Detecting spatial features from data-maps
the visual intersection of data as support to decision-making

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Abstract

The assessment of spatial systems can be supported by the analysis of data coming from different sources and describing different aspects such as economic, social, environmental, energy, housing or mobility issues. Nevertheless, the analysis of such a large amount of data is difficult. In order to improve the readability of data also with non-technicians, new methods of communication are needed, which could facilitate the sharing of information among people with different skills and backgrounds. In this context, the paper shows the developments in geo-visualisation to support and improve the processes of planning and decision-making. First, the use of a map-based visualisation is suitable for intuitively understanding the location and distribution of specific elements. Second, the graphic interface can be used to drive users in the investigation of data. It can provide a linear method that is more comprehensive to the human mind in dealing with the complexity of spatial systems. In addition, the possibility to select and filter data by single attributes allows databases to be explored interactively and read by differently skilled users. The intersection and overlapping of information enables users to discover the relationships between data, the inefficiencies and critical areas, thus providing suggestions for further reasoning in planning and decision-making. Furthermore, collaborative and participatory sessions require quick answers and simple readability. Thus, the real time response to simple queries widens the opportunities for improving the discussion. A case study describes the methodology used for sharing the data collected during an Interreg IVB NWE Project named "CoDe24" (INTERREG IVB NWE, 2005; ERDF European Territorial Cooperation 2007-2013, 2010). By the use of a web-GIS visualisation tool, namely GISualisation, the project partnership was allowed to explore the data concerning the railways and train typologies along the Genoa-Rotterdam corridor. Despite the high factor of usability of the tool, it was not employed much by participants to the project so that further reasoning is needed to evaluate how digital tools are perceived by professionals.

KEYWORDS

GISualisation; InViTo; geovisualisation; Data analysis; CODE24

1. INTRODUCTION

A massive change in the availability of data is occurring. Until a few years ago, data were provided by authorized institutions or agencies in charge of monitoring specific elements. Nowadays, official data are just a small part of available data. Sensors distributed across the urban space gather information on traffic and pollution while satellites monitor the Earth. However, huge numbers of records are constantly produced by conscious and non-conscious users who act in their own daily life (Grauwin, Sobolevsky, Moritz, Gódor, & Ratti, 2015; Chicago Architecture Foundation (CAF), 2014; Kokalitcheva, 2014; IBM, 2014).

While most of these data are private, a large part is open and can be accessed by the use of free Web APIs. This can offer great opportunities for obtaining information about cities and other built environments, providing interesting descriptions of economic, social behaviour, environmental, energy, housing, transport or mobility issues. Furthermore, a large part of these data is geo-referenced, so that it can be easily gathered and localised on a map. The analysis of such data can provide focused studies on a specific area, generating information on localised dynamics and activities and by improving the assessment of a spatial system and its quality of life (Szell, Grauwin, & Ratti, 2014; Resch, Summa, Sagl, Zeile, & Exner, 2014; Chua, Marcheggiani, Serrvillo, & Vande Moere, 2014; Goodspeed, 2011; 2012; Neuhaus, 2011; Bawa-Cavia, 2010). Very detailed statistics can be captured by monitoring real activities, offering outcomes which can often be competitive with the output of traditional complex models.

In this context of a huge amount of information, spatial planning demands innovative methods. The paper shows the developments in geo-visualisation as a support to improve the processes of planning and decision-making. Opportunities and needs are discussed, presenting possible methods for new developments. A case study describes the methodology used for the sharing of data collected during the evaluation of the network along the trans-European railway axis (TEN-T) 24 Genoa-Rotterdam (Arnone et al., 2016). The study is part of an Interreg IVB NWE Project named "CoDe24" (INTERREG IVB NWE, 2005; ERDF European Territorial Cooperation 2007-2013, 2010).

2. A NEW TOOL: THEORETICAL OPPORTUNITIES AND PRACTICAL REQUIREMENTS

As in all scientific and professional disciplines, also spatial planning can now exploit the opportunities given by ICT for the development of innovative tools and methods. The current state of the art is still a combination of traditional methods, which only occasionally make use of the new digital technologies. The last decades have strongly built up the trust in technology among professionals, so that also new communication and information sharing systems are often perceived too complex to be used in real planning processes.

2.1 The rise and fall of complex spatial models

During the last half century, spatial planning has evolved into a multidisciplinary science, which considers and analyses the spatial system as a multitude of heterogeneous elements linked to each other through intricate connections. The mono-functionalism of modern spatial planning, as well as the independent approach of professionals acting within the cities (Jacobs, 1961; Alexander, 1965), were no longer suitable for the growth of contemporary cities. Linear planning theories were substituted by the rising idea of the city as a complex living system.

New theories on complexity have generated a large number of visions of the world (Allen, & Sanglier, 1981; Batty, 2003, 2005; Portugali, 2011; Portugali, Meyer, Stolk, & Tan, 2012; Salingaros, 2000, 2006). As a natural consequence, spatial planning grew into a multidisciplinary science, where a large number of professionals contributes with specific expertise and insights into specific fields such as social sciences, environment or transport. In addition, spatial planning also has to consider a wide range of other non-scientific elements such as the interests and goals of both private and public stakeholders who commonly act in spatial systems. Therefore, the spatial configuration is the result of the unravelling of intricate knots which tie functions, activities and forms to a specific space.

While the reasoning around complexity was growing, the methods and tools for urban planning have been reviewed. In particular, large-scale models have generated a diffused interest within the scientific world. Since the Sixties, several studies have been produced with which to regulate and measure the planning of cities. Many theories have been developed but their outcomes failed to convince professionals. They reached a final peak in 1973, when Lee listed their more evident flaws as an obstacle to their usability. Nevertheless, during the Eighties the progress in computer science and, in particular, the development of graphic interfaces brought a new technological opportunity to continue the reasoning on large-scale models. During the Nineties and the first years of the second millennium, a vast production of literature arose on the theme of digital spatial models (Harris & Batty, 1993; Klosterman, 1994, 1999; Landis, Monzon, Reilly, & Cogan, 1998; Waddell, 2000; Waddell et al., 2003; Wegener, 1994, 1995; White, & Engelen, 1997, 2000; Wolfram, 1984). The introduction of powerful technological tools enables the idea of a new digital era able to face the challenges of large-scale models (Klosterman, 1994; Landis, 2001). Studies on the complexity of cities provided a strong theoretical background and support to the development of spatial models. In particular, they justified a general pursuit of translating the full set of qualitative spatial dynamics into an automatic quantitative process.

Cities, as well as their activities, dynamics and behaviours, have been analysed through a wide number of data, variables, parameters and indexes, using several methodologies which increased the common need for detailed, precise and complete data. The search for good quality data became an incessant challenge for implementing, calibrating and validating models. Therefore, the studies on large scale models developed into very complex instruments, whose structure was conceived to include different elements such as land-use and transport (also known as LUTI models), social, environmental or economic factors, considered statically and in their possible evolutions in time. As a result, this approach resulted in tech-oriented research, which forgot the ultimate goal of improving the spatial planning processes. Large scale models increased their performances but remained "hyper-comprehensive, gross, data hungry, wrongheaded, complicated, mechanical and expensive" (Lee, 1973), while their transparency, assessment abilities, suitability to particular needs, and simplicity were not improved as expected. Persistent attempt of reproducing the real world in order to automatically generate forecasts and solutions for a living system, deeply undermined their inner usefulness. According to Borges (1960), a 1:1 scale map of the empire is useless. Models should be an abstract selection of reality (Farinelli, 2007), which may be of practical use for obtaining information, knowledge and awareness about specific issues.

Nevertheless, many tools are still overly complex. Non-technicians are generally limited in the process of data exploration, while too often technical expertise is required for both the production and understanding of maps. The need for tools based on linear logic is now recognised. Today criticism of spatial models and their counterparts referred to as Planning Support Systems (PSS) or spatial Design Support systems (sDSS), confirms the point of view of Lee (1973) and points out the common need for simplicity, user-friendliness and transparency in order to be usable by a large variety of users (Uran, & Janssen, 2003; Couclelis, 2005; Vonk, Geertman, & Schot, 2005; Vonk, 2006; Geertman & Stillwell, 2003, 2009; Te Brömmelstroet, 2010). Some discussions have arisen in the last years in order to highlight the differences between complex and simple models (Klosterman, 2012; Hoch, Zellner, Milz, Radinsky, & Lyons, 2015). However, Information and Communication Technologies (ICT) significantly changed the perspectives and possible uses of automatic processes within decision-making processes. From the misconception of spatial models as a crystal ball, able to provide forecasting and spatial solutions, the study of living systems is moving towards the use of simpler frameworks and more user-friendly interfaces.

2.2 Data analysis as new approach to spatial planning tools

With Big data on one side and the need for more linear methodologies on the other side, spatial planning is being pushed towards a data-driven approach (Kamenetz, 2013; Lanzerotti, Bradach, Sud, & Barmeier, 2013). Subsequently, systems of spatial and/or visual analysis are being investigated to find new methods which could increase the readability of information contained in data (Grauwin, Sobolevsky, Moritz, Gódor, & Ratti, 2015).

Historically, human minds use analysis as a learning method, demonstrating how cognitive processes are facilitated by the use of a simple and linear approach. In fact, according to the etymological definition, analysis is the deconstruction of a whole in its simplest elements. The consequence is a linear process which implies the investigation of three main issues:

- The identification of each single part;
- The definition of the relationships and hierarchy between the parts;
- The definition of the relationships between the parts and the whole.

Analysis can provide information regarding location and the order of things on Earth (Schmitt, 1950), providing all the elements necessary for knowing a spatial system through a hierarchical and logic sequence. The analysis of flows of data can provide alternative applications to complex spatial models, offering a linear approach to spatial studies. In particular, geo-data analysis is currently characterised by the use of interactive and visual tools, namely geo-visualisation tools (Andrienko, & Dykes, 2011). Based on dynamic maps, geo-visualisation aims at sharing geographic information in order to improve the knowledge of spatial issues among different kind of users. Therefore, the exploration of data becomes a way for analysing huge amounts of data through a simplified visual interface. This has been shown to be particularly suitable for improving the comprehension of spatial issues by both people with no particular expertise or technical skill.

2.3 Requirements for data readability and usability

Data including geographic information are known as GIS data. They are collected in spreadsheets where each line corresponds to a geo-referenced geometry, and each column, namely field, contains an attribute of the geometries. Although these files can include a high level of information, their representation is generally provided by maps which show few fields of attributes. Thus, the resulting maps generally omit many elements which could be useful to their interpretation. These kinds of maps, also known as data-maps, show the spatial distribution of values, but do not reveal the hidden connections among data. Therefore, the message given by data-maps is often too simple and does not provide a relevant insight into the spatial features.

Today, geo-visualisation technologies, such as web-GIS tools, provide many opportunities for the development and customisation of mapping instruments. Common users can choose a large variety of tools from both commercial and open products, through a large variety of tools. Applications of such instruments are available worldwide and concern a number of fields. Nevertheless, only a limited number of existing tools are usable in real-life planning contexts. Generally, the reason is due to a misconception of tools. Frequently, the use of visualisation is oriented to eye-catch the users, rather than to improve their learning process on specific fields. Thus, the exploration of spatial data is often limited to a barren overlay of different maps. Furthermore, planners and decision-makers have to share their expertise, interests and opinions with people with different levels of expertise and skills. Thus, the readability of data should deal with the skills of people involved in the process of planning and decision-making. Data readability demands new instruments to help prevent misunderstandings, facilitate the sharing of information and enhance the communication value of analytic processes. Policy-makers, professionals and stakeholders should be informed about all project issues before the conclusion of the decision-making process. In particular, they need to be aware of all the possible consequences to their choices. The opportunities given by ICT can aid their activities, especially by simplifying the processes of information sharing and by enabling the exploration of data.

Furthermore, interaction can improve not only data readability, but also the usability of tools (Andrienko & Dykes, 2011; Andrienko, et al., 2007, 2011). Usability is now a keyword in the conceiving of support systems. Both expert and non-expert users are increasing their interest in data exploration systems working in real time. Even if the attractiveness of new technologies can play an important role in the diffusion of this trend, two main reasons can be noted in the opportunities provided by interactive systems.

First, only a few tools are conceived to cut across various disciplines and uses, so that their usability is confined to a very limited number of applications. Second, the interaction with data improves the direct dialogue between users and data. Instead of trusting on time-intensive calculations made by black box systems (Latour, 1987), users prefer to personally investigate the information contained within data. Thus, the learning process is facilitated by the personal construction of possible connections and hierarchies between the parts. Furthermore, the dialogue with data increases the respect for the human experience in front of calculations given by automatic processes.

Often, experts do not trust the outcomes of complex calculations because of the low transparency of processes. Avoiding black boxes reduces suspicions concerning digital tools. A number of workshops supported by the use of map-based tools have shown that experts often look for problem explanations instead of problem solutions (Abastante, et al., 2014; Masala, Pensa, & Tabasso, 2014). The absence of complex mathematical formulas and the direct comparison between the attributes of data can be a simple way to represent the information included in data. By using interactive and user-friendly interfaces, users can find their solution through a process of self-learning, which exploits the value of personal experiences enhancing the strengths of individual skills.

2.4 The development of a new tool

The research presented in this paper was looking for the integration between GIS technologies, spatial decision-making and communication. A new tool, namely GISualisation, was developed in order to satisfy specific requirements of usability in decision-making processes. Based on open web-platforms and applications, the tool is a geographical data viewer aimed at facilitating the reading, understanding and sharing of data. Its main goal is not to provide definitive solutions, but to help users identify elements corresponding to specific parameters and the relations between elements. New ways for using spatial data have been investigated in order to improve the process of communication and knowledge of cities and territories. In order to explore data, the tool works on dynamic maps, created by the use of free map-based web applications. Maps containing geo-referenced data can be easily explored, as with traditional WebGIS tools, but data can be filtered along different levels of details. On a lower level, information can be grouped in macro-categories such as layers or fields, while on a higher level, databases can be investigated on the basis of single records. Thus, geo-data can be analysed record by record, filtering data and locating their attributes. In order to overcome the low information value of data-maps, one possible solution was found in the intersection of attributes from different fields. By applying filters to the contents of one or more fields, map-users can obtain information about each single attribute and relate it to other elements such as its location on a map or the values of other geometries. The exploration of these relationships between data can allow people to deepen their knowledge on displayed data. Furthermore, the possibility of interacting easily with large databases could provide a support for planners and decision-makers to detect factors of inefficiency, ineffectiveness or critical areas which need further reasoning concerning their planning or design.

Information can be freely interpreted by the actors involved within planning processes, who can use their personal experience to analyse data and look for common and shared solutions. In this sense, the development of GISualisation has favoured human skills over technological power and automatic processes, attributing a new value to the presence and participation of people.

New methods of communication were investigated to improve opportunities for the sharing of information and learning. Benefits for improving the knowledge process can come from the use of the graphic interface as a fil rouge for guiding the user in the exploration of data. The interface was conceived as simple as possible. A vertical menu on the left side of the screen hosts all the instruments for data filtering, such as sliding cursors, scroll-down menus or checkboxes. The remaining area of the screen displays a dynamic map. These two elements form a necessary and sufficient condition for supporting the spatial decision-making processes. In fact, data can be grouped by users on the basis of families or ranges and visualised on the map. This combination between a phenomenon and its localisation produces a strong conceptual relationship, which is essential in understanding spatial dynamics (Dodge, 2005). Through an easy-to-use interface, both experts and non-experts can follow the sequence of filters, explore the interrelations between data, and collect visual information on cities and territories. Thus, data visualisation increases the intuitiveness in data reading, improving comprehension and increasing benefits for decision-making processes.

3. CASE STUDY: THE DEVELOPMENT OF THE GENOA-ROTTERDAM CORRIDOR

The flexibility of GISualisation has been proved through a number of applications, ranging from the investigation of inefficiencies in the public transport system of the Piedmont region in Italy (Pensa, Masala, Arnone, & Rosa, 2014; Isabello, Pensa, Arnone, & Rosa, 2014), to the analysis of health of urban population, from the study of pedestrian paths in urban areas, to the evaluation of social housing projects. In particular, this paper describes a further project concerning the study of the trans-European railway axis (TEN-T) 24 Genoa-Rotterdam (Arnone et al., 2016). The CoDe24 project focused on the European railway network connecting the ports of Genoa, Italy, and Rotterdam. The international scope of the project required a geographical diverse partnership. Project members represented all the nations crossed by the corridor: Netherlands, Germany, France, Switzerland and Italy. The same diversity was required from disciplinary backgrounds and skills. Since the main purpose of the Code24 project was the interconnection of spatial, transport, economic and ecological development along the railway services, the disciplinary fields of members were varied. As a consequence, the communication between the partners was complicated by the presence of several typologies of languages. Thus, a common platform was needed for information sharing. A first GIS platform hosted by the ETH of Zurich was used, after which all data concerning the Code24 project were moved into a GISualisation project.

3.1 Data collection and representation

Data about the Corridor 24 Genoa-Rotterdam project were gathered from different sources and collected in a number of databases. In order to share the information among the partners of the project and public users with different skills and backgrounds, databases were structured to be displayed in the simplest of interfaces. Four main typologies of data were identified:

- Quantity grouped by Nomenclature of Territorial Units for Statistics (NUTS);
- Typology of railway tracks along the corridor;
- Origin-Destination (OD) lines;
- Integrated services.

Each of these typologies of data was uploaded in GISualisation, through which it can be explored at different levels of detail (Figure 1).

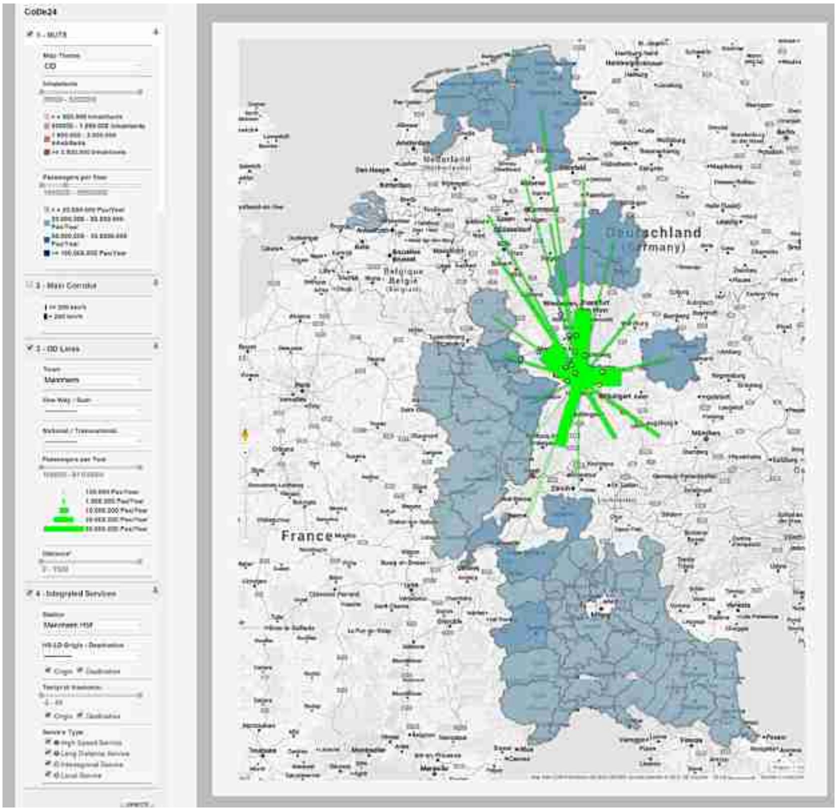

Figure 1. Screenshot of CoDe24 project within GISualisation, representing an example of data visualisation and map overlapping.

The first typology is conceived to show the territorial context in terms of the number of inhabitants and the number of passengers per year. Data are grouped into territorial units for statistics (NUTS) and are visualised by means of a colour gradient scale. Through a slider cursor, users can select are as corresponding to a specific range of values, so as to customise the views and to provide the possibility to visually inter-relate this data with other information (Figure 2).

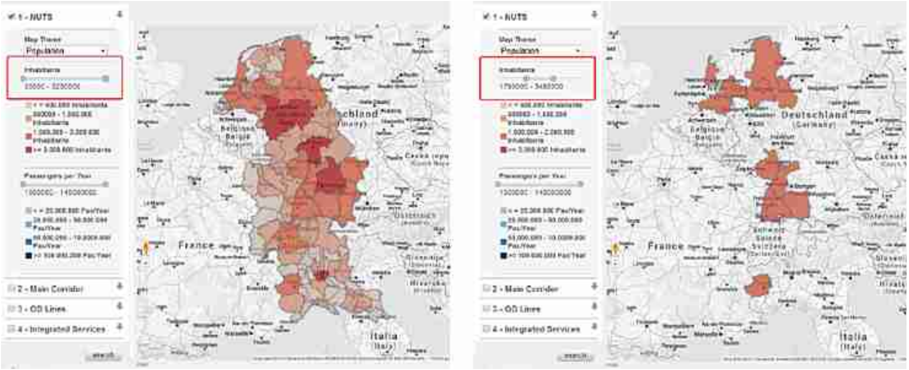

Figure 2:

Figure 2. The comprehensive data concerning the number of inhabitants along Corridor 24 (on the left) and the selection of regions within a specific range of population (on the right).

The second typology of data cannot be filtered but it is useful in understanding the route of trains along the corridor on the basis of their speed, that is, lower or higher than 200 km/h.

The third typology concerns the Origin–Destination (OD) Lines, and has been provided by ETIS+ project (ETIS plus, 2010). In this section, users can decide to display data by applying a number of filters, such as origin town, typology of direct services as one direction or sum of both directions, national or transnational services, number of passengers per year and distance in km (Figure 3).

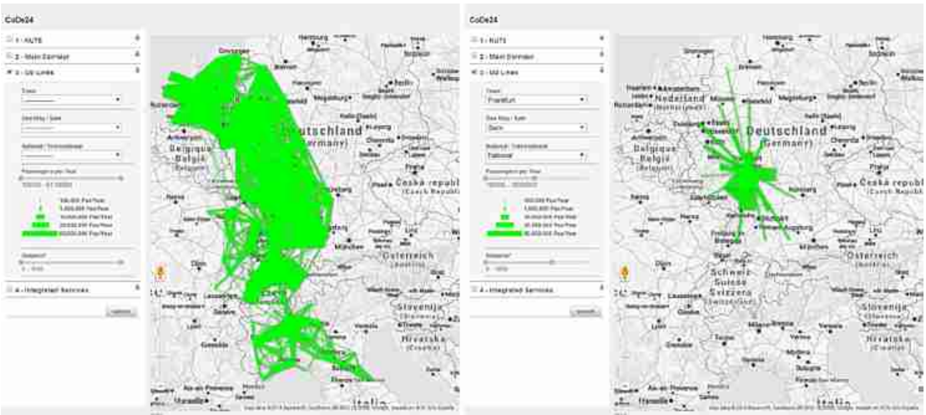

Figure 3. On the left, the figure shows all the OD lines along the corridor. On the right, data have been filtered in order to show the situation in the city of Frankfurt, by considering selected ranges of data.

The fourth and last typology is designed to investigate the integration among the different railway services (e.g. High Speed (HS) and Long Distance

(LD), or InterRegional (IR) and Local (L) trains) through several stations along the corridor. This section takes in consideration data concerning trains arriving in each station from 8.00 to 9.00 a.m. and provides information for all possible destinations that can be reached combining HS/LD with IR/L services within a specific transfer time frame (Figure 4).

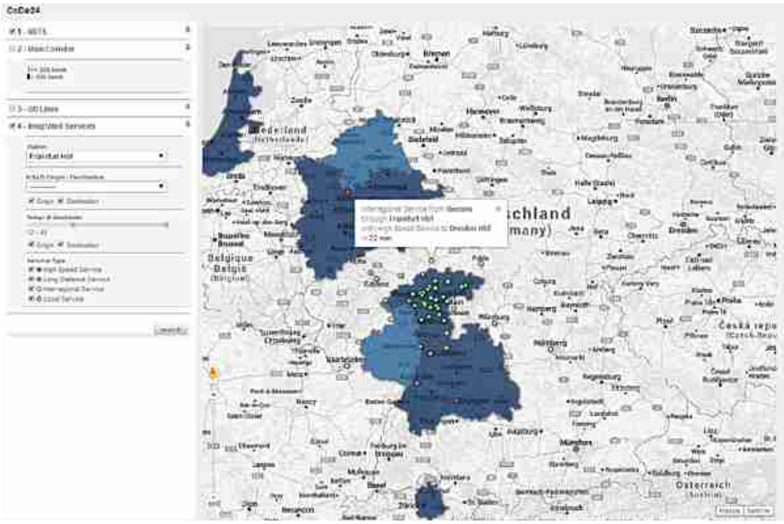

Figure 4. Selection of integrated services at the station of Frankfurt Hbf, with a transfer time ranging from 12 to 45 minutes, overlapped with NUTS areas with more than 85.000.000 Passengers per Year.

3.2 Visual analysis and collected information

The visualisation provided by the use of such WebGIS tool increases the opportunity for discovering the hidden information included in the records of a dataset. Charts, tables, filters and maps enable the visual analysis of data. At the same time, users have the possibility to overlap different maps and see the combination between several typologies of data (Figure 5).

Figure 5. Overlapping of different maps to see the combination between several typologies of data and to investigate the spatial distribution of services.

In particular, data can always be related to their spatial location, thus allowing users to understand the connections between data and their spatial influence. For example, users can easily understand the distribution of railway services along the corridor Genoa-Rotterdam. First, the different sets of data, and their sequence in the menu on the left side of the graphic interface, work as a guideline in the exploration of data, facilitating users in choosing the element to be investigated. Second, the use of maps makes it easy and intuitive to understand the localisation and distribution of areas with the highest and lowest levels of railway facilities. The map can show the density of connections between the Northern and Southern parts of the corridor, but they can also show if these connections are used. In fact, some slider cursors allow the user to customise the data visualised and to determine the values of parameters such as the number of passengers per year, the lines supporting high-speed trains or the integration between different trains in the stations of major cities along the corridor.

In this case study, the visual analysis of data has been applied to study the railway infrastructure and facilities along the corridor. Although it does not provide calculations, nor quantitative values, its outcomes can be used for the construction of a rationale, which can be shared on a common platform with all the actors involved in the process. Such a visualisation can be used later as the basis for the discussion of possible strategies or planning solutions. Therefore, the use of a dynamic visualisation tool proved effective in highlighting some issues in the European railway system that can be discussed with the partnership of the CoDe24 project.

4. CONCLUSIONS AND OUTLOOK

Through the visual analysis of spatial data, GISualisation offers a new approach to actors involved in the planning process, tasked with detecting critical areas and improving the urban planning process. Spatial data can be investigated and visually analysed so that users can perceive the direct relationship between data by their own visual experience, thereby reaching a new awareness of the information visualised. The visualisation of data can be organised on the basis of specific requests in order to meet the goals of a planning issue as far as possible. Its interactive interface removes the waiting times during collaborative meetings such as workshops or decision-making sessions, thus offering a dynamic platform for building shared knowledge. In fact, the visualisation acts as a common element on which discussions can be based, so that it can aid real time exploration of "what if" scenarios requested by the different actors.

In some cases, GISualisation can offer a valid substitute of spatial models, especially when the overlapping of geo-referenced data can provide exhaustive responses to the planning issue on its own. The visual analysis of the values of a specific element, also in its temporal evolution, can provide users with a large amount of information, so to enable users to apply their personal experience and skills in understanding trends, critical and robust areas, as well as possible planning solutions. In this way, users are supported in exploring and intuitively understanding spatial data, while, at the same time they are involved with the whole suite of their professional experiences in the reasoning about the future of an area. In other words, the tool can show the single pieces of a complete puzzle, but the responsibility of re-composing the final form is left to the human knowledge of the planners.

GISualisation is a tool for the visualisation of data. This means that it can work as a common platform for the sharing of information between people, especially in collaborative and participatory sessions, where the need for a homogenous form of communication is essential to improve the awareness of participants.

The tool is now facing a new implementation concerning the graphic interface, the back-end interface and its user-friendliness, which should increase usability by non-expert users. Further developments concern the integration of GISualisation within the Interactive Visualisation Tool (InViTo) (Pensa, Masala, & Lami, 2013; Pensa & Masala, 2014). GISualisation is now the data-filtering component of InViTo. This combination with a multi-criteria analysis tool strengthens the capabilities of the web platform. Today, their combination empowers users to manage and explore data concerning cities and territories, while also providing a method for applying mathematical curves in the visualisation of sets of data. Depending on the type of case study, the tool can be adapted and customised to visualise different type of data, ensuring the possibility to explore the relationships between data.

To conclude, GISualisation does not have the capability of replacing a large-scale model, but aims at opening the gaze on data-oriented landscapes which concern the management of a huge number of data sets, and the common need for simplicity and user-friendliness. Its purpose is to alleviate the daily practice of many planners who deal with large amounts of data which are often incomplete or unsuitable as an input in complex models. Furthermore, it offers a human-centred tool, which, while not providing a solution, supports planners in improving their idea and sharing it with the other stakeholders. Thus, a new approach to geo-referenced data in planning can be useful in finding new and simple systems which stand to improve the planning practice and the role of the planner itself.

The usability of the tool has been proven during a number of workshops and meetings. Nevertheless, additional considerations could be developed on how professionals, decision-makers and stakeholders perceive the usability and utility of digital tools. If individual technical skills affect the ease of approaching such instruments, a general mistrust manifests itself when the use of a tool is not adequately presented. This experience showed that single users do not autonomously use spatial support tools. Their utility is recognised only when they have been introduced with sufficient explanation. Thus, although the interface was studied to guide the users in the exploration of data, the use of the tool requires human interaction in the form of a facilitator who can lead the professionals in exploiting its utilities. Despite the high usability, tools by themselves cannot substitute the process of discussion and/or debate, nor can they substitute the presence of a project leader who can direct the process of data analysis, exploration and knowledge.

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