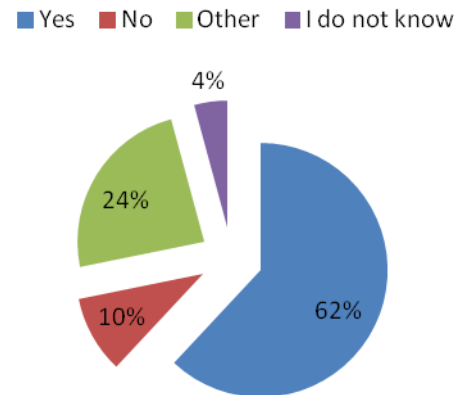
**Q10**



**Q11**



**Q12**







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