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Spatial Planning in the Big Data Revolution



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Spatial Planning in the Big Data Revolution

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Towards Knowledge-Based Spatial Planning 1

Robert Laurini, Knowledge Systems Institute, USA

For millennia, spatial planning has been based on human knowledge about the context and its environment together with some objectives of development. Now, with artificial intelligence and especially knowledge engineering, practices of spatial planning can be renovated. Presently, novel practices can be designed. In addition to human collective knowledge, some new chunks of knowledge can be introduced, coming from physical laws, administrative regulations, standards, data mining, and best practices. By big data analytics, some regularities and patterns can be discovered, which again will lead to new actions towards cities: in other words, there is a virtuous circle linking smart territories and big data that can be the basis for novel spatial planning. The role of this chapter will be to analyze those new chunks of knowledge and to explain how human knowledge, possibly coming from different stakeholders, can be harmonized with machine-processable knowledge as to be the basis for territorial intelligence.

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Many methods for intrinsic quality assessment of spatial data are based on the OpenStreetMap full-history dump. Typically, the high-level analysis is conducted; few approaches take into account the low-level properties of data files. In this chapter, a low-level data-type analysis is introduced. It offers a novel framework for the overview of big data files and assessment of full-history data provenance (lineage). Developed tools generate tables and charts, which facilitate the comparison and analysis of datasets. Also, resulting data helped to develop a universal data model for optimal storing of OpenStreetMap full-history data in the form of a relational database. Databases for several pilot sites were evaluated by two use cases. First, a number of intrinsic data quality indicators and related metrics were implemented. Second, a framework for the inventory of spatial distribution of massive data uploads is discussed. Both use cases confirm the effectiveness of the proposed data-type analysis and derived relational data model.

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Ramgopal Kashyap, Amity University Chhattisgarh, India

The period of vast information and examination has arrived and is changing the world significantly. The field of information frameworks ought to be at the bleeding edge of comprehension and deciphering the effect of the two innovations and administration to lead the endeavors of business to inquire about in the information period. In this chapter, the author investigates administrative issues of business change coming about because of the original appropriation and inventive uses of information sciences in business. The author ends by giving an analysis of big data that covers all the analytical processes and future research headings.

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The continuous evolution of internet of things technologies is constantly evolving the concept of smart cities as well as the surrounding environments. From pervasive sensors through computational nodes at the edge of the network to the cloud and final user applications, the data flow chain makes available to the user a very large and heterogeneous amount of data. IoT platforms are at the core of this chain, providing seamless access to data independently from the hardware devices and making possible the interoperability with other data sources (e.g., GIS, SIM, etc.). Despite the availability of IoT platform solutions either commercial and open-source, research is still very active to design and implement flexible, easy-to-use, and efficient web-service-oriented software infrastructures. This chapter will review the current IoT platform infrastructures making also reference to state-of-the-art solutions in literature and proposed in recent research projects. The chapter will outline the main challenges and directions about future platforms, putting them in the context of realistic case studies.

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The Walkability of the Cities: Improving It Through the Reuse of Available

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Franco Vico, Politecnico di Torino, Italy

The issue of city walkability is nowadays a theme in evidence. The chapter proposes a two-level reasoning. At the city level, the goal is to recognize the parts where actions aimed at improving walkability can be more effective. The second level is more detailed: lacking pedestrian paths' specific graphs, the urban space is modeled through a raster with 1x1 m. cells. Considering a series of criteria, an impedance has been assigned to each cell (i.e., the cost of travelling the cell on foot). This approach is applied to the city of Torino (Italy), but it is largely generalizable.

To calculate this impedance, inter alia, the Torino geo-topographic database was used. The elaborations described in this chapter are seen as an aid to stakeholders to reason on city walkability and to compare different points of view in an explicit and articulated way.

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The urban decision processes should be optimized according to the current “green” context. Despite the literature advocating for an open availability of data to facilitate higher quality science and a more effective science-policy boundary, one of the main challenges when dealing with energy processes is the absence of accurate data. This chapter aims at illustrating a stakeholder-oriented approach based on multi-criteria analyses (MCA) in defining the set of evaluation criteria and their relevance in supporting the development of “what if” urban energy retrofitting scenarios. In this regard, the SRF method has been used highlighting that the most important criteria for the problem in exam are related to economic and environmental aspects. In this context, big data visualization and geographical locations of the alternative scenarios, producing presentation features and performing spatial operations are fundamental. Hence, the authors supported the decision process through MC-SDSS to optimize the urban decision purposes. The results of this chapter are part of the national project EEB.

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In the last decade, the value of big data for social sciences is declared to be high for its social impact. This kind of data is currently applied to create a wealth of constantly updating information that in the spatial domain are generally used to support decision making. This chapter falls under this heading, and it presents the results of a research program developed by an interdisciplinary research team of the Interuniversity Department of Regional and Urban Studies and Planning of Politecnico di Torino for the Autonomous Province of Trento in which the

Territorial Integrated Evaluation methodology was applied for evaluating regional development and designing territorial scenarios. According to the results of the research, TIE methodology proposes a smart approach to territorial evaluation as it links the strategic dimension of evaluation to the regional planning process. Starting from the TIE methodology, the chapter aims to represent a small step in the theoretical discussion on the big data in social sciences discussing its potential role for territorial evaluation.

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Ecosystem Service Evaluation for Landscape Planning Policies: Addressing Data Availability Issues 177
Emma Salizzoni, Politecnico di Torino, Italy

Ecosystem services (ES) are the subject of a constantly growing attention at the international level. Although in the most recent years significant progresses in ES evaluation have been made, important methodological challenges still exist. Among these, data availability is perhaps the most urgent one. High quality, spatially explicit, appropriate to the evaluation scale, and accessible data are needed to pursue an effective and reliable ES evaluation. These criteria drove the selection of data in a research relating to the assessment and valuation of forest ecosystem services (FES) in the Sardinia Region. However, it is not always possible to reach such data-quality targets. Big data could be an important resource to fill information gaps in the field of ES evaluation, though certain big data limitations suggest their careful management. Starting from the current research’s outcomes with regard to assessment and valuation of FES in the Sardinia Region, the role of big data for supporting ES evaluation is eventually addressed.

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Liliana Ardissono, Università degli Studi di Torino, Italy

This chapter focuses on the theme of the spatial representation of cities and the territory and the collaborative construction of territorial knowledge. The described research concerns the “OnToMap. Mappe di Comunità 3.0” project, focused on the definition of a methodology that implements a semantic representation of territory. That type of representation supports the description of big and open data and of its properties in a unified language. OnToMap enables the sharing of information on

the web by providing an integrated perspective on territorial data, as demonstrated in an experimentation with Ph.D. students of the Politecnico di Torino. OnToMap is also part of the H2020 funded project WeGovNow, based on the integration of GIS tools, VGI practices and Web 3.0 applications: an example of citizens' involvement in the urban redevelopment process of Parco Dora in Turin, which aims was make more inclusive (in terms of empowerment) and efficient urban planning policies.

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This contribution presents the methodologies and the results of an action-research project called Teencarto carried out by the University of Turin and the City of Turin. The project involved more than 600 teenagers from 16 high schools, in a massive process of community mapping aiming at producing a representation of their urban geography. Data collected has been analyzed to make evident the way teenagers use the city as well as how they imagine a better city. The mapping process is based on First Life, a map-based social network, which aims at reconnecting digital and real spaces, using cartographic representations and crowdsourcing. The teenagers' geographies emerging from this large-scale mapping activity reveal the crucial role of four types of "piazza" (Italian word for square) as meeting points: real squares, green squares, commercial hybrid squares, and nightlife squares.

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A Territorial Dimension Can Be Useful for Managing Long-Term Regional

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Alessandro Sciullo, IRES Piemonte, Italy

Sylvie Occelli, IRES Piemonte, Italy

Analysis of road crashes at the local level is necessary for targeting and implementing effective countermeasures. This chapter presents a contribution to this task. It describes the research carried out in Piedmont, Italy, where an exploratory approach has been used to link road crash data with information about the spatial characteristics of urban settlements. The analytic strategy is developed in three steps. First, fine-grained spatial data for road crashes, land use, traffic counts, and population distribution are linked by GIS methods. Second, a selection of the data is implemented at the municipality level and processed through a cluster analysis to identify territorial accident profiles. Finally, to show their analytic potential, one case study is discussed that considers road segments as main observation units.

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Alessandro Scuderi, Università degli Studi di Catania, Italy

Luisa Sturiale, Università degli Studi di Catania, Italy

Social networks in the public sphere support the process of innovation that aims to make the action of the municipalities more efficient and participatory. Due to their characteristics, social media seem to be able to contribute significantly to the development of e-governance and e-democracy as tools based on dialogue and on the enhancement of the contribution of users-citizens or, more generally, of users-local stakeholders. Web 4.0 and social media are progressively taking on a role of primary importance in the contemporary socio-economic context, contributing to change not only the processes and methods of communication of individuals, citizens and businesses, but also the organization and business management itself. In the new dimension of the Web 4.0 the user's behavior is not predetermined, but the user can derive and autonomously build the services, as the web is decentralized and enriched by the experiences of the users who participate in the definition and improvement of content.

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Sarmada Madhulika Kone, Sri Venkateshwara College of Architecture,

India

A city is a real-time function with constantly changing variables. Rapid urbanization of the cities and increase in a number of mega cities has made the entire urban management complex. With many parameters involved in it, urban data has started to resemble the characteristics of big data. The nexus between spatial cognition and the frequency of data collection of an urban system explains the role of big data analysis in performance monitoring of the urban systems. Urban data collection and analysis can be possible through participatory planning and participatory citizens. This chapter focuses on understanding the correlation between spatial cognition and participatory planning.

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Preface

SMART AND RESILIENT CITY: A FUZZINESS OF DEFINITIONS

Smart city and *Resilience*, as *Sustainability* from the Nineties (Sen, 1985), if tend to widen their scope and application field, are likely to become less precise and lost their relevance. These concepts seem to appear unfocused and can be read as “semantic utopias” (Gabellini, 2016) or as “umbrella terms” (Cecchini, 2018). For this reason, it is not always easy to understand what is meant by *smart city*, or *resilient city* also because their meaning has taken on a more all-encompassing sense, as these concepts have been extended to respond to emerging issues.

But these concepts, in their strength of interpretation of the territory as a complex system, allow us to develop a different perspective regarding the traditional and also emerging problems and the analysis, evaluation, planning and management processes. This aspect is also well declared by the UN Sustainable Development Goal¹ n. 11 “Make cities inclusive, safe, resilient and sustainable”: “Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. With the number of people living within cities projected to rise to 5 billion people by 2030, it’s important that efficient urban planning and management practices are in place to deal with the challenges brought by urbanization”. To make effective these issues, the city needs to be “smart” and open to innovation based on data accessibility and knowledge sharing.

Many challenges exist to maintaining cities in a way that continues to create jobs and wealth without straining territorial and landscape resources. Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing, declining infrastructure and rising air pollution within cities. Rapid urbanization challenges, such as the safe removal and management of solid waste within cities, can be overcome in ways that allow them to continue to increase and grow, while improving resource use and reducing pollution. One such example is an increase in municipal waste collection. There is a need of a future in which

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cities provide opportunities for all, with access to information, basic services, energy, housing, transportation and more.

As comparing some recognized definition of smart city, it is possible to note the proximity to sustainable and resilient approach and the relevant fuzziness around these concepts. The set of many proposed definitions over the years can really be considered an ensemble of contradicting meanings and unclear measures (Cavada et al., 2014): “A smart city is one that has digital technology embedded across all city functions” (Smart City Council 2014); “A city can be defined as ‘smart’ when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement (Caragliu et al., 2009); “City building was highly democratized, decentralized, free-flowing and adaptive, just like its social and economic life . . . this organic growth of classical cities holds several lessons for future smart cities. First, by imposing a preordained design, centralized planners often fail to create a city that is tailored to inhabitants’ needs, that reflects their culture or that creates the rich mix of activities that distinguish great places. Second, top-down visions ignore the enormous innovative potential of grass-roots efforts. By providing finished solutions rather than new raw materials for building the physical and social fabric of smarter cities, top-down designs rob themselves of any capability to invent new ideas for how to make cities better. Finally, a focus solely on efficiency ignores fundamental civic goals such as social cohesion, quality of life, democracy and the rule of law. Improving sociability through technology, however, does target these needs, while also unlocking new approaches to efficiency” (Ratti & Townsend, 2014); finally, “Healthy cities and intelligent territories make a real and concrete realization of the right to the city and to the environment for all. . . . It is not possible to think about smart cities that are not primarily healthy cities, although it is true that the use of new technologies can give a fundamental impulse to rethink and realize the quality of urban life” (Cecchini, 2018). The Smart City, with the enthusiastic and widespread use of new technologies, has so far seemed the most convincing answer. According to Maurizio Carta (2017), in order to fully exploit the innovative and creative potential of cities, a new urban paradigm is needed, that of the Augmented City: a “spatial / cultural / social / economic device to connect the components of contemporary urban life, individual and collective, informal and institutional, generating well-being and happiness”.

Also for the Resilient City, definitions are numerous and heterogeneous: this term appeared in 2002 in the “Resilient Communities Program Concept” and in 2004 it was used as a “metaphor . . . to help link ecology and planning” (Pickett et al., 2004), as they “have the capacity to absorb disturbance and reorganize while undergoing change, so as to still remain essentially the same function, structure,

identity, and feedbacks” (Walker et al., 2004). Many other definitions have been provided by researches (Newman et al., 2009; Fusco Girard et al., 2012), others by organizations (World Bank Group, 2011) or private foundations (Rockefeller Foundation, 2014). Nevertheless, all the available definitions agree on the main idea that a resilient city is a city capable to absorb external pressures or to adapt or transform in front of such pressures, guaranteeing the safety of settled communities and the preservation of its basic functions during crisis.

Recent research works have further extended the concept of resilience, defining the latter as a “dynamic interplay of persistence, adaptability and transformability across multiple scales” (Folke et al., 2010). Moreover, some researchers have pointed out the importance of “continual learning” (Cutter et al., 2008), “co-evolutionary process” (Davoudi, 2018), providing an idea of resilience as “bouncing forward”, which includes the idea of “improvement of systems” essential structures and functions.

As a consequence, with regard to the smart city and resilient city concepts, there is no univocal definition (Moser et al., 2014), but there is a focus on environmental issues, on energy consumption, on the importance of human capital (Florida, 2003), on the sociotechnical controversies of urban phenomenon (Duarte & Firmino, 2018). We could add to this a technological approach that focuses on fixed territorial capital and a holistic approach that takes into account all the components that characterize urban systems (Kunzmann, 2014).

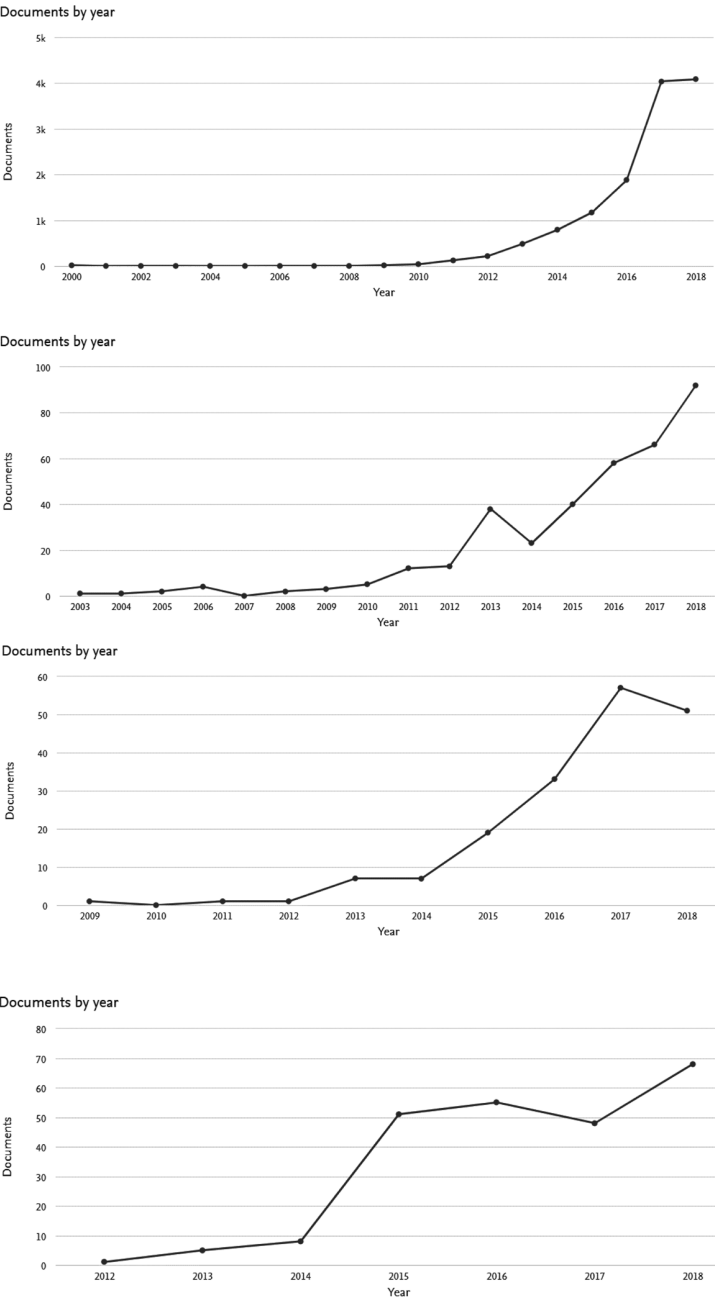
Therefore, the international theoretical consideration on these terms highlights an endemic use of these concepts: smart city is really consolidated in literature while resilience is strongly increasing in the last years, declined according to different meanings and variations (in terms of socio-ecological, environmental, climate change, risk and disaster, etc.). Alongside the theoretical thinking, a variety of international practices, a redundancy of terms and a growth of international literature that links the two concepts of *smart city* and *resilient city* are noted. Figure 1 shows the number of quotations of the documents comprising the definitions of “smart city” and “resilient city” included in the Elsevier’s Scopus database in the last years.

This redundancy, from a quantitative point of view, shows a significant attractiveness of the two concepts with respect to the urban question, because they offer solutions and opportunities to solve territorial problems and because they are recognized as concepts that are not uniquely defined above all from the operational point of view by the scientific community and considered as rhetorical attributes of an urban system (Hollands, 2008; Caragliu et al., 2009). These concepts are interpreted through an extreme variety of definitions and objectives, because they refer to multidisciplinary notions with vast possibilities of disciplinary and social aggregation around a generally vague and ambiguous definition (Cavada et al., 2014).

We can consider a kind of evolution: from a meaning that considered as “smart” a city where the role of technology was strong and pervasive, to a city

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Figure 1. Comparison between the number of citations of the terms “smart city” (first), “resilient city” (second), “smart+resilient city” and “big data+urban planning” (third) in the documents (titles, abstracts and keywords) included in the Elsevier’s Scopus database between 2000 and 2018.
Source: Authors’ elaboration.



whose multidimensional character makes it “resilient” thanks, first of all, to the empowerment of its citizens.

Smart City has moved from a technological to a digital meaning, which focuses attention on smart infrastructures (until 2000, see Mathew, 2013), towards the consideration of social inclusion that focuses on human capital (starting from 2005), and governance (Cohen, 2012). It finally has shifted towards the consideration of the need to guarantee a high quality of urban life (starting from 2010), thanks to the instrumental and big data analyses.

Resilience can be considered a shift from an engineering approach (that is linked to the set of techniques focused on ensuring, within a stressed system, the return to the initial state) to an ecological approach (in terms of searching for a new ecosystem equilibrium), up to the so-called socio-ecological approach (Berkes et al., 2000). Consequently, from the resilience we have moved on to the concept of “(anti)fragility” and “prospering in disorder” (Taleb & Douady, 2013). Resilience is therefore not just one additional urban policy, but is rather a paradigm that can have an impact on urban policies as a whole, to accompany their formulation and evaluation over the medium and long term, thanks also to a greater availability of urban data.

Big data is an important source from which to draw useful information for the development of a resilient city, because it is characterized by a high amount of data and a variety of information coming from multiple sources, which need an adequate analytics tool to be interpreted and processed correctly, in order to help decision-making and to improve the responsiveness of a city.

Albeit with due attention to the risky redundancy of concepts, it is useful to reflect on and analyse the wide overlaps between the plans and the urban projects based on a “smart” logic and those guided by the paradigm of the “resilience”. How digital technologies, openness and accessibility of big data can contribute to the smart and resilience of the city? And how, on the contrary, can these same elements represent risks or obstacles? These are open questions which an activity of comparison, exchange and evaluation among the chapters can begin to give some answers.

TECHNOLOGIES AND BIG DATA TO FACE URBAN CHALLENGES

New technologies are becoming more advanced to face complexities of the urban environment: the huge amount of constantly generated data (e.g., sensors) creates new urban data layers and is one of the many facets of what has been called “big data cities” and “programmable cities” (Kitchin, 2011).

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Big data are, in fact, directly connected with the possibility to include in the used databases, data and information that previously could not be treated as data. This information, as well as providing the necessary databases for the development of statistical high correspondence analyses, also interacts with new kinds of data basins, thus increasing the range of possible applications. This new dimension allows to develop methodological actions and to better manage urban transformations able to adapt in real time to different urban needs and to enhance urban quality and health.

The volume of data in the world is increasing exponentially. By some estimates, 90% of the data in the world has been created in the last two years, and it is projected to increase by 40% annually. A large share of this output is “data exhaust”, or passively collected data deriving from everyday interactions with digital products or services, including mobile phones, credit cards, and social media. This deluge of digital data is known as big data. Data is growing because it is increasingly being gathered by inexpensive and numerous information-sensing, mobile devices and because the world’s capacity for storing information has roughly doubled every 40 months since the 1980s.

This amount of data constitutes a digital city, contemporarily perceived and lived with the real one. This is the “big data revolution”: the opportunity to improve the data that is essential for decision making, accountability and solving development challenges but also to valorise everyday life. The big data revolution, which encompasses the open data movement, the rise of crowdsourcing, new ICTs for data collection, and the explosion in the availability of open data, together with the emergence of artificial intelligence and the Internet of Things (IoT), and data from other sources, such as qualitative data, citizen-generated data and perceptions data, is already transforming cities and citizen’s life.

Advances in computing and data science now make it possible to process and analyse big data in real time. New insights collected from data mining can complement institutional statistics and survey data, adding depth and nuance to information on human behaviours and experiences. The integration of this new data with traditional data should produce high-quality information that is more detailed, timely and relevant. Does this new pervasive dimension of continuous big data collection require a completely new urban space? Many initiatives underlying the development of smart cities, and therefore focused on the dissemination of information technologies, seem to respond not so much to a real need but rather to the justification of large-scale urban transformations, with the risk of ultimately producing unattractive urban areas.

The UN Secretary-General’s Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG) has made specific recommendations on how to address these challenges, calling for a UN-led effort to mobilize the big data revolution for sustainable development²:

- Fostering and promoting innovation to fill data gaps: new technologies offer new opportunities to improve data, if they are used for the common good. The IEAG proposes a program for experimenting with how traditional and new data sources (including big data) can be brought together for better and faster data on sustainable development, developing new infrastructures for data development and sharing (such as a “world statistics cloud”), and supporting innovations that improve the quality and reduce the costs of producing public data.
- Mobilizing resources to overcome inequalities between developed and developing countries and between data-poor and data-rich people: the need for increased funding and resources, used both to develop national capacity and global data literacy, and for public-private partnerships to leverage private sector resources and knowledge in the global interest.
- Leadership and coordination to enable the data revolution to play its full role in the realization of sustainable development: a global effort to improve cooperation between old and new data producers, ensure the engagement of data users, and develop global ethical, legal and statistical standards to improve data quality and protect people from abuses in a rapidly changing data ecosystem.

Therefore, considering these aspects that are all related to smartness and resilience, we can identify at least the following innovation topics:

- Improving knowledge and processes of spatial analytics and the evaluation activities;
- Enforcing territorial awareness and social learning.

Regarding the first topic, we can say that the greater availability of information (big data from web and sensors) is not only changing the process of analysis and knowledge of territory, but is changing the way we live the urban environment and with which the administrations deal with urban transformations. In this regard, central is the role of the “geographic knowledge” for information and planning (Laurini, 2018) which helps in understanding how the adaptive city that self-learning can guarantee: resilience is a way to ensure effective sustainability in the development of socio-ecological systems; it can contribute to the adaptation challenge. Big data could be an element of innovation of the current models of development of cities and territories and as a key to trigger adaptation responses:

- To face climate change and reduction of natural resources;

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- To guarantee territorial quality for local communities and socio-economic development;
- To tackling territorial risks and innovate risk management strategies.

Regarding the second topic, although, it is important to underline that technology should be first of all “empowering”, giving citizens enough information to let them make decisions and contribute to make urban policies effective. Technological advancements in the contemporary city have empowered people – especially in urban settings – to interact through a variety of social channels (e.g., phones, emails, and social network tools). Despite of this digital transformation, the roles of physical space in facilitating human social interactions have never become irrelevant. Understanding how effectively people are brought together in physical space is not only important to urban design, but also to the well-being of people and society.

But urban planning is following the same process as what happens on the web: too many information available to users, the difficulty of understanding what is useful, a rhetorical manipulation of the community engagement. In this view, “big data revolution city” has also negative aspects, as Richard Sennett thinks: “Let’s think about how our cognitive ability and our experience will diminish, for example, looking at the use of Google Maps: well, people have no idea where it is interesting to walk because they are glued to the phone to get in the most efficient way from A to B. More an experience is smooth, without clutches, more we stop learning” (Sennett, 2018).

Integrating concepts of smart city and resilience with respect to the urban and territorial issues, especially with reference to the characteristics of complexity and adaptivity (Batty 2008), accumulating of territorial knowledge through big data, it is expected to design new micro-theories regarding cities and their long-term innovation and co-evolution. Dealing with this uncertainty is the number one urban challenge and, as the cliché goes, urban planning is the number one opportunity to face this uncertainty (Batty, 2013).

However, smart and resilience thinking could offer a good opportunity to look at our cities with a time-conscious approach and in synergy with the goal of sustainability and a valuable analytical as well as planning model. In this regard, big data can contribute significantly to addressing the different challenges of understanding the complexity of urban systems, burdened by dynamic processes and sometimes difficult to fully understand as comprehensive.

ISSUES

If we try to talk about a next-generation city, we cannot ignore the data, in terms of opportunities but also of critical issues. For this reason, the question is: how big data can help to strengthen forecast scenarios for the next-generation city? Concepts sometimes come explicitly, or sometimes unclear, as relevant metaphors for urban planning and emphasize the three objectives of our book, which are also the parts according to which the book is composed:

1. Building Spatial Knowledge;
2. Supporting Territorial and Environmental Evaluation;
3. Strengthening Territorial Awareness and Social Learning.

In order to face this complex theme, we needed a transdisciplinary approach that involved many different competences and expertise, such as urban and regional planning, landscape planning and design, sociology, territorial and environmental evaluation, economic evaluation, GIS and geomatics, human and cultural geography, political and economic geography, computer science and data mining, territorial knowledge and representation.

Building Spatial Knowledge

The Robert Laurini's contribution "Towards Knowledge-Based Spatial Planning" is focused on a reflection about the notion of geographic knowledge infrastructure and the contribution of big data analytics. By big data analytics, some regularities and patterns can be discovered, which again will lead to new actions towards cities. Laurini explains how human knowledge (including stakeholders' knowledge) can be integrated and harmonized with machine-processable knowledge, that is the basis for the construction of territorial intelligence, extremely important for developing spatial planning scenarios.

Alexey Noskov, Asher Yair Grinberger, Nikolaos Papapesios, Adam Rousell, Rafael Troilo, Alexander Zipf present a work titled "Modelling and Assessing Spatial Big Data: Use Cases of the OpenStreetMap Full-History Dump" in which a low-level data-type analysis based on OpenStreetMap is discussed. It offers a novel framework for the overview of big data files and assessment of full-history data provenance (lineage) about two use cases: first, a number of intrinsic data quality indicators and related metrics were implemented; second, a framework for the inventory of spatial distribution of massive data uploads is debated.

Ramgopal Kashyap gives us in "Big Data and High-Performance Analyses and Processes" an overview about the information frameworks for the comprehension

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and deciphering the effects of innovation and administrative issues given by big data in business. This chapter propose a methodology for the analysis of big data that covers all the analytical process and framework future research headings in this field.

In the chapter “IoT Platforms and Technologies Driving Spatial Planning and Analytics,” Lorenzo Bottaccioli, Edoardo Patti, Anna Osello, Tania Cerquitelli, Enrico Macii, and Andrea Acquaviva propose a review of the current IoT platform infrastructures, making also reference to state-of-art solutions in literature and in some recent research projects. Despite the availability of IoT platform solutions either commercial and open-source, this chapter outlines the main challenges and directions about future platforms, putting them in the context of realistic case studies.

“The Walkability of the Cities: Improving It Through the Reuse of Available Data and Raster Analyses” is the title of the contribution by Luigi La Riccia, Antonio Cittadino, Francesco Fiermonte, Gabriele Garnero, Paola Guerreschi and Franco Vico. The issue of city’s walkability is nowadays a theme in evidence. The chapter proposes a two-level reasoning. At the city level, the goal is to recognize the parts where actions aimed at improving walkability can be more effective. The second level is more detailed: lacking pedestrian paths’ specific graphs, the urban space is modelled through a raster with 1x1 m cells. The elaborations described in this chapter are seen as an aid to stakeholders to reason on city’s walkability and to compare different points of view in an explicit and articulated way.

Supporting Territorial and Environmental Evaluation

Francesca Abastante, Patrizia Lombardi, and Sara Torabi Moghadam, in their chapter “Defining Energy Criteria in the Absence of Open Data: A Stakeholder-Oriented Approach Based on Multi-Criteria Analysis (MCA),” discuss the question of making a Multi-Criteria Analyses (MCA) in defining the set of evaluation criteria and their relevance in supporting the development of “what-if” urban energy retrofitting scenarios. Despite the literature advocate for an open availability of data to facilitate higher quality science and a more effective science-policy boundary, one of the main challenges when dealing with energy processes is the absence of accurate data.

In the chapter “Can Big Data Support Smart(er) Evaluation? Theoretical Consideration Starting From the Territorial Integrated Evaluation Approach,” Grazia Brunetta and Ombretta Caldarice present the results of the research developed by the Interuniversity Department of Regional and Urban Studies and Planning of Politecnico di Torino for Trentino in which the Territorial Integrated Evaluation methodology was applied for evaluating regional development and designing territorial scenarios. Starting from the TIE methodology, the chapter aims to representing a small step in the theoretical discussion on the Big Data in territorial evaluation discussing its potential role.

The contribution of Emma Salizzoni, “Ecosystem Service Evaluation for Landscape Planning Policies. Addressing Data Availability Issues,” is focused on the role of Ecosystem Services (ES), that today are the subject of a constantly growing attention at the international level. Although in the most recent years’ significant progresses in ES evaluation have been made, while important methodological challenges still exist, like the data availability. This chapter shows some criteria for the selection of data in a research relating to the assessment and valuation of Forest Ecosystem Services (FES) in the Sardinia Region. Big data is considered an important resource to fill information gaps in the field of ES evaluation.

Strengthening Territorial Awareness and Social Learning

In the chapter “Semantic Spatial Representation and Collaborative Mapping in Urban and Regional Planning: The OnToMap Community Project,” Angioletta Voghera, Luigi La Riccia, and Liliana Ardissono focus on the theme of the spatial representation of cities and the territory and the collaborative construction of territorial knowledge. The described research concerns the definition of a methodology that implements a semantic representation of territory, with a type of representation that supports the description of big and open data and of its properties in a unified language and that enables the sharing of information on the web by providing an integrated perspective on spatial data.

The contribution of Giacomo Pettenati, Egidio Dansero, and Alessia Calafiore, “Researching and Enabling Youth Geographies in the Digital and Material City: The Teencarto Project,” presents the methodologies and the results of an action-research project called Teencarto. This research involved more than 600 teenagers from 16 high schools, in a massive process of community mapping aiming at producing a representation of their urban geography. Data collected has been analyzed to make evident the way teenagers use the city as well as how they imagine a better city.

Alessandro Sciuillo and Sylvie Occelli, in the chapter “A Territorial Dimension Can Be Useful for Managing Long-Term Regional Road Safety,” describe an exploratory approach has been used to link road crash data with information about the spatial characteristics of urban settlements. The analytic strategy is developed in three steps. First, fine grained spatial data for road crashes, land use, traffic counts and population distribution are linked by GIS methods. Second, a selection of the data is implemented at the municipality level and processed through a Cluster Analysis to identify territorial accident profiles. Finally, to show their analytic potential, one case study is discussed, which considers road segments as main observation units.

In the chapter “Defining Urban Planning Strategy With Social Media Application,” Alessandro Scuderi and Luisa Sturiale underline the importance of social networks in the public sphere support process of innovation that aims to make the action

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of municipalities more efficient and participatory. It is confirmed that in the new dimension of the Web 4.0 the users' behavior is not predetermined, but decentralized and enriched by the experiences of who participate in the definition and improvement of urban policies.

Finally, in the last chapter, "A Planning Model for Cognitive Cities: Spatial Cognition Through a Participatory Approach," Sarmada Madhulika Kone supports the idea that the rapid urbanization of the cities, including the increasing number of mega cities, has made the entire urban management complex. With many parameters involving in it, urban data has started to resemble the characteristics of big data. The relationship between spatial cognition and the frequency of data collection of an urban system explains the role of big data analysis in performance monitoring the urban systems. As urban data collection and analysis can be possible through participatory planning and participatory citizens, this chapter focuses on understanding the correlation between spatial cognition and participatory planning.

The overview that has led our attention to the multiple dimensions of big data applied to natural, technological and social systems, opens new horizons and faces new problems. This book deals in a systematic way this theme and offers vast perspectives that stimulate new reflections on planning, more often interposing and suggesting disciplinary influences.

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- ¹ <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>
- ² <http://www.un.org/en/sections/issues-depth/big-data-sustainable-development/index.html>

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Introduction

We come to this topic from some research experiences in the field of regional, environmental and landscape planning, through in particular two closing research projects: “OnToMap: Mappe di Comunità 3.0 – Community Maps 3.0”¹ and “WeGovNow: Towards #WeGovernment: Collective and participative approaches for addressing local policy challenges”². These projects have been developed in an interdisciplinary research pool that has been compared, even with initial difficulties of mutual understanding, experts in the field of ICT and urban planners.

The project “OnToMap: Community Maps 3.0” (Fondazione CRT, 2014-2019, <https://ontomap.ontomap.eu/>) was developed to facilitate the dialogue between citizens and institutions, enhancing their communication skills through a digital map of the city of Turin. Through OnToMap it is possible to insert, on a specific point of the map, an idea, a proposal, a memory aroused by a specific place. The aim is to convey the knowledge of the perception of places, re-elaborating an indicator of the identity – or of the many characters – of the territory that inhabit the city. Draw with the citizens the spatial configuration of public spaces that best meets their needs, translating the desires into stimuli for the urban planning policies and for design of specific places. OnToMap is based on an ontology (knowledge representation formalism) that allows not only to consult spatial data or spatial information – and enrich them – but also to visualize the semantic relationships existing between spatial concepts. It is also possible to improve the information sources with new spatial data, appropriately classified and that can be integrated into dynamic source databases.

The idea at the basis of the project “WeGovNow: Towards #WeGovernment: Collective and participative approaches for addressing local policy challenges” (Horizon2020, 2016-2019, <https://wegovnow.eu/>) is to develop and validate a digital platform for effectively engaging local civil society in the co-production of citizen-centered services and in the co-development of strategic approaches to community development. The WeGovNow platform is a multifunctional community engagement platform composed of pre-existing civic engagement applications which have been

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integrated with newly developed software components. It includes five functionalities that allow people to: report local problems; vote for local policy actions; network with citizens; create and share information on customized local maps; match offering and demand for collaboration and support in different European territorial contexts (Municipalities of London, Turin and San Donà di Piave).

This book tries to reply to the main open question emerged from these two research activities. How can we build effectively a spatial knowledge, strongly based on the contribution of the communities to planning policies and territorial projects, through online platforms, social media, participatory GIS, that need big and open data? In fact, big data is being increasingly advocated as a fresh and promising approach to urban challenges, particularly through the notion of smart cities, able to contribute to the coping with climate change, citizen empowerment, disaster planning and resilience, health and quality of life, social equity, sustainability, equal access to ICT and urban competitiveness.

The field of big data and new ICT technologies is profoundly modifying the way territorial and urban planning is done, but at the same time it is a path of innovation whose long-term consequences and operational implications are difficult to foresee. It is certainly a very attractive field for researchers and technicians who can apply such theories in various disciplines. Nevertheless, this research issue requires significant awareness in using these data and tools with a real responsiveness of their applicability. Besides, it requires a deep consciousness by web users about the potential uses of community shared data.

The challenge, once again, is to launch curious glances between disciplinary sectors that normally do not communicate and offering new research perspectives on common problems. Applying the concepts and methods of big data science in spatial planning and urban studies is today necessary to understand the evolutionary processes of complex territorial systems: these systems are characterized by the interaction of institutional and socio-economic actors with environmental and landscape resources, making often difficult to understand the dynamics and actions towards predetermined objectives.

These issues are explored by representative experts of different research fields and recognizable in the international literature. In fact, this edited book discusses critical reflections and attempts to hybridize methods and disciplinary approaches to a new challenge. In the book continuous “field invasions” try to treat the complexity of the spatial knowledge by constructing new interpretative categories that are not aprioristically defined and integrated.

In this view, the volume structure collects all these challenges proposing three sections, focusing respectively to the main themes in the spatial planning in the big data revolution:

- Building Spatial Knowledge;
- Supporting Territorial and Environmental Evaluation;
- Strengthening Territorial Awareness and Social Learning.

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¹ <https://ontomap.ontomap.eu/>. The OnToMap project was coordinated by Angioletta Voghera (Inter-University Department of Sciences, Planning and Territorial Policies of the Polytechnic of Turin) and Liliana Ardissono (Department of Computer Science of the Università degli Studi di Torino), with support from Mauro Velluto (Csi Piemonte). Maurizio Lucenteforte (Department of Computer Science of the Università degli Studi di Torino), Adriano Savoca and Noemi Mauro (Department of Computer Science of the Università degli Studi di Torino), Rossella Crivello and Luigi La Riccia (Inter-University Department of Sciences, Planning and Territorial Policies of the Polytechnic of Turin) also collaborated in the project.

² <https://wegovnow.eu/>. WeGovNow project was coordinated by Empirica (Dr. Lutz Kubitschke), with the involvement of Università degli Studi di Torino (Department of Computer Science, Prof. Guido Boella), Politecnico di Torino (Inter-University Department of Sciences, Planning and Territorial Policies of the Polytechnic of Turin, Prof. Angioletta Voghera), Infalia (Dr. Ioannis Tsampoulatidis), LiquidFeedback (Dr. Andreas Nitsche), University College London (UCL, Prof. Artemis Skarlatidou), Mapping for Change (MFC, Dr. Louise Francis), Universität Heidelberg (UHei, Prof. Adam Rousell), Funka Nu AB (Dr. Andreas Cederbom), Fondazione Giacomo Brodolini (FGB, Dr. Antonio Dell'Atti), Città di Torino, (Dr. Fabrizio Barbiero), London Borough of Southwark (Dr. Sean Backhurst), Comune di San Donà di Piave (Dr. Giulio Antonini). This project was funded between 01/02/2016 and 31/01/2019 by the EU Programme Horizon2020.

Section 1

Building Spatial Knowledge

Chapter 1

Towards Knowledge-Based Spatial Planning

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ABSTRACT

For millennia, spatial planning has been based on human knowledge about the context and its environment together with some objectives of development. Now, with artificial intelligence and especially knowledge engineering, practices of spatial planning can be renovated. Presently, novel practices can be designed. In addition to human collective knowledge, some new chunks of knowledge can be introduced, coming from physical laws, administrative regulations, standards, data mining, and best practices. By big data analytics, some regularities and patterns can be discovered, which again will lead to new actions towards cities: in other words, there is a virtuous circle linking smart territories and big data that can be the basis for novel spatial planning. The role of this chapter will be to analyze those new chunks of knowledge and to explain how human knowledge, possibly coming from different stakeholders, can be harmonized with machine-processable knowledge as to be the basis for territorial intelligence.

INTRODUCTION

The use of computing in urban planning began with the Baxter's book (BAX, 1976) which was including several statistical and mathematical modeling aspects. Then gradually cartography and databases were integrated to give the well-known Geographic Information Systems in the 80s. Little by little some spatial analysis tools were included. Now the context is different for several reasons.

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- The existence of many sensors, especially for environment and traffic controls is now mainstream; the consequence is that the novel GIS must capture those data in real time.
- The new development of visualization, giving the so-called geo-visualization has greatly renovated cartography by integrating animation, research of salient features and so on.
- The development of big data has led local authorities to envisage new methods to use those data by enriching their knowledge about city's evolution.
- The trend of volunteered geographic information and the will of people to participate in decision making, under the banner of crowdsourcing have implied the necessity of dealing efficiently with those characteristics.
- Empowerment of people has increased the importance of several stakeholders who can have different logics; those logics can interfere with local authorities and can be in contradiction.
- The advances in artificial intelligence can also be integrated, transforming GIS into Geographic Knowledge systems.
- The multiplicity of experiences in various cities throughout the world has led to new organizations not only for technology watching, but overall by sociological watching, i.e. examining novel experiences which can be imported.

The objective of this chapter will be to study how urban knowledge can help smart urban planning. After presenting the background of this study, we will examine how to combine various types of knowledge.

BACKGROUND

In this section, the concept of knowledge and especially geographic knowledge will be examined. Then a structure of geographic knowledge base will be studied.

Knowledge and Geographic Knowledge

In information technology, it is common to distinguish data, information, knowledge and wisdom. According to Gurteen (1998), the cake metaphor can help understand the differences between those concepts: “data” corresponds to molecular components of the cake; “information” to the ingredients; “knowledge” to the recipe (how to make the cake); and finally, “wisdom” corresponds to know why and for whom to make the cake. In other words, for urban issues, “data” come from sensors, census, aerial or drone photos, satellite images, pools, etc.; “information” corresponds to

the meaning of the data as usual, and finally “knowledge” and “wisdom” for whom and with what objectives to make the city.

All those previous issues lead to consider new approaches in urban planning, especially based on knowledge. So, for our purpose “geographic knowledge corresponds to information potentially useful to explain, manage, monitor, understand the past, plan a territory and innovate”. Let me develop.

1. **Geographic Knowledge to Explain:** It corresponds more or less to Gollege’s definition. Synonyms can be to understand, to explore, to assess the context and to detect problems. Existing books and monographs can help a lot from an historical point of view. Techniques such as geographic text mining (Salaberry 2013) and, when databases are existing, spatial data mining can be the sources of this kind of geographic knowledge. An extension of this category is to consider knowledge to reconstitute the past landscape or to simulate future evolution.
2. **Geographic Knowledge to Manage:** One of the goals of local authorities is to manage the territory under their jurisdiction. The management could range from street and engineering network repairs to school and other public services such as waste collection. The knowledge they have to use is essentially coming from laws, by-laws and best practices. In other words, knowledge is identified in some natural language sentences and must be transformed to become machine-processable. Often, can knowledge be here seen as an extension to business intelligence applied to local authorities?
3. **Geographic Knowledge to Monitor:** This kind of knowledge can be seen as an extension of the previous one, but its nature is totally different. Indeed, local authorities in order to reduce pollution or regulate traffic, install sensors as previously explained to get raw data which are possibly transformed into knowledge by real time data mining.
4. **Geographic Knowledge to Plan:** In my understanding, this is the ultimate goal of geographic knowledge engineering, to plan smart cities or territories. It means to design scenarios of evolution, study alternatives and take citizen’s opinions into account within the scope of sustainable development.
5. **Geographic Knowledge to Understand the Past:** This is another usage of knowledge, for instance in archeology or in history. By examining excavation findings, already-known ancient knowledge can be used to understand, but also the findings can suggest novel theories, for instance for commercial exchange.
6. **Geographic Knowledge to Innovate:** This kind of knowledge is important for the future of the smart cities; it will be essentially based on technological and sociological watches.

Rules constitute a very important component of knowledge. In artificial intelligence, the representation of rules is based on several mathematical theories, such as classical logics. Moreover, according to Graham (2006), Morgan (2008), and Ross (2011), business rules should be considered as first-class citizens in information technology, and, why not, in urban planning? But before examining geospatial rules, it is necessary to revisit certain aspects of geographic object modeling so that to introduce them into rules. For them, rules can be modeled as IF-THEN-Fact and IF-THEN-Action, the first one for generating new data, for instance the calculus of VAT in business, and the second for launching a new action, this action being made by a computer, a robot or a human.

But, for geospatial rules, some other models are necessary (Laurini, 2018), namely:

- IF-THEN-Zone: for the creation of a zone, based for example of its coordinates;
- Co-location rules: “if something here, then another thing nearby”;
- Bi-location rule: “IF something holds in place P, then something else in place Q”, to model the so-called “butterfly effect”;
- Located rule: “IF in a place B, THEN apply RuleB”;
- Metarule: “IF some conditions hold, THEN apply RuleA”.

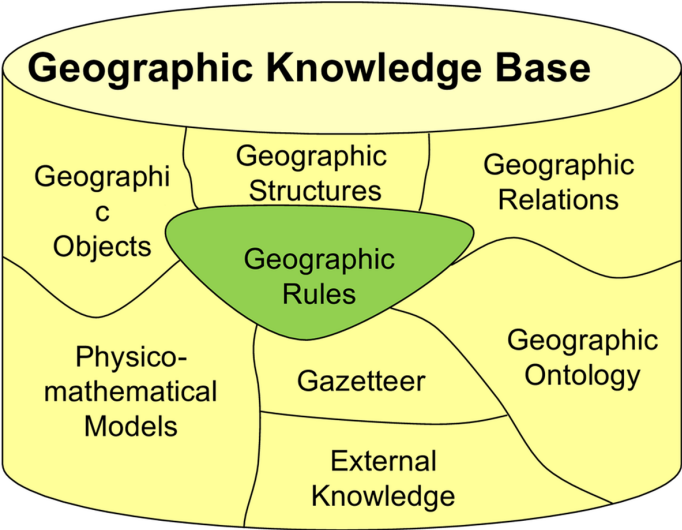
Structure of a Geographic Knowledge Base

In Laurini (2017) a new structure of geographic knowledge bases has been proposed as depicted in Figure 1. They will consist of a set of geographic objects, a set of geographic relations, an ontology, a gazetteer, a set of geographic structures, a set of physico-mathematical models and a set of rules; in addition, external knowledge can also be very useful. For more details, please refer to Laurini (2017a) and Laurini-Favetta (2017). Remember that a gazetteer is a repository for storing placenames, and ontologies for the description of all types and classes of geographic objects. By external knowledge, we mean two things: (i) neighboring knowledge to ensure reasoning continuity, and (ii) knowledge coming from outside for both technological and sociological watches which will be the background for innovation.

Big Data and Big Data Analytics

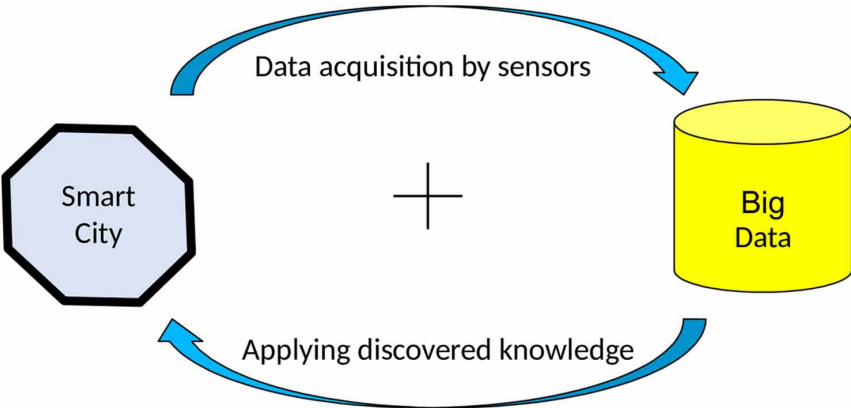
According to Snijders *et al.* (2013), “Big Data” is a loosely defined term used to describe data sets so large and complex that they become awkward to work with, using standard statistical software. Now, with telecommunications and sensors, cities can get lots of data, from which characteristics, regularities or patterns may be discovered through sets of algorithms generally named Big Data Analytics. Among those characteristics, novel knowledge chunks can be discovered.

Figure 1. Structure of a geographic knowledge base



According to Mitchell (2014), Big Data Analytics has several characteristics; among them, mention the necessity to use cloud computing, the importance of “big data lakes”, predictive analysis, new data models and deep learning. Even if the development of those technologies is outside the goal of this chapter, let me only explain the following; in the past, we first designed a data base model and then populated it; but now we do have a “data lake”, *i.e.* without any a priori model. The challenge of big data analytics is so more complex to be achieved. As a consequence, a sort of virtuous circle can be defined as depicted in Figure 2: throughout the smart

Figure 2. The smart city/big data virtuous circle



city, lots of sensors (including user-generated) can measure data which can generate knowledge about the smart city. By accumulating knowledge, it is expected to design new micro-theories regarding cities (Batty 2013).

But there is a great difference with big data relative to the business industry, it is the importance of GIS data. In the general discourses regarding big data, GIS data are rarely mentioned, maybe they are implicit, but rarely explicit as an essential component for smart cities. However, in addition to coordinates which can be easily assigned to sensors, either fixed or mobile, one must and needs to make connections with the shape and location (often 2D, but more and more 3D) of several geographic and urban features.

ORIGIN OF KNOWLEDGE IN SMART CITIES

In a smart city, knowledge chunks can come from different origins and have different semantic meanings. Let's examine some of them, namely physical knowledge, legal knowledge, practical knowledge, associative knowledge and correlative knowledge.

Physical Laws

Those rules are mandatory and must not suffer any exception; they can be considered as components of cause-effect chains. In this category, let us mention any physical geography rules such as rules linked to rivers (floods), diffusion of noise, pollution, earthquake, etc. In other words, they are true implications without any exception.

However, we have to face two categories, permanent conditions and incidental occurrences.

- Consider a city built on a steep mountain or another one on a flat plain: those physical conditions will imply different decisions regarding the structure and the organization of the city, essentially facing mitigation or not of possible disasters.
- Whereas a river traversing a city, the consequences are totally different whenever it is quiet or generating a flood. Similarly, remember the quiet Roman city of Pompei when suddenly the Vesuvius volcano erupted in AD 79. As nobody can forecast the date of the future disasters, mitigation actions must be developed as soon as possible. Another class corresponds to physical events for which some environmental regulations exist, for instance for air pollution. Among incidental occurrences, let also mention rain and hail storms which can damage houses and plantings. Sensors can help a lot to give early alarms.

Those types of knowledge chunks must always hold. However, the second category needs to integrate additional sensor information (often as thresholds) in the chunks.

As some rules can be stated as simple implications, the use of differential equation can often help model those mechanisms.

Rules Coming From Legal Issues

Those rules are mandatory whereas some of them can lead to several alternative options. For instance, in several countries, vehicles are running right. It means that it is mandatory to drive right, but it is possible that some vehicle do not follow this law. In this case, if there is a policeman, they will be subject to a ticket. Anyhow, when structuring a transportation plan, this law is used as a basis.

In urban planning, consider a law in which there are limitations for construction, for instance the number of floors. When a citizen is applying for a building permit, this rule, together with other rules, is mandatory. In addition, in a zone in which this law applies, it is possible that older buildings are higher than actually planned, for instance a very old listed monument (for instance a cathedral). Do we have to demolish them to follow the new planning rule, or to consider them as an exception?

In this category, we can also consider standards and norms relative to socio-economic ratios, such as the number of elementary school pupils.

Various styles of laws can be considered:

- Mandatory laws for which usually sanctions are defined whenever they are not followed;
- Laws allowing certain possibilities; for instance, the possibility to build a new camping site; maybe during years, there will be no camping site.
- Laws opening several alternatives; in this case, one day, one of them will appear.
- Laws prohibiting some types of construction, for instance a stadium downtown.

Those types of knowledge chunks must always hold, except if there are well-known derogations.

Best Practices

By considering a rule such as “when designing a new metroline, move underground networks”, it could be classified as an engineering rule or a best practice. It can look as a legal rule, but it is more a recommendation. In other words, the implication is not mandatory.

Associative Knowledge

The origin of associative knowledge comes from data mining in which one tries to exhibit so-called frequent associations such as $(A, B) \rightarrow C$ meaning that “if we have A and B, then we have often C”, often being characterized by various measures. For instance, Shekhar- Huang (2001) and Shekhar- Zhang, P. (2006) have found they have discovered the following spatial associations:

- (West Nile disease, stagnant water sources, dead birds, mosquitoes)
- (Tow, police, ambulance)
- (Cold front, warm front, snow fall)

Those types of knowledge chunks must hold only if the global performances are better than without using them.

Knowledge Coming From Big Data Analytics, Correlative Knowledge

Knowledge chunks coming from data analytics have a different status. As the causality is either physical, legal or practical, for knowledge chunks originating from data analytics, they are linked by correlation. And correlation does not mean causality. Two well-known Latin sophisms can help us, “Post hoc, ergo propter hoc” and “Cum hoc, ergo propter hoc” which respectively mean “after this, therefore because of this” and “together with this, therefore because of this”. In other words, as the antecedents are clear, and the consequents are also clear, the signification of the implication; maybe it is only statistical coincidence. Under the name of correlative knowledge, they can be considered as a sort of extension of associative knowledge.

But everybody has to be cautious of possibly detected spurious correlations. The website <http://www.tylervigen.com/spurious-correlations> gives a set of spurious correlations such as “the number of divorces in the State of Maine” and the “consumption of margarine” with a correlation coefficient of 0.992558!

Suppose one is interested to reduce the number of road accidents. He is facing two results:

1. The following relation was discovered: “the consumption of sour cream, and the number of motorcycle riders killed in accidents” (<http://www.dailymail.co.uk/sciencetech/article-2640550/Does-sour-cream-cause-bike-accidents-No-looks-like-does-Graphs-reveal-statistics-produce-false-connections.html>).
2. Kumar and Toshniwal (2015) have discovered the following cluster: *“It consists of 69% of two wheeler accidents which are distributed on intersections near*

markets, hospitals, local colonies across highways and non-highway roads. Those accidents which occurred on intersections and curves on highways involved one injury only. Two-wheeler accidents at non-highway locations are mostly involved two injuries”.

Does it mean that, if we want to reduce those accidents, we must either impose limitations of selling or buying sour cream in all shops of the city, or redesign some roads in specific locations? For anybody the second solution looks more relevant. But when we are facing several results from big data analytics, what could be the procedure to detect the more relevant chunks of knowledge? Are they criteria or rules to govern such a selection?

As a consequence, it is interesting when knowledge chunks coming from data analytics hold in one context; but in contrast, no matter when they are not taken into consideration. In other words, the various origins imply various statuses and various semantics. More developments look necessary to clarify those semantics and to imagine their outcomes.

A General Model for Rules

Based on the previous descriptions, a general diagram for rules can be designed regrouping all aspects, their origin, components, temporal dimension, mathematic tools, their management, their usage and the various modes of implication.

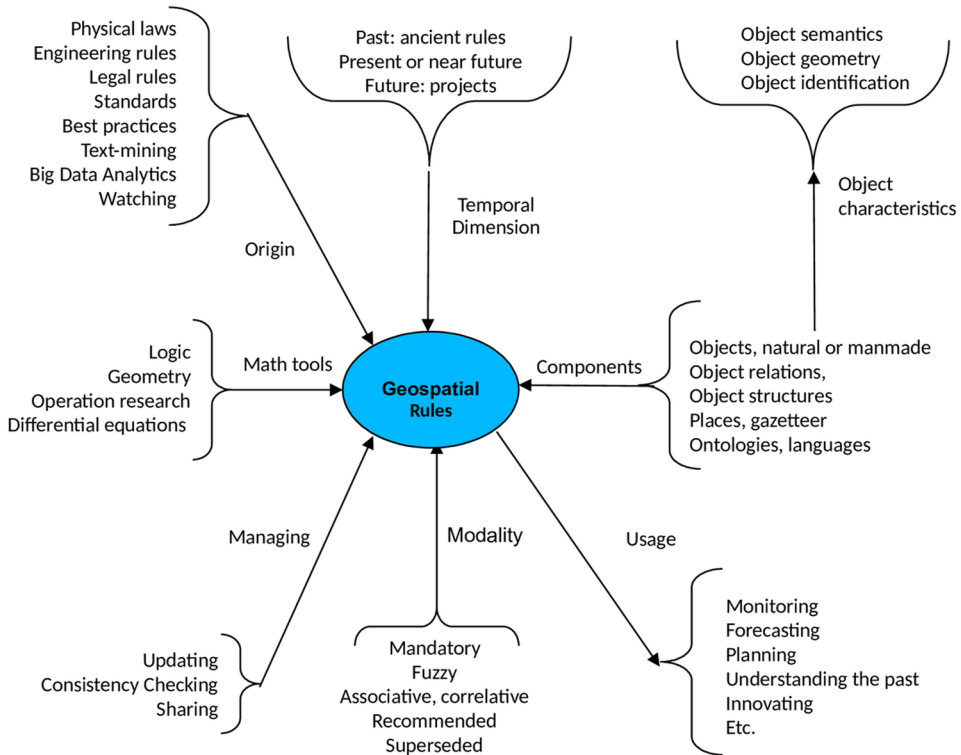
- For physical rules, the implication is mandatory;
- For legal rules, the implication is also mandatory, but the sanctions may or may not exist;
- For best practices, the implication is more or less a kind of recommendation; in other words, nobody is obliged to follow this kind of rules; perhaps some additional conditions could be considered; at a first approximation, random variates can help.

How to Combine Them?

Suppose we deal with many knowledge chunks coming from different origins, some of them being physical, legal, practical, associative or correlative, which can be useful to solve a problem. The big question is “how to combine them?” After eliminating the manual combination, we can face two solutions, the fully automatic, and a hybrid approach.

As far as we know, the solution to combine automatically knowledge chunks for different semantics is not in easy task. If all the chunks are logic-style, Boolean

Figure 3. Main characteristics of geospatial rules



logic is a good background already implemented in system such as Prolog. If we include geometric considerations, the task is a little bit complex. Let's say that more investigations are necessary to envision such an approach

However, by hybrid solutions, we mean solutions based on a man-machine cooperation; and the solution seems possible by some trial and error method by looking for consequences for each knowledge chunks. Let's develop a few cases in the next section.

SPATIAL KNOWLEDGE ON THE MOVE

As previously told, spatial knowledge, and especially geospatial rules can have different modalities and can be used for several key applications. Let us examine few of them.

Knowledge for the Formal Evaluation of Plans

Once a plan is designed, all knowledge chunks are considered to state whether they are followed. A solution is to present all chunks, one by one, against the designed plan. As previously explained, depending upon the variety of chunks, the outcomes can be different.

Concerning permanent physical laws, all the laws must be applied, but concerning incidental physical laws, some priority order may be selected according to some local policies. Those which in the top of the list must be followed. Let's call them mandatory chunks.

Regarding legal chunks, once having listed the exception, they must be followed. In the contrary, the system must inform the planners. They are also considered as mandatory chunks

Regarding best practices, associative and correlative knowledge chunks, it is nice if they are followed, but no direct consequences when they are not followed. Let's call them informative chunks.

As a consequence, three solutions are possible.

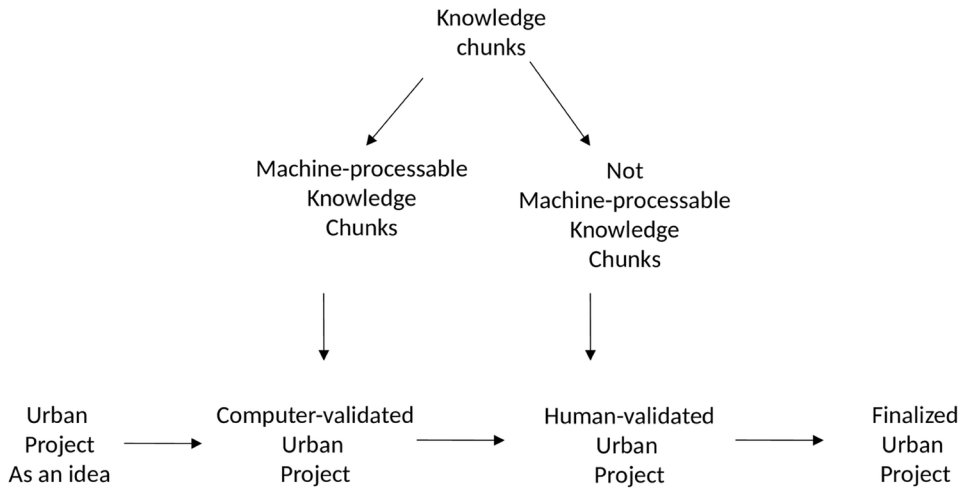
- According to the contexts, some chunks are not applicable, for instance rules concerning high mountains in a flat city.
- If all mandatory chunks are followed, one can state that the designed plan is formally validated. If they are not, either the planners must modify the plan accordingly, or be aware of the possible sanctions; the latter could be said negatively followed.
- But regarding informative chunks, it can be interesting to notify the planners when they are followed.

As an output of this formal evaluation, a possibility could to list all chunks with some comments, especially those negatively followed.

Knowledge for Monitoring

A lot of legal laws and best practices are linked to thresholds, especially for environmental monitoring based on sensors for measuring the quality of air, of water, or the approach of a big storm, and for traffic control. Here the rules can be easily applied, for instance such as the announcement of alarms. But the big problem is that nobody is sure that drivers will follow those announcements. For instance, in traffic management, three types of consequences can be figured out after the announcement of a jam:

Figure 4. Integrating various knowledge chunks for an urban project



- If nobody obeys the announcement, the jam problem will increase;
- If only a good proportion of drivers follows the announcement, the problem will be solved;
- If a very high proportion follows the announcement, the local problem will be solved, but other problems will emerge, such as a new jam in a parallel route.

In the last case, some additional best practices must be designed.

Knowledge for Specific Plan Design

Let consider rapidly some examples.

- A touristic city wants to optimize its resources by using big data. The problem is as follows: if we know tourists' itineraries in the city, we may propose ideal locations for shops, restaurants and hotels. How to solve the problem, or at least to recommend best practices? The first issue is to determine tourist's itineraries. Let's suppose we want to use mobile phone tracks based on GPS data; but how to distinguish tourist mobile phones from local phone numbers? An idea is only to use mobile phone numbers coming from other countries, so neglecting domestic tourists coming from other cities. After this step, we can extract trajectories, look for patterns, and possibly find some hints for international tourists.

- Another example is to find the optimal locations of advertising panels. Similarly, based on GPS data, vehicle trajectories can be discovered.
- Considering free access to Wi-Fi, a city wants to determine the open squares where it can be installed.

CONCLUSION

The goal of this paper is to show that big data, coupled with GIS data, can help urban planning, but only by combination with other sources of knowledge with different statuses. As previously mentioned, since often the antecedents and consequents are clear, the meaning of the implication can be various.

Knowledge discovery can be set as the goal of big data analytics; but as soon as a new associative or correlative chunk of knowledge is detected, how to determine its meaning? Is it casual, a spurious correlation, or the premisses of the discovery of a new generic hidden law? We mean to find solutions and procedures to identify those new laws, so they can help urban planners in planning the city of the future within the context of the knowledge society.

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KEY TERMS AND DEFINITIONS

External Knowledge: Knowledge describing issues located outside the jurisdiction of a local authority.

Gazetteer: A database for place names or toponyms.

Geographic Knowledge: To information potentially useful to explain, manage, monitor, understand the past, plan a territory, and innovate.

Geographic Knowledge Base: A repository for geographic knowledge.

Geographic Object: Computer description of a geographic feature as stored in a geographic data or knowledge base.

Geographic Ontology: A semantic network describing the relationships between types of geographic objects.

Geospatial Rule/Geographic Rule: In information technology, a rule in which geographic places are involved.

Internal Knowledge: Knowledge describing issues located inside the jurisdiction of a local authority.

Knowledge: In information technology, an information able to be used to solve a problem.

Spurious Correlations: A spurious correlation is a mathematical relationship in which two or more events or variables are not causally related to each other, yet it may be wrongly inferred that they are, due to either coincidence or the presence of a certain third, hidden factor.

Urban Knowledge: Information potentially useful to explain, manage, monitor, understand the past, plan a city or a metropolis, and innovate.

Chapter 2

Modelling and Assessing Spatial Big Data: Use Cases of the OpenStreetMap Full-History Dump

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ABSTRACT

Many methods for intrinsic quality assessment of spatial data are based on the OpenStreetMap full-history dump. Typically, the high-level analysis is conducted; few approaches take into account the low-level properties of data files. In this chapter, a low-level data-type analysis is introduced. It offers a novel framework for the overview of big data files and assessment of full-history data provenance (lineage). Developed tools generate tables and charts, which facilitate the comparison and analysis of datasets. Also, resulting data helped to develop a universal data model for optimal storing of OpenStreetMap full-history data in the form of a relational database. Databases for several pilot sites were evaluated by two use cases. First, a number of intrinsic data quality indicators and related metrics were implemented. Second, a framework for the inventory of spatial distribution of massive data uploads is discussed. Both use cases confirm the effectiveness of the proposed data-type analysis and derived relational data model.

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INTRODUCTION

Nowadays, effective processing of big data files is a significant challenge. Standard and well-known big data files are images and video files. In addition to them, a tremendous amount of information is registered in the form of log files. Data-centered services often record all contributions and modifications of datasets. In contrast to private data hidden from the public, open data services, like Wikipedia and OpenStreetMap (OSM), usually provide the history of all users' contributions in the form of full-history dumps (FHD). It is popular to provide full-history information of open data projects in either compressed XML format or Google's Protocolbuffer Binary Format (PBF).

Classically, big data files are converted to an indexed relational database for further processing. Recently, various big-data specific solutions have been introduced. Typically, such solutions are based on multi-core cloud solutions. The MapReduce concept is usually implemented for the development of software for multi-core based processing of big data files. Many approaches to big log data processing have been introduced in the last years. Apache Hadoop and Apache Spark are popular platforms for MapReduce-based novel solutions.

In this work, OSM FHD data are considered. Even though the article is focused on OSM, prospectively, proposed solutions can be extended to other sources of full-history data (e.g., Wikipedia). All introduced approaches are developed in an open-source manner. Hence, the developed solutions can be quickly adapted and improved for other projects. Several prepared tools are assembled as a part of Integrated Geographic Information Systems Tool Kit (IGIS.TK), which can be described as IDE for GIS projects. Currently, the parallelization is achieved by concurrent processing of FHD's clips. In the future, it will be modified by using threading libraries for optimal utilization of available CPUs.

In this work, a data-type model for universal analysis of full-history data is introduced. The model provides an overview of FHD and insight into the data provenance. The model is designed for the low-level data-type based analysis of full-history data. It allows comparing different clipped FHDs and observing dynamics and specific of users' contributions. Resulting statistics are presented in table and chart views. Table and charts are available as interactive HTML files. Moreover, using the prepared statistics, a novel relational data model for OSM FHD has been developed. Databases for several pilot sites have been generated according to the relational model.

Two use cases are based on the prepared databases. In the frame of the first use case, various intrinsic data quality indicators and related metrics were calculated.

The resulting data and charts allow users to compare the quality of the examined FHD datasets. In the frame of the second use case, the spatial distribution of massive data uploads is investigated.

BACKGROUND

Nowadays, processing of big data files is often focused on log data. Kreps et al. (2011) discussed this problem and proposed their solutions. They noticed that a vast amount of log data produced by large internet services. For instance, every day, China Mobile collects up to 8TB of phone call records, while Facebook harvests about 6TB of data related to user activity. For this, distributed log aggregators (Facebook's Scribe, Yahoo's Data Highway, and Cloudera's Flume) are delivered by various companies.

Such solutions can be described as traditional enterprise messaging systems. They play a role as an event bus for processing asynchronous data flows. For instance, IBM Websphere MQ allows applications to insert messages into multiple queues atomically. Some systems do not enable batching numerous messages into a single request; this raises performance issues. To resolve this, solutions like Facebook's Scribe aggregate log separately and, then, periodically dump them to HDFS. Moreover, various similar solutions are offered by Cloudera, Yahoo, and Linkedin. All these applications can be described as "messaging systems." Modern messaging systems support asynchronous distributed logging and processing.

Messaging systems described earlier collect log data. These data are used for various reasons, like monitoring of web services, exploring security and performance issues, debugging, etc. It requires applications for effective processing of big log files. Such tools were discussed by Breier and Branišová (2015). Often, these solutions are considered as data mining solutions or, in other words, software, which uses statistical and machine learning algorithms for disclosing standard and non-standard properties described by the processed information. It is very popular to use Apache Hadoop as a processing environment and MapReduce as a programming model. MapReduce (Xhafa et al., 2015) is a popular parallel-programming model for massive Big Data processing. Two phases are implemented by the model: map and reduce. Each stage has key-value pairs as input and output. Xhafa et al. (2015) explored the performance and usability of the Apache Hadoop system run on 64 nodes. They utilized big log data collected by Virtual Campus web applications, which manage about 46GB per day. A MapReduce application was implemented for this.

Breier and Branišová (2015) described another MapReduce implementation utilized for the anomaly detection from log files; it is based on data mining techniques. The application supports several logging types: security (reveal potential breaches, malicious programs, information thefts and to check the state of security controls), access, operational, compliance. They used three main detection methods for monitoring malicious activities: scanning, activity monitoring and integrity check.

Another type of log data is applications' debugging information. Ghoshal and Plale (2013) carried out research contributing to this topic. In the frame of the mentioned work, they have defined data provenance as the lineage of a data set, capturing transformations or derivations applied. This term is intensively utilized in the present article. Ghoshal and Plale considered the following log levels: trace, debug, info, warn, error and fatal.

Moreover, they distinguished two main classes of provenance: process provenance and data provenance. Quality of provenance data was examined in the context of several application cases: completeness, redundancy, timestamp, and error and failure. A relatively similar use case was covered by research conducted by Hao et al. (2016). An application was implemented for processing of game/simulation-based assessment log information. In contrast to the mentioned applications, a solution based on Python/Scipy/Pandas was developed.

Chaiken et al. (2008) discussed the disadvantages of the MapReduce model, where a map function performs grouping and a reduce function performs aggregation. The parallelism is achieved by splitting data into small parts and consequent parallel independent processing of these parts. The limitations of this model are as follows: the necessity of the map phase implementation (even for unnatural causes, like projection or selection) and the difficulty of the development of a complex application, which requires multiple map-reduce stages. In order to resolve considered issues, they introduced SCOPE. SCOPE is a SQL-like declarative programming language designed by Microsoft for the massive parallel computing.

In addition to normal log data processing, mentioned solutions can be effectively utilized for performing analysis of massive full-history dumps (FHDs). FHDs are provided by projects collecting volunteered information. Wikipedia and OpenStreetMap are two recognizable projects. The both provide FHDs as a compressed large XML file or a binary protobuf file. Various projects utilize Wikipedia's FHD. For instance, the BDpedia project (Lehmann et al., 2015) implements services based on the Wikipedia dump. Structured multilingual knowledge from Wikipedia is extracted and made freely available on the web using the semantic web and linked data technologies.

Among works strongly relied on Wikipedia FHD, one can mention a paper on Wikipedia's edit history efficiency assessment (Ferschke et al., 2011). The article

introduces an application, which facilitates the processing of full-history data by reducing the amount of data. It was proposed to apply the described solution by Natural Language Processing (NLP) algorithms. In addition to this, Pasternack and Roth (2010) suggested a framework for the trustworthiness assessment of information provided by Wikipedia. Like the previous one, it relies on Wikipedia's FHD. One can conclude that the performance of both solutions can be dramatically improved by utilization of the parallelization using systems like Apache Hadoop. For instance, the first application (Ferschke et al., 2011) is based on the Java Wikipedia library (JWPL). Normal processing of Wikipedia's FHD can take several days; a proposed by the documentation solutions (through the parallelization) allows reducing processing time to 1 to 3 days, which is still quite long.

Like Wikipedia, the OpenStreetMap (OSM) project offers FHD. OSM's FHD is considered in various research works overviewed in (Auer et al., 2018). The authors of the mentioned work propose "the OHSOME software platform that applies big data technology to the OSM full history data." It is implemented in and designed for the Java programming language. Two case studies for disaster management were discussed. In the present work, an alternative software platform is proposed; it is biased to the lower-level data processing.

SOURCE DATA PREPARATION

The planet service of OpenStreetMap provides FHD files in either XML.BZ2 or Protocol Buffers data format. In the frame of the present work, only data in XML.BZ2 format are processed. The current size of FHD is 64G4; the uncompressed size of the archive is about 1TB. Most OSM tools allow processing uncompressed data. For clipping FHD in required areas, OSM-history-splitter (MaZderMind, 2017) has been used. Data have been clipped in 5 pilot sites: San Donà di Piave (SD), Turin (TR), Southwark (SW), Heidelberg (HD), Israel (IS). SD is a town and part of the Metropolitan City of Venice. Both, SD and TR reside in Italy. SW is a district of Central London, UK. HD is a town in Baden-Württemberg, Germany. The IS pilot site covers the whole area of Israel and neighbor areas around the country.

Further processing has been conducted using tools designed within the IGIS.TK project (Noskov, 2018). The following tools are involved. First, `c/osh2sql.tcl` is designed for converting OSM raw data for SQLite relational database. Moreover, it can collect statistics useful for the low-level analysis of OSM full-history data. Second, `q/inventosmd3.tcl` is developed for visualization the collected by `c/osh2sql.tcl` statistics. Third, `q/introsmd3.tcl` implements a framework for the intrinsic quality assessment of OSM full-history data; it relies on some existing well-known

approaches. Both tools, i.e., `q/inventosmd3` and `q/introsmd3.tcl`, provide a series of D3/Charts.JS graphs and tables and store results of the visualization in HTML files. It allows presenting results of the inventory as a part of Geo-Spatial Data Repository (Noskov & Zipf, 2018). All mentioned tools are open source; anyone can download them from the online repository.

`c/osh2sql.tcl` generates SQLite database comprising OSM full-history data and line/tag statistics. All tables of SQLite resulting databases are indexed; thus, these data are suitable for the high-performance data analysis using regular SQL queries. Users may utilize any programming language and environment for implementing queries because SQLite is a very wide-spread and flexible library. IGIS.TK can be used as either SQL/Tcl code editor or command line console for preparing and executing for SQL queries. Line/tag statistics are saved in plain text files; these files are processed by `q/inventosmd3` to visualize the results.

The `planet-latest.osm.bz2` file was downloaded in June 2018. Using OSM-History-Splitter (MaZderMind, 2017), the FHD file was clipped according to the areas of the pilot sites. The downloading and clipping require about 8 hours. Then, the following command was carried out to generate SQLite databases and stats files.

```
tclsh ~/prs/igistk/c/osh2sql.tcl -i "l bunzip2 -c /home/fudeb/projectsdata/dq/southwark.osh.bz2" -s southwark.osh.sqlite -t tagstats.txt -l linestats.txt
```

The “-i” parameter sets the input files. Two file formats can be used with the parameter. First, uncompressed *.osh XML files can be set. In order to utilize compressed *.osh.bz2 files, the input string starting with “l bunzip2 -c ...” should be used. In this case, Tcl programming language, instead of opening a file directly, opens a socket which reads the output of bunzip2 Unix (MacOS, GNU/Linux) command. In Windows, an analog to bunzip2 command should be exploited. The “-s” parameter defines a path to an output database file. The “-t” and “-l” parameters set paths to outputs tag and line statistics.

Prepared raw statistics is not suitable for human analysis. For this, a tool for visualization of stats files was developed. The following command demonstrates the utilization of this tool.

```
tclsh ~/prs/igistk/q/inventosmd3.tcl -l "sandona_linestats.txt, turin_linestats.txt,southwark_linestats.txt,hd_linestats.txt,israel_linestats.txt" -t "sandona_tagstats.txt, turin_tagstats.txt, southwark_tagstats.txt, hd_tagstats.txt,israel_tagstats.txt" -n "San Donà di Piave, Turin, Southwark, Heidelberg, Israel" -o /tmp/fhdp_invn.html
```

The “-l” and “-t” parameters (optional, but at least one of them has to be set) define input line and tag (correspondingly) stats files separated by commas. The “-n” parameter provides names of pilot sites; it is used in output tables and charts. The “-o” parameter sets a path to an output HTML file comprising tables and D3 chars suitable for human analysis.

The prepared SQLite databases were utilized to calculate some measures and charts required intrinsic quality assessment of OSM full-history data. The following commands are carried out for this.

```
tclsh ~/prs/igistk/q/introsmd3.tcl -i "San Donà di Piave, sandona.osh.sqlite:  
Turin,turin.osh.sqlite:Southwark,southwark.osh.sqlite:Heidelberg,hd.osh.  
sqlite" -n sandona.poly,turin.poly,southwark.poly,hd.poly -o /tmp/fhdp_intr.  
html
```

The “-i” parameter defines names of pilot sites and paths to databases separated by commas; colons separate names of pilot sites. “-o” sets output HTML file.

OSM-History-Splitter utilizes *.poly files for establishing input areas for clipping. The q/introsmd3.tcl tool can digest these files for the normalization of results. In order to increase the results’ usability, data should be normalized. It is possible to normalize the results using the area or boundary length of a pilot site. It was decided that both metrics are not applicable. In the case of Israel, a significant part of the clipping polygon is covered by the Mediterranean Sea. Using the area for the normalization will senselessly decrease the output metrics. The length of a boundary is also not an option, because for pilot sites with detailed curvy boundary the length will be much bigger than for rectangular or circular areas; thus, such normalization is also senseless. In order to normalize the data and eliminate the mentioned problems, the length of a boundary of the convex hull of a pilot site’s polygon is used. Paths to *.poly files for the normalization are provided by “-n” parameter; it is optional.

DATA-TYPE ANALYSIS OF FULL-HISTORY DUMP

Concept

The present article offers a data-type analysis approach. All programming languages provide various data-type systems. Most languages distinguish Boolean, Integer, Float and String data types. One can call it “basic data types.” Boolean is True or False value. Alternatively, it can be 1/0 or yes/no. The string consists of characters; characters can be either ASCII or non-ASCII.

Moreover, various classes can be distinguished: digits, letters, spaces, lower- and upper-case, punctuations, printable, etc. In this work, a data-type system and character classes offered by the Tcl programming language are utilized to analyze the OSM full-history data. It allows defining imperfections in source datasets and discloses the provenance of full-history information.

Line Statistics

Line statistics is calculated for raw lines of XML files regardless of the document object model. Thus, if an object occupies several lines, each line will be assessed separately. This analysis allows users to detect imperfections of data and obtain a general overview of data. The number of lines and number of characters are two primary and trivial statistical metrics that are calculated. The ratio of the number of characters per line can be used as a quality indicator. It shows the density of FHD files. The number of lines is utilized for normalization of other parameters.

Further, a data-type model for calculation of line statistics is provided. Firstly, a line is trimmed to calculate how many space characters are resided at the starting (*sblank*) and ending of a line (*fblank*). Starting spaces (spaces or tabs) are used for indents. Ending spaces usually mark imperfection of data writing processes. Starting and ending spaces are excluded from further analysis. Next, the rest of a line is split to attribute (*attrs*) and non-attribute (*noattrs*) classes. “Attributes” means strings in double quotes. *noattrs* is all string outside double quotes. In the following three-line sample of XML data “36”, “true”, “2”, “way”, “268” and “inner” are *attrs*; all other strings are *noattrs*.

```
<relation id="36" visible="true" version="2">
<member type="way" ref="268" role="inner"/>
</relation>
```

In the XML listing, one can mention the special characters: less, more, slash, equal and space. Less and less-slash start an XML instruction; more character closes an instruction. The equal sign joins Key-value attributes; spaces separate words. First, the XML starting instruction characters’ frequency is calculated: less followed by a word (*stags*), less-slash (*ctags*) and less not followed by a word (*less*). *less* detects errors. Second, the ending instruction frequency is calculated: *slashmore* and *more*. Then, number equal signs are calculated. All recorded characters are excluded from further consideration. Next, space characters are reported. Spaces are split into two classes: one space character followed by non-space character (*mblanks1*) and several neighbor space characters (*mblanksmore*). Moreover, the frequency of equal signs is reported.

Now, the rest *noatrs* characters are evaluated one by one. Five classes are distinguished: ASCII digits (*noatrs09*), ASCII lower-case letters (*noatrsaz*), ASCII upper-case letters (*noatrsAZ*), the rest ASCII characters (*noatrsASCII*), and other characters (*noatrsany*).

Finally, *atrs* strings are evaluated. First of all, double quote frequency is calculated with the following elimination from the further processing. The rest characters are split into eleven classes. The first class is for spaces (*atrsblanks*). Three ASCII classes follow it: digits (*atrs09*), lower (*atrsaz*) and upper-case (*atrsAZ*) letters. Next, non-ASCII letters in lower (*atrslow*, e.g. Cyrillic letters а-я) and upper-case (*atrsup*, e.g., Cyrillic letters А-Я) are reported. Then, other letters without upper or lower case are reported (*atrsalpha*, e.g., Hebrew letters א-ת). Furthermore, non-ASCII digits are detected (*atrsdigit*, e.g., Thai digit seven ๗). And finally, punctuation (*atrspunct*) and printable (*atrsgraph*) characters are defined. All rest characters belong to the class *atrsany*. It discloses imperfections of an FHD file.

Tag Statistics

“Tag statistics” is a kind of historical name. The first prototype of the tool dealt with tags only, thus “tag” work was deeply hardcoded in the source code. Currently, the tool works with properties of all XML elements (nodes, ways, relations and members), thus, “tag” meaning could be interpreted as a description of XML elements. Moreover, some consider XML elements (especially HTML element, like, <p>, <form>,) as “tags”. More accurate meaning of “tag statistics” in the present work expressed as statistics regarding the values of attributes organized according to XML elements (or tags). Each XML elements has attributes encoded as key-value pair joined by the equal sign; values are enclosed in double quotes. For instance, in the attribute *type="way"*, *type* is key of the attribute and *way* is value. Thus, tag statistics is a collection of data-type information regarding XML attribute values for obtaining and visualization of data provenance information.

Document Object Model (DOM) of an XML data is a hierarchical tree of elements. <osm> is the main element of *.osh documents. It contains <node>, <way> and <relation> elements. Each of them may comprise <tag> elements. Topological connections are established by either <nd> elements of <way> or <member> elements of <relation>. <nd> points to existing <node> element; <member> points to existing <relation> or <way> elements. Each <node>, <way> and <relation> element has *timestamp* attribute. That allows deriving provenance information. Line stats represent recorded data outside of attribute values quite carefully in detail. This information is well established and generated mainly by software, while value information have relatively free format. Significant part of

value information comes from users. Thus, it is quite important to implement deep analysis of value information.

Further, a model for deep analysis of value information is presented. Statistics is assigned to entities named according to the following scheme: *maintag::tag::key::datatype*. As mentioned, OSH XML file have <osm> root element; it is ignored by the model. <node>, <way> and <relation> are *maintag* elements. If attribute values of *maintag* elements are considered, tag is equal to *maintag* (e.g., node::node::* or way::way::*). Otherwise, *maintag* represents a root element of the considered element (e.g., node::tag::*, relation::member::*, way::nd::*). It is followed by a key of an attribute (e.g., relation::member::role::*, node::node::lon::*, way::tag::v::*).

An entity name ends by data type number. The used list of numbered data type is as follows: (0) BLANK, (1) UNDEFINED, (2) NOASCIIList, (3) NOASCIIANY, (4) NOASCIIALPHA, (5) ASCIIList, (6) ALPHA, (7) ASCIIANY, (8) DOUBLE, (9) INTEGER, (10) BOOL. Thus, way::way::visible::10 means key “visible” of way element (<way> has no root elements, its name is duplicated in the entity) has the Boolean type. Notice that Boolean data can be recognized from the following case-insensitive forms: 0/1, false/true, no/yes and n/y. Hence, building height property equals “1” could be wrongly recognized as Boolean. Unfortunately, because of some minor imperfections in the tool implementation, some values are recognized as the UNDEFINED class. This class can be considered as an unspecified abstract string. Few of the following entity instances belong to the UNDEFINED: relation::member::type, relation::relation::user, relation::relation::changeset, relation::relation::uid, relation::relation::id, node::node::id, relation::relation::timestamp and relation::relation::visible. It should be fixed in the future. This bug does not affect the current results and can be considered as a minor shortage of the implementation.

It should be mentioned that, in contrast to line stats, for tag stats values are considered as a whole value’s string without splitting to separate characters. In the data classes, BLANK means an empty value or a value containing only spaces. UNDEFINED class was described earlier. NOASCIIList implies that string includes no-ASCII characters and spaces separating non-space characters. Such can be processed as Tcl list with length more than 1. In Tcl, lists are string separated by space characters. NOASCIIANY is a value containing non-ASCII characters without spaces, excluding ending and starting spaces, which can be trimmed. NOASCIIALPHA is a value comprising non-ASCII letters. ASCIIList represents values containing ASCII only characters without spaces. ALPHA is a value comprising only letters. ASCIIANY describes all others cases with ASCII-only characters that do not belong to any other ASCII classes described earlier. DOUBLE, INTEGER and BOOL are for Float, Integer, and Boolean data types.

Moreover, entities of tag statistics files have time range prefix. Statistics is aggregated for every 3 months from the starting of the OSM project (i.e., 01-10-2004 00:00:00). Time interval is presented a starting point of an interval (or tick). Number of a tick is used as prefix. Numbered list of ticks is as follows: (0) 01/10/04, (1) 01/01/05, (2) 01/04/05, (3) 01/07/05, (4) 01/10/05, (5) 01/01/06, (6) 01/04/06, (7) 01/07/06, (8) 01/10/06, (9) 01/01/07, (10) 01/04/07, (11) 01/07/07, (12) 01/10/07, (13) 01/01/08, (14) 01/04/08, (15) 01/07/08, (16) 01/10/08, (17) 01/01/09, (18) 01/04/09, (19) 01/07/09, (20) 01/10/09, (21) 01/01/10, (22) 01/04/10, (23) 01/07/10, (24) 01/10/10, (25) 01/01/11, (26) 01/04/11, (27) 01/07/11, (28) 01/10/11, (29) 01/01/12, (30) 01/04/12, (31) 01/07/12, (32) 01/10/12, (33) 01/01/13, (34) 01/04/13, (35) 01/07/13, (36) 01/10/13, (37) 01/01/14, (38) 01/04/14, (39) 01/07/14, (40) 01/10/14, (41) 01/01/15, (42) 01/04/15, (43) 01/07/15, (44) 01/10/15, (45) 01/01/16, (46) 01/04/16, (47) 01/07/16, (48) 01/10/16, (49) 01/01/17, (50) 01/04/17, (51) 01/07/17, (52) 01/10/17, (53) 01/01/18, (54) 01/04/18, (55) 01/07/18, (56) 01/09/18. Hence, `32::node::tag::*` means that the `<tag>` of the `<node>` belongs to a time interval from 01/10/12 to 01/01/13.

For each entity, four elements are recorded: summarized length of strings, number of evaluated values, minimal length of string or minimal value (of the value belongs for integer or float numbers) and maximal length of string or maximal value (of the value belongs for integer or float numbers). If a data type is Boolean, then, instead of the definition of minimal and maximal values, False and True values are recorded correspondingly.

In the following bulleted list, some entity samples from the raw tag stats file of the Southwark pilot site generated by the tool and their descriptions are provided.

- **39::relation::member::role::5 {381 26 9 23}**: Time interval 39 (i.e., 01/07/14 - 01/10/14), `<member>` of root element `<relation>` has values of the “role” key, which belong to type 5 (ASCIIILIST). Total length of all strings is 381 characters; 26 values were recorded; shortest value has 9 characters; longest – 23.
- **19::way::tag::k::6 {62340 10717 2 12}**: Time interval 19 (i.e., 01/07/09 - 01/10/09), `<tag>` of root element `<way>` has values of “k” keys, which belong to type 6 (ALPHA). Total length of all strings is 62340 characters; 10717 values were recorded; shortest value has 2 characters; longest – 12.
- **25::node::tag::v::7 {16984 1705 1 116}**: Time interval 26 (i.e., 01/01/11 - 01/04/11), `<tag>` of root element `<node>` has values of “v” keys, which belong to type 7 (ASCIIANY). Total length of all strings is 16984 characters; 1705 values were recorded; shortest value has 1 characters; longest – 116.
- **33::node::node::lon::8 {274807 27483 -0.2157702 0.0369058}**: Time interval 33 (i.e., 01/01/13 - 01/04/13), `<node>` element has values of “lon”

(longitude) keys, which belong to type 8 (DOUBLE). Total length of all strings is 274807 characters; 27483 values were recorded; minimal value is -0.2157702; maximal is 0.0369058.

- **33::node::node::lon::8 {274807 27483 -0.2157702 0.0369058}**: Time interval 33 (i.e., 01/01/13 - 01/04/13), <node> element has values of “lon” (longitude) keys, which belong to type 8 (DOUBLE). Total length of all strings is 274807 characters; 27483 values were recorded; minimal value is -0.2157702; maximal is 0.0369058.
- **42::way::way::version::9 {5973 5462 1 49}**: Time interval 42 (i.e., 01/01/13 - 01/04/13), <way> element has values of “version” keys, which belong to type 9 (INTEGER). Total length of all strings is 5973 characters; 5462 values were recorded; minimal version of the “way” is 1; maximal is 49.
- **12::way::way::visible::10 {48545 12007 517 11490}**: Time interval 12 (i.e., 01/10/07 - 01/01/08), <way> element has values of “visible” keys, which belong to type 10 (BOOL). Total length of all strings is 48545 characters; 12007 values were recorded; 517 ways were deleted (the “visible” key’s values are “false”); 11490 ways of the Southwark data are active (the “visible” key’s values are “true”).

Results

The presented data-type models are implemented by c/osh2sql.tcl tool of the IGIS. TK project. The results are saved in two text files with raw records. The tool q/introsmd3.tcl has been designed for the visualization of these text files in a human-readable form. Further, a general overview of the visualized results is provided for line and tag statistics. As mentioned, line statistics give an overall review of considered OSM data dumps, while tags statistics provide a detailed insight into the low-level evolution of data.

Line Statistics

In Table 1, a general overview of FHD files is provided. Columns provide data according to different pilot sites. Rows represent various data types. Further, various data-type classes are considered from top to bottom of the table. Mostly, character number is provided. In parenthesis, the number of characters divided by the number of lines of an FHD file (see the first row from the top). Normalized numbers are provided in an exponential format.

The pilot sites are ordered ascendingly from left to right column of the resulting table by the number of lines and characters as follows: SD, TR, SW, HD and IS. It is very important to normalize the resulting metrics because the variation of pilot sites’

areas is high. Thus, it makes no sense to compare raw values. It has been decided to use the number of lines of a considered FHD for the normalization. Hence, values in parenthesis right below corresponding raw integers are normalized. Further, the normalized results are considered according to their classes from top to bottom of the table.

sblank indicates the number of nested elements because child XML elements are written with an increasing starting indent. The value is growing gradually from SD to IS from left to right. Thus, IS has more nested elements and deeper XML trees in comparison to other FHDs. *fblank* class indicates imperfections of input data files because OSM XML tags should be written without any ending spaces. All the values equal “0”; thus, no problems have been recognized by the *fblank* class indicator.

IS, HD, and SW comprise relatively similar number *stags* per line. SD and TR FHDs have much less tag starting characters (i.e., the less sign followed by a letter). *stags* represents the number of XML elements. In contrast to it, *ctags* distinguish starting instructions of a closing tag (i.e., the less sign followed by the slash). This class represents the number of elements having child elements. Hence, IS has much more nested tags than all others pilot sites. It confirms the finding derived from the analysis of the *sblank* class. The difference of the meaning of the results based on *sblank* and *ctags* is that, *ctags* is showing the number of elements having classes, while *stags* reflects the number of child elements and depth of an XML tree. The *less* class helps to detect imperfection of formatting tags (i.e., the number of cases when the less sign is not followed by a letter). For the considered FHDs, no problems were detected by this class. *slashmore* indicates the number of one-line XML elements without child elements. IS and HD have the maximal number of such elements per line; they followed by SW, TR, and SD descendingly. As *ctags*, *more* shows the number of XML tags with child elements. Notice that *more* equals *ctags* minus one.

blanks1 and *blanksmore* examine space characters in FHDs. *blanksmore* disclose imperfections of XML files (outside of attribute values, number of neighbor space characters should not be more than 1, excluding indents). Such shortcomings were not disclosed in the considered data files. *blanks1* indicates the amount of XML entities separated by spaces. It is decreasing from left to right. Then, the possible rest variation of values is examined in the non-attribute-value strings. Among *nonatrs** classes, the only *nonatrsaz* has non-zero values. That indicates well formed OSH files. *dquotes* class reflects the number of attributes. *dquotes* raw values must be even integers. Again, the normalized values of the table are gradually decreased from left to right.

Further, attribute values (*atrs**) are considered. One crucial issue should be mentioned. Non-ASCII values are encoded as XML symbol entities. For instance, a string “ראש” in Hebrew and encoded into string “באר” in an OSH XML data file. Hexadecimal digits starting are used. Hence, the quantity of

the mentioned characters is dramatically increased in FHDs containing non-ASCII symbols. Thus, one can observe anomalies of the *attrs** classes ratio calculated for IS FHD. It has been decided not to decode XML entities because the proposed approach aims to FHD without any modification as it is.

In Figure 1, an overview of *attrs** classes is provided. Zero- and low-quantity classes are not depicted in the stacked bar chart. The effect of non-ASCII characters encoding can be easily distinguished in the figure. The values of *attrs09*, *attrsAZ*, and *attrspunct* (the ampersand and number signs belong to punctuation characters) are much bigger than in other pilot sites. The classes *attrslow*, *attrsup*, *attrsalph* and *attrsdigit* have been designed for catching non-ASCII characters. Because of non-ASCII characters encoding, all these classes have the zero frequency.

The class *attrsany* has been designed to catch wrongly written characters. Characters belonging to this class should not exist in FHDs. Such characters have been detected in SW, HD and IS data files. Most of them reside in the HD data file. It should be mentioned that the detected bad characters can be found in original big FHD. Thus, they are not produced by OSM-History-Splitter. In Figure 2, an example of `<way>` with bad characters appeared in a line starting with '`<tag k="addr:postcode"`'; defected characters are encapsulated in squares. It should be mentioned that examined defected characters affect only on values they resided. Currently, defected characters outside have not been detected outside of attribute value. Thus, they do not have a negative impact on other XML elements.

Tag Statistics

Tag statistics allows provenance assessment of OSM full-history data. As mentioned, data are aggregated for every three months from the beginning of the OSM project. The results of the aggregation are provided according to the XML tag tree, then, an XML key followed by the examining value, and, finally, the data type of a value. Because it is impossible to present highly-granulated data in the frame of the current article, the resulting data is aggregated according to the second level of the granularity (i.e., the parent tag and child tag).

In Figure 3, the results are demonstrated. Graphs on the left hand represent the summarized number of characters of values; graphs on the right hand illustrates the number of values. The statistics regarding the following entities is provided: `node::node`, `node::tag`, `way::way`, `way::nd`, `way::tag`, `relation::relation`, `relation::member` and `relation::tag`. Repeating tag name means that a tag does not have a parent tag.

The most recognizable entity in the graphs is `relation::member`; it is followed by `node::node`, `way::node`, `node::tag`, `relation::tag` and `way::tab`. In all pilot sites, excluding IS, `relation::member` occupied a dominating space. In SD and Turing,

Table 1. Line statistics

Attribute Name	San Donà di Piave	Turin	Southwark	Heidelberg	Israel
lines	6,697,526	7,819,818	25,963,886	39,117,310	71,403,578
chars	336,660,937 (4.715E+00)	413,949,061 (5.797E+00)	1,352,982,944 (1.895E+01)	1,955,812,558 (2.739E+01)	4,778,721,665 (6.693E+01)
sblank	26,093,138 (3.654E-01)	28,859,126 (4.042E-01)	99,119,404 (1.388E+00)	152,097,436 (2.130E+00)	240,219,384 (3.364E+00)
fblank	0	0	0	0	0
atrs	135,671,359 (1.900E+00)	198,373,021 (2.778E+00)	603,786,723 (8.456E+00)	810,088,473 (1.135E+01)	2,587,887,640 (3.624E+01)
noatrs	174,896,440 (2.449E+00)	186,716,914 (2.615E+00)	650,076,817 (9.104E+00)	993,626,649 (1.392E+01)	1,950,614,641 (2.732E+01)
stags	43,161,665 (6.045E-01)	40,056,175 (5.610E-01)	153,452,855 (2.149E+00)	246,679,654 (3.455E+00)	266,523,320 (3.733E+00)
ctags	90,636 (1.269E-03)	820,100 (1.149E-02)	1,253,524 (1.756E-02)	1,029,206 (1.441E-02)	5,701,186 (7.984E-02)
less	0	0	0	0	0
slashmore	13,213,782 (1.851E-01)	13,999,438 (1.961E-01)	49,420,726 (6.921E-01)	76,176,210 (1.067E+00)	131,404,786 (1.840E+00)
more	90,635 (1.269E-03)	820,099 (1.149E-02)	1,253,523 (1.756E-02)	1,029,205 (1.441E-02)	5,701,185 (7.984E-02)
mblanks1	20,309,981 (2.844E-01)	22,320,326 (3.126E-01)	76,628,332 (1.073E+00)	115,951,671 (1.624E+00)	232,704,576 (3.259E+00)
mblanksmore	0	0	0	0	0
noatrs09	0	0	0	0	0
noatrsaz	77,719,760 (1.088E+00)	86,380,450 (1.210E+00)	291,439,525 (4.082E+00)	436,809,032 (6.117E+00)	1,075,875,012 (1.507E+01)
noatrsAZ	0	0	0	0	0
noatrsascii	0	0	0	0	0
noatrsany	0	0	0	0	0
dquotes	40,619,962 (5.689E-01)	44,640,652 (6.252E-01)	153,256,664 (2.146E+00)	231,903,342 (3.248E+00)	465,409,152 (6.518E+00)
atrsblanks	114,529 (1.604E-03)	961,327 (1.346E-02)	3,222,440 (4.513E-02)	1,000,328 (1.401E-02)	9,040,857 (1.266E-01)
atrs09	66,195,216 (9.271E-01)	90,172,104 (1.263E+00)	261,391,671 (3.661E+00)	379,470,399 (5.314E+00)	1,467,798,691 (2.056E+01)
atrsaz	25,411,468 (3.559E-01)	51,360,874 (7.193E-01)	161,844,023 (2.267E+00)	177,569,944 (2.487E+00)	360,127,476 (5.044E+00)
atrsAZ	949,441 (1.330E-02)	4,370,843 (6.121E-02)	9,630,328 (1.349E-01)	6,811,893 (9.540E-02)	97,285,361 (1.362E+00)
atrslow	0	0	0	0	0
atrsup	0	0	0	0	0
atrsalpha	0	0	0	0	0
atrsdigit	0	0	0	0	0
atrspunct	2,376,719 (3.329E-02)	6,864,688 (9.614E-02)	14,433,469 (2.021E-01)	13,303,219 (1.863E-01)	188,188,756 (2.636E+00)
atrsgraph	4,024 (5.636E-05)	2,533 (3.547E-05)	8,033 (1.125E-04)	28,658 (4.014E-04)	37,341 (5.230E-04)
atrsany	0	0	95 (1.330E-06)	690 (9.663E-06)	6 (8.403E-08)

Figure 1. Lengths of major attribute string classes (per line)

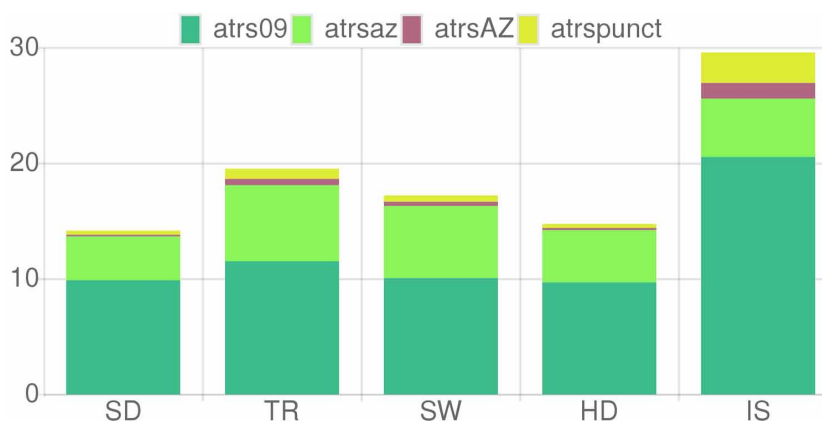


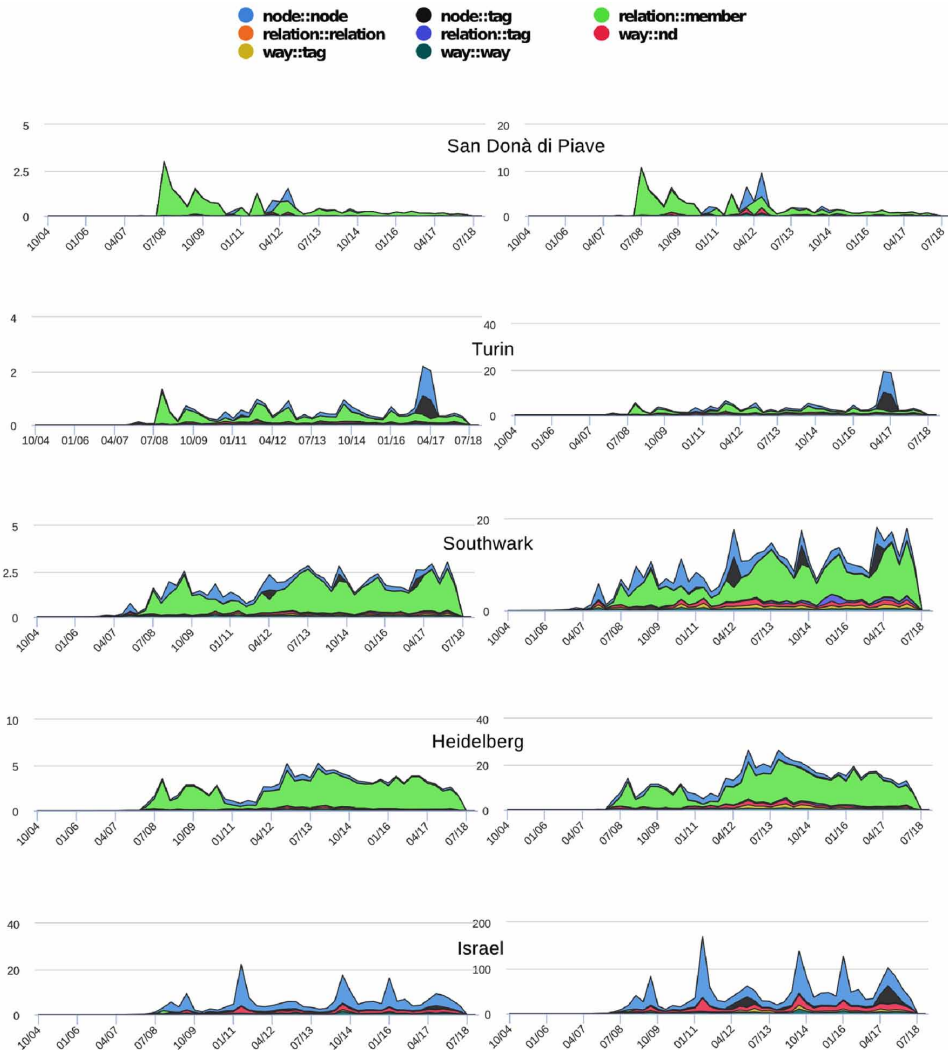
Figure 2. An example of <way> comprising bad characters (source FHD, not clipped data)

```
<way id="301308608" version="2" timestamp="2014-12-02T11:21:30Z" uid="626974" \
user="wiedergaenger" changeset="27176438" visible="true">
  <nd ref="3053858419"/>
  <nd ref="3053858417"/>
  <nd ref="3053858414"/>
  <nd ref="3053858416"/>
  <nd ref="3053858415"/>
  <nd ref="3053858418"/>
  <nd ref="3053858419"/>
  <tag k="building" v="yes"/>
  <tag k="addr:city" v="Wiesenbach"/>
  <tag k="addr:street" v="M&#xF6;nchzeller Weg"/>
  <tag k="addr:postcode" v="69257" 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 />
  <tag k="addr:housenumber" v="2"/>
</way>
```

the number of such objects was much higher at the beginning of the OSM project 2008 – 2012. After 2012, the number of commits has been decreased significantly. Nowadays, the activity of OSM contributors is quite low in both pilot sites. In SW, the activity is very high and increasing from at the beginning of mapping until today. In HD, the amount of contributions is high as well, but it is slightly decreased since 2013.

In addition to the relation::member, in SD FHD, one can notice recognizable contributions of node::node and way::node (the letter is mainly identifiable in the left chart). In 2017, charts of TR show a significant peak of commits of node::node and node::tag. Hence, one can expect that the quality of POI data has been increased significantly after this. In SW charts, the activity related to node::node, node::tag and way::nd is presented from the beginning until now. In 2015, contributions of relation::tag are distinguishable in the left chart. In HD, node::node and way::node

Figure 3. Tag statistics results



contributions are observable (especially from 2011 to 2015), but it plays much less role in comparison to SW data.

IS has a particular pattern which is highly distinguishable from the other pilot sites. The pattern mainly consists of node::node, way::nd and node::tag. Therefore, the contribution primarily consists of providing new node data, creating <way>s linked to <node> and committing node::tag data. Both chart types confirm it. Moreover, in IS datasets, recognizable peaks are illustrated. It can be related to political and military issues which happened at a time of emerging of these peaks.

OSM FULL-HISTORY DATA MODEL

The conducted data-type analysis allows us to prepare a rectified data model for management OSM data as an indexed relational database. Usually, OSM is managed by PostGIS; it is aimed to standard non-full-history data (i.e., *.osm* and not *.osh* source data files). We propose to use an SQLite database for the OSM full-history management. A novel rectified relational data model is proposed in the present article; it is based on the results discussed in the previous section.

The proposed data model is based on the analysis of the considered line and tag statistics. The full list of examined data-types of OSM FHDs is as follows.

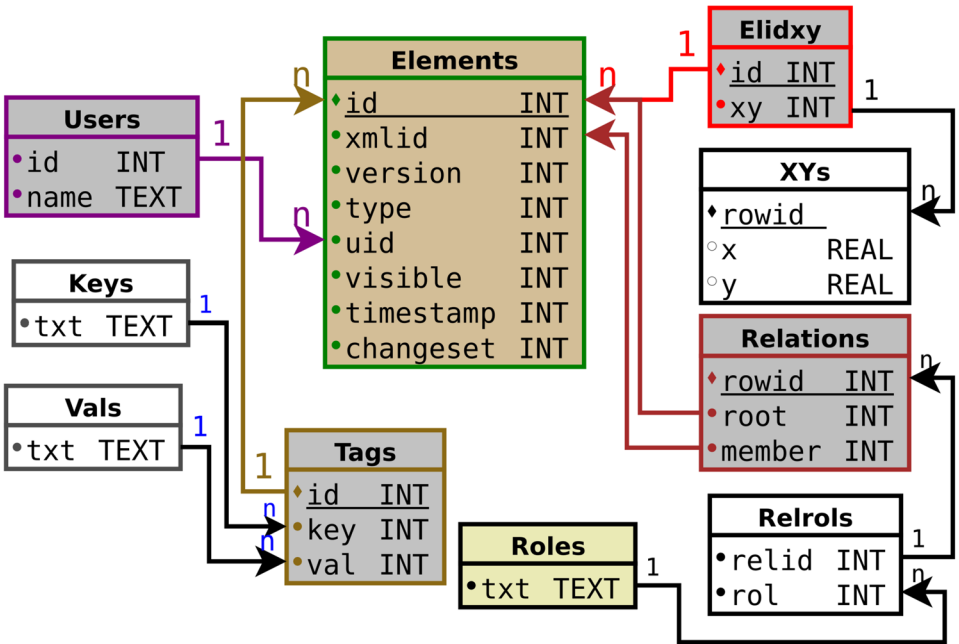
node::node::changeset::9, node::node::id::9, node::node::lat::8, node::node::lon::8, node::node::timestamp::9, node::node::uid::9, node::node::user::5, node::node::user::6, node::node::user::7, node::node::version::9, node::node::visible::10, node::tag::k::0, node::tag::k::5, node::tag::k::6, node::tag::k::7, node::tag::v::0, node::tag::v::5, node::tag::v::6, node::tag::v::7, relation::member::ref::9, relation::member::role::0, relation::member::role::5, relation::member::role::6, relation::member::role::7, relation::member::type::1, relation::relation::changeset::1, relation::relation::id::1, relation::relation::timestamp::1, relation::relation::uid::1, relation::relation::user::1, relation::relation::version::1, relation::relation::visible::1, relation::tag::k::0, relation::tag::k::5, relation::tag::k::6, relation::tag::k::7, relation::tag::v::0, relation::tag::v::5, relation::tag::v::6, relation::tag::v::7, way::nd::ref::9, way::tag::k::0, way::tag::k::5, way::tag::k::6, way::tag::k::7, way::tag::v::0, way::tag::v::5, way::tag::v::6, way::tag::v::7, way::way::changeset::9, way::way::id::9, way::way::timestamp::9, way::way::uid::9, way::way::user::5, way::way::user::6, way::way::user::7, way::way::version::9, way::way::visible::10

A novel data model for the relational database has been designed using the presented tag entities consisting of tag names, an attribute name, and a data type index. The novel data model is not based or related to a popular OSM data model which is used for PostGIS databases (OpenStreetMap, 2016).

In Figure 4, the proposed model is presented. *Elements* is a main table of the data model. *id* is a unique identifier of OSM history object (i.e., every version of an OSM object has a unique identifier). *xmlid* is not a unique value; it is taken from an XML's file. Various versions share the same identifier. *version* is a version of an element. *type* can be "0" (node), "1" (way) or "2" (relation). *uid* is a user identifier. *visible* can be either "true" or "false"; it indicates if an object is either active or disabled (removed). *timestamp* is an object creation time. *changeset* is a changeset's identifier.

uid provides references to the *id* field of the *Users* table. *Users* names are stored in the *name* field of the *Users* table; it prevents from the text values duplication. As

Figure 4. The data model of OSM full-history data



usernames, OSM tags key and values strings are stored in separate tables in *txt* fields – *Keys* and *Vals*, correspondingly. The *Tags* table establishes pairs of tags’ keys and values. The table provides references to *Key* and *Vals* through the *key* and *val* fields.

Geometry objects are formed by the topology definition using the *Elidxy* and *Relations* tables. Nodes are points which are bases for all other geometries. *Elidxy* establishes one-to-many relationships with *XYs* containing *x* and *y* coordinates. In addition to nodes, ways and relation geometric objects can be defined by the *Relations* table. The *Relrols* and *Roles* tables specify *Relations*; recursive processes construct ways and relations.

The *c/osh2sql.tcl* tool of IGIS.TK converts an FHD file to an SQLite database file according to the presented data model. In the next two sections, two use cases of the prepared database file utilization. First, a framework for the intrinsic quality assessment of OSM full-history data is provided. Second, an approach to spatial distribution of the massive data uploads is presented as the second use case.

USE CASE 1: INVENTORY AND QUALITY ASSESSMENT OF OPENSTREETMAP DATA – INSTINSIC APPROACH

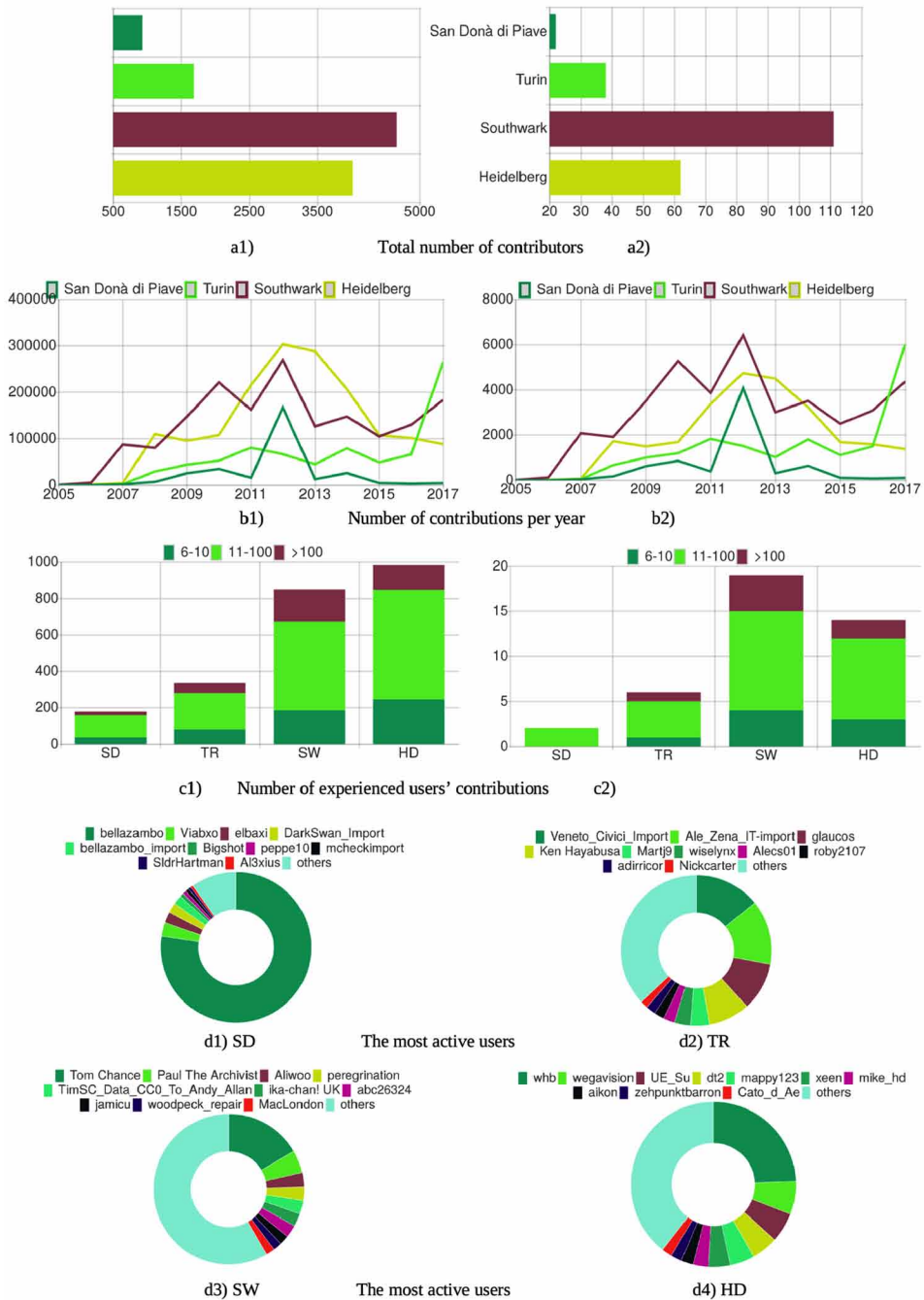
The `q/introsmd3.tcl` tool of IGIS.TK generates an HTML file comprising various charts useful for intrinsic and comparable assessment of OSM full-history data. Charts are generated for provided pilot sites. In Figure 5, calculated charts for SD, TR, SW, HD and IS are presented. On the left-hand side, raw data are presented; on the right hand, normalized data are presented. As discussed, data are normalized using the length of a boundary of a polygon's convex hull. Calculated lengths utilized for the normalization are as follows: SD - 41 km, TR - 44 km, SW - 42 km and HD - 64 km.

Data and correspondent charts *a1*, *a2*, *b1*, and *b2* are utilized by various approaches for intrinsic and comparable quality assessment of VGI data. For instance, Girres and Touya (2010) used such data for the lineage-based quality assessment of OSM data. *a1* and *a2* represent the number of contributors registered by FHDs and its normalized version. Notice the impact of the normalization on increasing the differences in the resulting values. The normalized quantity of contributors in SW is much bigger in comparison to others, especially the pilot sites in Italy. *c1* and *c2* show the dynamics of the number of contributions (number of elements with a correspondent timestamp) and its normalized values. One can mention that, after the normalization, SW is followed by HD.

Further, charts related to a trustworthiness aspect of the data quality are discussed (Kessler et al., 2013). Versions, the number of users' commits and the overall users' distributions are affected by the trustworthiness of OSM FHD data. *c1* and *c2* represent the number of users with more than five contributions with a version more than 5. Most of the users have 11 to 100 contributions. As in the previous charts, these charts confirm that SW FHD provides the highest quality of the dataset. It is followed by HD, TR, and SD, descendingly. *d1-d4* illustrate the distribution of contributions among various users. Variegated charts and charts with a bigger ratio of the "others" category indicate higher quality datasets.

It should be mentioned that, according to the presented charts in Figure 5, SD FHD provides the lowest quality dataset. Charts of TR indicate higher quality. With a significant gap, the data quality is increased from TR to HD. SW delivers the highest quality dataset significantly distinguished from the other pilot sites; it is showed by the all normalized charts of Figure 5. This fact is confirmed by collected line and tag statistics provided by Table 1, Figure 1 and Figure 3.

Figure 5. Carts for intrinsic and comparable quality assessment of OSM data



USE CASE 2: THE SPATIAL DISTRIBUTION OF MASSIVE DATA UPLOADS IN TEL AVIV-YAFFO AND THE GAZA STRIP

To explore the utility of the suggested data structure, we utilize it for studying the spatial distribution of OSM contributions in the city of Tel Aviv-Yaffo (TLV) in Israel and the Gaza strip (GZS). Some interesting patterns in these areas were noted before, where data in GZS is created mostly through external interventions which lead to massive contributions over a short period (Bittner, 2017) while TLV is characterized by a more gradual increase in dataset size, except for one event of a massive data import (Grinberger, 2018). Such massive events were found to affect data quality in terms of richness, the frequency of updates, and community structures (Grinberger, 2018), yet the spatial dimension of these dynamics have yet to be studied.

This use case adds to this by focusing on three massive data events (Table 2) – one for TLV in which an official addresses database which was made publicly available by governmental agencies was imported into OSM on December 2013 via an effort coordinated within the local community of OSMappers (yrtimiD, 2012); two for GZS, the first of which organized by a NGO which hired local residents to map the road network in the strip during 2009 (i.e. GZS-2009; JumpStart Mapping, 2009) and the second carried as part of a Humanitarian OSM Team (HOT) project during the summer of 2014 and the months following it, focusing on remotely mapping buildings within GZS using a high-resolution aerial image of the area (i.e. GZS-2014; OpenStreetMap Wiki Contributors, 2014). As noted above, these different dynamics and their relations to access the mapped area introduce different effects to data quality. Accordingly, they are expected to affect also the spatial coverage of contributions.

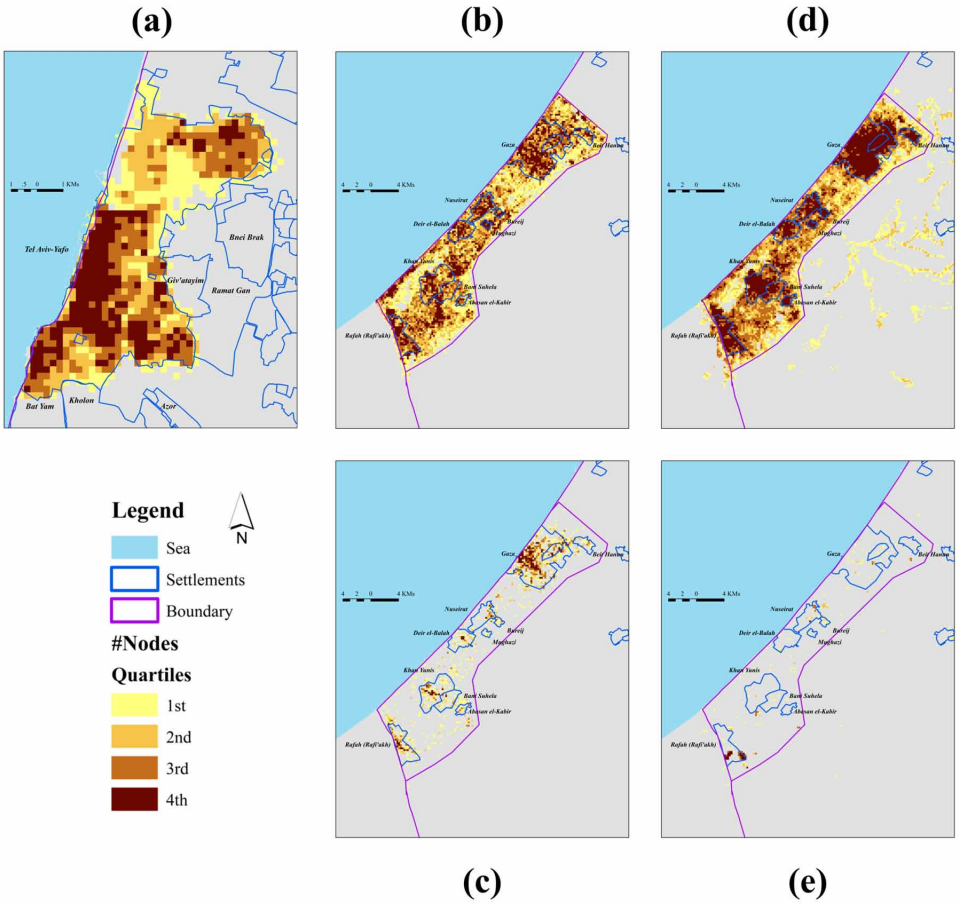
To better understand the coverage patterns of the data produced during each event (i.e. TLV-2012, GZS-2009, and GZS-2014), the framework suggested in this chapter was utilized to identify the nodes created during each event and to distinguish between nodes enriched with semantic information (i.e. ‘tags’) and nodes with no such information. For this, a series of simple SQL queries were written, used to join the elements table with coordinates and tags data and to filter contributions by time and location (see Table 2). The resulting dataset for each event was aggregated into a grid covering the study area with a spatial resolution of 250 square meters. For each cell, the total number of newly created nodes and the number of new tagged nodes was recorded.

The TLV-2012 event, which was based on a systematically collected authoritative dataset, can serve as a reference for the GZS events which are collected in a different manner. For instance, the spatial distribution of new nodes (Figure 6a) mirrors to a large extent the urban structure, with the historic cores of Tel Aviv and Yaffo densely covered and the relatively newer and wealthier neighborhoods of the north

Table 2. Characteristics of data events

Event	GZS-2009	TLV-2012	GZS-2014
Time Period	21-22/09/2009	22/12/2012	01/08/2014-30/11/2014
Organizer	JumpStart International	Local OSM Community	Humanitarian OSM Team (HOT)
Focus	Roads	Addresses	Buildings
Method of contribution	Land survey	Data import	Remote mapping
Bounding Box Coordinates(lat/lon – WN,ES - WGS84)	34.2, 31.2 34.6, 31.6	34.72, 32.03 34.85, 32.14	34.2, 31.2 34.6, 31.6
# new nodes	81,307	53,130	952,335
# new tagged nodes (% of total)	2,541 (3.12%)	53,130 (100.00%)	50,324 (5.28%)

Figure 6. Density of new entities and new tagged entities by event and case study: (a) TLV-2012, new nodes; (b) GZS-2009, new nodes; (c) GZS-2009, new tagged nodes; (d) GZS-2014, new nodes; (e) GZS-2014, new tagged nodes



presenting lower densities. The same is true for the GZS events, yet to a lesser extent, especially in the case of the 2009 event where data densities do not obey to municipal boundaries as strictly as in the 2014 event (Figures 6b and 6d). While this can be explained by the focus of each event on a different class of entities (Table 2), the differences in the coverage of semantic information (Figures 6c and 6e) require a different explanation. The picture these present is opposite to the overall picture – in the GZS-2009 event mostly urban centers are covered while in GZS-2014 the pattern is less random.

When these patterns are quantified by counting the number of new nodes within and outside official municipal boundaries (Table 3), these contrasting trends become even more evident – although only a third of the 2009 contributions are made within urban areas (and almost 20% less than in GZS-2014), a much greater share of these are tagged with semantic information in relation 2014, and a slightly larger share of all tagged nodes are concentrated within urban areas. The explanation for this may lie in how ancillary knowledge is gathered and semantic

information is produced in the two cases. The 2014 mappers had to rely only on visual assessments of the aerial image, meaning tags were only created when the image (or the existing data) provided relevant ‘clues’, leading a somewhat random pattern. The local residents mapping during the 2009 event, however, relied on their experience and local knowledge to identify what is ‘important’ and worthy of integration into the dataset. Hence, it is not surprising urban centers which take significant roles within the everyday lives of individuals are better represented. This analysis of data coverage, utilizing the suggested data structure, thus uncovers spatial patterns related to coverage, semantic information, and mapping dynamics that have not received full attention within the existing literature to this date. Understanding these via data structures that facilitate high-resolution mapping of data production dynamics can thus greatly contribute to the assessment of data quality.

Table 3. Distribution of nodes, by event, tags, and urban areas

Measure	GZS-2009	TLV-2012	GZS-2014
% nodes within urban areas	33.80%	100.00%	49.61%
- of these: % tagged	5.57%	100.00%	0.68%
% tagged nodes within urban areas	64.26%	100.00%	58.38%

FUTURE RESEARCH DIRECTIONS

As shown, the presented data-type model provides a novel type of line and tag statistics. In the present article, only part of generated data is considered. The implemented model generates highly granulated data, which should be presented and discussed in the future work. The introduced processes for data-type identification should be slightly refined. In order to demonstrate the advantages of the solutions, more chart types need to be utilized. A more in-depth analysis of the resulting data and charts should be conducted in the future.

As mentioned, the current implementations of the discussed tools contain minor bugs; it will be fixed in the next releases of IGIS.TK. Currently, only command line tools are implemented. In the next stage, their GUI wrappers will be prepared. IGIS.TK provides the functionality for the rapid development of such GUI wrappers and manages them as parts of IGIS.TK's IDE (main GUI programming environment comprising source-code editor, command-line console, map widgets, and SQLite database manager). Moreover, binary packages of IGIS for the delivery and quick installation of the software should be prepared for Unix (MacOS, GNU/Linux, BSD), Windows and Android.

A framework for the intrinsic quality assessment of OSM full-history data will be significantly extended and improved. Currently, few quality indicators and related measures are implemented. The list should be considerably expanded. Consequently, a broader analysis of the resulting data and charts should be conducted. Since the proposed relational data modes of OSM full-history data is universal, more used cases can be considered in the future.

CONCLUSION

The present work introduces the novel data-type model for the inventory of OSM full-history data. The model is implemented as the tool of the IGIS.TK open-source software. Any user may evaluate the proposed solutions using other parts of OSM FHD. Furthermore, because the software is released as an open-source project, anyone can improve the code and contribute modifications to the project.

The data-type model generates the line and tag statistics. The line statistics provides a general overview of examined FHDs. Much information can be extracted from the line statistics. The normalization (by the number of lines) allows users to compare FHDs covering non-similar (by size) areas. Apart from that, the line statistics help to detect imperfections of FHD. It can be a result of incorrect either clipping of OSM

FHD or preparation OSM FHD covering the whole planet. At least one problem has been detected and discussed in the result section. The tag statistics is useful for the data provenance analysis because the resulting data are aggregated by every three months (the time interval can be modified). The tag statistics shows the low-level dynamics of the OSM XML object model and distinct data types of values of XML tags attributes. Attribute values stores most information contributed by volunteers.

The introduced tools generate HTML5 charts. Main charts were discussed in this work. Several inferences have been disclosed in the charts and tables. The proposed data-model for the line statistics allows detecting imperfection in examined data. In FHD provided by the OSM planet, problem characters indicating possible faults in the process of full-history data dumping have been found. The tag statistics distinguished three lineage types of OSM FHDs. First, the pilot sites in Italy are not gradually developed; a significant part of the data is contributed by bulk imports. Very low contributors' activity follows short periods of massive contributions; that indicates possible problems with data quality in these Italian pilot sites. Second, the Southwark and Heidelberg pilot sites comprised information contributed gradually and intensively from the beginning of the OSM project till now. In contrast to Heidelberg, Southwark data are still contributed to the growing trend. Third, the Israel pilot site is distinguished by both type of committed data and the fact that contribution peaks are significantly related to the political and military events in the Middle East.

In addition to the mentioned inferences, the data-type model resulting data utilized for developing an optimal universal relational data model for storing and managing OSM full-history data. Each FHD was converted to the correspondent SQLite indexed relational file database according to the presented data model. These databases were utilized in the two discussed use cases. The use cases have confirmed the findings concluded from the data-type assessment in higher-level. It affirms that the introduced data-type analysis offers researchers a valuable set of tools for investigating full-history data.

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KEY TERMS AND DEFINITIONS

D3 (or D3.js): Is a JavaScript library generating interactive data visualizations, mainly charts, according to SVG, HTML5, and CSS web standards.

Data Mining: Is the process of discovering patterns in large datasets involving methods at the intersection of machine learning, statistics, and database systems.

GIS: Geographic information systems.

GUI: Graphic user interface.

Hadoop (Apache Hadoop): An operating system developed in the frame of the Apache project; the system allows distributed calculation among various detached virtual and physical servers called nodes.

HDFS: A distributed file system developed in the frame of the Apache Hadoop system.

IDE: Integrated development environment.

Log Data (Log Files): Data files containing the information registered consequently from oldest to newest (e.g., debug information provided by an application, users' requests registered by a web server, etc.).

MapReduce: Is a programming model for processing and generating large datasets in a parallel and distributed manner on a cluster.

Chapter 3

Big Data and High- Performance Analyses and Processes

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ABSTRACT

The period of vast information and examination has arrived and is changing the world significantly. The field of information frameworks ought to be at the bleeding edge of comprehension and deciphering the effect of the two innovations and administration to lead the endeavors of business to inquire about in the information period. In this chapter, the author investigates administrative issues of business change coming about because of the original appropriation and inventive uses of information sciences in business. The author ends by giving an analysis of big data that covers all the analytical processes and future research headings.

INTRODUCTION

The world has transformed into data society that hugely depends on information. Since data frameworks create colossal measures of records each day, consistently, it appears the world is achieving the level of information over burden. It is evident that keeping in mind the end goal to process such volumes of information a huge limit is required regarding stockpiling and figuring assets. Though the development of limit is restricted by the advancement of equipment and advances, the development of the information volume is in reality boundless. Getting more particular, these

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days numerous associations has embraced and extensively utilize data frameworks running on mechanical stages, numerous their motivation has progressed toward becoming dependent on information. In the developed association's information specifically influence the rationale of business forms; data has turned into a center of their business or business end. Thus business requests the information, besides accessibility of particular information in particular time. More unpredictable also, hazardous basic leadership process depends on rightness and straightforwardness of information.

Motivation

The intriguing driver identified with this subject says that the development of information is boundless. What is the general public going to do about the information overburden? The most effective method to deal with and additionally to process all the information? It appears as though we are having the big data issue. Another driver for this subject is recovering the data not to assemble all information for further examination. Among every one of the information, how to recover the applicable data and inside a required time? Which examination ought to be connected to information? What is the harmony between the cost of recovery and estimation of that data? What are the expenses of the ability to recover wanted data? It appears as though it is about the benefit, exchange off between estimation of data, the cost to get it. Furthermore to the two drivers the test is to picture the data such that its esteem is far reaching and justifiable. The primary issue is the data over burden. Examination in the conventional mode, as far as the big data, is securing information that may or may not be required for examination. This all requires a creative perspective, an alternate approach, design or framework, assuming any. A superior investigation is one of them. Embracing innovation requires to process, find and break down these gigantic informational indexes that can't be managed utilizing conventional databases and models because of the absence of limit assets as far as calculation and capacity. Elite investigation speaks to one of the creative methodologies that can be connected on the expanding volumes, speed and assortment of information.

Goals

Enormous data phenomenon, which is described by the quick development of volume, assortment and speed of information data resources, flourishes the change in perspective in explanatory information preparing. High Performance Analytics (HPA) can be considered as one of the methodologies. The point of the postulation is an exploration outline, order, and talks on issues and difficulties on the spearheading condition of specialty of cutting edge examination using different strategies HPA

techniques that could raise and improve the calculation execution of examination. Considering the way that they chose a region of research is as of now being refined and formalized and at the same time is rising quickly in restrictive definitions and arrangements from various sellers, the objective of the theory is to arrange and give outline and review with finish and reliable picture about the region of high performance analytics. In addition, usage of these strategies might be exhibited in down to earth task including handling of immense dataset.

Outcome

The extent of the theory is committed to research and methodologies of big data and high performance Analytics. A hypothetical piece of the theory is a result of complete investigate that abridges a condition of craftsmanship diagram for this issue, characterizes the drivers and results of big data phenomenon, and presents approaches for dealing with big data, in specific approach given High Performance Analytics. Particularly the result of the examination is situated on a review of HPA, order, qualities and focal points of particular strategy for HPA using the different mix of framework assets. A functional piece of the proposal is a result of exploratory task that incorporates explanatory preparing of expansive dataset utilizing investigative stage from SAS Institute. The analysis exhibits scientific handling for chosen HPA strategies that are talked about in hypothetical part. One a player in the analysis incorporates forming diverse scientific situations on which the preferences and accommodation of HPA stage are illustrated.

PROBLEM IDENTIFICATION AND SUMMARY

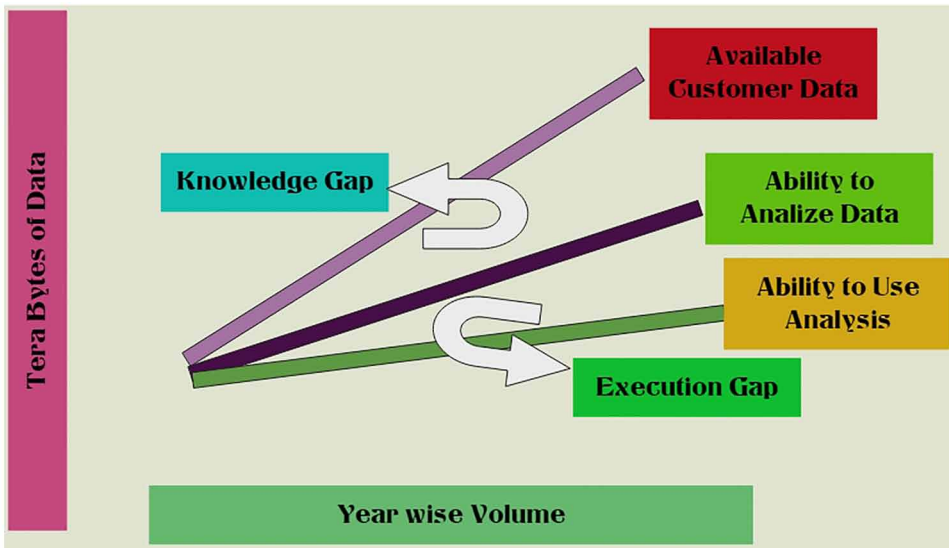
As said in the presentation a main issue of this postulation is information, information preparing, extricating data and stuff around it. Let us first begin with hypothetical approach of issue.

Theoretical Problem

The information volume speaks to a test all things considered, not simply like that, ought to be put inside a set. The accessible information like client information in their business setting that develops in all measurements are point by point in segments later, and they connected information with expository and execution limit (Kuner, Cate, Millard & Svantesson, 2012), delineated in Figure 1.

Thinking about the genuine patterns, when all of lines are developing, the accessibility of information has overburdened a capacity to break down information

Figure 1. The information volume challenge



examination, and in addition an ability to utilize the investigation either to run investigation or store examination registering and capacity limit. An information hole communicates the powerlessness to break down information because of the restricted expository procedures may incorporate information mining calculations, characteristic dialect handling, and so on, e.g. propelled feeling investigation of printed remarks of web based life (Hassani-Mahmooei, Berecki-Gisolf & Collie, 2017). An execution hole communicates failure to use investigation because of the restricted accessibility of assets may incorporate handling units, information stockpiles, and so forth for asked for a timeframe, e.g. undertaking to process the all day by day exchange at bank in asked for configuration of the clearing house more than one night.

WHERE IS THE ISSUE?

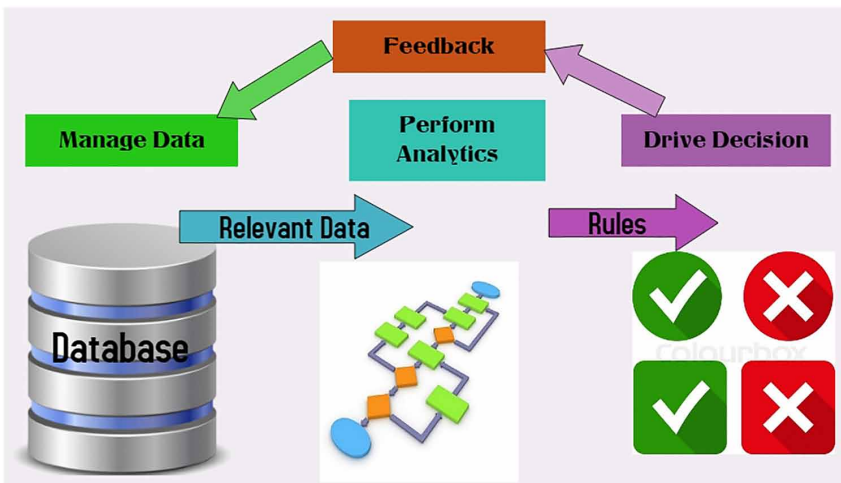
While an execution limit as far as equipment is developing a pretty much stable rate, information volumes are developing exponentially. In this way the learning hole is getting more extensive, and the territory of the lost data openings in set of accessible information containing the data significant regarding the data needs. The point is to boost the arrangement of important information that conceivably contains the profitable data. Hence, the volume and accessibility of information are not an issue instead of the preparing and association of information.

Enormous Information and Examination

Enormous information postures the two openings and difficulties for organizations to extricate esteem from enormous information, it must be prepared and examined in an opportune way, and the outcomes require being accessible so to have the capacity to impact positive change or impact business choices. The adequacy additionally depends on an association having the correct mix of individuals, process and innovation by unadulterated definition. Investigation is the disclosure and correspondence of important examples in information. However for business, investigation ought to be seen as the broad utilization of information, factual also, quantitative examination, utilizing informative and prescient models to drive reality based business administration choices and activities.

Examination streamlines key procedures, capacities and parts it can be utilized to total both interior and outer information analytics process is shown in figure 2. It empowers associations to meet partner announcing requests, oversee gigantic information volumes, advertising preferences, oversee hazard, enhance controls and, eventually, improve hierarchical execution by turning data into knowledge (Ahmadvand & Goudarzi, 2017). An investigation can distinguish creative open doors in key procedures, capacities and parts. It makes an impetus for advancement and change and by testing the norm; it can help to make new conceivable outcomes for the business and its clients. Advanced methods can enable organizations to find underlying drivers, examine micro segments of their business sectors, change procedures and make exact expectations about future occasions or clients' inclination to purchase, agitate or lock in.

Figure 2. Analytics process



It is never again enough for organizations to just comprehend current process or tasks with a view on enhancing what as of now exists when there is presently the ability to address if a process is applicable to the business, or whether there is another method for tackling a specific issue. The key driver for development inside associations is to continually challenge existing practices instead of reliably acknowledging the same. Most associations have intricate and divided design scenes that make the strong resemblance and scattering of information troublesome. The major goal of picture division is to segment the information picture into important non-covering locales sections for assist examination or perception. There is an assortment of methodologies tending to this undertaking, misusing different picture properties to accomplish the given objective (Kashyap and Gautam, 2017a). They traverse from low-level methods utilizing power limits, edge following or district developing, over chart based and measurable methodologies, to show based calculations also, other more elevated amount techniques. As of late, the mix based arrangement has been presented, where the last parcel is shaped utilizing a blend of aftereffects of a few division techniques and subsequently repressing their inadequacies (Kashyap, Gautam and Tiwari, 2018). In spite of the long-lasting push to grow fantastic division calculations, there has not been any all inclusive division technique discussed. Under these conditions, there is a predicament which strategy to decide for given specific informational collection and whether the mix of division results would be valuable (Kashyap, Gautam, 2017b). This endeavors to answer these inquiries for characterized classification of picture handling information set of pictures of minuscule images the execution of a few division techniques on pictures of minute examples in three unique modalities was broke down. The arrangement of ten quality lists was utilized to accomplish assessment as goal as could be expected under the circumstances. We appeared that there was no single division technique which altogether beat the others in the concentrated set. The normal execution of the techniques was at that point assessed with the conclusion that Mean Shift calculation played out the best and can be viewed as the best division technique by and large (Kashyap, Anderson, 2018). New logical arrangements are playing an essential part in empowering a viable Intelligent Enterprise (IE) is given in figure 2. An IE makes a single view over your association by using a mix of standard detailing and information perception (Rho & Vasilakos, 2017):

- Data from numerous source frameworks is rinsed, standardized and ordered
- External feeds can be assembled from the most recent research, best practice rules, benchmarks and other online vaults (Kashyap, R., & Piersson, A. D., 2018)

- Use of upgraded perception procedures, benchmarking files and dashboards can illuminate administration and shoppers by means of cell phones, PCs, tablets, and so on. In house or then again remotely

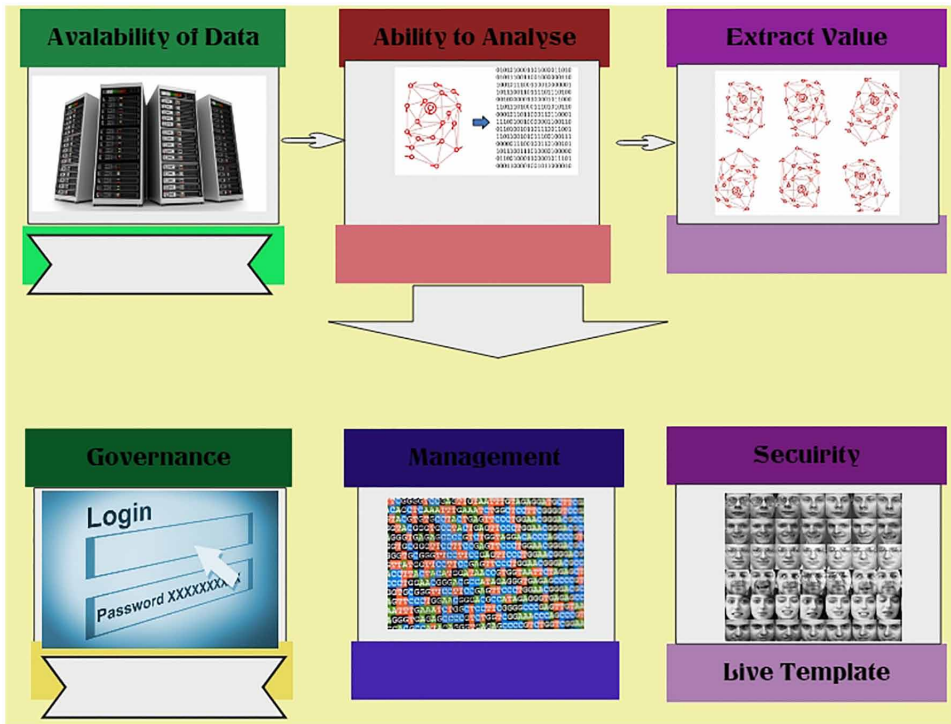
All organizations need to begin pondering gathering and utilizing significant huge information. Information driven choices can lessen wastefulness between the business, legitimate and IT, advance existing data resources and address separates between various elements of an association. In any case, it is important that the best information and the most progressive scientific devices and systems amount to nothing in the event that they are not being utilized by individuals who are asking the right inquiries. Enormous information, rising stockpiling innovation stages and the most recent diagnostic calculations are empowering influences to business achievement not a certification of it.

HUGE INFORMATION DRIVERS

The advantages and dangers of enormous information while there is almost certainly that the huge information upset has made generous advantages to organizations and customers alike, there are proportionate dangers that accompany utilizing huge information big data drivers is given in the figure 3.

The need to anchor delicate information, to ensure private data and to oversee information quality, exists whether informational collections are huge or little (Reydel-Castillo & Cardenosa, 2016). Be that as it may, the particular properties of huge information volume, assortment, speed, and veracity make new sorts of dangers that requires an extensive procedure to empower an organization to use huge information while staying away from the traps. This ought to be done in an organized manner with the goal that organizations can begin to understand the advantages of enormous information in venture with dealing with the dangers. The accompanying pages take a gander at the conceivable outcomes and dangers related with huge information and give cases of how enormous information is being utilized to understand a portion of the unpredictable issues organizations confront today. We distinguish conventional and new dangers and contemplations for the seven key advances to progress: administration, administration, engineering, utilization, quality, security and protection (Waterman & Hendler, 2013). The nature of informational collections and the deduction drawn from such informational collections are progressively winding up more basic what's more; associations need to fabricate quality and checking capacities and parameters for huge information. For instance, adjusting an information mistake can be considerably more exorbitant than getting the information

Figure 3. Big data drivers



right the first time and getting the information wrong can be calamitous what's more, significantly more expensive to the association if not remedied. For a long time the human services environment has grasped huge information. With the capacity to catch each patient touch point, the measure of information inside the social insurance biological system has detonated. The development of new information sources and the capacity to squash that information with existing information sources is advancing huge information is making the likelihood of new positive patient results.

A portion of these new information sources incorporate the combination of infection registries, tissue registries and genomic data, and afterward adjusting them to important utilizes clinical models. It is characterizing key care treatment approaches in light of new hereditary bits of knowledge and clinical convention coordinating calculations, and characterizing centered patient care treatment bits of knowledge prior inside the care conveyance process. The incentive from these new enormous information bits of knowledge will be precious for the patient. The quality of the information will likewise directly affect driving new key social insurance bits of knowledge in making superb results while successfully overseeing costs.

Analytics

Investigation is another popular expression in the innovation business and it “alludes to our capacity to gather and utilize information to produce bits of knowledge that educate certainty based basic leadership” before, the information that was broke down was for the most part used to foresee what may occur later on and was completely held onto by enterprises, for example, banks and protection organizations, yet not by associations, for example, retailers. Enormous data and investigation go as an inseparable unit in the current innovative age. Enormous data examination utilizes prescient and prescriptive examination and is changing the investigation scene (Hussain & Roy, 2016). Prescient examination utilizes information from the past to anticipate what may happen, and its probability occurring later on. Though, prescriptive examination is taking information from the past, utilizing it to choose what ought to be done alongside accomplish ideal outcomes.

Methodologies

The issue has diverse settling approaches theoretically; the information hole can be shut by constraining or diminishing development of information. Clearly, this is not going to happen. Explanatory limit is resolved and subject to look into cutting edge examination. All things considered, having developed level of examination may be a decent approach except if the investigation is physically conceivable to keep running on transfer innovations and equipment. The execution hole can be conceivably shut by expanding use limit, for example, disseminated or parallel preparing restricted by level of division of undertaking going with extra units for preparing CPU, RAM and putting away information. This approach has drawback in overall restricted assets and won't tackle the issue because of high proportion supply: demand of information. Aside from limit another point of view of improving might be input itself. Is all information required? Important to break down or store? In view of the prerequisites the repetitive or insignificant information that holds little, assuming any, data can be sifted through, with danger of lost data opportunity in missing information yet we don't realize what we don't have the foggiest idea. By applying “brute force” calculation on entire dataset the issue is starting over from the beginning.

Insights to Foresights

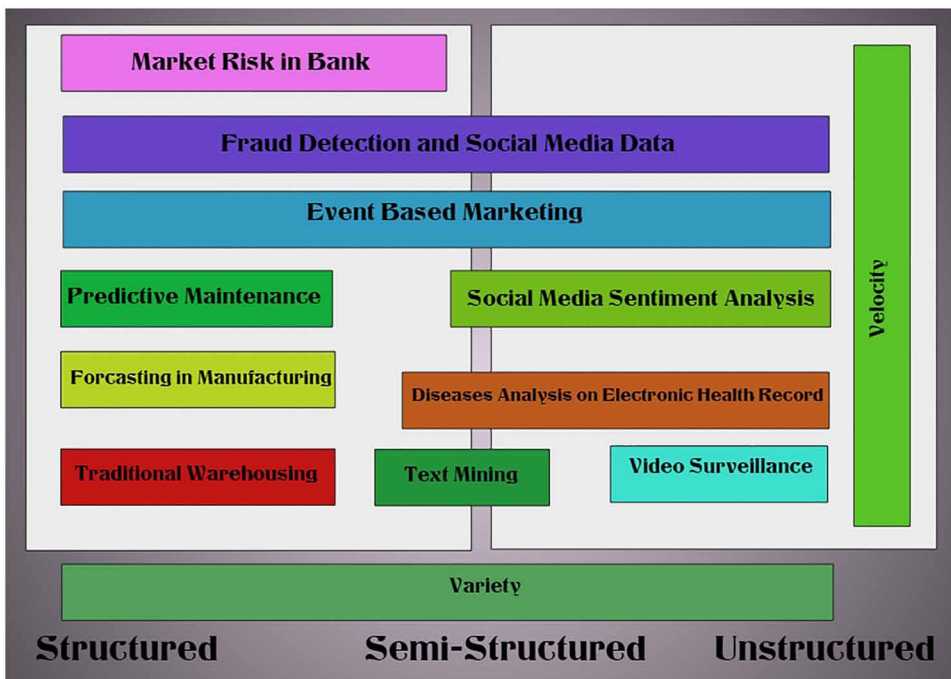
Progressed Analytics can be appropriate for different business investigation with respect to investigate client patterns conduct, rivalry, misrepresentation recognition, wastefulness in business process Capacity Maturity Model (CMMI), showcase crate examination conditions, causalities, relations in items' deals, and so on

(Weber, Königsberger, Kassner & Mitschang, 2017). All that really matters is various examination utilizations can be arranged by the speed of information with time conditions continuous, group preparing, or to the assortment of information organized, semi structured, unstructured. Review of utilization cases for examination is delineated in Figure 4.

It is vital to specify that examination can recover helpful data from information that may speaks to bits of knowledge. With facilitate examination can be possibly move into premonitions. New developing region of investigation is spoken to by unstructured information content with expansive utilization of online life (Lomotey & Deters, 2015). Content examination distinguishes and separates the important data and translates mines and structures it to uncover examples, conclusions and connections inside and among records.

- Automated content order makes data looks far quicker and then some successful than manual or review labeling strategies.
- Ontology administration joins content storehouses together, authorizing information quality with predictable and deliberately characterized connections.

Figure 4. Big data and high performance analysis



- Sentiment investigation naturally finds and recognizes assumption communicated in online materials, for example, person to person communication destinations, remarks and websites on the Web, and from inside electronic archives.
- Text mining gives intense approaches to investigate unstructured information accumulations and find already obscure ideas and examples.

Business Intelligence

BI and OLAP normally spend significant time in questioning, announcing, and breaking down chronicled information to comprehend and contrast comes about with date or for particular eras previously. Associations can utilize BI and OLAP counts to extend a perspective of what the numbers say is probably going to happen later on (Kekwaletswe & Lesole, 2016). In any case, progressed investigation can give a considerably more profound comprehension of why what more, a deductively based, prescient perspective is without bounds. Progressed examination gives clients with the capacity to investigate numerous factors to refine understanding. To give this more profound level of understanding, progressed examination regularly need to investigate crude, nitty gritty information as opposed to littler examples and accumulations, which are usually utilized for BI and OLAP.

BI frameworks offers client connections through dashboard interfaces that incorporate information get to what's more, representations, for example, diagrams and charts with cautions, pointers, and different changes trackers. While conventional BI reports now and again gives just static and restricted perspectives of chronicled execution. Current BI frameworks can revive information in dashboards all the more much of the time, enabling clients to track measurements that can caution spikes, plunges, or different deviations from anticipated standards in something closer to constant. What BI frameworks need is both the more profound, more exploratory point of view that best in class examination can give, and the bits of knowledge driven by prescient and other systematic models. By connecting with dashboard gateways, BI clients can devour progressed investigation through representations, and utilize information disclosure capacities to pick up a "why" comprehension of what the BI execution measurements are appearing. Associations can go further and make progressed investigation tasks themselves the drivers, and execute BI dashboards and measurements to give sees into the consequences of the logical tasks. Illustrations incorporate examination that gives understanding into consumer loyalty, accomplishment in extortion anticipation (Arbel, 2015). A vital piece of huge information investigation capacities is access to enormous information. Business associations are ending up increasingly mindful of the estimation of information. The development in business information usage rate is specifically identified with the

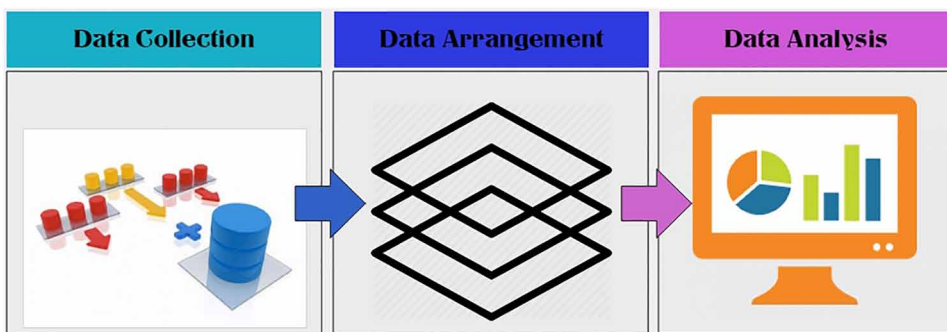
huge information development rate. Five information composes are distinguished: open information, private information, information debilitate, network information, and self evaluation information. The meanings of these information writes are source particular information e.g., non individual information when they characterize the accompanying information composes (Tromp, Pechenizkiy & Gaber, 2017). • Public information are regularly free information given by legislative establishments, private associations or people. • Private information is association claimed information. • Data deplete speaks to information with no or little incentive in its own unique situation yet may give profitable intel when associated with other information. • Community information is, for example, Facebook, Twitter and other web based social networking created information. • Self measurement information is information produced from wearable advancements like savvy watches, wellness groups and so forth (N. Smith, 2015). Information can be additionally isolated into outside and inner information: • Internal information is hierarchical information made by the authoritative procedures. Illustrations are stock updates, deals, exchanges or other inside procedures. • External information are information from outside sources, either open, private yet achievable through purchasing or exchanging, network information among others.

Huge Data Analytics

Enormous Data Analytics can be portrayed with the accompanying chain of activities with information to reveal groupings or connections and uncover useful perceptions: (Figure 5)

Huge data analytics offers an organization an understanding perspective inside its structure and acquires radiant data for present and future business arrangements. The objective for big data researchers is to pick up learning, got from the information

Figure 5. The handling ventures of big data analytics



preparing. Ongoing information alludes to floods of information that are conveyed specifically after information accumulation. So, there exists no deferral in the change from crude information accumulation to the data gave from continuous information (Kashyap, 2019a). Beside continuous information, organizations additionally confer assets to extricate an incentive from present and verifiable information. Over the top accentuation on constant information can lead bring about difficulties and disappointment of information driven basic leadership (Diesner, 2015). The accessibility of present and verifiable information is important to position constant information into setting of examples and patterns. Further, “right time information” and noteworthy information should be given to help basic leadership. Henceforth, applicable information should be assembled and incorporated for particular necessities or situations, types and source of data is given in table1.

The Principle of Work

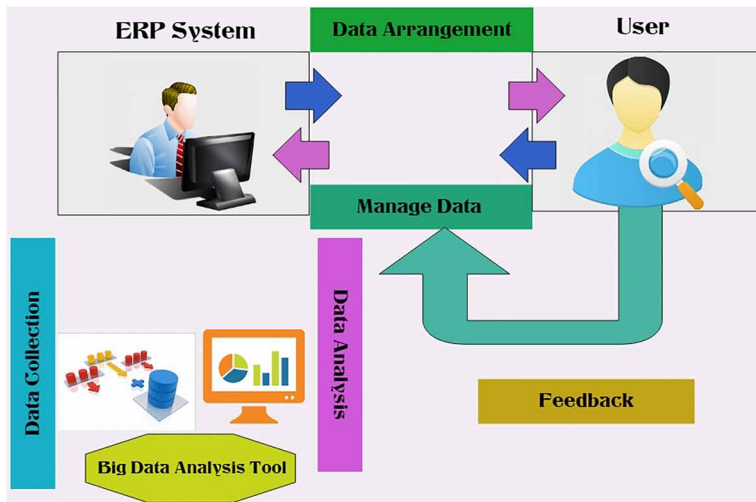
As indicated by the plan, the interchange between big data and the organization is portrayed by the accompanying advances:

- 1. The creation information, produced amid the assembling of the Intelligent Engineering Products, is sent to the organization’s ERP where the information is put away in the social databases. Additionally, the Case Company protects client’s criticism into the ERP also.
- 2. Next, the ERP programming naturally transmits crude information to the big data Analytics Tool that distributes it in the SQL Server and makes the

Table 1. Sort of data and data sources

S.N.	Types of Data	
1.	Organized Data	Table and Records
2.	Unstructured Data	Human Language, Audio and Video
3.	Semi Structured Data	XML and Similar Standards
4.	Occasion Data	Messages (typically in Real Time)
5.	Complex Data	Hierarchical or Legacy Sources
6.	Spatial Data	Long/Lat Coordinates and GPS Output
7.	Online networking Data	Blogs, Tweets and Social Networks
8.	Logical Data	Astronomy, Genomes and Physics
9.	Machine Generated Data	Sensors, RFID and Devices
10.	Metadata	Data that depicts the substance of other information

Figure 6. The working guideline of the big data analytics tool



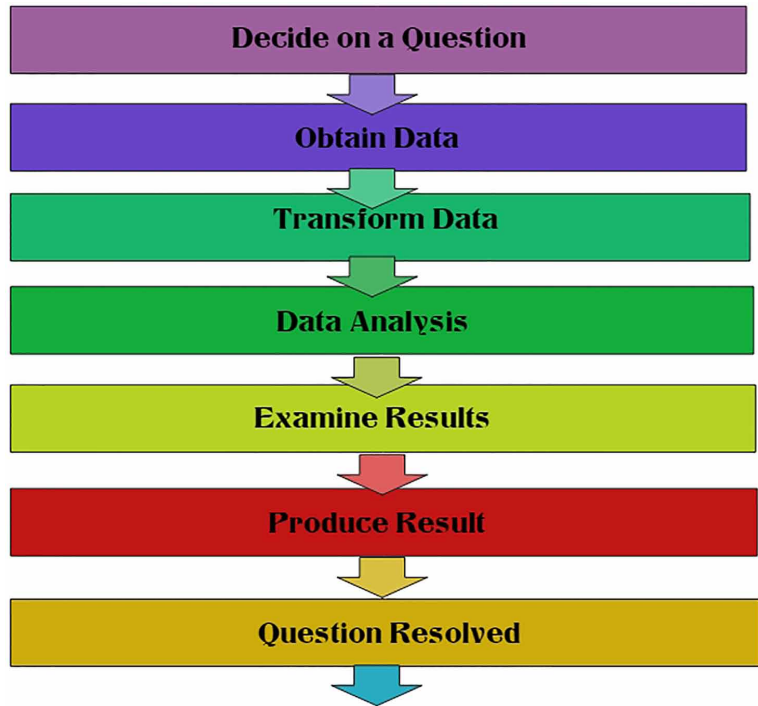
investigation to show the working effectiveness of the seller in different zones: apparatus use, time utilization, execution rate, false coefficient, quality degree, and so forth (Tromp, Pechenizkiy & Gaber, 2017).

3. At long last, the Case Company can track and streamline the work process, deal with the business procedures and complete new enhancements in the foundation procedure.

The investigation result can be hard to get with one preliminary extra information investigation works can be rehashed for a few times by confirming the outcome and deciding the estimation of examination result. The procedure of enormous information investigation may concede in every examination procedure so that the powerful result can be obtained just by rehashed exhibitions of different strategies as shown in figure 7.

Methodological paradigms and difficulties of big data methodologically, enormous information enables us to use both expectation and causal investigation. Best in class enormous information research and practice draws on an assortment of systems from machine learning, established measurements, and econometrics, to plan of tests industry calls this A/B or multivariate testing to test existing speculations and theories, creating new speculations, and making vast scale business esteem (Yu, Yurovsky & Xu, 2011). From the point of view of logical request, the whole comprehensively associated organized economy currently can be conceived as a large scale true lab where scientists can outline and lead analyses and gather the information expected to acquire answers to an assortment of inquiries including (1)

Figure 7. Big data analytics process



impacts of companion impact, (2) effects of the impact of dynamic ties, (3) effects of namelessness on online connections, (4) comes about from elective estimating methodologies for advanced media, (5) the influence of painstakingly composed cutting edge recommender frameworks, and (6) the changing inclination structures of Generation Y and Z shoppers. Breaking down these issues absolutely present methodological difficulties, however we see the difficulties as open doors for capable analysts.

The enormous information techniques specified above have likewise raised contentions. Late disclosures from two well known sites, Facebook and OkCupid, both of which explored different avenues regarding their clients, have started enthusiasm for the subject of what, if any, fitting applications exist for utilization of the online social space as a research center for promoting our comprehension of human conduct (Davalos & Merchant, 2015). The key question is whether such experimentation by organizations or potentially by scholastics as a team with organizations gives advantages to society everywhere, and, assuming this is the case, what moral examination is proper and implementable? We contend that there is a solid case for such experimentation, not simply to maintain a strategic distance

from expensive awful choices, yet additionally for quest for better comprehension of what drives human social communications. Awful choices hurt all that really matters of organizations as well as they cost society since terrible choices result in a misallocation of basic assets. As far back as that phlebotomy was a useful medicinal practice, precisely composed experimentation has driven logical investigation and learning disclosure. Presently, with the accessibility of vast scale experimentation yielding huge information, the potential for examination, testing, and new learning improvement are captivating.

While connecting with companions and scanning for sentimental accomplices go back to the posterity of Adam and Eve. The reality is that a huge part of this movement is direct on the web an ongoing PNAS examine demonstrates that 33% of later relational unions in the United States, begin from a web-based dating webpage in vigorously designed computerized stages with highlights that can be controlled (Soltani & Navimipour, 2016). The immense measure of small scale level huge information about human communications offers openings never accessible in the physical world because of cost or infeasibility of equivalent information accumulation. We currently have chances to produce new causal experiences, to test the viability of age old dependable guidelines and standards that represent social cooperation's. We can thoroughly test existing hypotheses and assemble and test new hypotheses. In short, we can go where social researchers could just dream of going before.

This conveys us to the need to precisely address the issue of regardless of whether such extensive scale field analyses would cause more societal mischief than great. This net thought of societal advantage is unquestionably of key enthusiasm for our individual colleges' morals and human subjects advisory groups otherwise called institutional audit sheets. Organizations need to take a leaf out of, or maybe team up with, the scholarly community and set up comparative morals advisory groups managing human subjects (Kashyap, 2019b). On the off chance that, as a general public, we put stock in interest about us as an animal varieties, at that point we have to gain from what probing the on the web social chart lets us know. As usual, we require our foundations to make up for lost time to innovation. Utilizing enormous information and investigation accompanies a large group of difficulties, a large number of which are ripe ground for future research. Huge information is more minds boggling to oversee than standard corporate information. Previously, organizations for the most part oversaw well structured information. In any case, organizations presently need to oversee a lot of inner and outer information that oftentimes will be unstructured or approximately organized. Including suitable what's more, entrepreneurial review information from any of the nearly omnipresent overview choices, firms currently can confront an enormous exhibit of inside, outer, and overview information.

Pervasive Informing

Today, people and organizations record what they find fascinating, store this data for themselves or others, what's more, share the information for individual and additionally business purposes. For effortlessness, we allude to this marvel as omnipresent illuminating since a definitive objective is to educate somebody about something extending from a brilliant dish, somebody's heartbeat, video catches, social cooperation's, vehicle tasks, and road reconnaissance for all intents and purposes any piece of data. Universal illuminating is conceivable in light of mechanical propels in versatile registering, video gushing, social organizing, savvy vehicles, and the Internet of things. Data snatching and trading are undoubtedly simple; the challenge is to discover an incentive in setting aside the opportunity to finish such assignments (Ding, Erickson, Kellogg & Patterson, 2011). The issue is whether one can utilize huge information and information investigation to get genuine esteem. Can an organization become more acquainted with its clients better? Can the organization distinguish its generally important customers and improve benefits through giving these clients with more customized client connections or better client administrations? Can the organization use data to increase more grounded advertise position? The difficulties from omnipresent advising incorporate growing far better enormous information building and examination to oversee and use enormous information to convey business esteem.

Usage Environments

From an unadulterated stockpiling point of view, stack situations, for example, Hadoop have been acquainted with oversee huge information 3D shapes. As with any new innovation, such creating situations ought to be drawn closer with clear vision and sound feedback. As noted (Nurika, Hassan & Zakaria, 2017), anyway delightful the methodology, one ought to at times take a gander at the outcomes. In many cases, stack situations remain vigorously underutilized with the danger of presenting yet another expensive heritage trouble and imperiling future huge information driven developments. More moderate inmemory setups could exhibit an intriguing option in the travel towards the develop enormous information association.

COORDINATION ISSUES

A key enormous information challenge for any firm is to distinguish and unravel the interrelationships of the huge information shape and draw out the esteem suggestions by connecting the different information streams utilizing properly characterized one

of a kind identifiers, it might end up conceivable to get a more total picture of client conduct (Mynarz, 2014). In a protection setting, a system of connected elements for example, claims, petitioners, policyholders, autos, locally available diagnostics gadgets, auto repair shops, charge cards, and portable numbers may be built to disclose an extraordinary point of view on complex intrigue practices or extortion designs.

Esteem Assessment

The troublesome effect and imaginative utilizations of enormous information cause genuine difficulties for the expository systems and models that will be manufactured. These models fundamentally begin from traditional measurements, econometrics, machine learning, or manmade reasoning. A key normal for these explanatory strategies is that they center on improving a particular precision paradigm or insights based target work e.g., limiting a mean squared blunder or augmenting probability. Ordinarily, execution is abridged utilizing comparing factual measures that can be troublesome to comprehend for end clients or no experts (Thompson, Varvel, Sasinowski & Burke, 2016). As diagnostic models acquire and more impact in the key choices of a firm, it is vital to connect this correspondence hole to create the important trust. In particular, to pick up trust in an investigative model, the two information researchers and chiefs ought to receive a most widely used language in which the idea of significant worth assumes a key part. This achieves an entirely new point of view on the development, execution, and assessment of a diagnostic model. As such, other as unadulterated factual execution e.g., estimated utilizing misclassification rates, mean squared mistakes, Gini bends, top decile, genuine esteem based criteria turn into the prevailing components. The suitable criteria are exceptionally needy upon the particular business setting.

Expository Models Ought to Be Justifiable to Chiefs

Clearly, this has a subjective component to it and relies upon both the portrayal and formal multifaceted nature of the systematic model and additionally the instruction or foundation of the end client. Black box investigative models in light of exceptionally complex scientific recipes are probably not going to be trusted to bolster key business procedures, for example, credit hazard estimation, misrepresentation identification, or even therapeutic finding. However, in the event that a discovery strategy conveys precise restorative analyze over and over, would the patient driven specialist select for less precise yet effortlessly reasonable choices? Esteem based execution basis concerns operational productivity including model assessment, show checking, and demonstrate refreshing (Kashyap & Tiwari, 2018). The first of these allude to the assets that are expected to assemble the fundamental information inputs, preprocess them,

run them through the model, and follow up on the acquired yield. Continuously basic leadership settings, quick model assessment are a key prerequisite. Consider the case of charge card misrepresentation location, where regularly a choice should be made in less than five seconds after the exchange is started. Recommender frameworks are another case where any client activity or occasion for instance, recorded utilizing area based administrations (Angelis & Kanavos, 2013). Notwithstanding model assessment endeavors, operational proficiency likewise involves the assets expected to screen, back test, and, where pertinent, stretch test the scientific models. At long last, the model must be invigorated or refreshed as new information develops or business conditions change. The organization that can recognize changing conditions and rapidly adjust its models is the organization that will succeed.

Overseeing Analytic Decisions

Drawing out choice prepared derivations from huge information investigation impacts and improves the association's basic leadership. With examination, we will see more choices being mechanized, in this manner affecting the choice procedures and obligations all through the association. With choices being mechanized possibly in light of enormous information examination, overseeing and demonstrating business choices is a rising test. Associations are intensely engaged with improving their business forms and empowering fast and compelling response to new difficulties, openings, or controls. By expressly demonstrating choices and the rationale behind them, choices can be overseen independently from the procedures, drastically expanding business spryness. This requires understandable choice examination methods for business (Ploskas, Stiakakis & Fouliras, 2014) and in addition strategies and measures to depict, show, what's more, oversee business basic leadership. The choice model what's more, documentation is such a standard for choice displaying, received by the Object Management Group, to conquer any hindrance between business process outline and business choices.

Quantifiable Profit and Trust

At long last, a diagnostic model should include monetary incentive by either producing benefits or cutting expenses or both. A profit driven assessment of a diagnostic model is vital to create trust crosswise over different levels and specialty units in any association. Administrative choices are ordinarily in view of monetary return, as opposed to a factually critical explanatory model, furthermore, that is the place examination can produce question and hence fall short. It is our firm conviction this ought to be catalyzed by more research in no less than two territories. To start with, inventive methodologies ought to be created to precisely measure

the arrival on venture of an investigative model considering the add up to cost of model proprietorship, including aberrant and opportunity expenses, and covering an adequately long and fitting time skyline. As a next subject on the exploration plan, the subsequent monetary bits of knowledge and measures ought to be specifically installed into a systematic model building process, as opposed to simply utilized as ex post assessment measures (Batarseh, Yang & Deng, 2017). In particular, logical models should never again indiscriminately center around improving a probability work or limiting a misclassification rate, however go for including business esteem where it is important, considering all the previously mentioned criteria. At exactly that point will the vital trust be acquired over all choice levels and specialty units in a firm?

STRATEGIES FOR ANALYZING BIG DATA: A NEW APPROACH

When you utilize SQL inquiries to look into money related numbers or OLAP devices to create deals estimates, you for the most part comprehend what sort of information you have and what it can let you know. Income, topography and time all identify with each other in unsurprising ways. You don't really comprehend what the appropriate responses are nevertheless you do know how the different components of the informational collection identify with each other. BI clients regularly run standard reports from organized databases that have been deliberately displayed to use these connections. Enormous information investigation includes making "sense" out of huge volumes of shifted information that in its crude frame does not have an information model to characterize what every component implies with regards to the others. There are a few new issues you ought to consider as you set out on this new sort of investigation: Discovery in numerous cases you don't generally comprehend what you have and how unique informational indexes identify with each other (Kashyap, 2019). You should make sense of it through a procedure of investigation and disclosure. Iteration because the genuine connections are not generally known ahead of time, revealing understanding is frequently an iterative process as you discover the appropriate responses that you look for. The idea of emphasis is that it here and there drives you down a way that ends up being a deadlock. That is alright experimentation is a piece of the procedure. Numerous investigators and industry specialists recommend that you begin with little, very much characterized ventures, gain from each cycle, and continuously proceed onward to the following thought or field of request (Yang & Yecies, 2016). Flexible Capacity because of the iterative idea of huge information examination is set up to invest more energy and use more assets to take care of issues. Mining and predicting big information investigation isn't highly contrasting. You don't generally know how the different information

components identify with each other (Kashyap, 2019c). As you mine the information to find examples and connections, prescient investigation can yield the experiences that you look for. Decision Management considers the exchange volume and speed. On the off chance that you are utilizing huge information investigation to drive numerous operational choices, for example, customizing a site or provoking call focus specialists about the propensities and exercises of buyers at that point you have to think about how to mechanize and improve the execution of every one of those activities.

For instance you may have no clue regardless of whether social information reveals insight into deals patterns. The test comes with making sense of which information components identify with which other information components, and in what limit. The procedure of disclosure not just includes investigating the information to see how you can utilize it yet in addition deciding how it identifies with your conventional endeavor information. New kinds of request involve what happened, as well as why. For instance, a key metric for some, and organizations is client agitate. It's genuinely simple to evaluate stir. Yet, for what reason does it happen? Examining call information records, client bolster request, internet based life analysis, and other client input would all be able to help clarify why clients imperfection (Pan, Wang & Han, 2016). Comparative methodologies can be utilized with different sorts of information and in different circumstances. For what reason did deals fall in a given store? For what reason do certain patients survive longer than others? Try to locate the correct information, find the shrouded connections, and examine it accurately.

Huge Data Analysis Requirements

In the past segment, Techniques for analyzing big data, we talked about some of strategies you can use to discover which means and find shrouded connections in enormous information. Here are three huge necessities for directing this request in a practical way:

1. Limit information development
2. Utilize existing aptitudes
3. Take care of information security

Limiting information development is tied in with moderating figuring assets. In customary investigation situations, information is conveyed to the PC, handled, and after that sent to the following goal. For instance, creation information may be separated from e business frameworks, changed into social information write, and stacked into an operational information store organized for detailing. Yet, the volume of information develops, this kind of ETL engineering moves toward becoming

progressively less effective. There's simply an excessive amount of information to move around. It bodes well to store and process the information in a similar place. With new information and new information sources comes the need to obtain new abilities. The current range of abilities will figure out where investigation should and ought to be possible (Horton & Tambe, 2015). At the point when the imperative abilities are deficient with regards to, a mix of preparing, procuring and new instruments will address the issue. Since most associations have more individuals who can dissect information utilizing SQL than utilizing MapReduce, it is critical to have the capacity to help the two kinds of handling. Information security is basic for some corporate applications. Information distribution center clients are acclimated not exclusively to deliberately characterized measurements and measurements and properties, additionally to a dependable arrangement of organization strategies and security controls. These thorough procedures are regularly missing with unstructured information sources and open source investigation instruments. Focus on the security and information administration necessities of every investigation venture and make beyond any doubt that the devices you are utilizing can oblige those prerequisites.

Database Processing With Oracle Advanced Analytics

Most Oracle clients are exceptionally acquainted with SQL as a dialect for question, announcing, and examination of organized information. It is the accepted standard for investigation and the innovation that underlies most BI apparatuses. R is a prevalent open source programming dialect for factual examination. Investigators, information researchers, scientists, and scholastics generally utilize R, prompting a developing pool of R software engineers. When information has been stacked into Oracle Database, clients can profit themselves of Oracle Advanced Analytics (OAA) to reveal shrouded connections in the information. Prophet Advanced Analytics, an alternative of Oracle Database Enterprise Release, offers a mix of intense in database calculations and open source R calculations, available through SQL and R dialects. It joins elite information mining capacities with the open source R dialect to empower prescient investigation, information mining, content mining, measurable examination, progressed numerical calculations and intuitive design all inside the database (Jin, Liu & Qi, 2012). Prophet Advanced Analytics gives all center scientific capacities and dialects on great in database engineering. These explanatory capacities incorporate information mining calculations actualized in the database, local SQL capacities for fundamental factual procedures, and incorporation with open source R for measurable programming and access to a more extensive arrangement of measurable methods.

This intense diagnostic condition offers an enormous scope of capacities to Oracle Database clients handling enormous information extends by limiting information

development and guaranteeing intrinsic security, versatility, and execution (Wao, Kashyap, & Jaiswal, 2010). It incorporates information mining apparatuses that let you make complex models and convey them on expansive informational collections. You can use the consequences of these prescient models inside BI applications. For instance, you can utilize relapse models to foresee client age in view of obtaining conduct and statistic information. You can likewise assemble and apply prescient models that assistance you focus on your best clients, create nitty gritty client profiles, find and counteract misrepresentation, and understand numerous other scientific difficulties.

Productive Data Mining

The information mining instruments in OAA empower information investigators to work specifically with information inside the database, investigate the information graphically, manufacture and assess numerous information mining models, and send forecasts and bits of knowledge all through the undertaking. It incorporates information digging calculations for characterization, bunching, advertises container investigation, misrepresentation identification, and content mining that can be connected to settle an extensive variety of information driven issues. It additionally incorporates a dozen calculations that you can use to fabricate and send prescient applications that consequently mine star diagram information to convey constant outcomes and expectations. Since the information, models and results stay in the Prophet Database, information development is wiped out, data dormancy is limited and security is kept up. Utilizing standard SQL charges you can get to elite calculations in the database to mine tables, sees, star constructions, and value based and unstructured information (Bacardit & Llorà, 2013). Any individual who can get to information put away in an Oracle Database can get to OAA comes about, expectations, suggestions, and revelations utilizing standard reports and BI instruments.

Factual Analysis With R

Prophet Advanced Analytics has been intended to empower analysts to utilize R on vast informational indexes. Investigative models can be composed in R. The related tables and perspectives in Oracle Database show up as R objects. Therefore there is no compelling reason to compose SQL proclamations. Examiners can compose R code to control the information in the database. By running R programs right in the database, there is no compelling reason to move information around. This coordinated engineering guarantees extraordinary security and execution, since you can apply enormous, versatile equipment assets to complex issues. OAA underpins existing R contents and outsider bundles too. All current R improvement abilities, devices,

and contents can run straightforwardly with OAA, and scale against information put away in Oracle Database 11g. The tight mix between R, Oracle Database, and Hadoop empowers examiners to keep in touch with R content that can keep running in three distinct conditions: a workstation running open source R, Hadoop running with Oracle big data connectors, and Oracle Database (Duque Barrachina & O'Driscoll, 2014). It is anything but difficult to connect the consequences of the investigation to business examination devices, for example, Prophet Business Intelligence and Oracle Analytics, as portrayed in the accompanying area.

Connecting Hadoop and Oracle Database

There are two distinct alternatives for connecting information and interval brings about Hadoop with your Oracle information distribution center. Contingent upon your utilization case, you might need to stack Hadoop information into the information stockroom, or abandon it set up and simply inquiry it utilizing SQL. Prophet Loader for Hadoop gives a simple method to stack HDFS information into an Oracle information stockroom. MapReduce to make advanced informational collections that can be proficiently stacked into Oracle Database. Not at all like other Hadoop loaders, has it created Oracle inward configurations, allowing it to stack information speedier with less framework assets. Once stacked, the information can be gotten to with conventional SQL based Business Intelligence devices (Hossen, Moniruzzaman & Hossain, 2015). Prophet SQL Connector for HDFS is a fast connector for getting to HDFS information straightforwardly from Oracle Database, conquering any hindrance amongst HDFS and information distribution center conditions. The information put away in HDFS can at that point be questioned by means of SQL, joined with information put away in Oracle Database, or stacked into Oracle Database.

Prophet's Big Data Platform

Prophet has three built frameworks that illuminate distinctive parts of the huge information issue. Every stage incorporates all the essential equipment and programming important for extraordinary information handling. All parts are pre coordinated what's more, prepared to send and work. Prophet has done the diligent work of integrating these built frameworks so that you can extricate an incentive from your information by means of a progressed huge information stage with coordinated investigation (Kashyap and Tiwari, 2017). This finish arrangement incorporates different frameworks dealing with information procurement, stacking, capacity, administration, investigation, combination and introduction so you can rapidly remove an incentive from enormous information with coordinated examination. Prophet big data Appliance incorporates a mix of open source programming and concentrated

programming created by Oracle to address huge information prerequisites. Dwelling at the front end of the enormous information lifecycle, it is intended to secure and arrange enormous information proficiently, and to be the savviest stage to run Hadoop (AlMahmoud, Damiani, Otrók & Al-Hammadi, 2017). For additional data on the adequacy of this approach, see the white paper “Getting real about big data: Build Versus Buy” from the Enterprise Strategy Group. Prophet Exadata Database Machine conveys extraordinary execution and versatility for a wide range of database applications. It is the speediest stage accessible for running Oracle Database and the related investigation talked about in this chapter.

Prophet analytics is a built framework that incorporates an endeavor BI stage, in memory investigation programming, what’s more, equipment upgraded for expansive scale examination. With apparatuses for cutting edge information perception and investigation, it empowers clients to acquire significant understanding from a lot of information. At the point when Oracle Analytics is utilized with Prophet Advanced Analytics, clients have a far reaching stage that conveys understanding into key business subjects, for example, beat forecast, item suggestions, conclusion examination, and misrepresentation alarming.

Analytics for the Enterprise

Associations in each industry are endeavoring to comprehend the monstrous deluge of huge information, and additionally to create diagnostic stages that can orchestrate conventional organized information with semi organized and unstructured sources of data. At the point when appropriately caught and investigated, enormous information can give interesting bits of knowledge into advertise patterns, gear disappointments, purchasing behaviors, support cycles and numerous different business issues, bringing down expenses, and empowering more focused on business choices. To get an incentive from enormous information, you require a strong arrangement of answers for catching, handling, and breaking down the information, from obtaining the information and finding new bits of knowledge to settling on repeatable choices and scaling the related data frameworks. Prophet advanced analytics is perfect for revealing shrouded connections in enormous information sources. Regardless of whether you have to foresee client conduct, envision cross/up offer openings, enhance showcasing effort reaction rates, counteract agitate, dissect “advertise containers” to find affiliations, examples and connections, use influencers in interpersonal organizations, decrease misrepresentation, or foresee future request, Oracle Advanced Analytics can help (Ravada, 2015). At the point when utilized as a part of conjunction with open source instruments, for example, Hadoop and MapReduce, this intense systematic arrangement conveys all that you have to procure, sort out, break down and expand the estimation of huge information inside the undertaking while satisfying

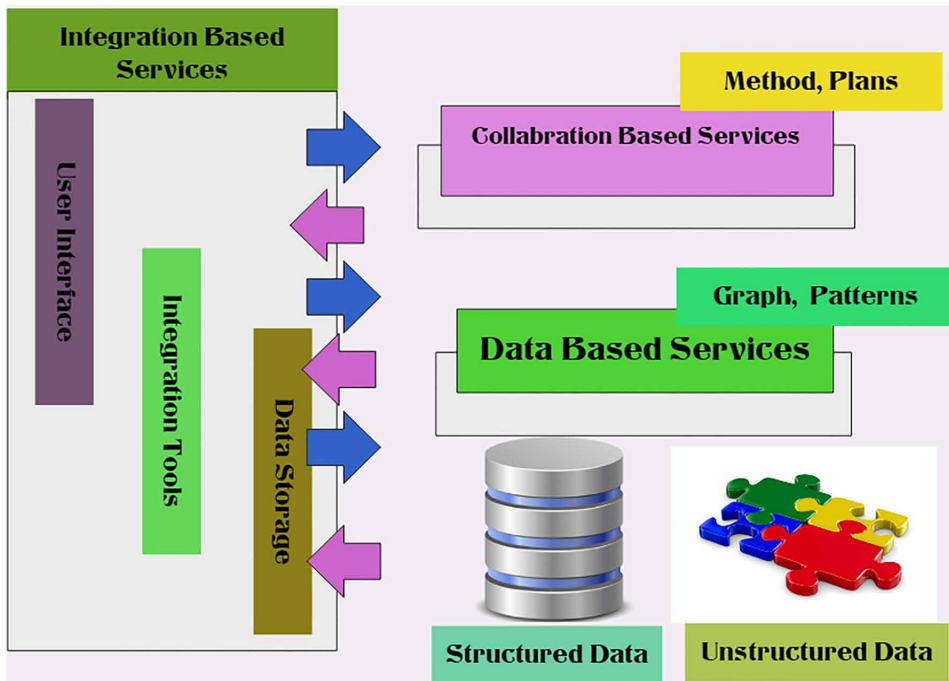
crucial prerequisites for limiting information development, utilizing existing ranges of abilities, and guaranteeing elevated amounts of security.

- A major information investigation arrangement comprises of administrations or calculations that adventure both machine ability information driven administrations and human knowledge collaboration centric administrations.
- To encourage and guarantee the reconciliation of machine capacity and human knowledge, joining driven administrations are expected to help clients connect with the two information driven administrations and joint effort driven administrations and give instruments to incorporate the aftereffect of two sorts of administrations.
- All administrations or calculations together help the enormous information change from crude organization to learning item (bottom up) or from theory to assets (top down) (Kuiler, 2014).
- Human knowledge ought to be associated with the entire procedure of information change, including designing information driven administrations, deciphering the aftereffect of information driven administrations, working together with different specialists on translating and sharing the outcomes.

As appeared in the design graph (Figure 8), there are three sorts of segments.

- Data driven administrations, which abuse substantial information handling innovation to genuinely look, break down and total information from heterogeneous information sources. The contribution of the information driven administrations is organized or potentially unstructured information from heterogeneous information sources. The yield of information driven administrations is looked or separated data, found examples or records and so forth. The information driven administrations expect to enhance the procedures of individual sense making (Luo, Zhang, Zukerman & Qiao, 2014).
- Collaboration driven administrations, which bolster individuals and their communication by catching and sharing assets, sentiments, contentions and remarks among members, so to encourage the aggregate comprehension of the issues identified with information investigation. The contribution of the joint effort driven administrations could be the yield of information driven administrations and in addition the cooperation's remarks, contentions and talks and so on (Luo, Zhang, Zukerman & Qiao, 2014) figure 9 shown this concept for social media. The learning item theory, techniques and so on ought to be the result of their association. The joint effort driven administrations intend to help synergistic sense making.

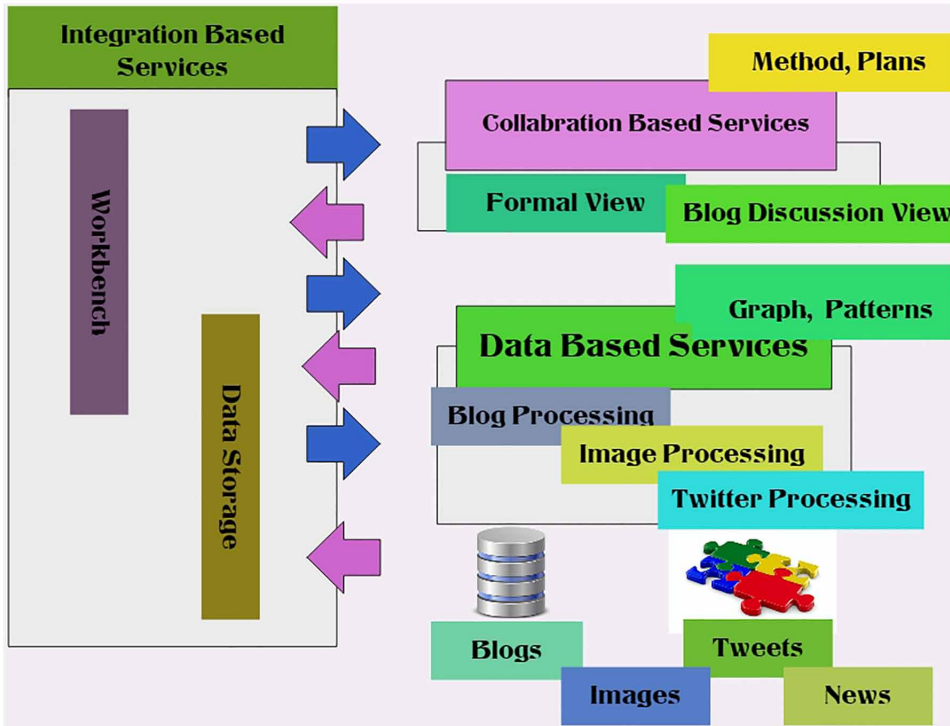
Figure 8. Conceptual architecture of big data analytics



- Integration driven administrations, which bolster information driven administrations and coordinated effort driven administrations. Coordination driven administrations are to guarantee and encourage the consistent coordination of the autonomous administrations created. Related capacities incorporate UI, information stockpiling and coordination components and so on. The mix driven administrations actualized in Dicode venture are the Dicode Workbench, the Dicode ONtology and the Storage Service (Dafferianto Trinugroho, 2014).

This approach opens up an additional channel to necessities displaying and examination, which depends on changing and breaking down hypothetical models from sociology and subjective science to a plan curio. The exploration work announced in this section gives a delineation of how hypothetical models were chosen and connected to the examination and outline of the design as shown in figure 9. We trust this unobtrusive endeavor at bringing sociology or psychological science models into prerequisite designing will supplement the conventional necessity displaying process. Considerably more work is expected to refine to meet the down to earth necessities of prerequisites expert and architects.

Figure 9. Conceptual architecture for big dataanalytics in social media monitoring



Approaches to Deal With Big Data

Huge data can be viewed as issue, then again as happenstance this area contains methodologies of taking care of the relative huge information from point of view of design, procedures, foundation, and advancements.

Approaches

The conventional BI engineering can be considered as a beginning stage for structures with its process counting arranging territory, information distribution center, information stores, ETL, and so on. Searching for impediments of this engineering, one may discover that it is probably not going to store all information in focal, venture information distribution center and not all information are important to be put away. There has been new design approaches developed: Hybrid Storage Architecture mix of stockpiles for different information composes and organizes, impermanent information stockpiles, information stream handling, Upstream Intelligence logical and measurable capacities are connected right off the bat in the process amid

securing of information that incorporates additionally particular Stream and event preparing based manage based frameworks, design distinguishing proof (Askitas, 2016). As consequences of this development, Post current BI Architecture speaks to an intricate arrangement that has been acquired, for the most part from conventional Business Intelligence and includes the idea of mixture stockpiling design, upstream insight, and stream an occasion preparing. Postmodern BI Architecture comprises of circulated information distribution center, merged Meta information layer, composed administration of information streams and coordinated effort learning administration (Kashyap & Gautam, 2017).

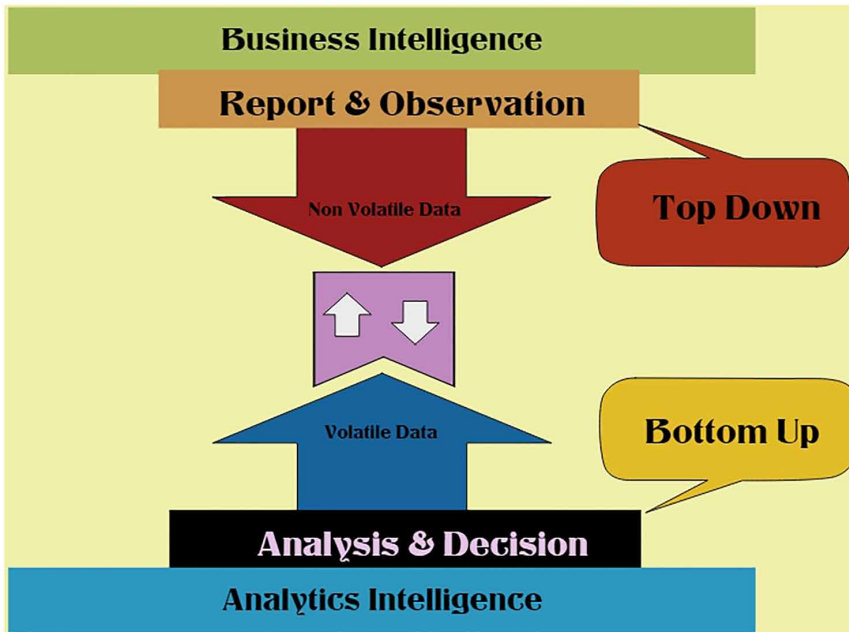
Post Current BI Architecture

Because of assorted variety of necessities from business symmetrical BI models advanced: a Top Down and Bottom Up engineering. The Top Down engineering worried a report driven or an information driven approach where an information stockroom demonstrate is made first in view of the business/announcing necessities. Procedure of this approach begins with an ETL routine to move information from source framework to the information distribution center, and afterward proceeds with making reports and dashboards to question information in DW. This approach for the most part fulfills easygoing clients with periodical revealing and checking. Aside from that, association's interests control clients to chip away at specially appointed investigation or undertakings in innovative work division. With past approach control clients are left aside to utilize specially appointed spreadsheets, independent/neighborhood database occasions, SQL and information mining workbenches with Top Down approach control clients discover BI instruments unyielding and a data warehousing structure excessively constrained for their worries (Kekwaletswe & Lesole, 2016). Open door for Bottom Up design approach has shown up.

The Bottom Up approach suits better for business examiners and information researchers who require the impromptu investigation of any information source, both inside and outside corporate limits, working intimately with business directors to improve existing procedures. Post present day BI design is an aftereffect of development of information warehousing structures, information administration programs and adding progressed investigation to adjust the dynamic between top down and base up necessities. This compositional idea is otherwise called half and half engineering portrayed in the Figure 10. Huge Data and HPA don't change information warehousing or BI structures. They basically supplement them with new advancements and get to techniques better custom made to meet the data prerequisites. Cross breed design can alternatively contain following correlative innovations like:

- Hadoop bunches to help stockpiling for semi organized information, utilized as a part of arranging region or then again expository sandboxes
- Streaming and Complex

Figure 10. Top down Vs. bottom up approach architecture



Event Processing Engines to help consistent insight, utilized as smart sensors that can be connected to streams with extensive volume of information and screen blend of occasions •Analytical Sandbox to support examination handling, specially appointed questions, to fulfill short-term investigation needs, utilized as a passages for other BI frameworks •Non social database framework to store unstructured or crude information, utilized as a part of expository sandbox, or arranging region •Data center point to encourage different frameworks and applications instead of to have revealing or investigation applications specifically, information stockroom utilized as a center (Shmueli, 2017).

Big Data Analytics Tools

BDA structures, conveyed on Cloud or in house data center, have end up basic to confronting the computational request errands. In the accompanying, we exhibit a review of the most utilized BDA apparatuses in writing.

Apache Hadoop

Apache Hadoop is an open source conveyed processing structure for conveyed capacity and group handling of huge informational collections on bunches worked from ware equipment utilizing basic programming models i.e. MapReduce. It is intended to scale up from single to thousands of servers, every one of which offers both neighborhood calculation and capacity. It permits preparing enormous information by utilizing bunch handling. As opposed to depend on equipment to convey high accessibility, the library itself is intended to recognize what's more, handle disappointments at the application layer (Mavridis & Karatza, 2017). Hadoop center segments give administrations to work planning, a conveyed document framework and information handling MapReduce, big data analytics for batch analysis is given in the figure 11.

Apache Kafka

Apache Kafka is a quick, versatile, strong, and blame tolerant publish subscribe informing framework. Kafka is regularly utilized as a part of place of conventional message merchants like JMS and AMQP due to its higher throughput, unwavering quality and replication [Kafka] figure 12 is demonstrating the structure streaming analysis. Apache Kafka can work in blend with various frameworks for constant investigation and the rendering of gushing information, for example, Apache Storm, Apache HBase or Apache Spark. More often than not, it is utilized for two kind of utilization, growing constant information work processes, trading messages between frameworks or applications in a dependable way, and ongoing spilling applications that change or respond to the information stream (Shaheen, 2017). Kafka is a message

Figure 11. Big data analytics structure batch analysis

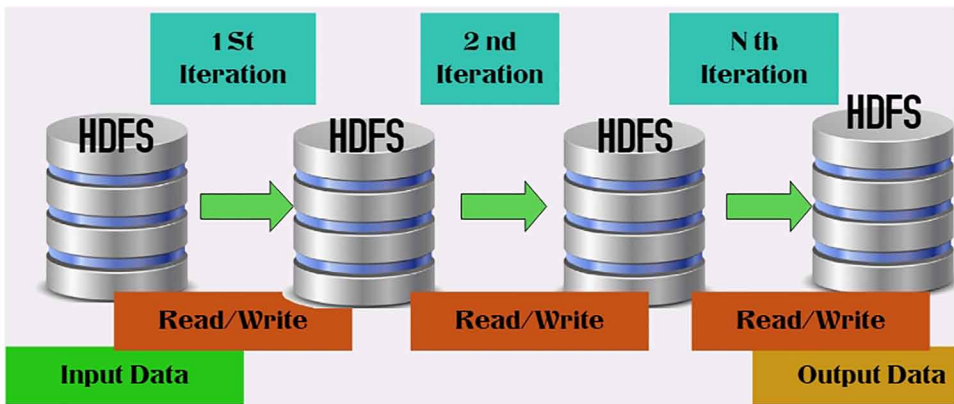
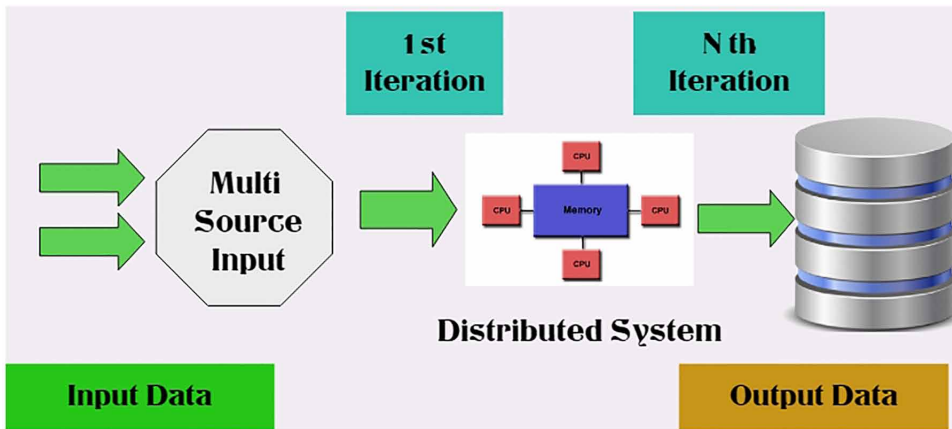


Figure 12. Big data analytics structure streaming analysis



representative on a level plane adaptable, and blame tolerant. Despite the utilization case, Kafka agent's huge streams of messages for low inactivity investigation in the Apache Hadoop biological system.

DISCUSSION

Enormous data phenomenon has been depicted in this segment with its causalities, definitions, impacts and effects. Mention that the change in perspective from information driven approach towards data driven approach might be seen dangerously on the conventional thought of focal information stockroom and physically authorized information respectability and consistency. Instead of that, it makes integral arrangements that fulfill necessities for adaptability and flexibility supporting information investigation. Data Driven Approach is a beginning stage for Upstream Insight. Enormous data rearranges engineering in that way that Post Modern BI Architecture created in mélange of Hybrid Storage Architecture Analytical Sandboxes, Hadoop, NoSQL, RDBMS, Upstream Intelligence especially bolstered by Complex Event Processing and customary information warehousing (Omidi & Alipour, 2016). Another wonderful thought, following the Hybrid Storage Architecture, is Information Federation that urges to find information on different apparatuses in different structures what's more, designs. Anyway it underpins examination and guarantees giving of constant access to information by means of essentially brought together information get to having the BI design thoroughly expanded post modern BI Architecture, there are however advances that flourish for creative ways to deal with handle Big Data. Region of high execution examination isn't extensively characterized and mapped.

The advancement of HPA is for the most part determined by business interest for having data after effects of information handling instantly and by accessibility of assets framework figuring, substantial memory with coordinate.

Diagnostic stages of HPA shift among the merchants and as a rule are actualized as restrictive arrangements. Specialization of stages depends on business prerequisites and business applications. Additionally different specialized drivers influence the usage of stage, which can be for example number of customers/supporters regarding applications and clients, information volumes, kind of information, fit in the worldwide design of BI arrangement e.g. arranging territory, data warehouse, subordinate/autonomous information bazaars, impromptu research and prototyping office. Talking about patterns, data storehouses venture information distribution center are moving towards pooled assets where information are separate as indicated by the information significance need preparing, information arrange organized, semi organized, unstructured. Foundation and design of information investigation and administration framework are moving from being execution tuned towards being directly adaptable in linkage with disseminated parallel preparing, network figuring, and in memory investigation (Hamoud & Obaid, 2013). Adaptability spurs another worldview that movements on premises organization towards half and half customary and apparatuses situated arrangement, where versatility can be flexible with private cloud.

CONCLUSION

Since the big data has been ceaselessly recognized for many years there is a considerable measure inquire about done in writing, white papers, and online references. In this postulation, the big data Phenomenon is outlined in a review including its causalities, definition, impact and effects. It speaks to a beginning stage and driver for High Performance Analytics regarding crude material that contains shrouded data, examples and esteem. Closing from look into, big data, with its dynamic measurements, ought not to be considered as an issue, as opposed to circumstance to transform it into advantage. Elite Analytics is broadly inquired about in this postulation as an approach towards taking care of big data because of this region it is as yet rising, being refined and formalized among sellers, explore on HPA is trying keeping in mind the end goal to bring diagram, characterization of HPA strategies and methods database analytics and parallel registering, their attributes, and fitting utilization. HPA is driven by business world with wide necessities to figure comes about as quick as conceivable on the biggest dataset. The development HPA winds up conceivable with innovative advancement very large memory, 64bit address, Grid Computing and moderateness of equipment costs, price: performance

marker. For the time being, HPA can be viewed as an answer corresponding to the Business Intelligence, yet exceedingly on premises the advancement will proceed further. The research could be stretched out to jump into HPA arrangements from other merchants contrasting different restrictive methodologies in subtle elements. Test assignments as it has been outlined, exhibit the execution of HPA approach on vast datasets. Distinctive logical activities and their mixes have been chosen to exhibit the advantages of logical stage in light of In Memory Analytics approach. In Memory Analytics engineering has found as helpful for the calculation extraordinary activities connection, slant lines, gauging, percentile, since all information are stacked in memory and can be specifically tended to. There are a few constraints of trial assignments. For the future work, the investigative activities can be tried on explanatory stages that actualize other HPA approaches, moreover against conventional approach in Business Intelligence e.g. OLAP. Once in a while, sellers offer the explanatory stage that would actualize all talked about HPA approaches and on the off chance that, it is testing to perform them on a similar framework foundation. Defeating the restrictions, the examinations are adequate for looking at the execution of investigative activity among each other, to recognize focal points and advantages of chose systematic stage.

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KEY TERMS AND DEFINITIONS

DM: Data mining Information mining is the way toward finding designs in expansive informational indexes including strategies at the convergence of machine learning, measurements, and database systems. An interdisciplinary subfield of computer science, it is a fundamental procedure where in insightful strategies are connected to extricate information patterns the general objective of which is to separate data from an informational index and change it into a justifiable structure for facilitate use. Aside from the crude examination step, it includes database and information administration angles, information pre-handling, model and surmising contemplations, intriguing quality measurements, multifaceted nature contemplations, post-preparing of found structures, perception, and online updating. Data mining is the investigation venture of the “learning revelation in databases” process, or KDD. The term is a misnomer, in light of the fact that the objective is the extraction of examples and learning from a lot of information, not the extraction (mining) of information itself.

HPDA: High performance data analytics with information investigation the procedure use HPC’s utilization of parallel handling to run ground-breaking scientific programming at speeds higher than a teraflop or (a trillion gliding point tasks for each second). Through this approach, it is conceivable to rapidly inspect expansive informational indexes, making determinations about the data they contain. Some examination workloads improve the situation with HPC instead of standard figure framework. While some “huge information” errands are proposed to be executed on item equipment in “scale out” engineering, there are sure circumstances where ultra-quick, high-limit HPC “scale up” approaches are favored. This is the space of HPDA. Drivers incorporate a touchy time allotment for examination, e.g. ongoing, high-recurrence stock exchanging or exceedingly complex investigation issues found in logical research.

Chapter 4

IoT Platforms and Technologies Driving Spatial Planning and Analytics

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ABSTRACT

The continuous evolution of internet of things technologies is constantly evolving the concept of smart cities as well as the surrounding environments. From pervasive sensors through computational nodes at the edge of the network to the cloud and final user applications, the data flow chain makes available to the user a very large and heterogeneous amount of data. IoT platforms are at the core of this chain, providing seamless access to data independently from the hardware devices and making possible the interoperability with other data sources (e.g., GIS, SIM, etc.). Despite the availability of IoT platform solutions either commercial and open-source, research is still very active to design and implement flexible, easy-to-use, and efficient web-service-oriented software infrastructures. This chapter will review the current IoT platform infrastructures making also reference to state-of-the-art solutions in literature and proposed in recent research projects. The chapter will outline the main challenges and directions about future platforms, putting them in the context of realistic case studies.

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INTRODUCTION

In 2015 all 196 participant states of the international conference on climate changes (COP21) agreed in the urgency of reducing greenhouse gas emissions to avoid the rise of 2°C of the mean atmosphere temperature with respect to pre industrial era United Nations (2015). Recently, the Intergovernmental Panel on Climate Change (IPCC) have analysed the difference between an increase of 2° and an increase of 1.5° Masson-Delmotte et al. (2018). The report states that keeping the increase of temperature below 1.5° with respect to the pre-industrial era will mitigate the catastrophic impacts of climate change. To achieve this goal IPPC states that we must reduce the level of CO₂ emission by 2030 of at least of 45% with respect to the levels in 2010 and have net zero emissions for 2050. Furthermore, the report states that *“pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems.”* Urbanizations are largely energy-intensive as reported by the UN habitat division, cities consume about 75% of the global primary energy supply and are responsible for about 50-60% of the world’s total greenhouse gases United Nations (2017). Moreover, the majority of the consumed energy is still supplied by fossil fuels (coal, oil and gas). In 2016, more than half of the overall world’s population is living in urban areas. Projections states that by 2030, urban areas will host around 60% of people globally and one third of the population will live in cities with at least half a million inhabitants United Nations (2016). The International Energy Agency (IEA) states that buildings represent 40% of total final energy consumption in most countries. Heating and cooling systems in buildings consume the 60% of energy in the residential sector and 45% in the service sector IEA (2014). On this regard, in the last years, many countries are providing incentives to promote the deployment of low-carbon and sustainable energy production technologies (Dusonchet & Telaretti, 2010), generation such as Photovoltaic (PV) Systems. In order to achieve a reduction of greenhouse gas emission an increasing installation of Renewable Energy Sources (RES), Distributed Generation (DG) and an optimization of consumption with a smart use of energy in our cities are required

IEA (2016). ICT technologies, in particular Internet of Things (IoT), allows to control and optimize energy consumption Wigle (2014), hence increasing energy efficiency. In the last years, we have assisted to the spread deployment of IoT devices in our lives and cities. Such devices allow to monitor and interact with objects through the Internet. Furthermore, a massive deployment of IoT devices in our city is constantly increasing the amount of collected data that needs to be stored and analysed. Big data techniques can help in managing and such huge amount of

information. In this context, we need distributed software platforms that can enable the concentricity and interoperability of such heterogeneous devices. Furthermore, such platforms will integrate Big Data technologies to deal with the volume and frequency of data generated by the IoT devices.

Such IoT platforms can be very useful in developing tools to perform both spatial planning and spatial analytics in our cities. A possible applications in our cities can be the analysis of energy efficacy and the planning of new energy strategies, that are becoming crucial for the transition to a low carbon and sustainable society. To achieve this goal, new systems must be designed to monitor a smart city environment in a continuous way and provide all stakeholders with tools that can permit an in-depth analysis of current situation and future deployments. The rapid growth of both Volunteer Geographic Information (VGI) and sensor networks to monitor different parameters in our buildings and cities have increased the amount of data available with temporal and spatial references. Thanks to Internet of Things Ashton (2009) communication paradigms Giusto et al.(2010) such huge amount of information is available on distributed ICT infrastructure, such as cloud computing systems. The IoT approach helps on integrating heterogeneous data sources by abstracting low-level technologies (e.g. adopted protocols) of both hardware and software components. For example, data about Building Information Models (Eastman et al. (2011) (BIMs), System Information Models Brundu et al. (2015), (SIMs) and Geographical Information Systems Tomlinson ((1969) (GISs) can be enriched with historical and (near-) real-time collection of data coming from heterogeneous IoT devices. So that, sensor data can be available at decision-making processes for planning the deployment of new renewable systems and analysing the overall energy efficiency at urban scale. To evaluate the efficiency of buildings, several research activities have been focused on using GIS, database management systems, exploratory data mining techniques and statistical tools in the simulation and analysis of energy data. In this chapter, we review the current state of the art solutions in Smart Metering Infrastructures (SMI), Photovoltaic (PV) tools for planning activities and spatial analytics tools for studding energy efficiency in buildings. Furthermore, we present an IoT distributed modelling and simulation platform that exploits IoT and Big Data approaches for spatial planning and analytics of energy systems at urban scale. The presented solution has been tested in Turin, in Italy.

The rest of the chapter is organized as follows: Section Background present the state of the art of SMI, planning tools for PV systems and spatial analytics of thermal energy consumption. Then, in section Methodology we present our IoT platform for spatial planning and analytics of energy systems in urban districts. Section Case Studies presents two use-cases for both PV planning and spatial analytics of energy consumption. Section Conclusion provides final remarks and future directions.

BACKGROUND: IOT AND SPATIAL ANALYTICS FOR SMART ENERGY

This section provides an overview of the state of the art for IoT platforms for spatial planning analytics in smart cities. Furthermore, this section will review the current state of the art of smart metering infrastructure and for data collection in urban contexts. In addition, this section will review the current use of IoT technologies in energy application for planning installations of PV systems and for spatial analytics of thermal energy consumption in buildings. Differently from the solutions presented in the state of the art, the our proposed IoT platform aims at creating a virtual model of a city district, by integrating IoT devices, to foster services for increasing the Smartness of our cities.

IoT as Enabling Technology for Spatial Analytics in Smart Energy Applications

IoT enables the interconnection of smart objects deployed across our cities. From such internet-connected objects, we can remotely retrieve information and/or perform actions. Hence, IoT devices represent an unprecedented source of information that can describe, monitor and interact almost with every object in our cities. Every IoT device can be georeferenced enabling spatial analyses. In the context of smart city applications, this georeferenced information can feed more complex algorithms, even in near-real-time for spatial analysis that before could be performed with statistical or low frequency and off-line historical data. In the energy domain, the integration of urban IoT data sampled in near-real-time opens new simulation and modelling processes for planning and operation of energy systems.

In the last years, ICT solutions have been widely adopted to optimize energy consumption in Smart City domains. This section reviews the most important works in this context. In Kim et al. (2010), authors prosed a datacentric middleware with the objective of decentralizing monitoring and control. It exploits a publish/subscribe model Eugster et al. (2003), that has been recognized as an appropriate paradigm for delivering information in near-real-time. However, the proposed approach is not yet sufficient to have data access that is independent of this communication model. Indeed, the request/response communication approach is also needed to offer innovative services that can eases the data retrieving without having to wait for new events.

In Patti et al. (2016), authors have presented a distributed software infrastructure for general purpose services in power systems. The proposed architecture eases the interoperability among different devices creating a trusted peer-to-per network. However, collecting data coming from IoT devices installed across the city and

monitoring the energy distribution networks is not enough. This because such data needs a correlation and integration with other information such as geo-referentiation or parametric information of buildings (i.e. BIMs). With this view, several middleware solutions have been presented to integrate heterogeneous data sources in a smart city scenario. The ReActOR platform Neves et al. (2015) is characterized by a tiny footprint and can be deployed as a service. ReActOR integrates three different layers: a facade layer (Web Service), a core layer, and an extensions layer (providing support for different technologies). ReActOR imposes a user authorization that allows to access to set of devices that can be managed and controlled. Finally, ReActOR provides only identifiers for the different agents in the system, hiding user and device data. This solution limits the integration of different data source, such as Database Management Systems, allowing only the integration of hardware. In Candido et al. (2009), authors proposed an evolvable and customizable infrastructure focused on interoperability, modularity, uncomplicated management and adaptation. It is composed by a set of different components that exposes its own services to the network by using open web standards. Such design enables the composition of interoperable modules. Unfortunately, the approach is applicable only to industrial automation scenarios. SensorGrid4Env (2011) is a service-oriented architecture for facilitating the design of open large-scale semantic based sensor network applications for environmental management. SensorGrid4Env eases a fast deployment of small applications (e.g. mashups) and enables the integration of real-time data with historical data from different and heterogeneous data-sources. This solution is custom-made for environmental management and it is not applicable unremittingly to city district setting. Several research projects contributed in defining models and guidelines for achieving interoperability among different application domains. The IoT-A project (Nettstraeter, 2012) proposes an IoT reference model that allows the description of: i) an IoT solution by using shared building blocks, ii) a reference architecture and iii) general advices to IoT architects. Furthermore, the OneM2M alliance oneM2M (2017) presented detailed technical specifications to define a common M2M Service Layer using existing IoT and Web standards. Unfortunately, such solution does not cover many aspects of IoT platforms, such as scalability, availability and deployment. In FI-WARE Project (2017) research project, the design of a service infrastructure for the Future Internet vision is presented. The FI-WARE infrastructure is composed by reusable components that can be selected and complemented with additional specific components.

In this context, the new generation of smart meters are IoT devices and key enablers of SMI. This will foster innovative services in the energy sector. In Aguirre et al. (2016) and LeMay et al. (2008), the authors present two Smart Meter Systems for enabling a bidirectional communication with a centralized energy management platform. Aguirre et al. (2016) proposed an innovative generation of smart meter

developed to offer the new requirements need by operation and control of the distribution network. LeMay et al. (2008) present a Meter Gateway Architecture that enables energy aggregator and integrated control of loads. In the smart grid management scenario, several infrastructures have been presented to satisfy the necessity of solutions for Smart Grid management and control. Kim et al. (2011) introduced a cloud-based platform with the objective of performing power reduction requests. SEMIAH Jacobsen et al. (2016) is a scalable infrastructure for smart management of residential loads by exploiting smart appliances connected to a Home Energy Management Gateway. Such gateway is in communication with a distributed platform that enables the interaction with a centralized appliances management system to change (by postponing or anticipating) appliances activation. Bhattarai et al. (2017) presented a hierarchical architecture that performs three levels of control and actuation to manage residential loads and resources (e.g. Plug-in Hybrid Electric Vehicle). In Müller et al. (2018), advertised the crucial role of the ICT in simulating and planning future power systems. Indeed, Smart Cities are complex systems where different entities cooperate by exchanging heterogeneous information.

Table 1 compares of our solution with the presented literature solutions. The advantages of our solution are: *i)* the integration of all the energy vectors present in a smart-city; *ii)* the interoperability between GIS, BIM and SIM; *iii)* the provision of tools to resource planning and spatial analyses.

Table 1. Comparisons of IoT platforms

	(Near)-Real-Time Data Integration	Gas Meter	Electricity Meter	District Heating Meter	Water Meters	BIM	GIS	SIM	Distributor Architecture	Planning and Spatial Analysis Tools
Our solution	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kim et al.	✓		✓						✓	
Patti et al.	✓		✓						✓	
ReActOR	✓								✓	
Candido et al.	✓								✓	
SensorGrid4Env	✓								✓	
IoT-A	✓								✓	
OneM2M	✓								✓	
FI-WARE	✓								✓	
Auguirre et al.	✓		✓						✓	
LeMay et al.	✓		✓						✓	
SEMIAH	✓		✓						✓	
Bhattarai et al.	✓		✓						✓	
Müller et al.	✓		✓						✓	✓

Using IoT Data: Spatial Planning and Analytics in Smart Energy Applications

The deployment of IoT devices allows to collect data from any kind of object. Those objects are deployed across the city and data can be georeferenced enabling an integration of such data in both planning and analytics processes. In this section, we review the current state of the art of platform for spatial planning of PV systems, characterization of building energy consumption and integration of IoT data.

In the last years, the study of Energy-Systems is focused in the de-carbonization of energy systems and in the widespread deployment of Renewable Energy Systems (RES). GIS and tools for spatial analyses are recognized as a driving technology in planning the deployment of RES, such as solar, wind and biomass systems Resch et al. (2014). In particular GIS have been applied in modelling and simulating solar potential in urban environments as reported by Freitas et al. Freitas et al. (2015).

For modelling Photovoltaic yearly potential, Bergamasco et al. (2011) and Kabir et al. (2010) exploited aerial and satellite images. Other approaches exploit Digital Surface Models (DSM) or 3D city models obtained by LiDAR data to calculate the yearly potential as presented in Hofierka et al. (2009) that estimated monthly and yearly solar potential in urban areas by using r.sun Šúri et al. (2004). Exploiting a similar approach Jakubiec et al. Jakubiec et al. (2013) presented a tool to estimate PV electricity production starting from LiDAR data combined with DAYSIM simulations. Lukac et al. (2014) exploited LiDAR data and presented an algorithm for simulating solar radiation on rooftops. Brito et al. (2012) also exploited LiDAR data to estimate yearly PV potential in Lisbon using ESRI Solar Analyst tool.

Limitations of the presented literature solutions are mainly related to time-domain and integration of real-weather data. Indeed, they are limited to yearly solar potential estimations. In both Freitas et al. (2015) and Resch et al. (2014), the authors highlighted that new developed tools and platform must integrate both spatial and temporal domains, with higher time and space resolutions. Such integration enables a better understanding of spatio-temporal dynamics in energy production. Achieving this goal opens a new vision to i) plan deployment activities; ii) evaluate business plans; iii) monitor existing plants and iv) promote smart energy use.

GIS solutions have been implemented exploiting a Web-Service approach to reach a large number of users. Li et al. (2010) implemented a service-oriented environment for sharing geoscience algorithms. The solution intended to make available with WEB-Services the open-source software GRASS-GIS exploiting both SOAP (Simple Object Access Protocol) technologies and OGC (Open Geospatial Consortium) standards.

Gwass Qiu et al. (2012) is a distributed Web-GIS platform built on top of the GeoBrain Web Services. Gwass takes advantage of a service-oriented architecture

to offer an alternative to commercial desktop solution. Other web-based solutions such as Brumenm et al. (2015), De Amicis et al. (2012), de Sousa et al. (2012), JRC (2012), Mapdwell Solar System (2013), Ménard et al. (2012) and Suri et al. (2008) have implemented web-gis tools that provide PV energy potential information coupled with the assessments of environmental and economic benefits as pointed out by Freitas et al. (2015).

PVWATTS Marion et al. (2000) is a web application for estimating yearly, monthly and hourly PV production using a Typical Meteorological Year (TMY) and a Digital Elevation Model of 40 km². PVGIS Suri et al. (2008) is a solar web-GIS that provides data on yearly and monthly PV production in Europe and Africa starting from a DSM with a resolution of 1 km. I-Guess de Sousa et al. (2012) is a web based system for urban energy planning in smart cities. I-Guess exposes only yearly solar radiation maps and rooftop PV potential. Mapdwell Solar System, (2013) provides information on rooftops and Region Of Interest (ROI) and yearly PV potential by computing solar radiation exploiting the methodology proposed by Jakubiec et al. (2013) and a TMY as weather file. I-SCOPE platform De Amicis et al. (2012) provides 3-D smart-city services and solar map with yearly and monthly PV potential. The web application developed by Brumenm et al. Brumenm et al. (2015) provides PV potential assessments and yearly and monthly PV Potential together with information on rooftops and ROI.

Table 2 summarizes the limitation of the presented solution. The limitations of such solution are related on overlooking a fine-grained spatio-temporal domain in simulating and modelling energy production and performance of PV systems. Almost all the revised solutions are focused on spatial domain by performing yearly or monthly simulations. The few ones that perform hourly simulations have a low-

Table 2. Comparison of WEB-GIS photovoltaic simulator

	Simulation Step			Sub-Hourly Clear-Sky Simulation	Sub-Hourly Real-Sky Simulation	Rooftop and/or ROI Details	Weather Station Data Integration	Distributed and Mobualr Architecture	REST API
	Y	M	H						
Our Solution	✓	✓	✓	✓	✓	✓	✓	✓	✓
PVWatts	✓	✓	✓						
PVGIS	✓			✓					
i-GUESS	✓								
Mapdwell	✓	✓				✓			
I-SCOPE	✓	✓				✓			
Brumen	✓	✓				✓			

resolution in spatial domain (e.g. resolution > 1m) that does not identify ROI of rooftops; hence, the available surface suitable to install PV systems. Moreover, all the presented solutions lack in simulating real-sky conditions by integrating IoT weather station coming from public or volunteered geographic information Resch et al. (2014).

GIS and spatial analytics can be used to map the efficiency of buildings and analyse priority areas of intervention. In the last years, many researchers have focused in developing GIS solutions for analysing energy consumption and environmental impacts of buildings heating systems as reported in Torabi et al. (2017)

In Dall'O'et al. (2012), the authors proposed a GIS methodology for evaluating the potential energy savings of retrofitting residential building stocks. Their methodology uses a linear regression between the primary energy use and the shape factor during different construction years. The method has been applied to five municipality of the Milan province, north-west of Italy. Howard et al. (2012) proposed a GIS statistical bottom-up model for estimating the end use of energy in the building sector by considering space-heating, electricity and domestic hot water. Mastrucci et al. (2014) exploiting the Ordinary Least-Squares method proposed bottom-up statistical method for estimating the retrofit on heating energy demand and indoor thermal comfort of building stocks in cities. In Ma et al. (2016), the authors integrated big data technology and GIS in a single framework for estimating building energy consumption in the urban scale. The framework has been applied, tested and validated against 3640 buildings in New York city. Braulio-Gonzalo et al. (2016) proposed a methodology based on Bayesian Statistical Inference for modelling energy efficiency performance of residential building stocks. The objective of the model is to help local authorities during energy refurbishment interventions at the urban scale. In Torabi Moghadam et al. (2018), the authors proposed a GIS bottom-up statistical model for estimating energy consumption related to space heating of residential building stocks in urban endowments. The methodology exploits 2D/3D maps and Multiple Linear Regression to provide georeferenced information for each single dwelling. The objective is to identify correlations and assess the demand-side consumption at the urban scale. Their methodology has been applied in the municipality of Settimo Torinese, north-west of Italy, and involved about 3600 building units.

The presented literature solutions on thermal analytics lack in the integration of real-data and none of the proposed methodologies integrates IoT devices and metering infrastructure. This limits the applicability in future smart-cities in both planning and operational phases. Differently from the above research works, this paper proposes an integrated and distributed system able to collect a large volume of energy related data and efficiently compute two key indicators based on the energy signature method.

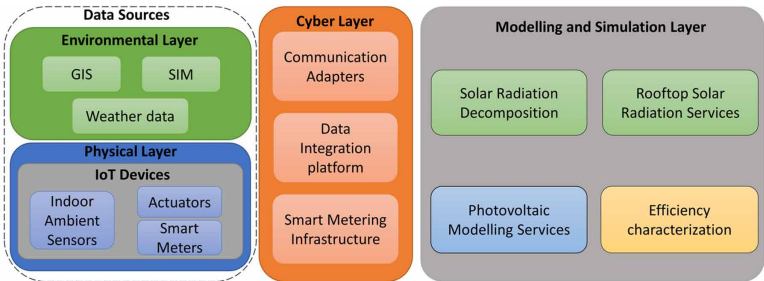
METHODOLOGY: AN IOT PLATFORM FOR SPATIAL ENERGY PLANNING AND ANALYTICS

In this section, we present an IoT platform for spatial planning of photovoltaic systems and characterisation of buildings’ efficiency in urban districts. Such platform has been designed fill the gap in both Photovoltaic planning and characterisation of buildings’ efficiency. In the photovoltaic planning, literature solutions lack on simulating PV power production with a sub-hourly resolution in real-sky conditions. Whilst in characterisation of buildings’ efficiency, literature solutions lack on integrating real-time and real-world data and managing large amount of data that needs for a big data approach.

The infrastructure presented in Figure 1 takes advantage of the microservice design pattern proposed in Fowler (2014), Newman (2015). This design pattern increases both scalability and extendibility of the system. In addition, the microservice design pattern eases maintenance of the resulting distributed infrastructures. The microservice approach views software architecture as a set of loosely coupled and collaborating services. The communication among the heterogenous entities of the infrastructure are preformed exploiting both the request/response (e.g. REST web services Fielding (2000)) and publish/subscribe Eugster et al. (2003) (e.g. MQTT protocol MQTT (1999)) communication paradigms.

The presented infrastructure consists of four layers as shown in Figure 1: the *Data sources* includes both *Environmental and Physical Layers* and integrates heterogeneous data-sources required by the different components in the system. The *Cyber Layer* is in charge of enabling the communication between the heterogeneous modules in the four layers by taking advantage of either the request/response or publish/subscribe communication paradigms. The *Modelling and Simulation Layer* is composed of different modules needed to simulate and model energy systems. The rest of this section provides an in-depth description of each layer.

Figure 1. Distributed infrastructure for energy planning and analytics



Data Source

The *Data Sources Layer* integrates different data-sources that collect real world data needed by the simulation modules of the *Modelling and Simulation Layer*. We grouped them in two layers, *Environmental Layer* and *Physical Layer*, as shown in Figure 1.

The *Physical layer* is in charge of integrating data retrieved by Internet-connected devices in near-real-time and data coming from physical systems. In particular, this layer integrates information provided by *IoT devices*, such as *Ambient sensors* (i.e. Indoor Temperature), multi-vector *Smart Meters* (i.e. electricity, gas, heating and water) and *Actuators* (i.e. Heat-exchangers).

The integration of IoT devices in the simulation and modelling process is achieved thanks to the design of Communication adapters, as reported in Section Cyber Layer.

Such approach enables the “*Smart Metering Infrastructure in-the-Loop*” that allows the integration of third-party smart metering infrastructures in the simulation and modelling process Patti et al. (2015, 2016). With this approach, each IoT device provides measurements to its related smart metering infrastructure that will forward them to the simulation and modelling framework, thanks either to MQTT or REST protocol. This enables a real-time integration of real data.

The *Environmental layer* provides data required to describe the urban environment. In particular this layer consists of:

1. The *Geographical Information Systems* (GIS) module integrates heterogeneous *GIS* data-sources that describe the different entities in cities (e.g. devices, buildings and pipelines). In particular, it integrates cartographies such as: cadastral maps, census section and Digital Surface Models.
2. *System Information Models* (SIM) module is used to describe the structure and size of energy distribution networks such as District heating systems. *SIM* is built by exploiting parametric and topological data.
3. *Weather Data* module integrates data coming from third party services, such as (Weather Underground, 2016). All this data coming from public and personal weather station is georeferenced in order to use the nearest available data. Furthermore, the module provides Linke Turbidity coefficients Linke (1922) to better model the attenuation of solar radiation due to air pollution.

Cyber Layer

The *Cyber layer* can be seen as the orchestrator of the presented platform. This layer plays a crucial role because it enables data exchange between the different modules of the infrastructure. This layer takes advantage of synchronous and asynchronous

communication paradigms such as REST and MQTT that are respectively request/response and publish/subscribe approaches. The Request/response eases a fast bidirectional communication to send/access information to/from heterogeneous modules of the infrastructure (either hardware or software), using, for instance, REST Web Services Fielding (2000). On the other hand, publish/subscribe is complementary to request/response and allows near-real-time data transmission. Furthermore, the Publish/subscribe paradigm decouples the interdependencies among consumer and producer of data. Such feature allows developers in designing software modules that can be distributed, independent from data-sources and react in near-real-time to certain events. Hence, publish/subscribe paradigm ensures the scalability of the whole infrastructure, as reported by (Patti et al., 2016), allowing both data-driven and event-based communications. In the implementation of the presented infrastructure, we exploited the MQTT protocol MQTT (1999).

The *Cyber layer*, presented in Figure 1, is composed by three modules the *Communication Adapter*, the *Data Integration Platform* and *Smart Metering Infrastructure*. The *Communication Adapter* eases the interoperability among the different entities of the Physical Layer. Although, the *Data Integration Platform* incorporates third party software and platforms in the Environmental Layer. The two discussed modules perform as a link among the modules of the platform and the heterogeneous technologies, that can be both software or hardware. Under this premise, each component requires a customized *Communication Adapter* or a *Data Integration Platform* that provides a shared and unique link to connect low-level capabilities exploiting REST Web Services and/or MQTT. Hence, both *Communication Adapter* and *Data Integration Platform* are crucial modules to connect each low-level technology transparently. The platform integrates also third party *Smart Metering Infrastructure*, such as Pau et al. (2018), to access historical data collected from real distribution networks that can be already post-processed information, output of other services.

Data Integration Platform

The proposed *Cyber Layer* incorporates a *Data integration platform* that offers modules that are specifically developed for retrieving and managing data, coming from different data sources. Such data integration platform takes advantage of a JSON-based REST APIs that is able to create a virtual District Information Model by correlating information from heterogeneous data-sources.

The *Data Integration Platform* exploiting Resource Catalogue furnishes a continuously updated version of the endpoints of the entities in the system. The Resource Catalogue is a software module that makes the whole platform flexible in adding, removing or changing ICT systems at run-time. Moreover, the platform

offers historical data to the simulation and modelling layer by providing a set of API to access to Historical Datastores (i.e. databases suitable for Big Data management).

The *Data integration platform* is completely based on REST Web Services with a distributed deployment. These REST Web Services are designed to provide uniform interfaces for each module in the system that are independent from the low-level technologies.

Communication Adapter

The *Communication adapter* is in charge of ensuring the communication among the heterogeneous components of the modelling and simulation layer.

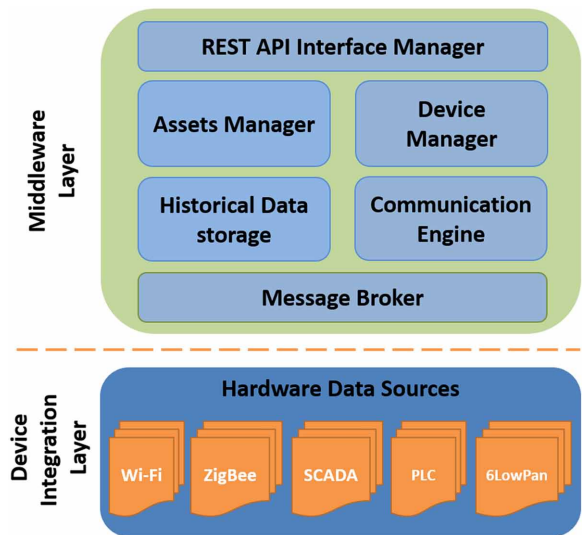
Furthermore, the *Communication adapter* is in charge of connecting *Smart Metering Infrastructure* to all the module of the platform. The *Smart Metering Infrastructure* is required for retrieving measurements from heterogeneous devices, either wired and wireless, that exploit different communication protocols (e.g., IEEE 802.11, ZigBee, PLC or 6LowPan). The interoperability between these technologies is achieved through *Communication adapters* called *Device Integration Adapters* (DIAs). Thus, the *Cyber Layer* integrates different IoT devices with traditional and industrial communication technologies by abstracting any communication language in a unique data format. DIA have been developed following a methodology described in Patti et al. (2013). Then measurements are sent to the rest of the platform by exploiting the MQTT protocol.

Smart Metering Infrastructure

The platform integrates existing *Smart Metering Infrastructure* in order to collect and retrieve measurement coming from heterogeneous IoT devices. In particular, we integrated the *Flexmeter* infrastructure Pau et al. (2018).

As shown in Figure 2, *Flexmeter* consists of different software modules to (i) allow bidirectional communication with DIAs, thus with devices; (ii) receive, control and store measurements; (iii) provide REST web services to access data, devices, assets and maintenance operations; (iv) send commands to devices. The infrastructure takes advantage of the MQTT protocol to enable a near-real-time asynchronous and bidirectional communication among devices. The Communication engine manages a bidirectional interaction with DIAs by storing measurements into the Data Storage and sending commands to devices. The Communication Engine works both i) as subscriber to receive measurements and store them in the *Historical Data Storage*; and ii) as publisher to send commands to the right IoT device. The *Historical Data Storage* module allows to orchestrate the connection with several

Figure 2. Schema of Flexmeter platform



time-series databases and non-relational databases which are specifically designed for Big Data management. The *Assets Manager* is a software entity that manages several information regarding people, places and things that are called assets in Flexmeter. Finally, the *Device Manager* manages the communication between the *Asset Manager*, the *Communication Engine* and applications that interact with the Flexmeter platform through the *REST API Interface Manager*. The *REST API Interface Manager* defines and provides REST web services that are developed to guarantee the connection to data regarding devices, assets and measurements, and manages these entities in the infrastructure. Authentication is required to request REST web services. Thus, only trusted applications and services can interact with the Flexmeter platform.

Modelling and Simulation Layer

The *Modelling and Simulation Layer*, in Figure 1, incorporates four software components to simulate environmental conditions (green boxes), electrical energy (light blue box) and thermal energy (yellow box).

The *Solar Radiation Decomposition* module is in charge of decomposing Global Horizontal radiation (GHI) into Direct Normal Incident radiation (DNI) and Diffuse Horizontal Incident radiation (DHI). Such decomposition is achieved by applying mathematical models such as Ruiz-Arias et al. (2010). The inputs are meteorological information retrieved by *Weather Data* module in the Environmental Layer. This

module is used when weather stations do not provide DHI and DNI but only samples of GHI. Hence, the integration of this module is mandatory because DNI and DHI are needed to compute solar heating gains and to simulate incident global solar radiation on tilted surfaces (e.g. buildings' rooftops).

The *Rooftop Solar Radiation* module integrates three sub-modules of the infrastructure presented in Bottaccioli et al. (2017). Starting from a DSM, provided by the *GIS* module in the *Environmental Layer*, it calculates incident global solar radiation of buildings rooftops by retrieving Weather Data from real measured DNI and DHI or from the *Solar Radiation Decomposition* module. This module provides simulation of real-sky conditions with a resolution of 15 minutes. Furthermore, this module identifies rooftop surfaces suitable for solar energy installations by detecting roof encumbrance (e.g. chimneys and dormers) and estimating their shadowing effects. This module is then used by the *Photovoltaic (PV) Modelling Services* in order to simulate the energy production.

The *Photovoltaic (PV) Modelling Services* module takes advantage of the methodology presented in Bottaccioli et al. (2017), S. Vinco et al. (2018) and Vinco et al. (2018). It receives data i) from *Rooftop Solar Radiation* simulation module to compute the global incident solar radiation and ii) from *Weather Data* module to consider the effects of the air temperature on the efficiency of PV arrays. By exploiting *GIS* cartographies, it identifies the most suitable configuration for PV installation on rooftops and simulates the energy production with a resolution of 15 minutes. Furthermore, the module integrates algorithms for an accurate modelling of tension current (I-V) curves of the PV system.

The *Thermal building characterization* provides tools to analyse the power demand of thermal systems in buildings connected to Heating Distribution Networks (HDN). Exploiting the KPIs (Key Performance Indicators) and the methodology described in Acquaviva et al. (2015) the module provides thermal characterization of the buildings. In particular, it implements the energy signature that is a recognized methodology for analysing energy consumption in buildings. This methodology was developed in the 80's, just after the oil crisis, by the American government. It has been introduced in the European regulatory framework (EN 156036:2008) and was recognized at Italian level in UNI (11300:2008). The energy signature methodology has been applied in several researches to compute the total heat loss coefficient of a building Belussi et al. (2012), Ghiaus (2006), and Vesterberg et al. (2014). The study of this total heat loss coefficient (K_{tot}) is performed by analysing the supplied power of the heating system (P_h) with respect to the difference between the indoor temperature in the building (T_{in}) and outdoor temperature (T_{ex}).

Equation 1

$$K_{tot} = \frac{P_h}{(T_{in} - T_{ex})}$$

The estimation of the K_{tot} is performed by exploiting a linear regression of average power samples at different time granularity levels with respect to the average difference between T_{in} and T_{ex} .

CASE STUDIES: IOT PLATFORM IN OPERATION FOR SPATIAL PLANNING AND ANALYTICS

In this Section, we present two applications of the presented distributed infrastructure. The first use-case is related to the planning phase for installation of PV systems. Whilst, the second use-case is related to the spatial analysis of thermal performance in buildings. For both applications, we highlight the modules of the platform involved in our simulations and we present the experimental results obtained in a urban environment.

Photovoltaic Planning

The proposed solution has been tested in *San Salvario*, a district in Turin very closed to our University campus. *San Salvario* is located in the city centre with an area of about 2.5 km² and around 1250 residential buildings. It has been selected because of its buildings, which are heterogeneous in terms of construction type and period. DSM and Cadastral maps for this area have been provided by the city council. The DSM is a high-density model with a resolution of 0.25m². With this high resolution, rooftops are represented with a high accuracy highlighting encumbrances like chimneys and dormers.

The following results have been achieved by exploiting the following modules of the infrastructure in Figure 3: GIS, Data integration platform and Rooftop solar radiation services. The GIS module provides the Digital surface model to the rooftop solar radiation services through the data communication platform. The rooftop solar radiation service computes the available surface and the amount of deployable PV systems starting from the DSM.

The simulation accuracy of the involved modules has been tested and compared with a real PV system in the Polytechnic of Turin. Figure 4 shows the simulated and measured power production values in real-sky condition for a sunny, cloudy

Figure 3. Modules involved to plan PV system installations

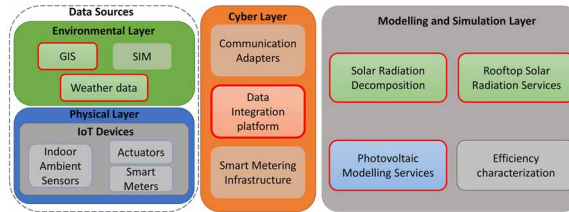
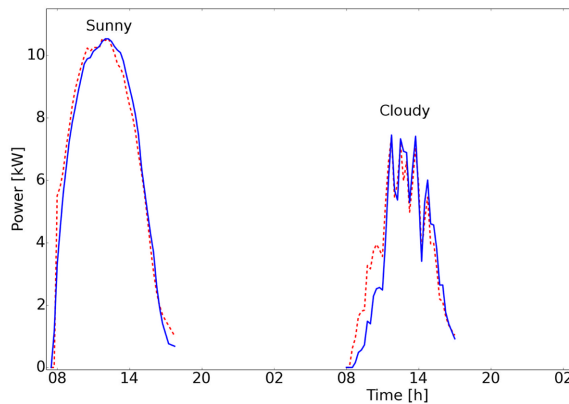


Figure 4. Campus PV system Simulated vs Measured values



and rainy day. The simulated power curve follows very well the measured values of power production in all the three days. In our previous work (Omitted for double blind review), we demonstrated how our solution outperforms the methodology proposed in Spertino et al. (2013) that studied the same PV systems.

Exploiting third-party web services provided by Polytechnic of Turin, the platform integrates a real weather station that embeds a *first class* pyranometer that samples every minute information about air temperature and GHI. This information is averaged and made available with 15 minutes time-steps. As proposed in Younes et al. (2005), the samples of solar-radiation with: i) an altitude lower than 7° and ii) a clearness index lower than 0 and higher than 1 are excluded from the simulation process. Furthermore, we excluded the measured samples of global horizontal radiation with higher values than in clear-sky conditions, as suggested by Younes et al. (2005). To obtain the available surface for building integrated installation, we set the parameters of the suitable surface module to select rooftop areas that have a slope (s) between 10° and 45° and an orientation (o) between 220° and 320° considering south equal to 270° . Values of slopes are chosen to select only those surfaces that can host building integrated photovoltaic systems. Values of orientation are chosen

to select surfaces that face south-east, south and south-west in order to maximize the production from PV systems. Than in the selected areas we calculate the whole number of PV modules that can be deployed having the following characteristics: Nominal power 283 [W], module efficiency 20.2 [%], temperature coefficient 0.38 [%/°C]. This provides a realistic Building integrated PV potential for every rooftop in the district. However, end-users can specify different values for all the parameters: slope and orientation boundaries and PV system characteristics. To present the experimental results in a map (Figure 5), we aggregated the value of available power for each building in census sections. The map in Figure 5 shows an homogeneous distribution of census sections with a PV power potential ranging between 0 kW and 93 kW. Only seven census sections do not provide any surface available for PV system installations. Whilst, just one census section has a PV power potential higher than 279 kW.

Figure 6 shows the map of the yearly production considering real-sky conditions. To produce these results, the following modules of the infrastructure in Figure 3 have been used: GIS, Weather data, Data integration platform, Rooftop solar radiation services, Solar decomposition and Photovoltaic modelling services. After the selection of the available surfaces, the rooftop solar radiation service calculates the incident solar radiation in real-sky conditions. Data of solar radiation are collected from the nearest weather station available that provides solar radiation measurements. In this case, the weather station does not provide data on DHI e DNI. Thus, the rooftop solar radiation module requested these values from the solar decomposition module. The photovoltaic modelling services, that uses the incident solar radiation calculated by the rooftop solar radiation services, estimates the power production every 15-minutes in real-sky conditions. As mentioned in the previous section, this module considers

Figure 5. Map of Photovoltaic potential of each census section in San Salvario district

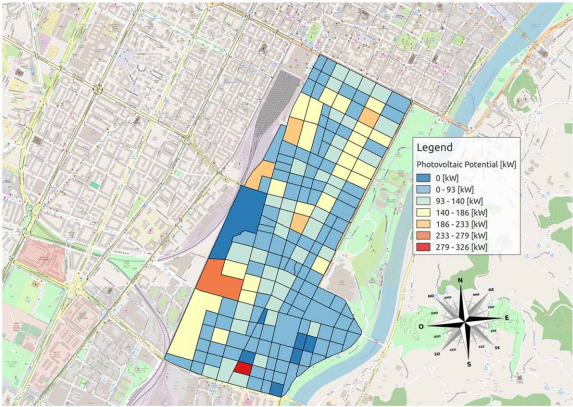
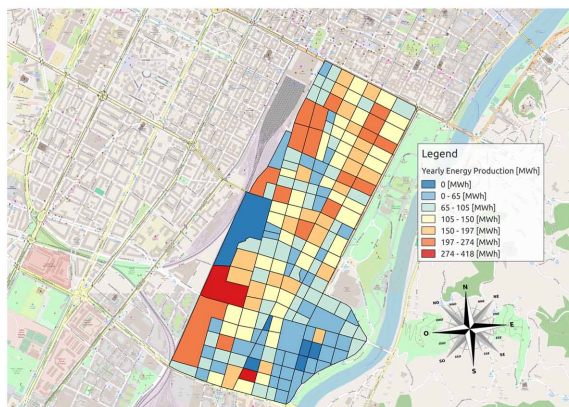


Figure 6. Map of yearly energy production for each census section in San Salvadio district



the effect of the air temperature on PV efficiency. The temperature values are directly requested to the weather data module from the nearest weaver station.

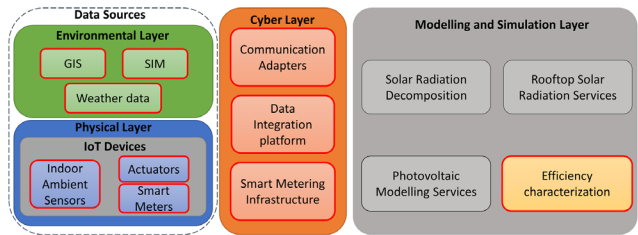
The map in Figure 6 shows less homogeneity with respect to the one in Figure 5. This dis-homogeneity is related to the different heights and orientations of the buildings. The different heights of the buildings provoke shadowing effects on surrounding buildings. In simulating the irradiance, the solar radiation algorithm considers the shadowing effects due to buildings and threes. The total production for one year is around 20'200 MWh with a total installed power of around 15.5 MWh.

District Thermal analytics

In this section, we present the results achieved by exploiting the infrastructure presented in Figure 1 applied to perform spatial analysis of thermal performance in buildings. Figure 7 shows the involved modules used for this use case. Form the environmental layer GIS, SIM and weather data are requested from the Efficiency characterization module trough the exploitation of data integration platform. Furthermore, data coming from the Physical layer are collected from the Smart Metering infrastructure thanks to the communication adapters. Finally, the data from the SMI is send to the Efficiency characterization module to estimate the efficiency of each building that is compared also with its neighbour stock.

This solution has been tested in a real-world environment. The case study is the district heating system of Turin, where more than 50% of buildings are served by the heating distribution network. To analyse thermal energy consumption, gateway devices have been installed in the monitored buildings. Each gateway is equipped

Figure 7. Module involved to characterize buildings' thermal efficiency



with a GPRS modem that provides an embedded programmable ARM CPU. An ad-hoc software has been developed to execute different activities: sensor management, GPRS communication, remote software update, data collection scheduling and collected data sending to a remote server.

Every gateway collects and sends data coming from all the sensors deployed in its building. Thermal energy consumption is recorded in all its aspects: instantaneous power, cumulative energy consumption, water flow and corresponding temperatures. In addition to energy consumption values, gateways are also collecting indoor and outdoor temperatures and the status of the heating system.

A Smart Metering infrastructure has been exploited to store and process all the monitored data. There are about 4,000 monitored buildings, each generating about 2,000 data frames per day. Hence, an expansive base of at least 8 million data frames per day are collected, managed and analysed. Before sending the measurements to SMI, each gateway is authenticated by a firewall and associated to a dispatcher. Each dispatcher distributes data to a cluster of computers, including different processing servers, where data are stored in an HDFS distributed file system.

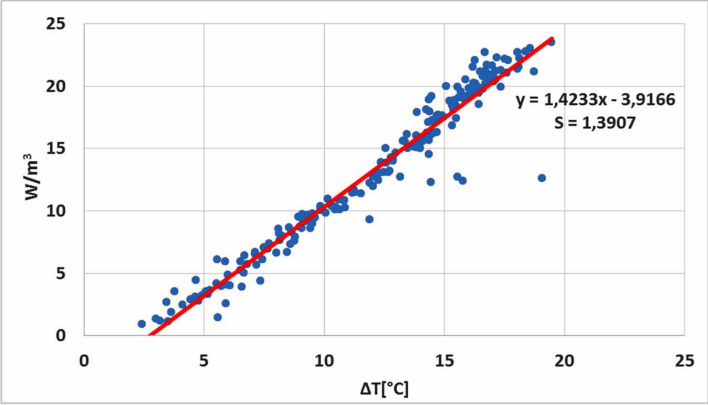
The meteorological data are collected from the web service Weather Underground (2016). The nearest weather station to the buildings under analysis is used to enrich the data with weather measurements.

To evaluate the quality of the linear regression that estimates the energy signature, we adopted the Standard error of regression. Figure 8 represents the energy signature of a building in Turin.

To evaluate the energy signature, all the collected values are chosen. The signature takes into account the daily mean power per unit of volume with respect to the difference between the daily mean outdoor temperature and indoor temperature. If buildings are not equipped with indoor temperature sensors, the analysis uses a fixed value of 20°C, since this is the typical value set by local regulations.

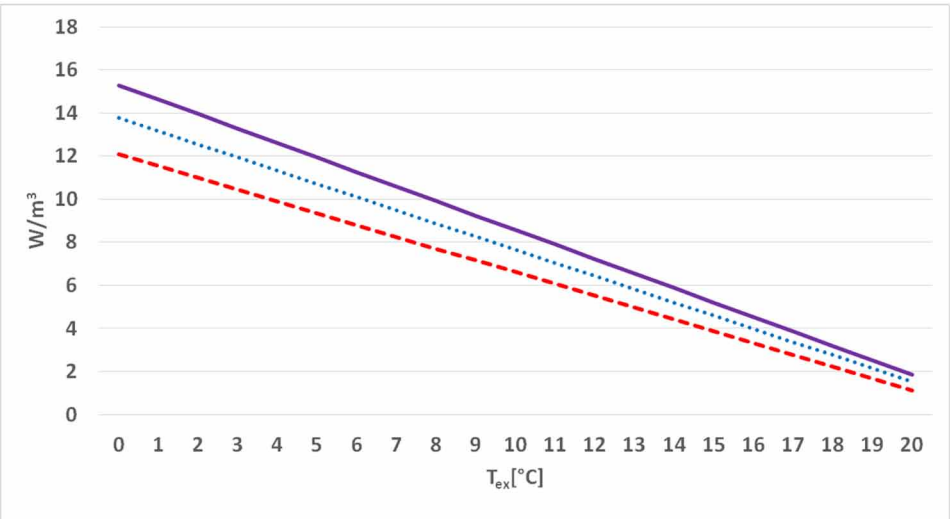
Figure 8 focuses on the daily scatter plot and its resulting regression (red line) estimates the energy signature. A standard regression error of 1.39 is obtained, whereas the estimated value of energy signature is 1.42.

Figure 8. Energy signature of a random building in Turin



In Figure 9, a comparison of the performance of buildings located in the same block is presented. The solid purple line represents the mean energy signature of the buildings present in the block. The dotted blue line represents a random building of the block. Meanwhile, the dashed red line represents the best building in the block. The plot in Figure 9 shows a comparative information of the buildings' performance among buildings present in the same district. With such information, an energy manager or a decision maker can highlight the buildings where a possible intervention of energy efficiency is more effective and more urgent.

Figure 9. Comparison of different energy signatures of buildings located in the same district



CONCLUSION

This chapter presented the design and implementation of an IoT platform to perform distributed modelling and simulation for spatial planning and analytics of energy systems. The presented solution takes advantages of IoT communication protocols, Big Data approach, real measurements and innovative analytics to offer to final users a simple and effective tool. Furthermore, the chapter reviewed the current literature solutions on IoT platforms and smart metering infrastructures for smart cities. The review of such solutions included the application of such technologies in planning an analytics of energy systems.

Summarizing, IoT devices and platforms foster a new generation of tools for planning and analysing the spatial dimension of our cities and lands. In particular, the energy sector, the proposed solution overcomes the conventional platforms by integrating IoT devices enabling new spatial planning and analytics tools to asses: *i)* PV potential and simulate the related production; *ii)* to analyse the efficiency of building at the building and district scale. The application of the proposed solution in real-world case studies, using real data, show the effectiveness and the usefulness of the infrastructure. From the planning point of view of Building Integrated PV systems, it allows to automatically identify available surfaces and to display the energy potential on map as show in Figure 5. Furthermore, it can simulate such PV system in real-sky condition with different time scales, from 15 minutes (Figure 4) up to yearly (Figure 6) resolution. This features overcome the literature solutions for PV planning (see section Background) that do not provide an automatic selection of available surfaces and do not perform real-sky simulations.

For characterization of buildings' efficiency, our solution analyses and enriches near-real time data coming from IoT sensors and meters with weather, GIS, BIM and SIM data. This feature allows perform a regression analysis on building energy consumption to construct the energy signature of buildings. With such signature is possible to: *i)* compare new measured values with expected values in order to identify possible malfunction or bad behaviours; *ii)* compare similar buildings and identify the most efficient in the same block, district or city.

From our point of view the main limitations of the proposed platform are related in the modules of the modelling and simulation layer (see Figure 1). By now the platform can be used only for the planning phase of Building integrated photovoltaic systems and the efficiency characterization of buildings. To enable future smart cities, new tools are needed to evaluate the availability and plan the installation of other renewable energy sources (e.g. Wind and Geothermal). Furthermore, tools for evaluating the integration of such resources in the distribution networks and the effects on the energy markets are need. In the analyses of the thermal demand of buildings, tools and algorithms that can learn from IoT sensors the dynamic response

of a building is needed to evaluate and improve heating and cooling systems. Such algorithms and tools can be used to plan the electrification of heating and cooling system or the expansion of district heating networks. Furthermore, those algorithms can be used for developing and evaluating novel strategies for demand response and demand side management by involving heating and cooling system of buildings. Finally, tools for planning the deployment and the management of storage system are needed. However, we believe that the proposed solution can be the basis for the development of such tools and algorithm. Indeed, it enables the integration and the interoperability of heterogeneous data sources and IoT devices exploiting simple and light communication paradigms.

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Chapter 5

The Walkability of the Cities: Improving It Through the Reuse of Available Data and Raster Analyses

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ABSTRACT

The issue of city walkability is nowadays a theme in evidence. The chapter proposes a two-level reasoning. At the city level, the goal is to recognize the parts where actions aimed at improving walkability can be more effective. The second level is more detailed: lacking pedestrian paths' specific graphs, the urban space is modeled through a raster with 1x1 m. cells. Considering a series of criteria, an impedance has been assigned to each cell (i.e., the cost of travelling the cell on foot). This approach is applied to the city of Torino (Italy), but it is largely generalizable. To calculate this impedance, inter alia, the Torino geo-topographic database was used. The elaborations described in this chapter are seen as an aid to stakeholders to reason on city walkability and to compare different points of view in an explicit and articulated way.

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INTRODUCTION

The walkability of the city has been the subject of consideration for at least fifteen years, but today it is certainly in evidence. In February 2018 the small volume *Pedestrians First* (ITDP 2018) was published, that was inspiring in particular for two reasons: it was conceived in a context and with a vision absolutely global; it has a clear operational objective, to support the different subjects (policy and decision makers, planners and technicians, pro-active subjects at a local level, etc.) involved in the promotion and planning of the increase of the city's walkability, as a factor of sustainability and growth of the its livability.

The city's walkability theme intersects several relevant current themes. The reasons reported in the literature to deal with it are surprisingly varied, ranging from the sustainability of urban mobility, from soft mobility (recovery of walking as a solution to the problems of transport over short distances), to the health of people (contrast of obesity (Agampatian 2014) prevention of cardiovascular diseases, osteoporosis (Eynard, Melis and Tabasso 2017). In the middle there is a wide range of motivations concerning the livability of the city, security, pollution, urban densification. Some analyzed researches often describe a path that led to the construction of walkability indices, taking into consideration, along with other aspects, such as the physical form of the city and its way of functioning, that is population, building density and the mix of urban activities and functions (which, together, lead to multiplication of possible origins and destinations of movements), security (which concerns both the intersections between pedestrian paths and vehicular routes, that anthropic safety), the pleasantness of the environment (quality of the sidewalks, presence of shops and other activities along the pedestrian paths, presence of green, low level of pollution and noise, etc.).

For people, to decide to get walking a little more, instead (specifically in Italy) to use their car, involves reviewing their own habits and building new mental maps of their city.

If the ultimate goal is to provide views of the walkability of the city, useful for people to reconsider the possibility of walking different areas of the city, and the accessibility of different interest points on foot, the specific objective of this chapter is to demonstrate the possibility of constructing effective views of city's walkability, using existing data, extensible (more or less easily) to the entire urban or metropolitan area, bypassing the lack of specific networks related to foot mobility, which allow municipal technicians and policy-makers to focus on critical points of pedestrian paths, considering all the factors that influence the walkability.

BACKGROUND

Definitions of Walkability

Walkability and accessibility with alternative mobility are conditions for the development of the quality of urban and territorial life, as well as a way to deal concretely with the great issues of the “right to the city” (Lefebvre 1968; Harvey 2008) and the relationship between city and welfare.

In literature, there are many definitions of “walkability”. For Abley (2005) *walkability* or *walkable* is “the extent to which the built environment is walking friendly”: this definition enables the opportunity for a subjective or qualitative assessment against specific criteria. These criteria may be characteristics such as the “5 Cs”: connected, convivial, conspicuous, comfortable and convenient, or other criteria specific to a particular user.

For Seilo (2004), walkability “is a measure of the urban form and the quality and availability of pedestrian infrastructure contained within a defined area. Pedestrian infrastructure includes amenities developed to promote pedestrian efficiency and safety such [as] sidewalks, trails, [and] pedestrian bridges”.

Walkability for a More Livable City

In the policy “Walking action plan. Making London the world’s most walkable city” (Mayor of London and Transport for London 2018), walking is considered “(...), in many ways, the mode of travel that is most important to the aims of the strategy. It makes efficient use of street space. It is good for individuals’ health. It produces no emissions or noise. It is safe and encourages interaction, which improves lives. It is good for business”.

Then, USA’s Walkable Communities Inc. website defines walkable communities “those who put urban environments back on a scale for sustainability of resources (both natural and economic) and lead to more social interaction, physical fitness and diminished crime and other social problems”.

The concept of walkability is a way of looking beyond the presence, distribution, and accessibility of urban facilities: spatial quality and the ability to accommodate and promote the pedestrian mobility of the urban environment and in particular of the road influence the way in which people perceive and use the city.

In this regard, many studies show how the psychophysical wellbeing of individuals, as well as urban studies, corroborates the thesis that better urban quality is given by the walkability and the development of the possibilities of action of the individual

in urban space. Planning strategies need to be built through empirical research that identifies correlates of walking behavior.

While socio-demographic (i.e. ethnicity, income, age) correlates of walking have been widely probed in the literature (Saelens et al. 2003), physical environmental variables have been studied with much less rigor. However; the limited number of studies on the link between the built environment and walkability demonstrate that physical environmental variables are significantly associated with walking behavior controlling for socio-demographic factors (Jacobs 1961; Handy and Clifton 2001). Walking activity promotes also social life and public participation by providing opportunities for face-to-face contact and casual interaction, all of which subsequently are proven to improve mental health and well-being (Robertson et al. 2012). A vibrant, economically viable and safe community needs people on streets and in public places. A walkable environment can also provide significant health benefits and independence to specific groups such as children and third age people who rely more on their local neighborhoods (Berke et al. 2007).

There are also numerous case studies of public policies and projects that have shown how the quality of the city and the urban environment improve considerably in case of walkable friendly environments or soft mobility policies. In particular, several attempts are being refined and disseminated to make the concept of urban walkability operative in terms of physical well-being and improvement of the urban quality of life. These researches are aimed at systematize and simplify procedures for the formal assessment of the concept and the possibility of using walkability in a more rigorous way as a tool to support decision making, urban planning and mobility planning (Saelens and Handy 2008, Talen and Koshinsky 2013).

Measuring Walkability

Effectively understanding and measuring the complexity of walkability has proven challenging for many organizations and governments, given the various levels of policy-making and implementation involved. With a better understanding of walkability, and more consistent and frequent measurement of the walkability of urban environments, decision-makers could be empowered to push policies that create more walkable urban areas.

Over the last two decades, there has been in literature considerable progress regarding measuring walkability, various different measurable features of the built environment have been incorporated to models, and different approaches have been developed.

A first method is based on interviews or questionnaires. Questionnaires can potentially reveal the extent to which individuals perceive various elements of the built environment and how a person experiences a neighborhood. This method is

considered as “subjective” because two unique individuals may perceive the same environment differently. The most commonly assessed measurable environmental features of perception are land use, traffic, aesthetics, and neighborhood safety from crime (Tomalty et al. 2009).

A second approach uses built environment characteristics obtained by systematic observations or audits that quantify the environmental attributes of an area, including the presence or absence of features hypothesized to affect physical activity. Audit tools are used for measuring and assessing physical features through direct observation, and include one or more measurable characteristics, such as: land use (i.e. commercial space), streets and traffic (i.e. crosswalks), sidewalks (i.e. presence, width, and continuity of sidewalks), public space and amenities (i.e. presence of benches), architecture and building characteristics (i.e. height), parking (i.e. presence of parking lots), maintenance (i.e. presence of litter), and other indicators related to safety (i.e. presence of graffiti) (Brownson et al. 2009; Pelletier 2009; Gauvin et al. 2005).

Finally, another method uses geospatial databases and Geographic Information Systems (GIS) in order to assess or develop relevant indicators that measure walkability. A GIS “is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth. This is a broad definition... a considerably narrower definition, however, is more often employed. In common parlance, a Geographic Information System or GIS is a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data” (Tomlin 1990). The increasing use of Geographic Information Systems (GIS) has made them an essential part of urban planning research. Nowadays, GIS techniques are being utilized more frequently also by the public health sector. In particular, GIS has been used to assess potential associations between a number of built environment characteristics and walking (Butler et al. 2011), taking into account the physical location of areas, boundaries, people, and services, as well as types of land use and natural features, and facilitating researchers by providing them the ability to create maps, measure distances and travel times, as well as define the extent and nature of spatial relationships.

One of the latest advancements in GIS methods and techniques that are used to measure walkability is the employment of composite indices (WalkScore 2011). These indices are expected to measure the degree to which an area provides opportunities to walk to various destinations (Manaugh et al. 2011). This is achieved by measuring both form and content of neighborhoods, which eventually captures the interrelation of various built environment characteristics, minimizes the effect of spatial collinearity and facilitates the communications of results. Understanding the potential impact of the built environment on walkability requires relevant, easy-to-comprehend, and reliable measurable features (Brownson et al. 2009, Hollenstein and Bleisch 2016). These measurable characteristics can assist in determining how much the

built environment affects the people. These measures can also provide indirectly evidence of the state of population health for the area under study. Composite measures of walkability are also expected to provide more consistent predictors of walking behavior than single component measures (Vargo et al. 2011).

Many attempts to measure walkability fail to capture all of its nuances in an urban context. Other attempts to measure walkability involve complicated indices that leave the user with a score, but with little understanding of how that score was calculated, or how to improve it, or how it relates to walkability. Although conventional approaches to the assessment of quality of life usually measure the distribution, density and distances of different opportunities in space, other studies take into account the quality of accessibility and urban opportunities (Blečić et al. 2014). Besides the mere distance, it matters a great deal if a place can be reached also by foot or by bicycle, if the pedestrian route is pleasant and spatially integrated with the surrounding by good urban design, if it is brim-full of urban activities, if it is well maintained and (perceived as) secure, if it is not submissive and surrendering to the car traffic whether by design or by predominant social practices of use of that space. At the same time, it is important to go beyond the simple presence of urban services, to understand their characteristics, if they are able to serve different categories of individuals, if their relevance is on the neighborhood, urban or metropolitan/regional level, if there are possibilities of choice between two or more relevant places.

Walkability suffers from the metrics problem: that is the subject to be measured is influenced by a large number of factors. For this reason, a simplified tool is preferable and metrics must not be overly resource and time consuming, but must also capture the elements of a city that are most important to the basic building blocks of walkability. Meanwhile, they have to be easy to measure with as reliable and objective as possible data.

The already mentioned ITDP's *Pedestrians First* (2018), aiming to improve understanding and measuring walkability, defines a set of criteria and tools, based on the following key concepts:

- Data inputs that are relatively quick and inexpensive to collect;
- Metrics that are easy to understand and are designed to avoid hidden biases;
- An understanding of walkability at multiple levels (citywide, neighborhood, single stretch of street).

In following paragraphs, we explain in what these concepts influenced our work.

A DIFFERENT APPROACH: OVERVIEW

Walkability is typically “the forgotten mode of transport” (ITDP 2018): consequently, few analytical techniques are available to help practitioners identify low standard walking environments. But walkability is a crucial first step in creating sustainable mobility in an urban environment and the basis in creating sustainable city. Improving it means support a green type of mobility which except crowding reduction and also has low level of environmental influence, energy conserving without any air and noise pollution. It can be more than a purely useful type of travel to shopping, school and work: also have both social and recreational importance. For this reason, our approach proposed in the chapter takes on the theme of walkability as a fundamental piece of more sustainable urban mobility.

A Raster Model of Urban Walkable Space

The approach proposed here is applied to the case of Torino (Italy)¹, but it is largely generalizable given some conditions that are however widespread. It allows, first of all, to get around the obstacle of the lack of pedestrian paths’ specific graph. The urban space is modeled through a raster with 1x1 meter cells, a rather small cell in order to obtain a high level of detail. An impedance is assigned to each cell, that is a *cost* to be traveled on foot, more or less pleasantly and safely. Cells that cannot be traveled because they are included in areas destined to vehicular traffic or because they are non-public, are excluded. This raster is often named *cost raster*.

Reuse of Torino Large-Scale Geo-Topographic Data Base

The second distinguishing feature of proposed approach is that, in order to build the cost raster, the information contained in the Torino municipal large-scale digital map was used above all. A technical map is normally seen and used as a representation of the forms of the territory, often materialized as a printed map or saved as a PDF file. In the case of Torino, this topographic map is at high level of detail and is structured according to the national specifications for geo-topographic databases. Territorial objects (*features*) are organized into classes (very numerous); each feature has attributes... a lot of information. The explicit and implicit information of this cartographic database were used to characterize the location of each walkable area, their context, the level of separation with respect to the areas dedicated to vehicular traffic, the type of paving, etc. In no case, in the literature, we found cases of such extensive use of cartographic information.

Reuse of Some Alphanumeric Data-Set

Various other data-sets of different types have been used: population, commercial activities, noise, etc. All of them contain georeferenced information. Most of them were available as *open data*. However, it was not easy to use them for the reasons that will be explained later.

On one side, having in mind the criteria to be taken into consideration to evaluate the walkability, and, on the other, the information obtainable from the municipal geotopographic database and from the data-sets actually available and usable, a series of indices have been built. These indices have been reported, in different ways, to the grid of 1x1 meter cells, producing a series of rasters whose weighted sum (the map algebra was used) led to the final construction of the cost raster.

This cost raster is a view of the walkability of the city: it is an exploitable result in the evaluation of walkability per se, as well as being a fundamental information for the next step.

Accessibility Computed as Cost Distance

Almost always in researches on walkability there is an analysis of accessibility, expressed as walking distance to certain services. This distance is usually computed on the center street lines, using data and tools developed for vehicular traffic. This is obviously due to the unavailability of pedestrian paths' graphs. But in this way significant distortions are introduced.

Moreover, if the analysis stops calculating a distance, the distance is taken into account but not the quality of paths. Walkability and accessibility are related but walkability means more.

The cost raster plays a fundamental role in calculating accessibility to some destinations of urban mobility on foot. Accessibility has to take into consideration also the quality of walking paths, that is has to be calculated as cumulative distance weighted on the base of cost raster. The result is an overlapping raster with the same properties as the cost raster: it is often called *cost distance*.

Using this procedure, various raster accessibility maps were produced, referred to different possible destinations. They can be added, using the map algebra, as weighted sum, obtaining synthetic views of the walkability that include the accessibility to different groups of activities and points of interest.

Is this Approach Really Different?

In the analyzed literature on walkability we found some papers in which raster analyses are used. For example: Holbrow (2010) generates network distance buffers around various destination points, measured on street centerlines (i.e. calculates the *service areas* using ESRI ArcGIS Network Analyst), and converts distance buffers in raster to make possible a weighed sum of them: in this way a walkability raster surface is produced (cell size 5 meter). Eynard, Melis and Tabasso (2017) follow the same approach (but the cell size is 50 meter).

Hollenstein and Bleisch (2016) apply the concepts of cost raster and cost distance, but the cost raster is very simplified, taking into consideration only the presence of sidewalks, the car speed, the presence of crossings.

A single case of a more substantial use of cost raster and cost distances was found. It is the website *Walkshed find your walkable way through the urban jungle* (<http://www.walkshed.org/>; Ogle, undated) that allows you to build your own personal walkability maps, varying the weight attributed to different criteria. The term walkshed echoes watershed. It is a very interesting case, precisely because it allows to build your own maps. But it seems that the grain at which the analyzes are conducted, too wide, and the excessive simplifications make the result less significant. However, this evaluation of *Walkshed* is provisional, because, if the key passage is the production of the cost raster, it is not enough documented how the impedances are calculated.

EVALUATION OF WALKABILITY AT THE NEIGHBORHOOD LEVEL

As mentioned, in *Pedestrian first* (IDT 2018) more levels of analysis / intervention are suggested: this is very reasonable. The first is the entire city/metropolitan area. The second one is the neighborhood level²: what has been described in the previous paragraph on cost raster and cost distance, applies to this second level.

For reasons of better exposure, analyzes on the neighborhood level are presented first.

For neighborhood level ITDP 2018 (page 31) suggests 1 km² areas, but this is merely to avoid too large and expensive data collections.

In our case, the analyzes could potentially be extended to the entire city of Torino, as all data-sets used cover the entire municipal area. With the exception of one, the pedestrian crossings data-set which is completely missing. In order to model the pedestrian circulation areas, pedestrian crossings are essential to generate the continuity of the pedestrian paths when these intersect the areas of vehicle circulation.

Table 1. Neighborhood level: criteria considered, indices and macro-indices constructed, weights attributed in the weighed sum

Indices			Macro indices			Summary Index
Description	Name		Description	Name	Weight Attributed in the Weighted Sum	
Presence of sidewalks, pedestrian crossings, curb ramps, paths in the parks, steps...	I_NPER_MAR	100%	Practicability, possibility of moving on foot	I_NPER	40%	
Presence of sidewalks businesses: stores, bars and restaurants, stalls...	I_NSIC_COM	20%	Security	I_NSIC	30%	
Low number of pedestrian incidents	I_NSIC_INC	20%				
Presence of crossroads regulated by traffic lights	I_NSIC_SEM	20%				
Separation between pedestrian paths and vehicular traffic	I_NSIC_SEP	40%				
Presence of trees	I_NPIA_ALB	10%	Comfort/pleasure	I_NPIA	30%	
Presence of street furniture	I_NPIA_ARU	5%				
Presence of sidewalks businesses: (same as I_NSIC_COM)	I_NPIA_COM	15%				
Presence of covered paths	I_NPIA_COP	10%				
Presence of historical buildings	I_NPIA_EDI	10%				
Presence of fountains	I_NPIA_H2O	5%				
Quality of pavements	I_NPIA_PAV	10%				
Low noise level	I_NPIA_RUM	15%				
Contiguous paths with green areas	I_NPIA_VER	15%				
Presence of visuals and panoramic points	I_NPIA_VIS	5%				

Incidentally, we have adopted a narrow definition of pedestrian circulation areas, not providing the possibility that pedestrians cross vehicular traffic areas outside pedestrian crossings. In other research (Hollenstein and Bleisch 2016), this possibility has been considered, which, on the other hand, corresponds to real pedestrian behavior in the roads covered by low-speed vehicles.

Lacking the pedestrian crossing data-set, it was therefore necessary to digitize them ad hoc. For this practical reason, the analysis of walkability is limited, for the moment, to a test area, San Salvatio district, of 193 Ha. It is a rather central area,

which has various socio-economic and environmental characteristics: we do not consider San Salvator as a representative area of the entire city, but just a test area.

In identifying the criteria at the neighborhood level, the starting point was the *Walkability Hierarchy of Needs Pyramid* (ITDP 2018, pages 13-14). The 6 criteria proposed were compacted in 3 macro-criteria: practicability (physical possibility of moving on foot), safety (physical safety and anthropic safety), comfort/pleasure.

On the base of available data-sets 15 indices were identified. Some alphanumeric georeferenced data-sets were punctual: data have been spatialized using the Kernel Density Estimation (KDE) which, given the value of a phenomenon in one point, represents its diffusion and attenuation in a circular neighborhood, with a radius defined appropriately in relation to the phenomenon represented³. The 3 macro-indices were calculated as weighted sum of indices. The cost raster is the weighted sum of these macro-indices. Since indices and macro-indices have different values, mean, deviations, they have been normalized, which was done using the 0-100 scale. High values of macro-indices mean high practicability, high security, high pleasure, while the cost raster values represent a cost, an obstacle to walk the cell. Then the cost-raster values were calculated as the complement to 100 of the normalized sum of the macro-indices. Table 1 displays the complete process, from criteria, to indices, to macro-indices.

In addition to the criteria considered, listed in Table 1, it would be reasonable (and likely possible) to consider other criteria that at the moment have not been implemented because the necessary data were not available. We list some of them: presence of traffic calming areas and protected intersections with vehicular traffic, muggings and other street crimes, lighting levels, presence of dehors, presence of artworks.

Figure 1 shows the cost raster for a portion of the test area. On the right a part of the large urban park of Valentino stands out, with its pathways. On the right the urban fabric made up of more or less regular blocks. [To make the map more readable a dotted buffer line is drawn inside the blocks at 5 meters from the buildings' front line (same for the maps in Figure 2 and 3).]

Figure 2 is a zoom in of the map of previous figure. The 1x1 meter cells become visible. You can see the sidewalks, with variable costs; pedestrian crossings, with a higher cost; a tram platform, raised but inside the vehicular traffic area, which took the maximum cost value...

Figure 1. Neighborhood level: the cost raster. The color, from light gray to dark gray, represents increasing impedance, that is increasing “cost” of walking through the cell.



NEIGHBORHOOD LEVEL: ACCESSIBILITY OF POINTS OF INTEREST

The overall evaluation of walkability has to consider the accessibility to attractive activities and to points of interest, present within a walking distance. The cost distance represents the cumulative cost of the movement, where the *cost* is given by the value of the cost raster cell. Therefore, the cost distances calculate a weighted accessibility, which, in our case, takes into account distance, practicability, safety and pleasantness of walking. A value of accessibility to a certain activity or point of interest is attributed to each 1x1 meter walkable cell. Using cost distance algorithm, the accessibility to some attractive activities and significant intermodal points in urban mobility was calculated. The weighed sum of various cost distances can lead to synthetic views of accessibility. It should be noted that at this point the computation of accessibility is simple and it is easy to explore different aspects of the matter.

Table 2 lists some cost distances that were calculated, within the San Salvador test area, and displays how the overall accessibility to intermodal points in urban

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Figure 2. Neighborhood level: cost raster. Zooming, you see the raster cells of 1x1 meter.

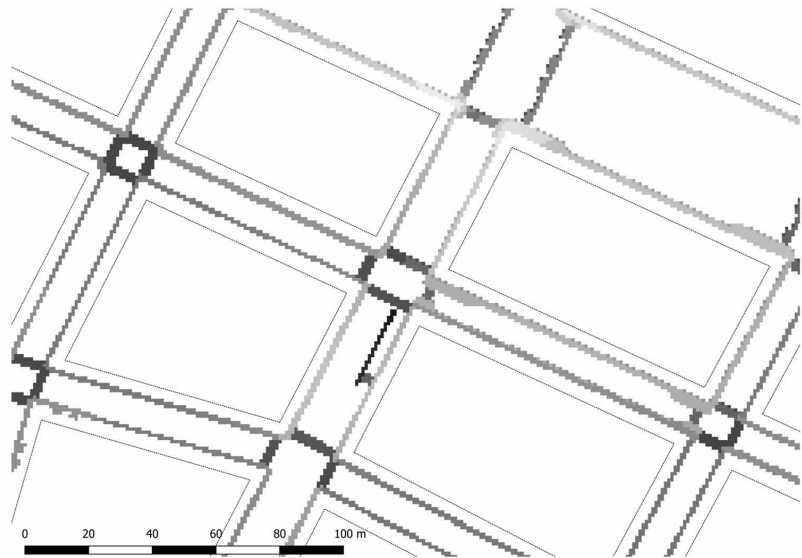


Table 2. Neighborhood level: accessibility to attractive activities and points of interest. Calculated cost distances, accessibility indices and macro-indices, weights assigned in weighed sums.

Accessibility Indices		Macro-Indices of Accessibility		Summary Index
Cost/Distance Relative to Points of Interest	Weight Attributed to the Weighted Sum		Weight Attributed to the Weighted Sum	
Childhood schools	20%	Accessibility to 3-14 years old schools		
Elementary and middle schools	80%			
Metro stops	30%	Accessibility to intermodal points in urban mobility		
Main Torino transports stops	30%			
Bike sharing stations	20%			
Car sharing stations	5%			
Taxi stations	5%			
Train stations	10%			
High schools	100%			
Universities	100%			
Hospitals	100%			
Catholic churches	80%	Accessibility to religious facilities		
Other places of worship	20%			
Cinemas	50%	Accessibility to leisure facilities		
Theaters	20%			
Museums	30%			

mobility and to 3-14 years old schools was calculated as weighted sum of several cost distances. As previously the cost distances were normalized using the scale 0-100 before being summed.

Figure 3 shows the cost distance to intermodality points in urban mobility for a portion of the test area (the same as in Figure 1) as weighted sum of the 6 related cost distances. Weights assigned in the weighted sum are shown in table 2.

An overall summary accessibility can be computed, as weighed sums of all cost distance rasters: however, at this stage we preferred to stop and compute summary accessibilities only for groups of activities or points of interest.

COST RASTER AND COST DISTANCE ALGORITHMS: SOME ADDITIONAL CONSIDERATIONS

All processings were done in the QGIS environment (various releases from 2.18 to 3.4). The choice of a *Free and Open Source Software* (FOSS) is not casual and should be seen together with the choice of using open data (ex post we must say, only predominantly). It should also be remembered that QGIS is promoted by City

Figure 3. Neighborhood level: cost distance to intermodal points in urban mobility



of Torino and adopted in its technical offices for all GIS elaborations. The guiding idea is that the overall elaboration path had to be easily repeatable and generalizable.

While we used QGIS we took into consideration the similar algorithms in ESRI ArcGIS, well known and widespread proprietary SW. This is not the place to introduce a comparison between the different implemented algorithms. Anyway in this chapter we decided to use the widely enforced terms *cost raster* and *cost distance* (used also by ArcGIS) rather than the various corresponding terms used in QGIS, that are cost surface, local cost, unit cost layer, cumulative cost, accumulated cost and may be others.

Cost Raster does not refer to a specific algorithm or sw tool: it is in fact a concept and does not necessarily imply financial cost. In general, this raster is the result of a multi-criteria approach: it is the weighted sum of several rasters whose cells values represent various aspects of cost, i.e. of impedance or friction in traveling the cell. In previous paragraphs the considered aspects of cost are listed. By the way, the slope is a cost aspect often considered in building cost raster, but we did not because the test area is basically flat.

In building the cost raster the raster layer of macro index I_NPER (see table 1), which contains only the pedestrian circulation areas, was the first one. All cells not included in these areas became “null cells”. In the following sums with the rasters relative to the other indices, these null cells are left out, so it is not necessary to introduce any kind of masking.

As far as *Cost Density*, generally speaking, it works this way: starting from target points or cells it is calculated the cost of moving to the 8 neighboring cells, as average cost, two by two. This value is multiplied by the cell size (in our case 1 meter) or, if the cell is traveled diagonally, by $1 * 1,41$. This computation is repeated in all directions and costs are added up, choosing the least cost increment at each step. This process is propagated on the whole cost raster (de Smith, Goodchild and Longley 2018).

We used the QGIS/GRASS algorithm *r.cost*. Various options are available (e.g. different movement rules from cell to cell, how null cells have to be dealt...), none of these has been used. Incidentally we have to report that some problems of SW instability occurred updating the sw from one release to the next one.

An interesting optional output of the cost distance algorithm is *allocation*, that is the identification of the area of influence of each activity: the result can be usefully interpreted if referred to destinations of the same kind. Some allocations have been calculated, together with the cost distances, but they are not shown and discussed here.

Table 3. City level: criteria considered, indices and macro-indices built, weights attributed in the weighed sums

Indices			Macro indices			Summary Index
Description	Name		Description	Name	Weight Attributed in the Weighted Sum	I_LIV_CITTA
Population density 0-14 (per census section) ab/ha	I_DNS0-14	25%	Population density	I_POP	40%	
Population density 15-64 (per census section) ab/ha	I_DNS15-64	40%				
Population density over 64 (per census section) ab/ha	I_DNS65+	35%				
Density of employees (per census section) employees/ha	I_DNS_ADD	40%	Density and mix of economic activities	I_ATTTECON	20%	
Density of local units (per census section) N. LU/ha	I_DNS_UNIT	30%				
Mix of economic activities (per census section) N.	I_MIX	30%				
Blocks Density. N. blocks/km2	I_BLKDENS	50%	Urban physical structure	I_STRUFIS	20%	
Density of public areas of pedestrian traffic (per census section) sqm/sqm	I_DENSPED	50%				
(see Table 4)	(see Table 4)	All weighted the same 2,56%	Presence of attractive activities	I_ATTATT	20%	

EVALUATION OF WALKABILITY AT CITY LEVEL

As mentioned, the first levels of analysis/intervention suggested in *Pedestrian first* (IDT 2018) is the entire city/ metropolitan area. The goal (there and here) is to recognize the parts of the city where actions aimed at improving walkability can be relatively easier and more effective. With this in mind, criteria to be considered were focused and indices to make them operable were developed. For reasons of easier data availability, the reference area is only the Municipality of Torino, but it makes sense and it would be possible to extend the analysis to the entire Torino metropolitan area⁴.

The walkability analyzes developed at the city level are relatively more common.

Also for this level the approach has been raster. Some useful data-sets are referred to the statistical areas (average area 138 Ha), others to the census track (e.g. population, economic activities, employed: average area 3.3 Ha), others are punctual data. Data referring to statistical zones and census track have been rasterized, with a 20×20 meter cell (therefore much larger than the one used for the neighborhood

Table 4. City level: indices related to the attractive activities (I_ATTATT) divided by “services”, “leisure”, “intermodality”

Service Activities	Leisure Activities	Intermodality Activities
Local health companies Public bathrooms Libraries Churches Other places of worship Counseling Pharmacies Local markets Hospitals Carabinieri Finance guard Municipal police Civil protection Police stations Fire fighters Childhood schools Primary schools Secondary schools Administrative offices Registry offices Post offices Social-assistance structures Fiscal Assistance Centers Italian National Institute for Insurance against Accidents at Work offices Italian National Social Security Institution bisogna che si capisca che non sono ulteriori elementi della lista Universities	Cinemas Sport centers Thematic markets Museums Touristic offices Theaters	Taxi parking lots areas Car sharing stations Bike sharing stations Suburban bus stations Parking lots for disabled people Parking lots Metro stops

level). In this way, the fact that the data do not refer to a single type of areas becomes irrelevant. Furthermore, these data are referred to predefined statistical areas, that is they are affected by a distortion related to their dependence on the delimitation of the areas themselves, defined a priori with respect to the analysis (areal dependence of data). The raster approach attenuates this distortion.

Several used data-sets were referred to points: they have been spatialized using the Kernel Density Estimation algorithm (see before). In this case radius has been assigned considering the area of influence of each activity, setting a maximum limit (1200 meter) corresponding to 20 minutes walking. The cell size was the same, 20×20 m.

Ultimately, all produced maps are raster and all with the same cell size.

The various rasters have been then simply summed giving to each one an appropriate weight, using the map algebra. Having used only weighed sums, avoiding more complex statistical algorithms, here and also for the neighborhood level, is functional to maintain a certain control on the meaning of the results: this is very appropriate because these results derive from a procedure which contains several debatable steps. To make indices and macro-indices comparable and summable

they were normalized on a 0-100 scale. Table 3 and Table 4 list produced indices and display the complete process.

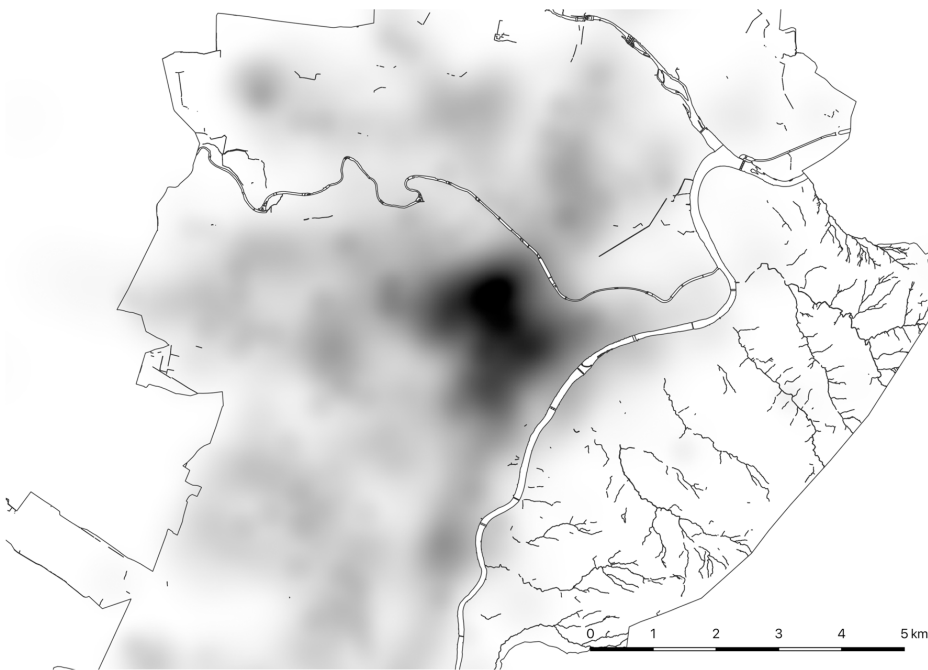
Figure 4 shows the result of the weighted sum of each Kernel Density Estimation related to the attractiveness index at the city level. The individual indicators, shown in Table 4, which make up this index concern three basic categories: services, leisure, intermodality.

Figure 5 shows the result of the weighted sum of all the indices at the city level (see Table 3). The darker areas are those that are best suited to walkability. Note that they are identifying some semi-peripheral areas with respect to the central ones, where the weighted walkability index is higher.

SOLUTIONS AND RECOMMENDATIONS

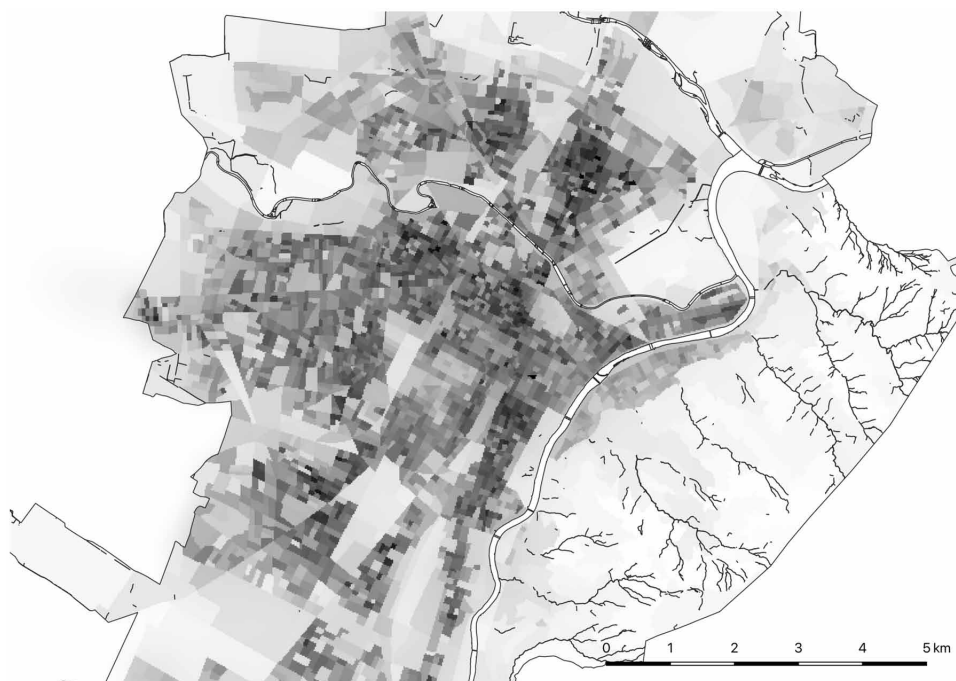
For the development of this research, the involvement of some officials of the City of Torino and of some staff members of the City of Torino Authority for Urban Mobility was fundamental. It took place within the *Framework Agreement... of collaboration between the City of Torino and the Politecnico of Torino to promote the culture*

Figure 4. City level: weighted sum of the Kernel Density Estimation related to the attractive activities listed in Table 4



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Figure 5. City level: in darker gray the parts of the city most suitable for the development of walkability



and dissemination of geographical information among the institutions, signed in September 2017. This involvement was helpful for the retrieval of various data-sets, for their correct use, and also for the identification of the criteria to be considered and the definition of the weights to be attributed to indices. This involvement will be obviously fundamental also for the desired future developments.

Despite this privileged conditions in which the collaboration with the City of Turin allowed us to operate, despite the current presence of European and national standards regarding metadata and interoperability of geographical data, despite the principle of *open by default* established by Italian law with regard to public property data, we had some difficulty in accessing data and in their (re)use. We had problems of absence or insufficient meta-documentation (e.g. code-list lacking, unexplained coding rules...), but also of inconsistencies in coding, as well as missing data.

In conclusion, the easy retrieval and reuse of data is still an unearned goal.

In addition to integrating missing data, making consistent enumerations etc., in the spirit of INSPIRE, of multiple use of information resources, it would make sense to revisit some existing data sets, also thinking of possible wider uses than those for which they were originally produced. An example can clarify. We used

intensively Torino Geo-Topographic Data Base: the *forms* of the various objects and portions of the territory are represented, but other important aspects are not included, for example “pedestrian circulation areas” are not distinguished between “in public areas” or “in private areas”. Another example: the areas that still retain the shape of vehicular road are classified as “vehicular circulation areas” even if a municipal deliberation has declared them only pedestrian. We understand the reasons (non-trivial) behind considering only the physical form, but this weakens the usability of the resource.

The views on walkability presented in this chapter (Figures 1-5) have been commented little or nothing at all because we think that their reading on paper is difficult and above all that it is not very stimulating. It is better to analyze these views, on a monitor, in a GIS environment that allows turning on and off layers, zooming, querying etc.

This statement is also based on some partial experiences we made: the views were presented and discussed, in a GIS environment, with some of municipal officials involved in the research. They obviously know the city well. These views are *objective* and depend on the data used, and may differ from the people’s perceptions of the walkability. So, in front of these views, many questions arose, to understand how and why the analysis got those evaluations.

We think this is exactly the usefulness of our research: looking at walkability from multiple, partly new, points of view.

FUTURE RESEARCH DIRECTIONS

In fact, we think that the elaborations described in this chapter have to be seen as an aid to the various stakeholders to compare different points of view in an explicit and articulated way. Many steps of elaborations are questionable, in the sense that they imply choices, evaluations: it makes sense therefore, precisely, to use these elaborations to discuss on it.

Among the desirable developments (the chapter describes a work that is still ongoing) there is a certain automation of (at least) parts of the procedures, so that they can be used *live*, in operational contexts or in communication and participation situations. Some automation is also essential to produce sensitivity tests on the various indices and weights used, tests that help to focus on what is really important.

From the point of view of the Torino municipal mobility sector, the key point to the future development of walkability is not only to improve and increase the space for pedestrians but also that people take into consideration the possibility of walking on short distances, that is, they have to review their habits and build new

mental maps of neighboring urban spaces. In 2015 the Municipality distributed a map named *Walk To* (where *To* stands for Torino), which contains some suggestions: some circumferences centered on the city center are drawn with the indication of the distances and the time to move on foot, but calculated as the crow flies, not significant and not very useful.

More stimulating information is required, for example, indications on what is the most pleasant and/or safe route and some highlights on the urban opportunities that can be encountered along the pedestrian paths. With this in mind we are thinking of making accessible meaningful parts of information that was elaborated and displayed in this research, producing an app for smartphone. Very important, this app shall allow also those who walk to provide some feedback to the Municipality.

CONCLUSION

The cost raster seems to be, and partly proved to be, a flexible and effective tool for reasoning, in detail, on the walkability of the city: it can be useful at neighborhood level, in discussion groups of interested people who know the places. The approach is objective, in the sense that the views of walkability are based on data, but we know that they depend to a large extent on implemented indices and weights. We think that people can be led to reconsider their perceptions of urban spaces and their urban mobility habits, also by varying the considered these indices and weights: questions and suggestions can arise. Perhaps even more questions and suggestions can arise when looking at the cost distances. It is with this process in mind that we avoided to use complex statistical algorithms that is we put it into practice the concept of IDTP 2018 *metrics ... easy to understand*.

Another concept of IDTP 2018 is *data... relatively inexpensive and quick to collect*. Hence the idea of using above all open data and of extracting thoroughly the information contained. If the San Salvario test area is limited, the extension of the survey to the whole city, and also to the urbanized parts of the metropolitan area, is feasible, not without costs but with sustainable costs.

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ENDNOTES

¹ Torino is a city in the North-West of Italy, in the past it was a typical one company town (car industry), in profound transformation since the 90s. It currently has almost 900,000 inhabitants. It was discovered as a tourist destination after the 2006 Winter Olympics Games.

² *Pedestrian First* (IDT 2018) suggests also a third level of analysis/intervention, named *street level*, that concerns the redesign of urban space: this level is beyond our competences and the purpose of this work.

³ For example, shops, bars and restaurants overlooking the sidewalk, which can be seen both as pleasure and security factor (social control), in this context are not considered as a destination of movement and has been given to them a radius of 50 meters.

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- ⁴ Various Torino metropolitan area definitions have been given over time. In the context of this chapter it makes sense to refer to the urbanized continuum area that includes Torino and 14 neighboring municipalities: this area currently has about 1,3 million inhabitants.

Section 2

Supporting Territorial and Environmental Evaluation

Chapter 6

Defining Energy Criteria in the Absence of Open Data: A Stakeholder-Oriented Approach Based on Multi-Criteria Analysis (MCA)

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ABSTRACT

The urban decision processes should be optimized according to the current “green” context. Despite the literature advocating for an open availability of data to facilitate higher quality science and a more effective science-policy boundary, one of the main challenges when dealing with energy processes is the absence of accurate data. This chapter aims at illustrating a stakeholder-oriented approach based on multi-criteria analyses (MCA) in defining the set of evaluation criteria and their relevance in supporting the development of “what if” urban energy retrofitting scenarios. In this regard, the SRF method has been used highlighting that the most important criteria for the problem in exam are related to economic and environmental aspects. In this context, big data visualization and geographical locations of the alternative scenarios, producing presentation features and performing spatial operations are fundamental. Hence, the authors supported the decision process through MC-SDSS to optimize the urban decision purposes. The results of this chapter are part of the national project EEB.

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INTRODUCTION

Nowadays, many cities are defining urban energy scenarios and plans in order to reduce energy consumption and Greenhouse Gas emissions (GHG) (Fokaides et al., 2017) according to the European Directive 2010/31/EU of 19 May 2010 (European Directive 31/2010), which obliges the member states to adapt the heating systems to the new energy standards. In Europe, the highest amount of energy usage belongs to cities (United Nations, 2015). In particular, the building sector is responsible for around the 40% of the total energy consumption and the 36% of the CO₂ emissions (IEA ETP, 2016; Hilty et al., 2013). This is partially due to the old age of the existing buildings stock having, consequently, low energy performances.

In this perspective, new dynamic urban energy scenarios are needed due to the long life and the low demolition rate of existing buildings stock, in order to make successful energy savings objectives (Torabi Moghadam et al., 2017; Lombardi et al., 2018).

However, developing urban energy scenarios choosing the most appropriate improvement is a very complex process which is configured as a political and environmental choice rather than a technical and economic issue (Head, 2008; Abastante et al. 2017) and involves a number of different stakeholders.

Hence, the aforementioned process is characterized by many levels of difficulty such as: 1) technical (technologies features, spatial boundaries); 2) economical (investment and management costs); 3) environmental (reduction of the CO₂ emissions, NO_x emissions, energy requirements); 4) regulatory (compliance with local standards, and national and international regulations); 5) social (directly related to the citizens' behaviors); 6) political (connected to the strategic vision for city development). It emerges that the development of urban energy scenarios is a delicate decision process that requires a huge number of data and information.

Despite the literature advocate for an open availability of data to facilitate higher quality science and a more effective science-policy boundary, one of the main challenges when dealing with decision processes related to the energy field is the absence of sensible and complete information about energy consumption and pollutant emissions (Pfenninger et al., 2017). This is mainly due to privacy constrictions, ethical and security concerns, unwanted exposure, additional workload, and institutional or personal inertia (Pfenninger et al., 2017).

As a result, qualitative and quantitative information still dominate the process of decision-making in energy, but they are often tricky or comprehensible only for people experts in the field.

In this panorama, in order to define and support urban energy scenarios, it is necessary to rely on innovative integrated approaches overcoming the traditional

perspective based on numerical data. The new approaches need to be able to deal with the scarcity of the information available involving experts and stakeholders that are asked to support the decision process. According to the literature (Abastante et al., 2018; Abastante, 2016; Beccali et al., 2003) we can define this particular family of methods as “stakeholders-oriented” approaches since they can make up for the lack of data and open data in energy through the interaction between actors and experts.

The present paper aims at illustrating an on-going research which investigate the application of a stakeholders-oriented approach in order to define the fundamental decision criteria to further support the definition of urban energy scenario through a Spatial Decision Support System (SDSS). The proposed approach is mainly based on Multicriteria Decision Analyses (MCDA) and SDSS.

The MCDA are powerful methodologies able to consider different aspects of complex problems in order to provide priority rankings both in term of alternative scenarios and qualitative/quantitative decision criteria (Neves et al., 2018; Figueira et al., 2005). Moreover, the MCDA can structure a multi-stakeholders decision problem, stimulating the discussion. In parallel, the SDSS consist in a family of systems devoted to support the decision processes in spatial problems identifying the hot-spots zones using maps (Chalal et al., 2016) and performing spatial operations (Arciniegas et al., 2011). The SDSS can therefore support evaluations at the urban scales about the complexity of the related energy strategies scenarios (Caputo et al., 2013), being able to integrate different subsystems and database. The synergetic capabilities of MCDA and SDSS are recognized since they can potentially enhance both spatial decision processes helping reaching the consensus (Aşlıoğlu and Memlük, 2017; AbuSada and Thawaba, 2011; Boroushaki and Malczewski, 2010). In this sense, they can structure and support the decision process, helping the stakeholders express their preferences with respect to the decision criteria and/or the alternative scenarios into a visual interface optimizing the conditions (Andrienko and Andrienko, 1999; Jankowski et al., 2001).

Although many studies focused on the development of MC-SDSS for urban energy planning purposes, the stakeholder-oriented approach has been rarely considered, which is crucial to address such complex interactions. Moreover, the main difference between the methodology proposed in this paper and the previously mentioned studies is due to its simplicity to be implemented and its strong stakeholders' acceptance. Interestingly, the stakeholders-oriented approach (Hamdy et al., 2017) is a very intuitive and engaging method, which allows clearly to select and rank a set of preferred evaluation criteria. Hence, the novelty of this paper is based on the stakeholders' involvement from the early phase of urban energy decision-making processes.

The application takes place in the general framework of the National Smart City & Communities project EEB (Zero Energy Buildings in Smart Urban Districts-www.smartcommunitiestech.it). In particular, the stakeholders-oriented approach proposed is applied to the case study of Settimo Torinese (Italy) identified as pilot test.

The reminder of the paper is organized as follows. The next section (2) provides an overview of the stakeholders-oriented approach proposed. Section 3 describes the case study and the application conducted providing a discussion about the results obtained. We end the paper by offering some conclusions and describing the future development of the research (section 4).

METHODOLOGICAL APPROACH

Determining the importance of the decision criteria and their relative weights to support the decision choices is complex.

The literature suggests many methods able to help solving this issue (Abastante et al., 2017; Lami and Abastante, 2014). According to (Wang, 2009), these methods are categorized in two main groups: the equal weights and the rank-order weights.

1. “*Equal weights*” method, where the weights of criteria are evaluated as “ $w_i = \frac{1}{n}$, $i = 1, 2, \dots, n$ ” equal weights method was popularized and applied in many decision-making problems;
2. “*Rank-order weights*” method, where criteria weigh takes into account the relative importance among criteria as “ $w_1 \geq w_2 \geq \dots \geq w_n \geq 0$, $\sum_{i=1}^n w_i = 1$ ”.

This method is classified into two main categories: (i) Subjective weighting method (e.g. SIMOS, Pair-wise comparison, AHP), and (ii) Objective weighting method (e.g. TOPSIS method, Minmax deviation method). Particularly, the subjective methods are mainly based on the stakeholders and decision makers’ preferences and visions. Hence, errors are not avoidable due to different stakeholders’ background and knowledge. While, the objective weights are more robust since they are evaluated based on mathematical methods.

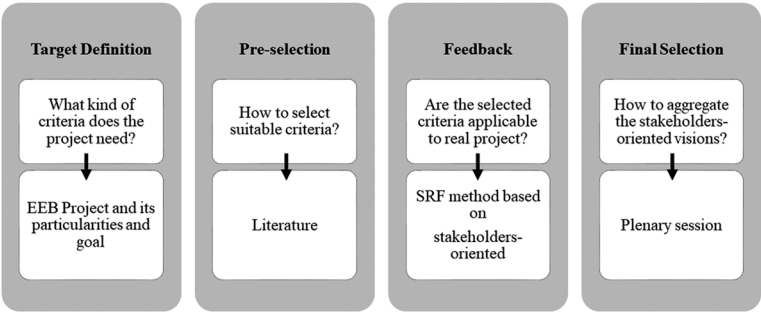
However, considering the absence of available data in the energy planning field, the stakeholders-oriented approaches seem to be the most promising in managing decision-making processes. This fact satisfies the stakeholders needs in order to ensure long-term stable results. Therefore, we have chosen a “Playing card” method as a basis of our analysis, which is a subjective approach proposed by Simos, 1999.

This method helped us in ranking the criteria based on stakeholders’ preferences. However, the SRF method proposed by Figueira and Roy (2002) has revised the weights of criteria Simos’ procedure (for more comprehensive details the readers can refer to Figueira and Roy, 2002).

Figure 1 gives an overview of the workflow. Details of the proposed methodology are introduced below, where a synthetic description of the stakeholders-oriented approach proposed based on MCDA and SDSS is illustrated.

As it is shown in Figure 1, the first step is defining the targets and the specific particularities of the project. The present study intends to define the scenarios regarding the mix of the energy retrofit measures that improve the energy efficiency of the building and the plants system efficiency. Afterward, we have pre-selected the relevant criteria based on the existing literature (Wang, 2009; Strantzali and Aravossis 2016) . In particular, Wang et al. (2009) and Strantzali and Aravossis (2016) conducted a comprehensive literature review based on 229 articles related to MCDA techniques for the sustainable energy decision-making issues. This study showed that the efficiency (31%), investment cost (52%), operation and maintenance cost (34%), NO_x emission (22%), CO₂ emission (52%), land use (33%), social acceptability (28%), and job creation (46%) were the most widely used evaluation criteria in energy planning, energy management, and resource allocation studies. Then, the three set of the evaluation criteria was established through a workshop considering stakeholders’ feedback. Indeed, we used the SFR method (Figueira and Roy, 2002; Corrente et al., 2017) in order to rank and weight the pre-selected criteria (see section 2.1). Lastly, the Plenary session is organized in order to aggregate the result of different stakeholders’ feedback and to provide the final set of criteria (section 3.2).

Figure 1. Methodological workflow



The SRF Method

The SRF method (Figueira and Roy, 2002) is a generalization of the consolidated approach proposed by Simos in 1990 (Simos, 1990a, 1990b) generally called “Playing Cards” (Siskos and Tsotsolas, 2015; Aşlıoğlu and Memlük, 2017). The SRF can be considered as a MCDA since it allows the stakeholders involved to think about and express the way in which they wish to hierarchize multiple criteria in a given context (Figueira and Roy, 2002; Zheng et al, 2016).

In the SRF method, the stakeholders are asked to express their preferences on the considered decision criteria using sets of cards. Operatively, each criterion is associated to a card called “criterion card”. The stakeholders are asked to order the “criterion cards” with respect to their relative importance, from the last important to the most important one, providing a complete pre-order. In this way, the stakeholders will rank in ascending order according to the importance they want to ascribe to the criteria (Figueira and Roy, 2002).

If some criteria show the same relative importance, the stakeholders can build a subset of *ex equo* “criterion cards” holding them together with a clip or simply disposing them on the same line. The stakeholders are then asked to think about the fact that the importance of two successive decision criteria in the ranking can be more or less close.

Accordingly, the stakeholders insert “white cards” between two successive “criterion cards” in line with the logic expressed by Figueira and Roy (2002): no white card means that the criteria have not the same weight but that the difference between the weights can be chosen as the unit for measuring the intervals between weights; one white card means a difference of two times; two white cards mean a difference of three times and so on. Obviously, the greater the difference between the mentioned weights of the criteria, the greater the number of white cards.

Finally, the stakeholders are asked to express the so called “z value”, whose calculation constitutes the main difference between the original “Playing Cards” proposed by Simos and the SRF method. According to the ranking provided by each stakeholder, the “z value” represents how many times, the last criterion is more important than the first one in the ranking.

After the stakeholders’ provided a complete ranking and the ratio through the “z value”, the preferences expressed are converted into weights using the SRF algorithm by the dedicated software (Maystre et al. 2004).

The reader can refer to Figueira and Roy (2002) for more comprehensive details, since providing a detailed description of the algorithms supporting the SRF method is beyond the scope of this paper.

Spatial Decision Support System (SDSS)

Generally, the SDSS is an interactive computer system for helping the stakeholders and decision makers to perform efficiently decision processes (Malczewski, 2006). In this sense, the SDSSs are able to visually support the participative decisional approaches during different workshops to understand how the criterion trade-offs evolve when one or several decision parameters change (Chakhar and Martel, 2003; Lotov et al. 2003; Andrienko et al., 2016). Particularly, the SDSS is able to manage and store a big number of geo-referenced data in order to perform the analysis of spatial problems. Moreover, it provides an interactive environment for performing effective visual activities (Chakhar and Martel, 2003) thanks to the visual interface, which enables a dynamically interactive session in a real-time exchange of information between the stakeholders and the system to support the stakeholders through all decision phases (Sauter, 1997); (Malczewski, 1999).

From the methodological viewpoint, the process needed to define and assess urban scenarios can be described according to the three following phases (Simon, 1977; Malczewski, 2006).

1. **Process Model (Intelligence Phase):** The decisional context analysis for structuring and identifying the decision problem should be provided in this phase. In this phase the relevant decision criteria as well as the strategic definition of the alternative scenarios should be established, identified and assessed. The Process Model can be in turn split into three consecutive steps: i) data collection and integration; ii) criteria definition; iii) scenarios definition;
2. **Planning Model (Design Phase):** Once the alternative scenarios have been defined, it is necessary to carefully choose the appropriate MCDA method in order to structure the decision model and the evaluation matrix (criteria and alternatives matrix) (Tsoukiàs, 2008);
3. **Evaluation Model (Choice):** After choosing the appropriate MCDA method, it can assess and evaluate the alternative scenarios in order to rank, sort, choose and describe them (Roy, 1985). During this phase, a sensitivity analysis is suggested in order to examine the constancy of the obtained outcomes and the robustness of the model.

Particularly, SDSSs include nine general features: (i) solve ill-structured problems; (ii) user friendly interface; (iii) analytical models with data integration; (iv) able to find spatial solution through building alternatives; (v) support a variety of decision-making techniques; (vi) interactive and recursive problem solving; (vii) spatial data input; (viii) application of spatial analysis; (ix) produce geographic outputs according

to different spatial forms including maps, graphs (Aydin, 2014; Malczewski, 2006; Densham, 1991).

The MC-SDSS are part of a larger field of SDSS (Ferretti, 2011). In the framework of MC-SDSS, two interrelated instruments existed. On one hand, GIS supports in big data storage, management, visualization of maps and analyses the decision problems. On the other hand, MCDA provides a full range of methods for structuring decision problems and for designing, evaluating and prioritizing alternative decisions (Malczewski, 2006). In other words, digital maps are meant for communication among workshop participants and an interactive mapping device (Arciniegas et al., 2011).

According to the aforementioned phases, the on-going research presented in this paper aims at defining the evaluation criteria able to assess alternative energy urban scenarios in a short-term period perspective. In particular, the focus of the research presented refers to the Process Model phase with a sink on the step “criteria definition”.

APPLICATION TO THE CASE STUDY

Description of the Case Study

The National Smart City & Communities project EEB (Zero Energy Buildings in Smart Urban Districts - www.smartcommunitiestech.it) is a national project funded by the Ministry of Innovation. The project aimed at exploring energy consumption patterns at an urban scale and provide a methodology for evaluating different urban energy retrofitting scenarios based on MCDA in the context of sustainable urban planning. During this project the Politecnico di Torino played a crucial role in defining alternative urban energy scenarios through the use of SDSS tools. Despite the project ended in 2017, we are continuing in the development of the SDSS tool taking into account the results of the EEB and organizing different focus group involving real stakeholders in order to test the Dashboard.

In order to test the stakeholders-oriented approach proposed and described in the previous section, we analyzed the case study of Settimo Torinese (Italy) identified as pilot case for the EEB project.

The application of the methodology in the urban area is performed by a significant selection of buildings belonging to the “beating heart” of the Italian city of Turin (Piedmont), named Settimo Torinese. The residential building stock of this city is located in North-West of Italy in the continental temperature climatic zone. This municipality represents a proper demonstrator due to the presence of a various

Defining Energy Criteria in the Absence of Open Data

Table 1. General information about the case study (source: Municipality of Settimo Torinese)

Municipality	Settimo Torinese
Province	Turin
Region	Piedmont
State	Italy
Coordinates	45°08'21" N; 7°46'12" E
Climatic zone	E
HDD	2664
Altitude	207 m above sea level
Surface	32,37 km2
Inhabitants	47 785
Density	1476,21 In/km2

buildings’ typology, size and age of construction. Settimo Torinese (45°8’ North, 7°46’ East, 207 m asl) is a medium-sized city. The city is composed of 300 census sections and about 3600 residential buildings with 47,831 inhabitants, and it occupies an area of 33 km², as visible in Figure 2, showing aerial views of the city of Settimo Torinese. Moreover, the total heated volume of the residential buildings is equal to 8.55 Mm³. Table 1 summarizes the generic information and characterization of Settimo Torinese.

Figure 2. Map of Settimo Torinese, Torino (Italy)



After having characterized the case study, it was necessary to analyze the current energy consumption in order to provide some useful information to the stakeholders involved. Consequently, the district buildings were clustered in 5 categories, according to their geometrical, and their construction period national database TABULA (Ballarini et al., 2014) taking into account their thermo-physical features.

Definition of the Decision Criteria

In order to define a coherent family of decision criteria able to support urban energy retrofitting scenarios, we first considered the comprehensive literature review in the context of energy performance of buildings (European Directive 31/2010). In parallel, we considered the relationships among the legislative framework and projects of reducing energy consumption and the impacts on the territory in exam in terms of qualitative/quantitative aspects. In this sense, we selected the relevant decision criteria starting from international studies and a deep literature review about urban energy projects.

The decision criteria considered in the present research are described in the following subsections divided in environmental, financial, technical and social criteria.

Global Emissions (Environmental Criteria)

CO₂ is a kind of gas without color, smell and taste, which may contribute about 26% to the GHG effect (Kiehl and Trenberth, 1997) and it is measurable according the equivalent emission of CO₂ avoided by the different energy urban retrofitting scenarios. They represent a big environmental concern acknowledged at both at National and European level and highly stressed in the scientific literature review (Jovanović *et al.*, 2009; Beccali et al., 2003; Marinakis et al., 2016; Giaccone et al., 2016).

Local Emissions (Environmental Criteria)

The local emissions criterion considers the emissions of NO_x and PM₁₀. They are very harmful to the human health, such as lung diseases, heart attacks and arrhythmias, cancer, atherosclerosis, childhood respiratory disease and premature death (EEA, 2014). They have a direct impact also the social state of the community (Jovanović *et al.*, 2009; Wang, 2009). In particular, different studies have reported associations between increases in local emissions concentration and increases in morbidity and mortality among people with respiratory or cardiovascular diseases (Künzli et al., 2003; World Health Organisation, 2000).

Payback Period (Financial Criteria)

The Payback Period (PBP) is understood as the performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. In this sense, the PBP gives an indication about the length of time required to recover the cost of an investment. It refers to the investment and maintenance costs but ignores the time value money (Volvačiovas et al., 2013). Nevertheless, it is considered an important and understandable parameter of whether to undertake a project of urban transformation.

Investment Costs (Financial Criteria)

In finance, the investment costs are a monetary asset purchased in order to provide incomes in the future generating a profit (Bartov, 1993). In the present research, the investment costs are related to the number of euros needed to provide the refurbishment of buildings and the new heating systems for the different hypotheses of energy urban retrofitting scenarios. Moreover, they are not expected to simply generate a financial profit but also economic benefits. In this sense it the sum of efficient investment and infrastructure investment (Becchio et al., 2015) and it is one of the information necessary to calculate the PBP.

Maintenance Costs (Financial Criteria)

The maintenance costs usually consider the costs needed for the ordinary and extraordinary upkeep of a project (Bartov, 1993). In the present research, the maintenance costs are understood as running fixed and variable costs due to the ordinary maintenance of the heating systems but they do not consider extraordinary works devoted to the increase in the value of the project. According to the literature (Cavallaro and Ciraolo, 2005), the maintenance costs avoid the fuel costs considering the repair and service costs. Moreover, they take into account the heating power installed and the age of the system since it is recognized that the older the system is, the higher the costs are.

Reliability (Technical Criteria)

The reliability considers the efficiency of the technology and the requalification result (Ertay et al., 2013). According to Beccali et al. (2003), the reliability is essentially based on the state of art of the applied refurbishment technologies and it is expressed

in a qualitative scale as follows: 1) technologies that are only tested in laboratory; 2) technologies that are only performed in pilot plants; 3) technologies that could be still improved; 4) consolidated technologies.

Technical Life (Technical Criteria)

The technical life refers to the durability of the whole strategy in relation to the service life of each retrofit measure (Dall'O' et al., 2013; Giaccone et al. 2016) It is measured in the number of years during which it is expected that the retrofit strategies and heating systems, having a multi-year duration, can expose its usefulness for the society. In this sense, long-lasting strategies also bring long-lasting benefits.

Visual Impact (Technical Criteria)

The visual impact takes into account the improvement or deterioration that the hypotheses of energy refurbishment scenarios can cause in the existing built environment. It is expected that the retrofit measures will lead to a modification of the aesthetic quality of Settimo Torinese both in positive and negative impacts (Dall'O' et al., 2013).

Social Acceptability (Social Criteria)

The social acceptability concerns the perception of the society related to specific impacts due to the refurbishments (Ertay et al., 2013). It emphasizes the complex process underneath in order to convince the society that the projects proposed are good and imply an improvement in their quality of life. In this sense, the social acceptability is currently a forefront of broader debates in energy field (Fornis and Fortin, 2017).

Local Job Creation (Social Criteria)

The local job creation refers to the possibility of creating new jobs and improving the regularity of the employee (Dall'O' et al., 2013). This aspect is considered a positive externality caused by the project being able to produce macroeconomic impacts in terms of economic growth (Janssen and Staniaszek, 2012).

Socio-Economic Feasibility (Social Criteria)

The socio-economic feasibility reflects the ability of the people to support the transformation in financial and economic terms considering both the capability and willingness of the society involved. It analyses how many different resources the society involved in the transformation is able to put in play in order to absorb the activities necessary for the project.

APPLICATION OF THE SRF METHOD

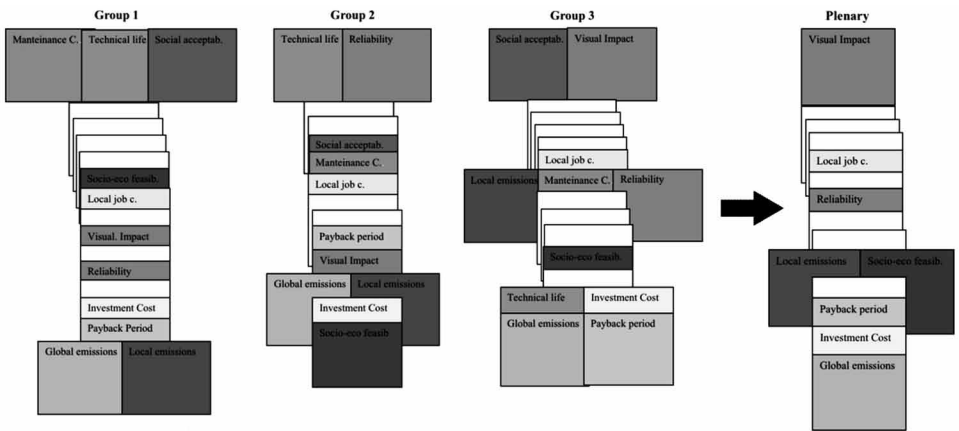
After setting up the decision criteria, a focus group has been organized in Turin (Italy) in order to discuss and define the most important criteria that can support the assessment of urban energy scenarios through SDSS.

The stakeholders involved in the discussion had different background and skills. They were experts in visual tools and SDSS, academics, building administrators, designers and representatives of the public administrations.

The focus group has been structured into three main working sections. During the first one, we presented to the stakeholders the objectives of the EEB project, the main characters of the area in exam, the decision criteria identified as well as the SRF methodological approach.

In the second section, the stakeholders involved worked into three heterogeneous groups supported by facilitators. Each group provided a ranking of the decision criteria using the sets of “criterion cards” and “white cards” according to the SRF method Figure 3).

Figure 3. The ranking of cards provided with SRF



It is fundamental to stress out that the rankings must be read from the top to the bottom, from the last important criterion to the most important one, in line with the indications of the methodology applied.

During the third and final working section, the stakeholders faced a plenary discussion. After having presented the three rankings the stakeholders talked about the decision criteria exchanging different opinions in order to come to a final common ranking (Figure 3).

From the plenary ranking provided in Figure 3, it is possible to notice that the criteria “social acceptability”, “technical life” and “maintenance costs” have been removed from the analysis according to the stakeholders’ requests emerged during the third working section. As far as it concerns the “social acceptability” criterion, first the stakeholders highlighted that the possible and probable discomfort that will occur during the construction phase of a project is necessary and uncontrollable. They stated also that the construction phase is theoretically very short and therefore the “social acceptability” cannot be considered as a decision criterion. The “technical life” and the “maintenance costs” criterion have been considered not crucial for the stakeholders since they are fundamental elements to calculate the “PBP” and are therefore already considered in the “PBP” criterion.

The final ranking provided by the stakeholders through the use of the cards, have been finally insert in the SRF software to obtain the normalized weights of the ranking provided (Table 2).

From the results obtained and showed in Figure 3 and Table 2, it is possible to notice that the environmental and financial criteria are strongly more important that the technical and social ones.

In particular, the criterion “global emissions” has been considered the most important one (18,7 points) together with the criteria “investment cost” (17,4 points) and “PBP” (16,2 points). This is due to the public and private souls of the stakeholders involved which affirmed that the CO₂ emissions are a big concern highlighted by the EU (European Directive 31/2010) and therefore cannot be neglected. Similarly, the investment costs required to start the transformation and the consequent PBP need to be consistent but as low as possible at the same time in order to convince the society to support the project.

The last important criteria turn out to be the “visual impact” (2,7 points) and the “local job creation” (7,6 points). This is due to the fact that the visual impact of the new energy technologies is extremely reduced thanks to the national and international norms, while the creation of local jobs is very difficult to estimate and guarantee. However, it is interesting to notice that, even if the literature strongly suggests considering the social criteria as fundamental (Liposcak et al 2006; Doukas et al. 2007; Wang et al. 2009), the practice tends to partially deny this trend (Lami and Abastante, 2017; Lombardi et al., 2017).

Table 2. Final ranking of the criteria

Rank	Criteria	Interval	Non-Normalized Points	Normalized Points
1	Visual impact	/	1	2,7
	White cards	3	/	/
2	Local job creation	/	2,85	7,6
	White cards	1	/	/
3	Reliability	/	3,77	10
	White cards	2	/	/
4	Local emissions	/	5,15	13,7
4	Socio-economic feasibility	/	5,15	13,7
	White cards	1	/	/
5	PBP	/	6,08	16,2
	White cards	0	/	/
6	Investment cost	/	6,54	17,4
	White cards	0	/	/
7	Global emissions	/	7	18,7
Z Value	7		SUM	100

CONCLUSION AND FUTURE DEVELOPMENT

Many cities have started to define future strategies to reduce energy consumption and GHG emissions. One of the main problems, in relation to urban energy retrofitting scenarios, is the lack of proper data and relevant evaluation criteria. Hence, this paper illustrated a stakeholders-oriented approach for defining and ranking the decision criteria required for assessing urban energy scenarios. The approach proposed is called SRF method and consists of an implementation of the Playing Cards method.

The method proved to be a flexible and participative approach able to consider social and urban planning aspects and suitable to support decision processes in the absence of open-data or sensible and complete information (Pfenninger et al., 2017). The main features of this approach can be summarized as following (Lombardi et al., 2017):

- Selecting and weighting method: subjective (subjective scale)
- Participation Structure: semi-structured participative based on free discussion
- Approach: participants are asked to rank the cards according to their personal knowledge and background

- Importance ranking: rank importance position by inserting a set of cards “white cards” between colored cards
- Stakeholders acceptance: intuitive and entertaining

Particularly, the SRF method is stakeholder-based approach and it is based on stakeholders’ preferences. This method showed to be flexible with the ability to stimulate the discussion among the stakeholders involved in the focus group. Thanks to its characteristics, the method is useful to support decisions with subjective criteria. Moreover, the stakeholders perceived the SRF method as a very intuitive and engaging method, able to support discussion on the criteria involved and useful for ranking them according to their preferences. Playing card method highlighted that the most important criteria for the development of energy urban retrofitting scenarios are related to both economic and environmental aspects. Contrary, the social criteria were considered less important in the field of energy retrofitting.

It is notable to underline that this study will support decision makers to deliver retrofitting GIS-based (i.e. Dashboard) alternative scenarios. In particular, the main advantages of the Dashboard in the field of urban energy planning can be summarized as follows: to allow the participative processes; to give a visualization opportunity for the decision process in specific areas; to consider multiple criteria (e.g. economic, environmental, technical and particularly social aspects); to manage and store a huge amount of geo-referred data; to illustrate results requested by users according to different spatial forms (e.g. maps, graphs); to show the distribution of buildings geometrical characterization and buildings energy consumption.

The main limitations regarding the present study are the difficulty of the workshops that are time-consuming since there is a need to involve the relevant real stakeholders. Moreover, the difficulty of the inclusion of conflicting point of views and then aggregation of stakeholders’ preferences in a participative decision-making context is another important issue that should be considered.

Finally, it is important to underline that the application of the SRF method presented in this study represents a validation step aiming at verifying whether the key issues have been appropriately considered in the decision making process (Tsoukiàs, 2008) and testing the model by using experimental or real data.

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Chapter 7

Can Big Data Support Smart(er) Evaluation?

Theoretical Consideration Starting From the Territorial Integrated Evaluation Approach

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ABSTRACT

In the last decade, the value of big data for social sciences is declared to be high for its social impact. This kind of data is currently applied to create a wealth of constantly updating information that in the spatial domain are generally used to support decision making. This chapter falls under this heading, and it presents the results of a research program developed by an interdisciplinary research team of the Interuniversity Department of Regional and Urban Studies and Planning of Politecnico di Torino for the Autonomous Province of Trento in which the Territorial Integrated Evaluation methodology was applied for evaluating regional development and designing territorial scenarios. According to the results of the research, TIE methodology proposes a smart approach to territorial evaluation as it links the strategic dimension of evaluation to the regional planning process. Starting from the TIE methodology, the chapter aims to represent a small step in the theoretical discussion on the big data in social sciences discussing its potential role for territorial evaluation.

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THE TERRITORIAL INTEGRATED EVALUATION METHODOLOGY IN TRENTINO¹

The Territorial Integrated Evaluation (TIE) is a scientific methodology² designed to support institutional innovation in territorial governance and policies (Brunetta, 2013). TIE methodology aims at providing an overall evaluation of the territorial system under examination, employing multidimensional indicators and synthetic indexes useful to support regional planning and management processes. Additionally, TIE methodology proposes to articulate the strategic dimension of the evaluation in planning process fostering institutional innovation (Alexander, 2006). As experimented in the Italian context, TIE methodology is not intended to take the place of legally mandated assessment procedures, as Strategic Environmental Assessment (SEA), but it is meant to be a voluntary evaluation process that helps decision-making for planning and designing territorial transformation and development. In other words, TIE methodology fosters a ‘meta-evaluation’ process intended to act as a new institutional framework to innovate the capacity building of territorial policies. In this perspective, TIE’s main strategic action is to foster ‘technical knowledge’ as a learning process for institutional authorities.

TIE articulates this strategic approach following three main features (Brunetta, 2015: 16):

- TIE is a gradual learning process continuously evolving thanks to the monitoring system that follows the implementation of territorial development;
- TIE is oriented towards the creation of policies as it is not just an analytical methodology;
- TIE is a form of dialogue among institutions, and between institutions and citizens as it aims to improve the level of cooperation and subsidiarity.

Following these principles, the Interuniversity Department of Regional and Urban Studies and Planning (DIST) of Politecnico di Torino research group³ implemented from 2011 the TIE methodology in order to radically rethink the planning approach to local development of the Autonomous Province of Trentino (APT). The reasons for this innovative wave can be traced back to two basic institutional conditions, i.e. the reform of APT spatial planning framework, initiated by the approval of a new inter-municipal level of VCs (Valley Communities), and the reform of APT retail planning legislation, conducted with the enactment of the European reform regulations and national decrees on local services. In this context, the APT has had to face a formidable challenge, namely to orient news direction for territorial development policies concerning the use of qualitative parameters without giving up the territorial planning and the conservation of the landscape values. The goal of

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TIE methodology, therefore, was to design a new orientation of provincial policies while harmonizing the needs of territorial development with those of conservation of landscape values. This institutional context means that the TIE's approach to designing territorial scenarios needs to look simultaneously at different themes, such as retail, tourism, infrastructures, environment and landscape, meeting both the need for economic growth and the need for landscape conservation values.

Technically, TIE methodology in Trentino is structured in six consequential phases:

1. Definition of TIE evaluation themes;
2. Definition of the TIE evaluation scales, i.e. macro-scale (VCs level) and micro-scale (local level);
3. Definition of the TIE evaluation criteria and indicators (see Table 1 for the macro-scale);
4. Evaluation of the spatial dynamics of the VCs in view of the indicators of the TIE matrix;
5. Identification of territorial scenarios for each VCs among Scenario 1 'Retail – Designing the territorial retail system', Scenario 2 'Marketing – Designing the integration of retail, tourism and landscape', and Scenario 3 'Landscape – enhancing the landscape identity of the territorial system';
6. Identification of systems of territorial scenarios relationships among VCs.

Firstly, TIE identifies five evaluation themes that are closely interconnected to territorial, environmental, and economic aspects. They are:

- **Theme A:** Territorial retail supply
- **Theme B:** Tourism
- **Theme C:** Land use
- **Theme D:** Ecosystem and Landscape
- **Theme E:** Local governance.

Within the Trentino framework, 'Theme A - Territorial retail supply' supports the quantitative and qualitative evaluation of retail dynamics in relation both to the existing retail offer and to the potential retail demand helping APT to identify if the retail system is a factor of opportunity for the development of VCs. 'Theme C - Land use' analyses the level of urbanization and demographic dynamics of APT, while 'Theme E - Local governance' treats the level of local initiative that characterizes the APT when they design actions improving the quality of the retail system in city centres. 'Theme D – Ecosystem and Landscape' focuses on the values, critical issues, and dynamics of natural and cultural resources that can spur the development of the local economic system. Finally, 'Theme B – Tourism' evaluates the intensity of tourist

Table 1. TIE themes and indicators on the macro-scale

THEMES	INDICATORS	DESCRIPTION	DATA SOURCE
Territorial Retail Supply	A1M Retail consistency	VC retail surface / Province retail surface	APT Retail Office (2010)
	A2M Retail operators	VC retail operators / VC total operators	APT Statistical Office (2009)
	A3M Dynamics of retail operators	VC variation in retail operators (2001-2009)	APT Statistical Office (2001/2009)
	A4M Dynamics of retail consistency	VC variation in retail surface (2005-2010)	APT Retail Office (2005/2009)
	A5M Retail density	VC number of shops for every 1.000 inhabitants	APT Retail Office (2010)
	A6M Retail integration	VC retail surface by merchandise category / VC Retail surface	APT Retail Office (2010)
	A7M Retail typology	VC neighbourhoods shops / Province total shops	APT Retail Office (2010)
	A8M Retail specialization	VC Food and non-food GLAs / Province GLAs	APT Retail Office (2010)
	A9M Index of retail choice	VC number of GLAs within a 15 minute drive	APT Retail Office (2010)
	A10M Index of retail loss	Number of GLAs that intercepted the VC within 90 minute drive	APT Retail Office (2010)
Tourism	B1M Tourism intensity	VC annual nights spent / VC inhabitants	APT Statistical Office (2010)
	B2M Tourism intensity (winter)	VC winter nights spent / VC inhabitants	APT Statistical Office (2010)
	B3M Tourism intensity (summer)	VC summer nights spent / VC inhabitants	APT Statistical Office (2010)
	B4M Dynamics of tourists	VC variation in annual nights Spent (2001-2010)	APT Statistical Office (2001/2010)
	B5M Accommodation capacity	VC number of hospitality facilities / VC inhabitants	APT Statistical Office (2010)
	B6M Hospitality operators	VC number of hospitality operators / VC number of operators	APT Statistical Office (2009)
	B7M Dynamics of hospitality operators	VC variation in the number of hospitality operators 2001-2009	APT Statistical Office (2001/2009)
	B8M Extension of bicycle paths	VC bicycle paths / Province bicycle paths	APT Environmental Office (2010)
Land Use	C1M Dynamics of demography	VC variation in resident population (2001-2010)	APT Statistical Office (2001/2010)
	C2M Urbanized areas	VC urbanised surface / VC territorial surface	APT Planning Office (2008)
	C3M Retail areas	VC retail surface / VC territorial surface	APT Planning Office (2008)
	C4M Agricultural areas	VC agricultural surface / VC territorial surface	APT Planning Office (2008)
	C5M Pasture areas	VC pastured surface / VC territorial surface	APT Planning Office (2008)
	C6M Infrastructure density	VC infrastructure surface / VC territorial surface	APT Planning Office (2008)

continued on following page

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Table 1. Continued

THEMES	INDICATORS	DESCRIPTION	DATA SOURCE
Landscape	D1M Ecological network elements	<i>VC surface of the Ecological Network elements / VC territorial surface</i>	<i>APT PUP (2008)</i>
	D2M High quality agricultural areas	<i>VC surface of high quality agricultural areas / VC territorial surface</i>	<i>APT PUP (2008)</i>
	D3M Representative landscape areas	<i>VC representative landscape areas / Province representative landscape areas</i>	<i>APT PUP (2008)</i>
	D4M High quality scenic views	<i>VC number of high quality views / Province number of high quality views</i>	<i>APT PUP (2008)</i>
	D5MD High-risk hydrogeological areas	<i>VC surface subject to high hydro-geological risk / VC territorial surface</i>	<i>APT high-risk areas (2006)</i>
	D6M High-danger hydrogeological areas	<i>VC surface subject to high hydro-geological danger / VC territorial Surface</i>	<i>APT high-danger areas (2006)</i>
	D7M Traffic pollution	<i>VC annual emissions of macro-pollutants from traffic</i>	<i>APT air quality data (2007)</i>
	D8M Air quality (PM10)	<i>VC annual concentration of PM10 / Max permitted concentration</i>	<i>APT air quality data (2003/2011)</i>
	D9M Index of urban growth	<i>VC surface of urbanized ex-natural, semi-natural and agricultural areas / VC surface of urbanized areas</i>	<i>APT Planning Office (2005/2008)</i>
	D10M Index of loss of land	<i>VC surface of urbanized ex-natural, semi-natural and agricultural areas / VC surface of natural, semi-natural and agricultural areas</i>	<i>APT Planning Office (2005/2008)</i>
Governance	E1M Municipal grants for retail areas	<i>Presence or absence of Municipal grants</i>	<i>APT Retail Office (2010/2011)</i>
	E2M Consortium grants for retail areas	<i>Presence or absence of Consortiums grants</i>	<i>APT Retail Office (2010/2011)</i>

Source: (Brunetta, 2015)

flows and the socioeconomic effect these flows have on the resident population. It also evaluates the conditions of the hospitality facilities as well as of bicycle paths.

These five evaluation themes aim to focus on and help to develop policies that integrate natural resources, the tourist industry, local agricultural activities, and retail areas. In APT, in fact, tourism plays a leading role in the APT economy and can play a further role in correlating retail and landscape in an effective and sustainable way as new models of tourism are being defined in harmony with the exceptional natural and cultural resources. Such an integrated system can put forward offerings that are rooted in the territorial context, attractive, and firmly anchored in the local characteristics.

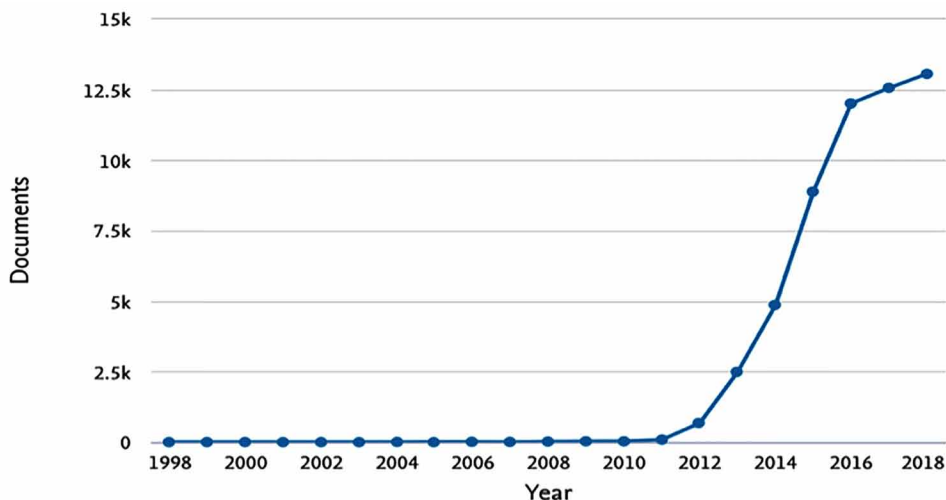
These five themes are evaluated thanks to an evaluation matrix composed by thematic indicators identified in reference to two territorial scales of evaluation, i.e. the micro-scale (indicated by a small ‘m’) and the macro scale (indicated by a capital ‘M’). Thirty-six indicators compose the TIE evaluation matrix for the macro-scale

(16 VCs), while twenty-one indicators compose the TIE evaluation matrix for the macro-scale covering the five most populous cities of the APT (Trento, Rovereto, Riva del Garda, Pergine Valsugana and Arco). On both territorial scales, the principal objective of defining these indicators was the achievement of a complex and dynamic representation, detecting both qualitative and qualitative aspects as well as their evolution over time.

Technically, TIE evaluation matrix limits the overall number of indicators working out an evaluation grid that was substantially complete but that was also agile and easily to work with (Table 1). The number of indicators was limited and validated data could be retrieved easily and periodically updated by various agencies in public administration. In this way, the five evaluation themes could become operative for actions of designing and monitoring the emerging scenarios of enhancement and development in the APT. Another objective that guided the structure of the TIE matrix was indicators were correlated to the particular characteristics of the territorial, landscape-related and economic system in the APT, and therefore those rooted in the local conditions. For example, the indicators for Theme E, Local Governance, specifically refer to the normative initiatives of Provincial laws. Also the indicators for Theme B, Tourism, were calibrated to the characteristics of the local phenomena. In addition, TIE uses indicators on the basis of which evaluation scale they would be applied to that more appropriately described the various phenomena. In the evaluation matrix, for example, the indicators for 'Theme A' reveal the quantitative consistency of the retail phenomenon, but also they reveal also the characteristics of the types of retail (A6M, A7M, and A8M). In addition, they trace the evolution of the territorial retail system over recent years (A3M and A4M). The indicators for 'Theme D' attempt to get the complex and dynamic characteristics of landscape delineating the plurality of landscape values when they describe their ecological (D1M), scenic (D4M) and cultural-historical and identity-related values (D3M) and the main processes that transform these values (D9M and D10M).

Fostering some theoretical consideration on the possible integration of Big Data (BD) in territorial evaluation practice, this chapter concentrates upon the TIE macro-scale evaluation. In a nutshell, the contribution aims to investigate the potential of BD in the field of territorial evaluation organising some theoretical reflections starting from the results of the research project of TIE methodology applied in Trentino. To describe these arguments, the chapter is articulated as follows: this section set out the methodology, section two outlines the rapid rise of BD in social sciences, section three tested the applicability of BD in TIE. The discussion is presented and conclusions are drawn in the last section.

Figure 1. The rise of big data concept (1998-2018)



THE RAPID RISE OF BIG DATA IN SOCIAL SCIENCES

Big Data is a concept rapidly spreading in the academic discourse attesting in November 2018 to more than 13.000 publications of which more than 5.000 pertain to social sciences (Figure 1). These available studies have mainly pointed on definitions, ethics, and the methodological challenges of the phenomenon (Boyd and Crawford, 2012; Davis, 2012).

To date, an enormous number of studies have been carried out on BD, but their interest in social science is more recent (Arnaboldi, 2018). In the five last years, therefore, there has been growing consideration on how BD could revolutionise regional science and, more in general, urban studies (Rae and Singleton, 2015) as BD has a great potential to properly deal with complex adaptive systems. As a matter of fact, territorial systems are example par excellence of complex adaptive systems (Portugali et al., 2012), and they are characterised by two main aspects. Firstly, the many components of territorial systems interact and affect each other so that it is challenging to individually recognise their performance because of the state of components that partly depend on the state of other parts affecting them in turn (Gershenson, 2008). Secondly, territorial systems are always changing, and the changes expected as a result of environmental, social and economic tensions will be unprecedented in both scope and speed (Nel et al., 2018). As BD has the ability to capture, store and link temporally richer data within regions, it has the capacity to introduce a new 'cognitive framework' able to understand interactions and manage changes in complex systems. In other words, this situation makes problematic to

study complex systems with traditional linear and reductionist approaches⁴ (De Roo et al., 2012) as territorial performances depend not only on the physical infrastructure but also on the availability and quality of the knowledge communication and the social infrastructure (Caragliu et al., 2011). However, planners are often unaware of how to orient decision-making for change, especially in the context of the multiple complexities in territorial system (Watson, 2003) so that BD is actually understood as a new angle to observe and evaluate territorial systems as it supports new perspectives for social interaction and for a more informed decision-making (Bettencourt, 2014).

In the spatial dimension, BD is framed as data that are large, fast-moving, often produced and disseminated in real time, heterogeneous in formats, and with varying levels of fidelity and reliability (Schintler and Chen, 2017). These data are built as part of complexity theory as they highlight the more in-depth understanding of the 'disruption' of territorial systems (Batty, 2013). In a nutshell, BD for territorial systems, as its name suggests, is primarily characterized by size and volume of data, and it pertains to any and every aspect of the territorial system measured with respect to its population, buildings, transport, and so forth. In this perspective, BD allows the better evaluation of how territorial systems are becoming more complex, smarter, sustainable and resilient (Batty, 2016). Technically, BD approaches to managing territorial data, characterised by huge amount and variety, creates a wealth of constantly updating information that can be used to support decision-making and aid monitoring and evaluation in the spatial domain.

Amongst the excitement surrounding BD overall, there has been little time for thought about the kinds of application are most suited⁵. The literature review on the topic underlines four main critical considerations on BD (Lim et al., 2018). The first challenge pertains to quality of the available data to be effective in their use. The second refers to the integration of data from different sources in order to produce a high level of knowledge and high-quality information for citizens and local institutions. The third concerns data privacy and source. The fourth, lastly, pertains to the dependency with geographic information systems, as it is the key success factor of BD to have information visualised.

But, what exactly is the potential of BD for territorial evaluation? At the most general level, the appropriate use of BD can provide reliable snapshots to describe the features of territorial systems, evaluate their patterns of development across territorial scales, and monitoring their changes over time. In other words, BD can enrich the traditional data sources, such as survey data or official statistics, overcoming the limitations and biases of available data allowing their adequately understanding into the territorial evaluation process. This first consideration allows moving to another issue, i.e. what is the practicability of BD in the evaluation methodology? In other words, how can BD turn imperfect, complex and unstructured data into actionable information to allow decision-makers to track development progress,

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Table 2. BD integration in TIE matrix

THEMES	TIE INDICATOR	BIG DATA INFORMATION SOURCE
Territorial Retail Supply	A1M Retail consistency	
	A2M Retail operators	
	A3M Dynamics of retail operators	
	A4M Dynamics of retail consistency	
	A5M Retail density	
	A6M Retail integration	Twitter data on shopping behaviours (Lovelace et al., 2014)
	A7M Retail typology	Monitoring of loyalty schemes (Aktas and Meng, 2017)
	A8M Retail specialization	Geolocated survey dataset on shopping habits (Michael et al., 2014)
	A9M Index of retail choice	Travel flow matrix derived from mobile records (Lovelace et al., 2015)
	A10M Index of retail loss	Service process perceptions for shopping habits (Aloysius et al., 2018)
Tourism	B1M Tourism intensity	Online textual data and photo (Hanjalic and Larson, 2011; Lu et al., 2017)
	B2M Tourism intensity (winter)	Online textual data and photo (Hanjalic and Larson, 2011; Lu et al., 2017)
	B3M Tourism intensity (summer)	Online textual data and photo (Hanjalic and Larson, 2011; Lu et al., 2017)
	B4M Dynamics of tourists	Web searching/Online booking and purchasing (Vaughan and Chen, 2015)
	B5M Accommodation capacity	GPS and Wifi data (Shoval and Ahas, 2016)
	B6M Hospitality operators	GPS and Wifi data (Shoval and Ahas, 2016)
	B7M Dynamics of hospitality operators	Online booking and purchasing (Vaughan and Chen, 2015)
	B8M Extension of bicycle paths	Online textual data and photo (Hanjalic and Larson, 2011; Lu et al., 2017)
Land Use	C1M Dynamics of demography	Mobile phone data (Deville et al, 2014)
	C2M Urbanized areas	
	C3M Retail areas	
	C4M Agricultural areas	
	C5M Pasture areas	
	C6M Infrastructure density	
Landscape	D1M Ecological network elements	Social media data monitoring visitors in protected areas (Tenkanen et al., 2017)
	D2M High quality agricultural areas	
	D3M Representative landscape areas	Social media data monitoring visitors (Wood et al., 2013)
	D4M High quality scenic views	Social perception of perceived landscape (Chiesa and La Riccia, 2017)
	D5MD High-risk hydrogeological areas	
	D6M High-danger hydrogeological areas	
	D7M Traffic pollution	Monitoring and detection by social media and sensors (Yu et al., 2018)
	D8M Air quality (PM10)	
	D9M Index of urban growth	Monitoring and detection by social media and sensors (Yu et al., 2018)
	D10M Index of loss of land	Monitoring and detection by social media and sensors (Yu et al., 2018)
Governance	E1M Municipal grants for retail areas	
	E2M Consortium grants for retail areas	

Source: Authors' Elaboration

improve social protection, and understand where existing policies and programmes require adjustment? This chapter falls under this heading, and it aims to discuss the potential of BD in the field of territorial evaluation to complement traditional data sources already used in TIE by adding unique and up-to-date data that can be used to form a complete framework of territorial evaluation.

TESTING BIG DATA IN TERRITORIAL INTEGRATED EVALUATION

As alluded above, TIE indicators are based on the traditional data sources, such as survey data and official statistics transformed and consolidated into a central repository of data. These are all speaking the same language that becomes the reference for the monitoring phase that will be handled by the APT in the next years. In other words, TIE methodology does not integrate BD in the TIE matrix to capture, store and link such temporally non-official data within Trentino. In order to test the meaningful operationalization of BD, this chapter proposes the integration of TIE indicators with a set of BD deriving from the analysis of the relevant literature on the topic as summarised in Table 2. Fitting to the existing literature, a variety of BD can be applied to some of the indicators that have been used in the TIE matrix. BD sources can be classified into three main categories. The first type of Big Data pertains to UGC data, i.e. User Generated Content data, as online textual data and online photo data actively provided by users. These kinds of BD has aroused an increasingly large attention in tourism research as *“photos uploaded by tourists contain a rich of useful information in relation to users, locations and time, providing a new perspective to study tourist behaviour, tourism recommendation (e.g., tourism spots and traveling plans) and tourism marketing”* (Li *et al.*, 308). In TIE methodology, they can be particularly useful in supporting the quantification of tourism dynamics together with the data provided by the APT Statistical Office.

Together with tourism, these data can be meaningful help to better analyse retail integration and typology. Twitter data, for instance, are alternatives to more established sources of shopping behaviour with an emphasis on Twitter’s veracity (Lovelace *et al.*, 2014). In addition, retail typology can be supported by the loyalty cards (Aktas and Meng, 2017) despite the fact that their analyses are limited to a specific retailer, and they provide only a partial summary of consumer behaviour from a potentially non-representative sample. Lastly, social media data can be applied in landscape and environment issues, i.e. geolocated Flickr and Twitter data are reliable proxy for supporting a spatially-explicit model of park characteristics and facilities (Hamstead *et al.*, 2018), while social media monitoring that can be a valuable information for

risk alert and warning as a tool to communicate information during disasters (Yu et al., 2018). Finally, geo-referred information resulting from social network contains a series of data that can be used for the identification of points of view, landmarks and other relevant elements as perceived by people oriented to the better identification of high-quality scenic views (Chiesa and La Riccia, 2017).

The second type of BD pertains to device data collected passively through devices, i.e. GPS data, mobile roaming data, Bluetooth data, WIFI data, and so forth. These type of data are particularly interested in supporting the quantification of travel flow related to retail derived from the matrix of mobile records. As outlined by Lovelace, Birkin, Cross and Clarke (2016), this dataset is not “geolocated” as the Twitter data but mobile telephone data provides information about the WIFI network to which each phone is connected at any point in time. More appropriately, Van der Spek, Van Schaick, De Bois and De Haan (2009) demonstrated the usefulness of GPS to track tourists, combining GPS and survey data to understand visitor behaviour, and to explore tourist spatial behaviour adopted GPS tracking data to find out how tourists moved around a city. Additionally, device data can monitor the dynamic of population thanks to the mapping of mobile phone data, as already experimented in France and Portugal (Deville et al, 2014). Finally, sensor data are the major BD sources for early warning system development for urban growth and soil sealing.

The third type of BD pertains to transaction data provided by operations as web search data, webpage visiting data, and online booking data. In TIE matrix, these kinds of data can find direct operationalization in the tourism sector as the recordings of the web searching on site operators should indicate the dynamics of tourists and the hospitality potential of VCs (Vaughan and Chen, 2015).

According to Table 2, the typologies of BD deriving from the literature review are not able to adequately cover all the issues that TIE matrix evaluated in the designing territorial scenarios for the APT. In the Theme A – Territorial Retail Supply, BD can support the better specification of consumer behaviours but are not able to support the quantitative consistency of the retail phenomenon related to territorial density and distribution. At the same time, BD is not able to properly deal with the indicators of Theme E – Local Governance and Theme C – Land Use, excluding the indicator on the dynamics of demography. For the Theme D - Landscape, BD is able to support the social awareness of perceived landscape that the Provincial Territorial Plan (PTP) of the APT is not able to properly orient. Lastly, BD seems to be more appropriated to better support real-time data on tourism sector related to the flow of tourist, the quantification of accommodation capacity and, indirectly, of the extension of bicycle paths.

CAN BIG DATA SUPPORT SMART(ER) EVALUATION?

Even with amazing improvements and innovations, there still ample room to develop regional research using BD, especially from the perspectives of expanding research area and developing analytic techniques on territorial evaluation. In other words, can BD, therefore, be framed as an innovative approach to observe, analyse, evaluate and monitoring territorial development helping territorial evaluation to move the theoretical field towards its practical implementation in order to propose ground-breaking approaches and methods to assess territorial development? As alluded above, BD can build a relatively small contribution to TIE matrix, mainly due to the tricky challenges of their use in fitting the theoretical approach of the TIE methodology, but BG cannot replace all the information that TIE matrix uses for the evaluation of territorial systems. Basically, the use of BD in TIE methodology should be oriented towards three theoretical dimensions:

- BD's potential in TIE should be about the effective use of this kind of data not about their volume. This is particularly evident in the difficulties of BD to completely replace or act as a proxy for official statistics that for TIE methodology has provided valuable insights. In this perspective, BD in TIE methodology should provide an entry point to understanding pathways of change across territorial that complemented official data by adding depth and nuance focusing practical attention on the relationship between data accessibility and the capacity to analyse data to apply to decision-making. In other words, the potential of BD in TIE methodology is not just to implement size and speed of data but also enrich the nature of the information that data streams contain.
- BG should offer both opportunities and challenges for TIE methodology. TIE framework has faced the growing awareness about the risks inherent in working with large volumes of data, about the importance of openness and accessibility, and the need to ensure veracity and quality of data while safeguarding privacy, security and ethical management of the information. Continued knowledge sharing and collaboration with APT has been crucial.
- BD's role in TIE is not 'value-neutral'. In the TIE framework, value and evaluation are strictly related as values depends on the evaluation (Archibugi, 2006), and it take on variable properties over time that depend on the socio-economic, territorial, institutional and regulatory factors – that is the conditions, opportunities, circumstances and expectations within the territorial system (Brunetta, 2006). This implied the better understanding of value in regards to the use of BD, as the core of the TIE approach to evaluation

is the construction of shared knowledge and technical framework through the re-composition and progressive integration of resources, selection criteria, and stakeholders.

In a nutshell, this work supports the view that BD can be a strength or weakness for territorial evaluation, depending on context and by the requests of the evaluation methodology. In other words, although the great potential of BD for academics, future researchers have to be aware to have important consideration before jumping on the BD ‘bandwagon’ (Kwon et al., 2014) encouraging a new approach to measure and evaluate territorial dynamics⁶. In this perspective, BG sources should not be assumed to be better than existing sources merely because they are bigger. In other words, BD does not directly means smarter evaluation. The work presented in this paper fell under this heading and it represents a small step in the theoretical discussion on the role of BD in spatial planning and territorial evaluation.

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ENDNOTES

- ¹ The chapter is the result of the combined work of the two authors. The final written version of paragraphs 1 and 4 can be attributed to Grazia Brunetta and that of paragraphs 2 and 3 to Ombretta Caldarice.
- ² TIE methodology is the result of a research program coordinated by Grazia Brunetta and conducted from 2004 to 2008 for Piedmont Region. The research had to do with the designing and preliminary experimentation of this methodology to support the planning of the retail territorial development in particular large retail areas (Brunetta, 2008).
- ³ The research project “The Application of Territorial Integrated Evaluation Methodology for Designing Retail Territorial Scenarios in Trentino (2011-2012)” was carried out by a team of researchers from the Interuniversity Department of Regional and Urban Studies and Planning of the Politecnico di Torino: Grazia Brunetta (scientific coordinator), Ombretta Caldarice, Silva Giordano, Patrizia Lombardi, Roberto Monaco, Franco Pellerrey, Lorenzo Piacentino, Attilia Peano, Emma Salizzoni, and Antonio Cittadino and Francesco Fiermonte from the Laboratory of Territorial and Urban Research.
- ⁴ In the last decade, several scientific disciplines once characterized by a low rate of data production have recently become disciplines with a huge rate of data production. Today a huge amount of data easily accessible in electronic form is produced by both research and, more generally, human activity.
- ⁵ On this point, see the different interpretation by Taleb (2013) that highlights how Big Data may mean “more information”, but at the same it also means “more false information”.
- ⁶ This view seems to be shared by national statistical agencies that are considering the possibility that Big Data could eventually replace official datasets altogether as the UK’s Office for National Statistics which is looking into how synthesised datasets could replace the National Census after 2021 (Coleman 2013).

Chapter 8

Ecosystem Service Evaluation for Landscape Planning Policies: Addressing Data Availability Issues

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ABSTRACT

Ecosystem services (ES) are the subject of a constantly growing attention at the international level. Although in the most recent years significant progresses in ES evaluation have been made, important methodological challenges still exist. Among these, data availability is perhaps the most urgent one. High quality, spatially explicit, appropriate to the evaluation scale, and accessible data are needed to pursue an effective and reliable ES evaluation. These criteria drove the selection of data in a research relating to the assessment and valuation of forest ecosystem services (FES) in the Sardinia Region. However, it is not always possible to reach such data-quality targets. Big data could be an important resource to fill information gaps in the field of ES evaluation, though certain big data limitations suggest their careful management. Starting from the current research's outcomes with regard to assessment and valuation of FES in the Sardinia Region, the role of big data for supporting ES evaluation is eventually addressed.

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INTRODUCTION

Experiences and studies concerning the assessment and valuation of Ecosystem Services (ES) are flourishing at international level, both in academic and institutional contexts (among the latter we can recall the following main institutional initiatives: the Millennium Ecosystem Assessment - MEA, The Economics of Ecosystems and Biodiversity - TEEB, the Mapping and Assessment of Ecosystems and their Services, MAES). The increasing attention paid to ES can be explained both with the existence of international frameworks, such as the European Biodiversity Strategy, that expressively ask Member States to map and assess, within 2020, the state and economic value of ecosystems and their services (Strategy's Target 2: "Maintain and restore ecosystems"), and, more generally, to the widespread acknowledgment of the potential of the ES concept itself for regional and landscape planning policies. The ES concept – namely the benefits that people obtain from ecosystems (MEA 2005), according to an eminently anthropocentric perspective (Wunder and Thorsen 2014) – is a bridging concept between environmental and socio-economic spheres (Braat and de Groot 2012). It effectively connects biophysical-ecosystem aspects and human welfare, by translating a wide range of ecosystem "functions" (from provisioning to regulation and cultural functions) into "benefits" for people. Thus, it clearly highlights the added value which environmental and landscape conservation provide for society and the economy, effectively communicating the advantages of sustainable development policies and also enlarging participation processes (Von Haaren et al. 2016).

These potentials of the ES paradigm are of course closely linked to the explanation and communication of the benefits connected with ES through their assessment and valuation. To this regard, the suitability of a joint assessment of both biophysical and economic values of ES is acknowledged at the international level (UN 2010), in relation to the need not only to take account of the actual "stock" of available natural capital but also to communicate the value of this natural capital in the most effective way (Häyhä and Franzese, 2014). Economic valuation of ES has undeniable power in terms of raising awareness among social actors with regard to the role played by ES (Nasi et al. 2002). In addition, it supports the development of policies and decision-making by highlighting the economic consequences of an alternative course of action (Mavsar and Varela 2014). Moreover, the definition of systems of Payments for Ecosystem Services (Wunder 2005, Muradian et al. 2010), connected to ES valuation, can promote the empowerment of local actors in landscape management. This can increase the effectiveness of landscape planning policies at the local level, assuring an actual link between landscape planning, design and action.

The mapping of the values connected to ES is also a crucial step (Maes et al., 2012; Schägner et al., 2013; Albert et al., 2017). Maps have a high "educational"

value (Hauck et al. 2013), as they can convey otherwise complex information simply and effectively. The “spatialisation” of values connected to ES is essential not only for communicative aims but also for orienting spatial planning policies towards the conservation and enhancement of ES. Several studies that use GIS-based ES maps to address spatial planning policies have been recently developed. To this regard, the highlighting of spatial trade-offs among ES, and so of the supply and demand territorial hotspots (Syrbe et al. 2017, Frank and Fürst 2017, Barò et al. 2016), is of particular importance, as well as the showing of the spatial connections between ES providing areas and service benefiting areas (Walz et al. 2017).

The valuation and mapping of ES, if systematically integrated into spatial planning policies, can thus support them not only in reaching sustainable development objectives but also in increasing the policies’ effectiveness (through better communication, involvement of local actors, clear definition of spatialised environmental and landscape targets), both at the regional and local scale (Voghera and La Riccia 2018).

DATA CHALLENGES IN ASSESSMENT AND VALUATION OF ECOSYSTEM SERVICES

Although significant progresses have been made in the last two decades concerning the evaluation of ES, the task is still challenging. The above-cited double evaluation approach – entailing both biophysical assessment and economic valuation – and the great variety of SE themselves (according to Common International Classification of Ecosystem Services, CICES, around 90 different ES are classified under three general classes: provisioning, regulation and cultural ES), requires the integration of different assessment and valuation methods (see TEEB 2010 for the valuation of economic aspects). Moreover, competences from various disciplines (such as geology, agronomy, biology, landscape planning, economy, sociology etc.), are usually necessary. ES evaluation can thus actually be considered, especially in cases where multiple ES are evaluated, as a multidisciplinary and interdisciplinary research field par excellence.

ES evaluation can be different as well: data vs simulation-based approaches (*i.e.* the estimation of environmental variables through advanced computer-based modelling), specific vs entire portfolio-based approaches, local vs regional approaches (Pandeya et al. 2016).

Anyway, beyond the great variety of methods and approaches, the underlying common challenge, and perhaps the most crucial issue in ES evaluation, is data availability. An appropriate level of data and information is vital for evaluating ES (De Groot et al. 2010). Generally speaking, data should be of *high quality* (veracity and reliability), *spatially-explicit*, to allow the drafting of GIS-based ES map (Maes

2012), and *appropriate to the evaluation scale*. The scale is actually a matter of first concern. An evaluation carried on large scales (*e.g.* at a European level) needs harmonised data, that are not always available. Several indicators defined by MAES (2014), for instance, are highlighted as “red indicators” since they cannot rely on homogeneous data at the continental or even at the country level. An evaluation carried at a local scale can be challenging too, since in this case empirical and in-situ data would be highly advisable for a reliable assessment. Moreover, modeling tools, that have been widely developed in recent years¹ and that are generally useful for assessing services at regional and river basin scales, are not always effective at local scale, due to a lack of methodological robustness (Pandeya et al. 2016).

Data should be also easily *accessible*. In this regard, some international initiatives have been developed to create accessible databases specifically concerning ES (*e.g.* the Ecosystem Services Valuation Database, ESVD, by TEEB and Ecosystem Service Partnership, ESP, <https://www.es-partnership.org/services/data-knowledge-sharing/ecosystem-service-valuation-database/>).

In this chapter, we are going to present an experience of ES assessment and valuation carried on in the context of the Sardinia Region. More specifically, we will highlight the methodological path we pursued in order to collect high quality, spatially explicit, homogeneous and accessible data in order to build reliable and replicable indicators. Starting from the current research's outcomes and considering the envisaged further development, the role of big data for supporting ES evaluation is eventually addressed.

A RESEARCH CONCERNING FOREST ECOSYSTEM SERVICES ASSESSMENT AND VALUATION: ADDRESSING DATA QUALITY FOR RELIABLE INDICATORS

The AF3 research project (Advanced Forest Fire Fighting, funded under the Seventh European Framework Programme, involving 19 international partners including Politecnico di Torino, ended in July 2017) acknowledged the need for effective policies to prevent and reduce the risk of forest fires and to overcome current shortcomings in the management of fire risk by developing new methods and technologies (af3project.eu). As part of the project, the DAD/DIST research group of the Politecnico di Torino² developed a method for assessing and valuing Forest Ecosystem Services (FES), applying it to the Sardinia Region (Ingaramo et al. 2017, 2019).

The research aimed at developing a highly communicative assessment tool to help raise awareness among both public administrators and stakeholders regarding

the value of forest landscapes, and to effectively support forest landscape planning policies (Salizzoni and Voghera, 2018). In line with this main objective, the developed method involved not only a biophysical assessment but also an economic valuation of FES. The obtained values were “spatialised” by means of GIS tools in order to draw up maps, that were conceived as highly communicative tools. In order to assess and value FES, we used indicators rather than complex computer-based modeling tools, to enable public administrators to assess and value themselves FES also for monitoring purposes.

On the basis of the ES classification framework provided by CICES, six indicators were selected (Table 1) according to: (i) the representativeness of the main ES classes (provisioning, regulation and cultural); (ii) the representativeness of the main functions performed by forests as commonly identified in the literature (among the others, Pearce 2001, Merlo and Croitoru 2005); (iii) the importance of the FES with respect to the local context of the Sardinia Region.

Table 1. Biophysical and economic indicators and data sources for the valuation of Forest Ecosystem Services in the Sardinia Region

FES		Biophysical Indicator	Structure	Data Source	Economic Indicator	Structure	Data Source
PROVISIONING	Timber	Volume of timber extracted	m ³ /ha/yr	ISTAT - National Institute for Statistics	Market value of timber	€/ha/yr	ISTAT - National Institute for Statistics
	Fuel wood	Volume of fuel wood extracted	m ³ /ha/yr	ISTAT - National Institute for Statistics	Market value of fuel wood	€/ha/yr	ISTAT - National Institute for Statistics
	Cork	Amount of cork extracted	q/ha/yr	Agris Sardegna – Agriculture Regional Agency	Market value of cork	€/ha/yr	Agris Sardegna – Agriculture Regional Agency
REGULATION	Hydrogeological protection	Surface area protected by forests from erosion phenomena	ha	Arpa Sardegna – Regional Agency for the Protection of the Environment	Substitution value of the protective function of forests	€/ha/yr	Sardinia Region price-list for public works
	Carbon sequestration	Amount of carbon absorbed	t/ha/yr	INF- National Forest Inventory	Market value of carbon absorbed	€/ha/yr	EU Emissions Trading Scheme
CULTURAL	Tourism	Annual visitors in forests	visitors/yr	FoReSTAS – Forest Regional Agency	Value of annual visits in forests	€/ha/yr	Ciancio et al. 2007 (Benefit Transfer)

Data availability played, of course, a crucial role in the selection of the indicators as well. The research was aimed at building indicators based on:

- *High-quality* data, namely reliable data, coming from institutional authorities competent for collecting, processing, verifying and constantly updating data on specific issues;
- *Spatially explicit* data, that is data that could be linked to the main GIS-source, namely the Sardinia Region's Land Use Map, in order to draw up FES maps;
- *Homogenous* data for the regional scale, in order to allow the assessing, valuing and mapping of FES in the entire Region;
- *Easily accessible* data, in order to enable public administrators to replicate FES evaluation for monitoring purposes.

Consistently with these criteria, data sources (Table 1) consisted mainly of structured national and regional inventories drawn up by institutional bodies (such as the National Institute for Statistics - ISTAT, the National Forest Inventory – INF or the Regional Agency for the Protection of the Environment - ARPA, with relation to indicators: “Timber”, “Fuelwood”, “Hydrogeological protection”, “Carbon sequestration”). These sources ensured, though with some constraints (see hereafter), high quality, homogenous and accessible data.

In few cases, we had to use direct interviews of experts, since public data-sets were not available (“Cork” indicator), and we had to make use of data not homogeneous and complete (“Tourism” indicator was assessed only for 13 Sardinian forests).

All the collected data – except for the tourism data – were referred to the Sardinia Region's Land Use Map. This is a GIS-based map based on photo interpretation of aerial photographs, satellite images and onsite inspections. Forest areas, in particular, are classified with reference to both species and land-cover density. The Sardinia Region's Land Use Map is a valuable, open-access tool that allowed us to draw-up FES maps for the whole Region.

In the following section, data sources, calculation methods and results for each indicator are detailed.

Indicators: Data Sources and Calculation Methods

The provisioning function of Sardinian forests was evaluated in relation to FES connected with the provision of both Wood Forest Products (WFPs) and Non-Wood Forest Products (NWFPs). WFPs were evaluated with reference to both timber and fuelwood. The indicators *timber* and *fuel wood*, were calculated by correlating the annual production data (m³ of timber and fuelwood extracted/year), provided by the

National Institute for Statistics – ISTAT by type of forest (broadleaf, coniferous and mixed) for the whole Region, and the class of land cover density of the three types of wood available in the Regional Land use Map (21-50%, 51-80%, >80%). The volume thus defined was related to the average selling price for timber, once again provided by ISTAT, in order to obtain the monetary value. It is, however, worth specifying that information provided by ISTAT undervalue the actual volume of extracted wood. This is true in particular with reference to fuelwood, that is often informally extracted and thus only partially registered in ISTAT data.

With reference to *cork* production, a homogeneous production indicator (q/year) was assigned to cork forests. The indicator was directly provided by Agris Sardegna, the Agriculture Regional Agency, through an interview. For a monetary valuation of production, the average market price of cork (€70/q, 2016) was taken, once again provided by Agris Sardegna.

The regulating function performed by forests was assessed with reference to two FES: hydrogeological protection and carbon sequestration. The function of *hydrogeological protection* was assessed with specific reference to the capacity of the forests concerned to counter – by intercepting and attenuating the kinetic force of rainfall – soil erosion phenomena. The FES biophysical assessment was based on geomorphological and species parameters (see hereafter), while the economic valuation entailed the use of the substitution cost method, highlighting the costs that would be necessary to compensate for the protective function of the forest by means of environmental engineering projects. The use of this method, although it presents some limits (Barbier 2007, Ayres 2007), is in line with the most common valuation approaches used to estimate the economic value of regulation ES (TEEB 2010). In order to assess the hydrogeological protection function, information regarding the following was analysed together: (i) the slope class of land areas (<40%, 40%-70%, >70%), assuming that the protective function of the forest increases the greater the slope; (ii) type of forest (broadleaf, coniferous, mixed), with a higher or lower capacity to perform the function of protection from erosion each species; (iii) vegetation cover class (21-50%, 51-80%, >80%), assuming an increasing capacity to intercept rainfall. All these data are provided by the Regional Land Use Map and the Regional Agency for the Protection of the Environment (Arpa Sardegna) with relation to the different protection capacity of species. This biophysical assessment, which gives the surface area of the forest areas that perform a significant function of protection, was then combined with an economic assessment, which in this case used as mentioned above the substitution cost method. In order to calculate the costs, reference was made to hydro-seeding works for areas with slopes of between 40% and 70%, while for areas with a greater slope (>70%), works with live double crib walls. The Sardinia Region price-list for public works provided costs for this kind of environmental engineering works.

With reference to the *carbon sequestration* function of forests, the assessment was performed by applying the unit values of sequestration (t/ha), as defined by the National Inventory of Forests - INFC (Gasparini et al. 2013), to the different species recorded in the Regional Land Use Map. The market price of emissions was then applied as regulated by the European Union Emissions Trading Scheme. This is one of the possible methods for monetary valuation of carbon sequestration. Compared to other methods, such as the calculation of the carbon social cost or the carbon social value (Mavsra et al. 2014), it has undoubted advantages in terms of valuation rapidity, but also some critical points such as the great variability of the reference price, both on the medium period (just think to the impact of the 2008 crisis on the carbon price) and on the short one (the price is subject to daily fluctuations).

Finally, the cultural dimension of FES was evaluated by examining the recreational and *tourism* function performed by forests. Forests perform a wide range of cultural ES: beyond the recreational and tourism function, also aesthetic, symbolic and educational ones (Ritter and Daukstra, 2011). However, the recreational and tourism function is the most addressed in the literature (Milcu et al. 2013) due to the undeniable complexity in valuing cultural “immaterial” aspects (Hirons et al. 2016), that, also, usually demand not economic and alternative valuation methods (Edwards et al. 2012, Plieninger 2013). The choice made in this study to investigate the tourism function is linked to data availability, since the study could rely on data concerning annual numbers of visitors to the forest areas (Sardegna Foreste 2011). However, these data were limited to 13 forests (corresponding to around 9% of the island’s total forest area), thus tourism indicator was not calculated for the whole region. The economic value of a tourism day visit was then calculated by means of a Benefit Transfer approach, borrowing value parameters established for other similar contexts (Italian forest areas, Ciancio et al. 2007) and adjusting them to the Sardinian context (“unit value transfer”, Brander and Crossman 2017).

Indicators: Application and Results

The valuation method was applied at the regional scale (the total forests of the Sardinia Region). Table 2 shows the annual biophysical and economic values for six indicators calculated at the regional scale as well as the TEV (which in this case does not take into account the FES relating to tourism, as this was calculated for only 13 forests).

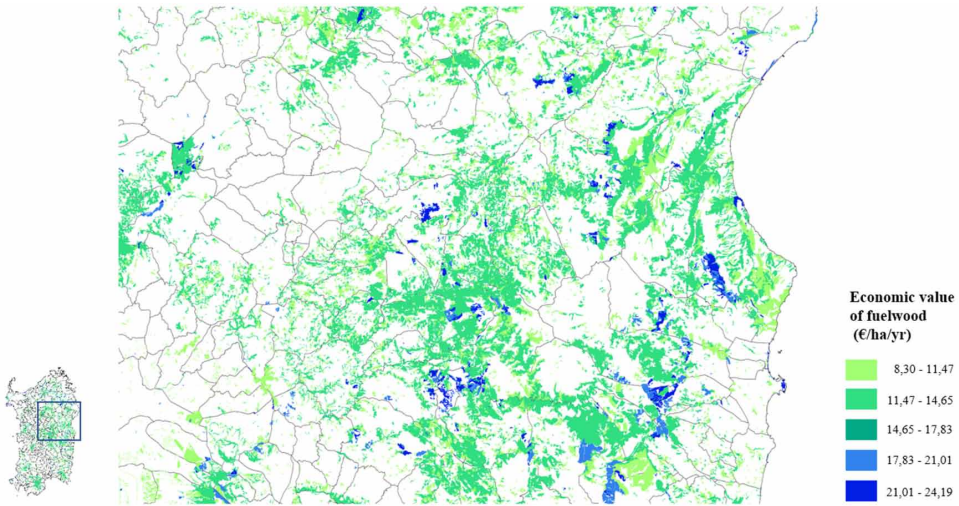
An analysis of the data highlights the primary role played by the FES connected with *hydrogeological protection*. The high economic value, in this case, is connected to the significant costs of substitution which would be need in order to compensate for the protective function of the forest, especially in areas with particularly steep slopes (>70%).

Table 2. Annual biophysical and economic values of FES in Sardinia

FES		Biophysical Value	UM	Economic Value	UM	TEV (%)
PROVISIONING	Timber	2,593	m ³	184,711	€	0.14%
	Fuel wood	113,921	m ³	497,148	€	4.12%
	Cork	166,091	q	11,626,376	€	8.88%
REGULATION	Hydrogeological protection	167,241	ha	111,226,897	€	84.90%
	Carbon sequestration	497,148	t	2,565,283	€	1.96%
CULTURAL	Tourism	150,764	num	[940,345]	€	-
TEV				130.997.261	€	100%

Other indicators show a poorer performance. More specifically, the values relating to the production of *timber* and *fuel wood* (Figure 1) are extremely low. This is only partially due to the undervalue by ISTAT of wood extraction, since Sardinia’s forests actually are not managed and exploited systematically for this purpose. The timber extracted from the island’s forests accounts for just 0.13% of Italy’s production, while for fuel wood the figure is 4%.

Figure 1. An example of a FES map, concerning per-unit and annual economic values (€/ha/year) for fuel wood production (central-western Sardinia, Gulf of Orosei). Source: Author, with the collaboration of Antonio Cittadino, LARTU, Laboratorio di Analisi e Rappresentazioni Territoriali e Urbane (Laboratory of Territorial and Urban Research), Politecnico di Torino.



A much more significant contribution, compared with timber and fuelwood production, comes from *cork* production: Sardinia contributes around 80% of Italian production (over 160,000 q/year) and the pre-extraction annual value from cork oaks totals over 11 million euros.

Despite the fact that the Sardinia Region has the fourth-largest extent of forest cover at the national level, its contribution in terms of *carbon sequestration* is relatively small (Sardinia ranks fourteenth in Italy, Gasparini et al. 2013) as species with low per-unit (t/ha) carbon sequestration values dominate. The low economic value of the FES concerning carbon sequestration is also connected to the price set by the European Union Emissions Trading Scheme, which has been subject to drastic reductions since 2009 connected to the fall in energy consumption caused by the economic crisis.

WHICH ROLE FOR BIG DATA IN ECOSYSTEM SERVICE ASSESSMENT AND VALUATION?

The research developed in the Sardinia Region is going to be further developed by focusing on a more local scale, thus selecting some specific territorial contexts for FES evaluation. To this aim, the information needed is likely to change, as more detailed data – primary and in-situ data – will be required. Moreover, the research will focus mainly on Cultural Ecosystem Services (CES), trying to overcome the current research's shortcomings in CES evaluation.

How big data could support the envisaged research further development? As explained in previous sections, as today, we mainly based our analysis on governmental structured data-sets, while some topics could be addressed only through direct interviews (*i.e.* cork production evaluation) or using data which are not homogeneous for the entire Region (*i.e.* tourism evaluation). It is thus worth wondering if, in the context of the so-called “big-data revolution” (Mayer-Schonberger and Cukier 2013), the use of big data could actually improve our analysis, considering, in particular, the research's future targets (local scale and CES oriented evaluation).

Big data are a highly promising source for evaluating ES and, more generally, for ecological science (Hampton et al., 2013): thanks to remote-sensing technologies, an increasing amount of spatial data is becoming available, potentially filling data gaps in many territorial contexts. In Europe, for instance, the European Commission, in partnership with the European Space Agency and the European Environment Agency, is implementing the European Union's Earth Observation Programme *Copernicus* (<https://www.copernicus.eu/en>), which provides accessible and nearly real-time data on thematic issues such as land use, climate change and atmosphere, collected by Earth observation satellites and in-situ sensors. With specific reference

to forests, it is worth mentioning the forest monitoring systems *Global Forest Watch 2.0* (<https://www.globalforestwatch.org/>), which use satellite technology and data collected with remote sensors to deliver information about the state of forests in the world. These huge data platforms are certainly helpful to constantly update local Land Use Maps, such as that of the Sardinia Region.

Nevertheless, we should recall that big data in themselves (intended as data characterized by high volume, velocity and variety, Laney 2001) pose some specific challenges. Even if they are often spatially explicit, they can present issues in terms of *quality* (veracity and reliability), *appropriateness to evaluation scale* and *accessibility*. Big data can be structured data as well as semi-structured and non-structured data, that are not collected with a clear research objective. Moreover, most datasets tend to have a lower level of accuracy at the local scale, and they are not always accessible to the general public. Last but not least, the large computer power needed to process big data and the requirement of specific software and technical skills need to be taken into account as well (Galleguillos and Grêt-Regamey 2018).

Studies concerning the use of big data for ES evaluation are being conducted in particular in the field of CES evaluation. In this case, data from social-media, such as uploaded photos or check-in data, are used to assess the values attributed by people to CES. The potential of this kind of analysis is evident since, differently from local surveys (*e.g.* connected to contingent valuation methods), these methods are usually more time efficient. Still, they present some limitations. With respect to the photos uploaded in the social media, for instance, the limited coverage of different types of CES by photos, that mainly express aesthetic values neglecting other CES, has been pointed out (Lee et al. 2019). Moreover, it can be very difficult to distinguish the varying motivations of a same photo (which can be aesthetic, as well as symbolic-religious, etc.). Additionally, the absence of photos in a certain place does not entail necessarily that no perceived value is present, but it can indicate other factors, such as a place's low accessibility (Guerrero et al. 2016). More generally, the use of social media as data sources implies some limitation in terms of socio-demographic representativeness of the collected data: social media users are not a representative sample of the whole population and, in addition, it is usually hard to obtain the users' sociodemographic characteristics (Zhang and Zhou 2018). Finally, we have to remember that this kind of valuation do not provide monetary valuation (in fact, according to Hirons et al. 2016, they can be classified as "methods that prioritize nonmonetary values").

Big data represent, therefore, an extraordinary potential for ES valuation and also for CES since they can provide a huge amount of data also in scarce-data regions. However, like any rough material, they need to be carefully managed in ES assessment and valuation in order to extract their value. Integrating them with more traditional valuation methods and data sources could be a wise path to pursue so as to obtain an

efficient and effective, as well as reliable, valuation. In our research, with specific relation to a local scale valuation centred on CES, we will try to complement in situ data (e.g. contingent valuation surveys) with remotely sensed data (e.g. social media data), but always keeping in mind the research's main objectives: that is trying to propose simple but robust methods and tools (Albert et al. 2017), possibly replicable by public administrators in order to effectively incorporate ES valuation in the regional and landscape planning process.

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ENDNOTES

- ¹ See, among the others, ARIES (<http://aries.integratedmodelling.org/>), or InVEST (<https://naturalcapitalproject.stanford.edu/invest/>).
- ² Research group: Angioletta Voghera (Interuniversity Department of Regional and Urban Studies and Planning, DIST, Politecnico di Torino) and Roberta Ingaramo (Department of Architecture and Design, DAD, Politecnico di Torino) - coordinators, Emma Salizzoni (Interuniversity Department of Regional and Urban Studies and Planning, DIST, Politecnico di Torino).

Section 3

Strengthening Territorial Awareness and Social Learning

Chapter 9

Semantic Spatial Representation and Collaborative Mapping in Urban and Regional Planning: The OnToMap Community Project

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ABSTRACT

This chapter focuses on the theme of the spatial representation of cities and the territory and the collaborative construction of territorial knowledge. The described research concerns the “OnToMap. Mappe di Comunità 3.0” project, focused on the definition of a methodology that implements a semantic representation of territory. That type of representation supports the description of big and open data and of its properties in a unified language. OnToMap enables the sharing of information on the web by providing an integrated perspective on territorial data, as demonstrated in an experimentation with Ph.D. students of the Politecnico di Torino. OnToMap is also part of the H2020 funded project WeGovNow, based on the integration of GIS tools, VGI practices and Web 3.0 applications: an example of citizens’ involvement in the urban redevelopment process of Parco Dora in Turin, which aims was make more inclusive (in terms of empowerment) and efficient urban planning policies.

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INTRODUCTION

Recent innovations in ICT are significantly changing the technology-society relationship. At the same time, the procedures used to conduct scientific research are being revolutionized by the exponential increase in the amount of available data. This condition is having a profound influence on the methodologies which are used to analyse, study and develop scientific research related to urban planning and primarily concern territorial data usage and, for this reason, are independent from the method used for data processing and mapping. For instance, big data analysis enables to synthetize and include in the used databases data and information that previously could not be treated as data. This information, as well as feeding the necessary knowledge sources for the development of statistical high correspondence analyses, can be related with new kinds of data basins, thus increasing the range of possible applications: it is possible, for example, to build and obtain geo-information regarding flows (people, things and information), perceptions and personal evaluations of specific places and landscapes.

The European Smart City model¹, meaning the set of strategic actions to make cities intelligent, digital and inclusive, is closely connected to the development of infrastructures devoted to collect and process public administration and social data and to develop communication and social participation. The Smart City concept has been quite fashionable in the policy arena in recent years: compared with the concept of digital city or intelligent city, the main focus is not limited to the role of ICT infrastructure but is mainly on the role of social, economic and environmental issues. There are various different forms of expression of the Smart City in practice: “eGovernment”, or “e-gov” (AOEMA 2005) identifies the possibility to improve the quality, rapidity and reliability of services provided to citizens by public administrations, thanks to the digitalisation of administrative apparatus (Clift 2004). However, this model also refers to *learning communities*, meaning communities focused upon sharing knowledge.

In this area, attention is paid to the use of ICT for sharing geographical knowledge in support of spatial design and urban planning. In line with institutional practices of transferring geographical knowledge on digital media through the construction of Geographic Information Systems (GIS), within web 2.0, new possibilities were configured for citizens to construct geographic knowledge voluntary and spontaneously, using different digital media (Goodchild 2007, 2009).

This chapter presents a reflection about the theme of collaborative production of geographical knowledge by constructing a technical framework at international level, showing a recent experimentation conducted in Politecnico di Torino with the Ph.D. students of Urban Planning course on Urban and Regional Development of the Politecnico and Università degli Studi di Torino. The experimentation was

carried out by exploiting the OnToMap PGIS, developed within project “OnToMap – Mape di Comunità 3.0”. The peculiarity of the OnToMap application, which makes it suitable for the type of activity to be supported, is the fact that it is based on an ontology in the terms described by Gruber (1995) as “an explicit specification of a conceptualization”.

Constructing a territorial ontology involves choosing concepts and relationships between territorial conceptualization, through which the representation of the territory and landscape can be expressed. In general, the application domain is that of participatory decision-making processes, aimed at favouring the reflection on territorial identity and on inclusion of citizens in the territorial transformations.

BACKGROUND: FROM PARTICIPATION TO E-PARTICIPATION

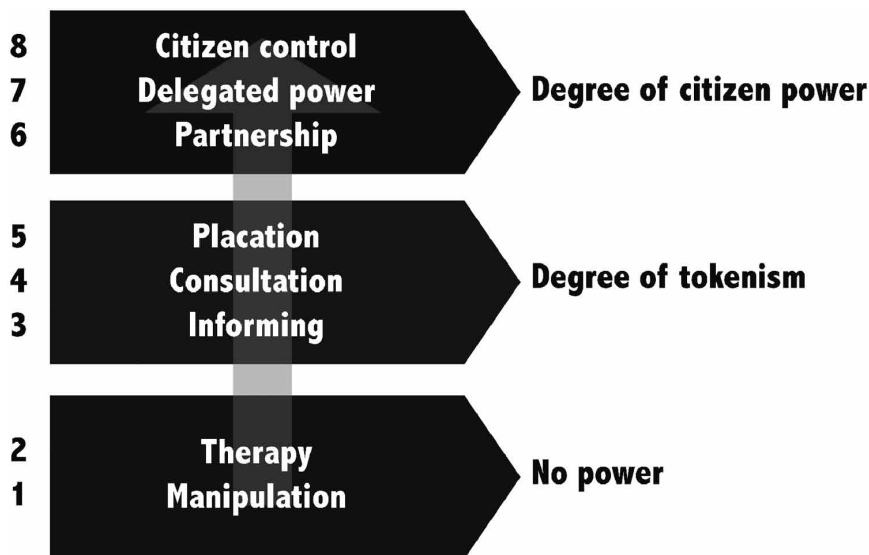
The intuitions which led to interpret the World Wide Web as an environment for new opportunities and spaces of democracy originated even before the development of Internet. This is not the place to remember important researchers as Terry Winograd (Stanford University) or Douglas Schuler (promoter and theorist of the community networks), and others, but that path opened new frontiers for the evolution of computing and new research areas as the participatory design and participatory GIS, which are now well known.

Since 1970, public participation in decision-making processes has been considered as a useful and effective practice to encourage dialogue between administrators and citizens, essential for building consensus around policy choices (Dennis 1970). In particular, as the field of territorial planning is interested to build open and agreed processes, traditional methods of consultation and information do not appear sufficient to ensure that all public application will be heard (Turkucu and Roche 2008) and numerous researchers focus on defining new theoretical approaches capable of operationally integrating grassroots applications.

Arnstein defines the participation of citizens as *the redistribution of power that enables the have-not citizens, presently excluded from the political and economic processes, to be deliberately included in the future* (Arnstein 1969).

The central principle of this interpretation model (Fig. 1) develops around the use of participation as a tool for increasing the empowerment level of citizens. The eight proposed stages of participation match different purposes, ranging from the manipulation of the public to control by citizens of decision-making processes. The concept of “control by citizens” is the highest level of participation, in which all citizens, even those usually excluded, take part in the process of planning and devising public policies and controlling their implementation. The lowest rung of the ladder consists of “manipulation”, which sees the purpose of the participation process as

Figure 1. Ladder of citizen participation. Interpretation of the scale proposed by Arnstein (1969). Source: Voghera and La Riccia (2018)



maintaining consolidated power by building public consensus, through the education of citizens. Those stages of participation are grouped into three subsections, which represent general degrees of participation, from the level of “non-participation” to “tokenism” to “citizen power”. Arnstein also considers the levels that cannot really be said to be participation – non-participation – but which conversely imply efforts by the decision-making politicians to prevent contrasts and conflicts on decisions which have already been processed (manipulation and therapy). Arnstein even considers two different levels (placation and delegated power), which take account of the different nuances of the degree of power attributed to citizens.

The use of ICT in participation and decision-making processes is relatively recent; different technologies have been developed since the end of twentieth century (Cunha et al. 2011). The concepts of government, democracy and participation applied to the virtual context are accompanied by the prefix e- (electronic), thereby acquiring new meaning. In particular, the distinction between participation and e-participation is particularly clear in the diverse methods of constructing participated processes.

The digitalization developments allowed to bring democratic processes closer to citizens and the first ideas on ICT-based participation were introduced in the 1980s. In this regard, Kersten (2003) compared the forms of e-voting, e-consultation and e-participation for involving citizens in societal decision-making processes through the use of ICT (such as web platforms).

Since e-participation today receives attention from a number of different disciplines and scientific backgrounds, it becomes increasingly perceived as an autonomous research area. However, the scientific literature about this research area is diversified: this is seen as an impeding element concerning the consolidation of the topic and the development of theory building (Susha and Grönlund 2012).

For this reason, there is not a shared definition of e-participation. An interesting definition of OECD (2003) describes it as active participation via ICT in the form of “a relationship based on the partnership with government in which citizens actively engage in defining the process and content of policy-making”. Macintosh (2006) defined e-participation as “the use of information and communication technologies to broaden and deepen political participation by enabling citizens to connect with one another and with their elected representatives. According to the description of the United Nations (2014), e-participation includes the three dimensions of e-information, e-consultation and e-decision-making. Thus, e-participation enables “participation by providing citizens with public information and access to information without or upon demand”, engages “citizens in contributions to and deliberation on public policies and services”, and empowers “citizens through co-design of policy options and co-production of service components and delivery modalities”.

Although these definitions show differences, there are substantial overlaps: a common element is that e-participation uses ICT interconnections between the government and stakeholders. Thanks to the closer connection, the stakeholders practice an empowerment, allowing them to have influence on policies and planning processes, and thus supporting their active engagement in policy-making.

Softwares such as Ideascale², LiquidFeedback³, OnToMap⁴, FirstLife⁵, Community Maps⁶, Geokey⁷ Ushahidi⁸ have been developed to allow the collection of people opinions from the crowd and could be considered in this way as more complex tools, models and processes than those of direct democracy (“one head, one vote”). As Tim Berners-Lee et al. (Hendler et al. 2008) have noted in the article “Web Science: An Interdisciplinary Approach to Understanding the Web”, the web can promote greater public engagement in the political sphere, but there is a need to proceed to trial, use and refinement of this tool.

In particular, the distinction between participation and *eParticipation* is particularly clear in the different methods of constructing participated processes. On the theoretical level, a substantial divergence must be highlighted within the virtual domain itself, relating to the approaches between the concepts of governed and governing: from “top down” processes of *eDemocracy* and *eGovernment*, *eParticipation*, on the other hand, sees the role of citizens assume greater significance, favouring a “bottom up” type approach. In this perspective, it becomes crucial to understand how and under what conditions the virtual community can become political entities, capable of producing actions that guide the choices of the decision-makers.

The e-participation tool can be used in different ways: to involve citizens in defining public policies, to monitor the impacts of large works on social and environmental contexts and/or to develop territorial analyses with the involvement of local entities. There is no standardised e-participation application model; instead, it is necessary, by assessing the objectives of the research and the relevant social actors, to devise the method suited to the participatory model to be applied each time (Maier and Reimer 2010).

Finally, e-participation cannot be considered an increasingly positive tool, able to ensure outright transparent and inclusive processes: each case must be evaluated individually. Different experiences show, in practice, the criticality of the instrument. For a discussion on the critical issues of e-participation see Prieto-Martin et al. (2012); in many cases the result of e-participation needs to be developed by a traditional process (Medaglia 2007).

While the concepts of participation and e-participation have various different conceptual nuances, linked mainly to scope and methodology, it is, however, possible to attribute the two cases to a theoretical paradigm of common reference, connected to the objectives and entities involved in the projects.

FROM GIS TO DIGITAL ONTOLOGIES

In the mid-1980s, GIS (Geographic Information Systems) tools, which enable the acquisition, transformation, organization and visualization of spatial data from the real world (Burrough 1986) were mainly used in companies, due to the high costs and the need for specialized technicians for their use (Obermeyer 1998). GIS is a field that in the past has been widely explored by planners and geographers since the late 1960s and later integrated by other disciplines specialists around a core of experts in management of spatial databases.

Even though current GIS applications are still too similar to those of 30 years ago, effectively described by Samet (1990) and Laurini and Thompson (1992), these tools have been optimized to become essential key component for all public and private organizations dealing with territorial planning. In parallel to the increasingly widespread use of these technologies, research on GIS has added to the more purely technical issues, questions about the “multidisciplinary” potential of the tool, with special reference to applications in the social sphere (Craig et al. 2003; English e Feaster 2003). In fact, new collective web-based geographic production practices include references to territorial governance concepts and participative democracy applied to the virtual context, pointing to a bottom up approach, meaning greater relevance placed on the role of citizens “from below”, favoring the construction of a network of relationships between social and political actors. Since the mid-1990s,

questions related to the social aspects of GIS applications have become an issue of interest for the involvement of participatory processes using the so-called PGIS (Participatory GIS) (Schroeder 1997), thanks to the highly representative visual character (Al-Kodmany 2001).

The potentials of Geography 2.0 and the diffusion of geospatial technologies (e.g. Google Earth, Maps API) proliferate the principles of PGIS: how GIS technologies empower or marginalize individuals and communities in terms of their social, political, economic, and technical conditions (Sieber 2006). In this regard, Kingston (1998) argued that web-based GIS application can engage public participation in environmental decision making by a progressive public participation ladder through their rights to:

1. Know;
2. Be informed;
3. Object;
4. Define interests, actors and determine agenda;
5. Assess risk and recommend solutions;
6. Make a final decision.

Helped by the improved web infrastructure, general public is more aware of, attentive, able in using innovative tools to interact with the social web and physical environment more than ever before. The enhanced interconnectivity and interactivity extend the research agenda about PGIS and open up new frontiers in the so-called neo-geography and GIScience.

The comprehension of new cartography, using ICT technologies from non-expert users, takes the name of “Neogeography” (Eisner 2006) to differentiate it from geography linked to traditional cartography and is based on the overlapping or combination of two or more sources of geographic information. The voluntary dimension of these practices is at the heart of the volunteered geographic information (VGI) approach that sees citizens as “sensors” (Goodchild 2007) involved in gathering information using mobile devices equipped with GPS sensors and web access.

Whether or not the true meaning of such practices differs from the objectives of conventional geography is still open for debate: neogeography implies extending the power of mapping and spatial exploration to non-geographers. The construction of social networks within the web domain has produced what is called “crowdsourcing” (Howe 2006), one of the most significant developments in Web 2.0 and neogeography.

Crowdsourcing applied to neogeography produces the “crowdmapping”, that is a collection of information that does not come from professionals alone, but from all those who have access to the Internet and want to share data, representations, prospects with other people.

Today, crowdmapping sees the most disparate uses, from environmental complaint to signaling car parks available in cities, to emergency management and crisis situations (an example is the “Ushahidi” application, which can be translated as “testimony” in Swahili, born in Nairobi and developed to map violence reports in Kenya after post-election turmoil in 2008. Since then, thousands of people use this crowdmapping application to “make their voices heard”).

The problem of defining new methodologies for knowledge representation has a great influence on ICT and, from a general point of view, on cognitive science. In particular, the wide spreading of communication technology forces the modern information systems to manage big data.

New techniques have been developed to solve these problems: VGI is not the only innovation within the set of tools dedicated to spatial representation; a second innovation is marked by the so-called “ontological turn” (Jogan 2002) operated since the late ‘90s with which GIS is integrated with the theories of language. Ontologies are intended to reduce conceptual or terminological mess and to have a common view of the same information. The ontological aspects of information are intrinsically independent from information representation, so the information itself may be isolated, recovered, organized, and integrated with respect to its content.

A formal definition of ontology is proposed by Gruber (1993) according to which “an ontology is a formal and explicit specification of a shared conceptualization”: *conceptualization* refers to an abstract model of a specific reality in which the components concept are identified; *explicit* means that the type of the used concepts and the constraints on them are well defined; *formal* refers to the ontology propriety of being machine-readable; *shared* refers to the fact that an ontology captures the consensual knowledge, accepted by a group of people.

We could also consider other definitions of ontology: in Neches et al. (1991) “an ontology defines the basic terms and relations comprising the vocabulary of a topic area, as well as, the rules for combining terms and relations to define extensions to the vocabulary”. This definition indicates the way to proceed in order to construct an ontology:

1. Identification of the basic terms and their relations;
2. Agreeing on the rules to arrange them;
3. Definitions of terms and relations between concepts.

From this point of view, an ontology includes not only the terms that are explicitly defined in it, but also those one that can be derived using defined rules and properties. Thus an ontology can be seen as a set of *terms* and *relations* among them, denoting the concepts that are used in a specific domain.

If until now the link between GIS and ontologies has appeared more implicit, mainly through the spatial translation of “relational” (first) and “object” (then), now affiliation to the themes of representation of knowledge is quite clear. Referring to the concept of ontology in informatics, it becomes a way of formally representing the structure of a system, that is the relevant entities and relationships that emerge from its observation, and which are useful for our purposes. A domain conceptualization based on ontologies allows to model a subset of reality that surrounds us by making understandable concepts and relationships relevant to the software application within a common language and a universal vocabulary.

It therefore radically changes the point of observation with respect to spatial thinking: spatial relations are no longer the privileged object of the scientific investigation, the priority problem becomes the conceptualization of the territorial system, that is, its translation into corresponding object systems (*lexicon*), defined in the unambiguously and universally intelligible semantic profile.

Ontologies are today largely exploited in projects found within the smart city approach. Developing an urban ontology means, at first instance, constructing technical-scientific consensus on a glossary that includes conceptual definitions (Laurini 2007, 2016, 2018). The use of ontologies for representing the territory places particular attention on semantic aspects of territorial representation which seems useful in this sense as it leads to a more dynamic pattern of representation. Space constantly changes over time, based upon the construction of adequately defined elements and their intrinsic relationships. An ontology allows for a fixed but flexible structure to be constructed, enabling the creation of different representations of changing data (Las Casas and Scorza 2013).

In the case of OnToMap, as explained later, the structure of the ontology was organized based upon a specific research topic: to build a useful tool for technicians and for the population, capable of putting citizens and institutions in contact by promoting language uniformity. The construction of ontological representation, particularly attentive to processes of construction of identity and the perceptive dynamics of the locations, guides the interpretation of the territory, which is assessed in accordance with three constituent dynamics: natural, artificial and regulatory (Voghera et al. 2016). For this reason we could consider a territorial ontology as a classification of spatial relations between the territorial entities that also highlights the political and regulatory relationship. The natural dimension refers to all physical elements not altered by man; the artificial dimension includes elements produced by man; and the regulatory dimension considers the technical and design aspects relating to the sphere of responsibility of the public administration. The three proposed levels of observation consider issues relating to different domains of representation, linked to tangible aspects, represented with GIS techniques, socio-

economic aspects, highlighted by semantic relationships, and perceptive elements, linked to the voluntary construction of knowledge.

In the ontological representation we have defined different types of relations, based upon the guidelines on the subject (Noy and McGuinness 2001). The interrelationships between the concepts are mainly based upon inclusion relationships (is part of, is composed by) and upon regulatory constraints (norm, has focus, connects) identified from the main planning instruments.

Based upon this initial subdivision into categories, the subsequent phase of identifying the concepts and attributes which specify the identified dimensions is developed; each concept and attribute is assigned a summary definition, as formal and agreed as possible, thereby developing a dictionary of ontology. Each definition was developed in a general perspective, processed by consulting dictionaries and encyclopedia, and a technical perspective, processed on the basis of the relevant regulations.

The decision to structure a double glossary was made in order to guarantee the objectives of language uniformity; however, it was prepared within a research program attentive to the themes of urban planning and territorial design. Any changes to the ontological structure may be proposed by scholars of different and related disciplines, such as geography, sociology or economics. However, it is useful as a starting point, albeit limited, for initiating a discussion on the issue, still scantily investigated both in the national and international context.

The OnToMap project is mainly focused upon social and planning issues; the former identify an emotional approach to cartographic representation, oriented towards the development of social cohesion and to stimulating local planning and design linking citizens to public administration that can recognize social perceptions and values related to local places; the latter takes into account the legislative implications, expressed as institutional constraints and planning. In the structure of the ontological representation, the interrelations between the concepts are based upon regulatory constraints identified on the basis of the main urban instruments, at local and supra-local level. OnToMap is designed as a useful tool for public administrations, which could benefit from its use both as a channel of disclosure but, above all, as a tool of empowerment.

The purpose of the project was to create a description of data that would be as complete as possible; however, the influence of the territorial context on which the experimentation of ontology was designed and developed remains clear. The scale itself constitutes a key element in the selection of the concepts, dealing with the vast point of view of the territory in place of the more restricted perspective of the city. Considering the spatial and temporal dimensions to be intrinsically constitutive and directly represented through the map, the contributions of users will delineate these aspects through comments and reports.

THE ONTOMAP PROJECT

Harper (1988) defines *visual sociology* as recording, analysing and communicating social life through photography, movies and videos. We can consider in this interpretation four fundamental aspects of visual sociology:

- The purpose of the analysis and the knowledge the researcher seeks to bring to light;
- The importance of support from registration;
- The use of images to represent a culture;
- The analysis of images produced by a culture to understand it.

The Ontomap project has been pursued with this aim: applying the methodological perspective of visual sociology to the collective production of virtual maps (or “community maps”) through web-based tools, which allow easy dissemination of information over the Internet.

Traditionally, community maps are made up of cartographic representations developed by the community through a participatory approach (Parker 2006). OnToMap allows for online consultation of spatial data and the creation of interactive virtual maps that reflect individual information needs and point out to the public administration and planners the territorial critical aspects and project proposals, noting geographic areas and individual elements displayed in the maps.

OnToMap is based on a semantic representation of domain knowledge that provides a formal model for man-machine interaction management in search, display, and sharing of spatial information. Unlike traditional GIS that generally use digital ontologies to integrate heterogeneous sources of information (Fonseca et al. 2000; Fonseca et al. 2002; Buccella et al. 2011), OnToMap uses ontologies to mediate the specification of information elements with different perspectives on the data that users can adopt: as regards the information representation, the ontology supports the management of data such as *linked data*⁹, that is, as data linked to each other through hyperlinks in the web. The links between the data result from the semantic relationships that associate them, allowing to describe the relationships between information layers to express spatial or thematic associations, as well as the different levels of abstraction in their description (providing a taxonomy that binds general concepts to the specific ones).

From the point of view of information search, ontology offers two main features: the first provides the user with a graphical tool to explore the information space by navigating the concepts defined therein and the semantic relationships between them. The selection of concepts on the graph allows you to populate the map with individuals’ information items that are their instances. Starting from ontology,

graphic exploration is performed by navigating thematic views, each one containing a subset of relevant concepts from a specific point of view (“semantic around”, for example, the natural or the normative);

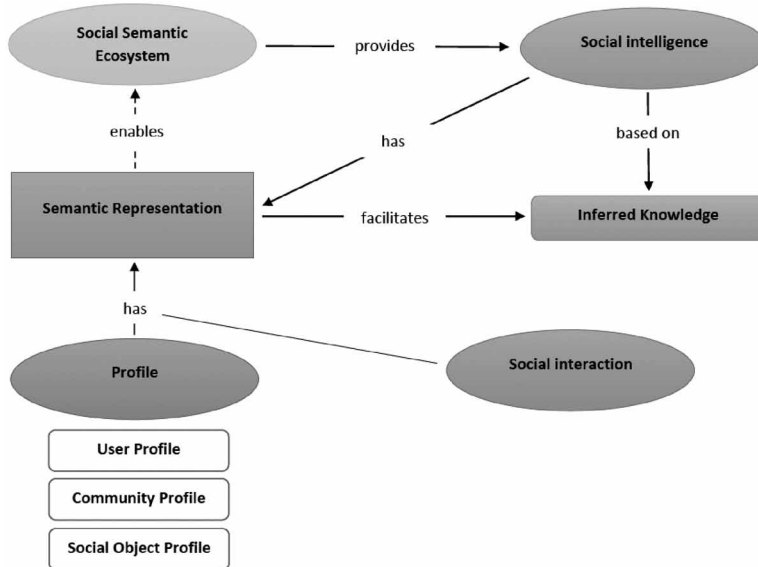
the second feature is the search support = based on text queries, typical of search engines, but based on semantic interpretation rather than on a simple match of keywords. This function is based on the association of encyclopaedic knowledge with the concepts of ontology, to describe its meaning, and to enrich the concepts with linguistic terms that allow flexible recognition from user-written phrases (e.g. using synonyms of the concepts, and synonyms of the terms that they need in their encyclopaedic description, to recognize the concepts to which the user refers). Matching textual queries and concepts of interest is established using natural language analysis techniques that allow you to abstract from the user’s specific vocabulary (Ardissono et al. 2016).

Finally, as far as crowdsourcing is concerned, the ontology supports the description and classification of new information elements that can be integrated into the information space in a structured way, making it easier to retrieve them when searching for data.

The general aim of the OnToMap project is to create a tool capable of responding to requirements of an informative nature and encouraging inclusive urban processes. It is clear that applications of different types must be used to create a unique tool that contains the potential of each of them. It is precisely a case of creating a hybridisation between different cognitive systems, implementing what is defined here as a semantic approach to cartographic production, *social semantic mapping* (Voghera and Crivello 2018; Voghera and La Riccia 2018). The social dimension is understood in this sense to be a generator of the mapping process, built, therefore, on the basis of the social actors. This element must not, however, be confused with the purposes of mapping, which do not concern the strictly social dimension but, more generally, the territorial aspect, meaning the set of social, spatial and regulatory elements.

The process of Social Semantic Web is divided into four phases. In the first instance, the social dimension refers to the collective construction of territorial knowledge, as a process of issuing interpretations, perceptions, tales of urban space and landscape, by the community. The territorial visions elaborated by the comparison between the actors are articulated in unitary representations of knowledge obtained thanks to digital media and, specifically, thanks to the territorial ontology (semantic representation of knowledge, see Fig. 2). The knowledge representation takes place on a map (spatial representation). The knowledge gained in the process, and its formal representation, can then be used to supplement the institutional knowledge and to support policy decisions.

Figure 2. A light model for the Social Semantic Web by using concept maps. Source: authors' reworking from Pileggi et al. (2012).



The OnToMap homepage shows a map (the platform uses OpenStreetMap cartography), on which the results of the semantic queries submitted in textual format, or by browsing the ontology graph, are displayed (Fig. 3).

Despite the page having characteristics similar to those of traditional PPGIS in terms of display of categories, by selecting a specific type of data of interest, a profoundly different action is performed.

Figure 5 shows a portion of the basic ontology of the OnToMap system. The representation guides the interpretation of the territory, which is read in the project according to three constituent dimensions: natural (*natural dimension*), artificial (*cultural dimension*) and normative (*norms*). The natural dimension refers to the physical elements considered unaltered by the hand of man; the cultural one includes all the anthropic elements; Finally, the regulatory dimension considers all the technical and project aspects related to the sphere of competence of the public administration, spatializing the rules and rules of local government, expressed as institutional constraints or planning.

These three dimensions take into account problems related to different domains representing the material aspects represented by GIS; socio economic aspects, highlighted by semantic relations; and perceptual aspects, typical of the voluntary construction of territorial knowledge. Therefore, ontology is the means used to provide a unified description of the territory, which abstracts from specific data

Figure 3. The OnToMap Interface. By querying and navigating the menu, you can explore the concepts of ontology. Source: screenshot of the OnToMap web interface.

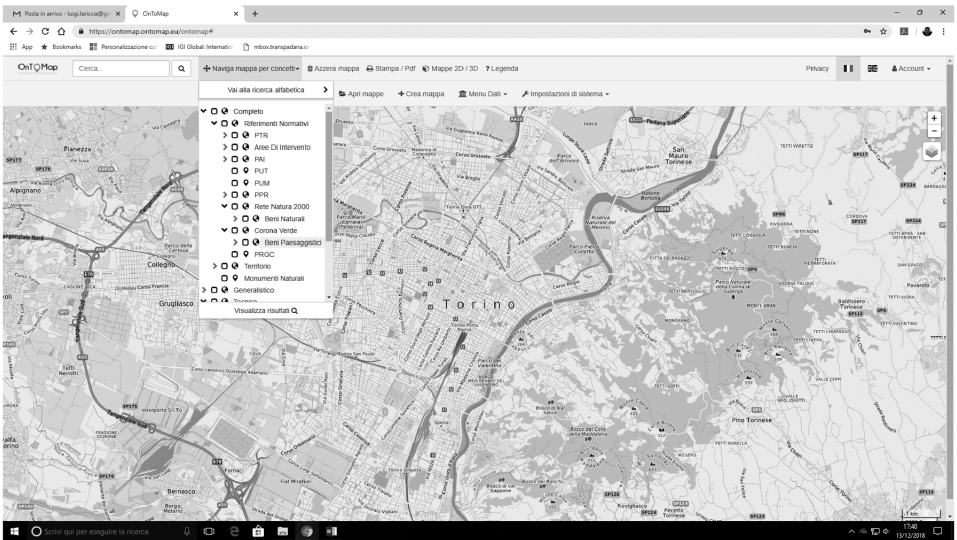


Figure 4. A conceptualisation of ontology in OnToMap: simple arrows represent the relations of specialization (from general concepts to the more specific ones); bold arrows point to the normative and the dashed ones represent the conceptual relationship between concepts. Source: Voghera et al. 2016

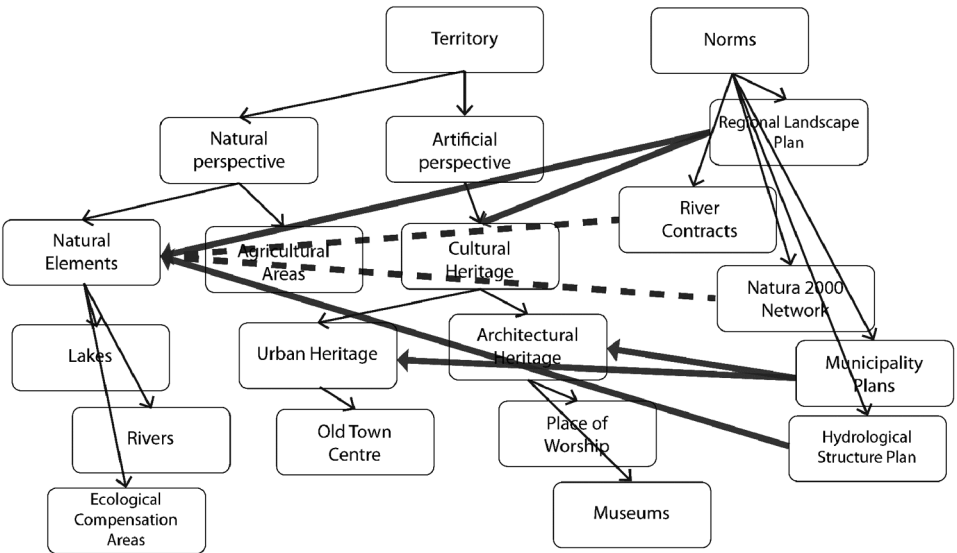
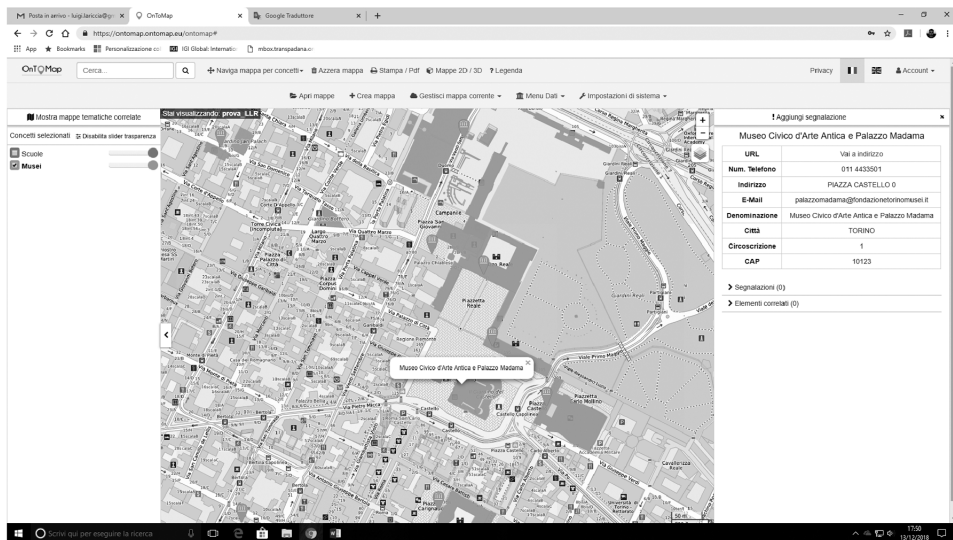


Figure 5. Example of map displaying data selected (e.g. Palazzo Madama in Turin). Screenshot of the OnToMap web interface.



representation formats, supporting integration between them. In addition, it also plays the role of “common language” among the different subjects involved in content analysis from different points of view and the retrieval of information at various levels of detail. For example, a geographic element could represent at the same time a service for the citizen and an element of the cultural heritage, and so on.

At first instance, it is necessary to define whether to query the entire ontology or just a portion of it. By selecting a point of view, it is, in fact, possible to use predetermined points of view, to speed up the data search operation. Currently, six separate points of view are set, excluding the complete one which returns the ontology in its entirety. The points of view are designed to meet the information requirements closest to citizens: the tourist point of view selects all elements of the territory that may be of interest to those visiting the city; the childhood point of view is focused on places of leisure and education. The young point of view cites transportation services, spaces of sharing and sports areas; the older point of view gathers together health services, trade and transport. Finally, the technical point of view cites all regulatory instruments underlying the government of the territory. Those points of view can be integrated and customised by users and will constitute an initial useful filter on which to articulate the analyses of the data collected; in addition, they can be redefined and re-aggregated during the course of some experimentations on the application, with the aim of articulating plural approaches to ontology, as close as possible to the participatory requirements.

At this point, when selecting a precise concept within the ontology, the items with which it is related can be displayed. The relationships that connect the elements are essentially conceptual and regulatory relationships. For example, by selecting the theme of connecting infrastructures, the networks of vehicle roadways, public transport systems, cycle paths, pedestrian walkways, tourist routes and natural paths will be displayed. In addition to this, the SUMP (Sustainable Urban Mobility Plan) and the UTP (Urban Transport Plan) instruments, which regulate the planning of mobility, will also appear as connecting elements.

Each item that makes up the ontology includes a spatial representation that is superimposed on OpenStreetMap (OSM)¹⁰, and a set of metadata displayed in a separate window. That information, taken from the vector data, is more or less rich, depending on the selected concepts. Each regulatory instrument is linked to the web page through which it can be read and downloaded.

User reports follow the same mechanism, allowing information to be added to an element by selecting it by type and geographical location (Fig. 5). The importance of this element is clear as regards the informative purpose; in fact, all data is re-processed so that it can be queried in a semantically relevant manner.

Users can create customised private or public maps, selected areas and concepts. All the maps are, on the other hand, visible to the facilitator, which performs the role of filter between the different representations of the territory.

The territorial views gathered using the maps produced by users are summarised in a single integrated map created by the research team. The OnToMap application does not provide, in its current version, a specific function for combining or overlapping maps. It is therefore the researcher's task to gather the maps produced and to analyse them, defining homogeneous interpretation criteria and producing a summary view. It is worth noting that the territorial ontology facilitates the task in this sense, providing uniformity of the concepts inserted by users. The latter must in fact choose from the concepts present in the ontology which ones to combine with the design on the map. In the working phase on the maps, it is therefore possible, using OnToMap, to assess which concepts have been used, how frequently and in what territorial context.

In future, OnToMap will be equipped with a special function for automatically overlapping the maps and selecting certain concepts of the ontology, to facilitate the comparison between representations and to simplify the summary work. The role of the researcher is, however, essential and irreplaceable as a mediator and interpreter of the data gathered.

OnToMap has been tested in several areas. A recent experimentation was carried out within the Ph.D. course in Urban and Regional Development (Interuniversity Course between Politecnico di Torino and Università di Torino): Ph.D. students (15) used the web application in a laboratory equipped with computer and internet access,

under the supervision, under the supervision of the research team that accompanied the creation of personal geographic maps.

The experimentation consisted in using the application to represent the themes of interest of its territorial project in an innovative way: 15 analytical maps were created. These products have been verified and analysed according to four reading keys: (i) how the instrument is used to read the territory; (ii) the use of semantic relations between the elements useful for the construction of the territorial representation; (iii) the use of semantic relations to represent the concept of “territorial identity”; (iv) the presentation of possible actions. The representations generated using OnToMap have been articulated in two distinct levels: a “spatial” level related to direct drawing on the personal web map (*crowdsourcing*, Figure 6); a “semantic” level related to the use of concepts defined on the ontology (Figure 7). This distinction is useful for the purposes of the research as it allows to understand how the two representations are in relationship to each other, producing visions that may be similar, different or integrated. The maps produced were also considered as a possible starting point for building a “perception index” of a particular social group (in this experiment, the group of students of architecture).

The conducted experiment has shown that some territorial elements, appropriately selected, displayed and modified by students on OnToMap, are recurring in most of the maps created. We can therefore deduce that the highlighted territorial elements reveal the expectations and the vision of a given social group with its own specific cultural background.

Figure 6. Classification of new design actions and proposals created in the 10 project maps (crowdsourcing). Source: authors’ elaboration

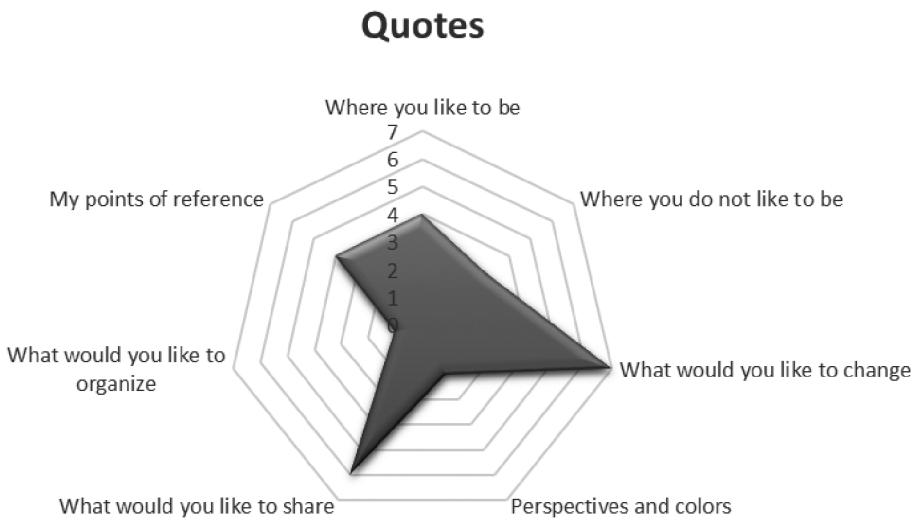


Figure 7. Classification of the use of concepts selected from ontology in the 10 project maps. Source: authors' elaboration



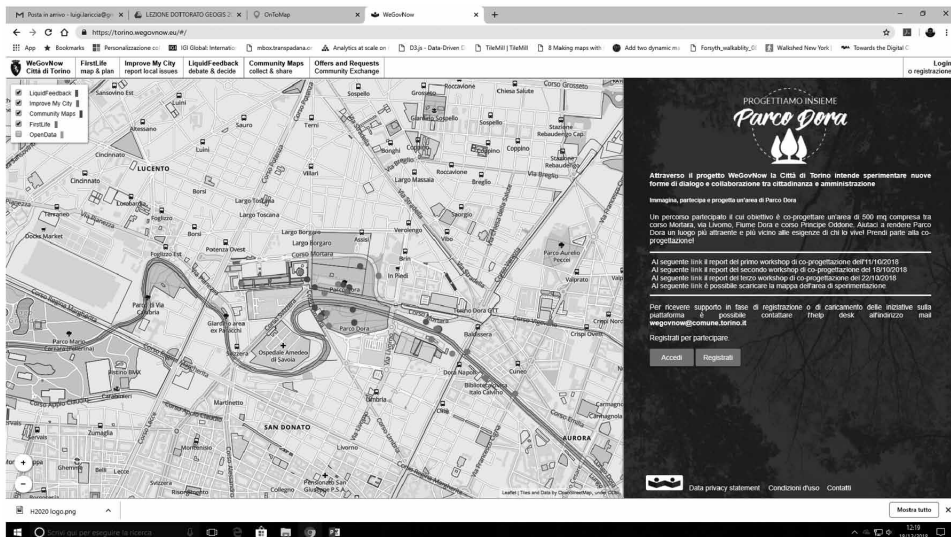
OnToMap is currently used in the EU funded project “WeGovNow: Towards #WeGovernment: Collective and participative approaches for addressing local policy challenges”¹¹, aimed at creating a unique web platform (Fig. 8) for public discussion concerning the co-design of services of general interest. The ontological structure of OnToMap was therefore fundamental for the usability of the platform itself. In addition to OnToMap, WeGovNow exploits the aforementioned tools such as FirstLife, Improve My City, LiquidFeedback and CommunityMaps to collect proposals directly from citizens, who have been able to interact with each other through a web forum and, finally, vote for the best ideas using the ideas obtained to face during two workshops organised on the study area of the Parco Dora in Turin.

The aim of the two workshops was to make the area of Parco Dora in Turin (about 500 square meters) included between Corso Mortara, Corso Principe Oddone, Via Livorno and Dora Riparia, which is currently in a state of neglect: the participants were divided into two groups, to allow them to finish working on the proposals, before presenting them in plenary, with the support of the technicians of the public works department of the City of Turin and of the Polytechnic students.

Representatives of two proposals uploaded on the web platform have presented their respective projects in plenary:

- The representative of the “Comitato Spina 3” (residents’ committee¹²) illustrated the proposal to build a public “agora” on the area, a meeting place with a strong cultural and recreational value that could be used by the

Figure 8. Example of the WeGovNow web platform displaying project proposal selected on the Parco Dora area in Turin. Screenshot from the website: <https://torino.wegovnow.eu/#/>



local community as a meeting place. The proposal is identifiable on the web platform as i76: “Agorà: una piazza pubblica, punto di incontro e luogo di aggregazione culturale”.

- The sports associations “LongboardCrew Italia”¹³, “Torino Sul Filo”¹⁴, “Skateboarding Torino”¹⁵ and “Parkour Torino”¹⁶, together with the “Comitato Ingest”¹⁷ propose the creation of an aggregation and sports centre, equipped for the practice of “street” sports (slackline, longboard, parkour) meeting and aggregation spaces, expressing interest in the future taking care of the area, which will obviously continue to qualify as a public space. This proposal is identifiable on the platform as i78: “Area sportivo aggregativa” (project chosen as winner).

After the public discussion, the project proposals became definitive: the proposals had to reach a quorum of 10 supporters to be admitted to the voting phase (lasting 5 days). This voting phase provided that each user, through the web platform, could express his opinion (yes, neutral, no) and to order the project proposals according to his own preferences. It should be noted, however, that the use of the web platform, including several tools, also showed some weaknesses to be improved: the aggregation of different web tools, including the OnToMap architecture, was not easy because each tool was previously it had been thought for a different purpose.

Figure 9. Discussion phase of the two project proposals on the Dora Park in Turin (October 2018). Source: Authors' photos.



CONCLUSION

In conclusion, it is worth citing the innovative aspects that characterise the OnToMap project and emphasising the contribution of research to urban studies. There are essentially two aspects to which attention should be paid: the implications of a semantic analysis for spatial representation and the relationship between these and the processes of territorial governance.

Reasoning on the semantic dimension means making a *conceptualisation*, thus a structured interpretation that can be used to think and to communicate. The cartographic representation of the space is therefore connected to a mental representation, related to the possibilities of meaning implicit in the space. The representation of space is traditionally entrusted to the geographic map, a representation element par excellence of the state of locations. Its aim is to reproduce, as effectively as possible, the characteristics existing in the real world, through a symbolic representation on the level of the map. The semantic representation, on the other hand, implies a scientific study of meaning, oriented in particular towards defining concepts and the type of information that they record. These are therefore two methods of representation that bring to the field intrinsically different types of

knowledge. Connecting the two perspectives allows us to produce a complete level of knowledge of visual dimensions and meaning. As regards the territorial dimension, the subject of this study, the ontological perspective is particularly interesting as it allows us to break down all the conceptual levels that traditionally make up the definition of the territory, expressing their relationships. The semantic perspective is then linked to the cartographic representation thanks to the digital platform, which connects to each concept (*meaning*) a depiction (*sign*) on the map. Signs and meanings are then expressed through the cartographic representation. This step is an important element which has direct implications in the participation processes.

In a learning process, the geographic map is not only a tool for displaying locations and territorial phenomena. Based upon the idea that the map is an extension of the process of representation of meanings, this becomes capable of producing semantic functions and, thanks to these, of producing specifications of mapped places. In this semantic approach to cartography, the representation becomes the expression of cognitive and symbolic control (*sign and meaning*) of the (*territorial*) reality, defining a digital model of crowdsourced territorial map or Community Map 3.0 (such as ICT Perish Maps).

This aspect is worthy of particular attention, precisely because it could contribute to guaranteeing a level of *empowerment* of citizens (as defined based upon Arnstein's participation approach) which not only results in the stimulation of local planning, but is expressed, more profoundly, in the cultural training of citizens. It is worth keeping the two expressions of empowerment separate so as to better clarify the issue.

The experience of viewing the graph of territorial ontology gives users a complete but schematic conceptualisation of the relationships between the economic, social and regulatory components of urban space. The visual expression (through the graph) of the concepts and their relationships becomes important for a more effective understanding of the system itself. The presence of a technical definition and a general definition, for each aspect, further clarifies the more specialist aspects. The very possibility of viewing all the regulatory instruments that regulate the government of the territory, the cartographic space on which they act and the concepts directly linked to the individual official plans, texts and tables, makes a substantial contribution to the education of citizens and to the possibility to understand social needs by the public administrations. This is an initial level of empowerment connected to the possibility of increasing the awareness of citizens, accompanying a process of collective learning.

A second level is, on the other hand, directly related to the implementation of the new awareness of citizens, which can be translated into planning actions of the territory and the landscape, part of a unique process for the generation of cultural and territorial identity.

The ontology is the mean used to provide a unified description of the territory, which abstracts from specific data representation formats and supports data integration. However, it also plays the role of an “inter-lingua” between human stakeholders, who might be interested in analyzing content under different points of view and in retrieving information at different levels of detail: e.g., a geographical item could represent, at the same time, a service for the citizen or a cultural heritage element, and it might be described taking different information needs into account.

In conclusion, the basic question underlying the research activity revolves around the possibility of using the semantic approach to cartographic representation as a tool with the value of knowledge and education. The response achieved by the research is positive, considering that the semantic representation attributes meanings, expressing relationships and the causal link between the things represented, while the cartographic representation acts by codifying the concepts into visible signs. In this approach, it is therefore possible to connect sight and speech, cartography and semantics, in a more complete perspective, while the map alone is incapable of producing knowledge of the territory being represented, because it actually constructs an image of it. By adding language to the map, it is possible to attribute the spatial representation to the narration of the place, only by overlapping with the locations the narrations (and the place names that often reveal them), will the territories, landscapes and gardens incorporate traditions and history and will societies start to construct new identities.

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ENDNOTES

- ¹ https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en
- ² <https://ideascale.com/>
- ³ <http://liquidfeedback.org/>
- ⁴ <https://ontomap.ontomap.eu/>
- ⁵ <https://www.firstlife.org/>
- ⁶ <http://mappingforchange.org.uk/>
- ⁷ <https://geokey.org.uk/>
- ⁸ <https://www.ushahidi.com/>
- ⁹ As reported in <http://linkeddata.org/>, the so-called “linked data” allows the web to correlate previously unrelated data over the web, or to use the web to break down the obstacles associated with linked data between them with other methods.
- ¹⁰ <https://www.openstreetmap.org/#map=12/45.0630/7.6492>
- ¹¹ Horizon 2020 – Research & Innovation Action. Overcoming the Crisis: New Ideas, Strategies and Governance Structures for Europe EURO-6-2015: Meeting new societal needs by using emerging technologies in the public sector. For more information: <http://wegovnow.eu/>
- ¹² <http://www.comitatodoraspina3.it/>
- ¹³ <http://www.longboardcrewitalia.it/>
- ¹⁴ https://sportorino.com/cerca/scheda.php?Torino-sul-Filo-Slacklining&id_c=3921
- ¹⁵ <http://skateboardingtorino.blogspot.com/p/associazione.html>
- ¹⁶ <https://www.parkourt torino.it/>
- ¹⁷ <http://www.comune.torino.it/comitatoparcodora/comprensori/ingest/>

Chapter 10

Researching and Enabling Youth Geographies in the Digital and Material City: The Teencarto Project

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ABSTRACT

This contribution presents the methodologies and the results of an action-research project called Teencarto carried out by the University of Turin and the City of Turin. The project involved more than 600 teenagers from 16 high schools, in a massive process of community mapping aiming at producing a representation of their urban geography. Data collected has been analyzed to make evident the way teenagers use the city as well as how they imagine a better city. The mapping process is based on First Life, a map-based social network, which aims at reconnecting digital and real spaces, using cartographic representations and crowdsourcing. The teenagers' geographies emerging from this large-scale mapping activity reveal the crucial role of four types of "piazza" (Italian word for square) as meeting points: real squares, green squares, commercial hybrid squares, and nightlife squares.

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INTRODUCTION¹

Some categories of citizens are excluded by most decisions about how to use, transform and manage urban space. Among these weak categories of citizens there are teenagers, who are the object of specific urban policies, but at the same time are rarely involved as active subjects of policy making processes (Childress, 2004). This contribution² presents the methodologies and the results of the research project Teencarto, carried out in 2014 and 2015 by the University of Turin and the City of Turin. The project involved more than 600 teenagers from 16 high schools, in an ambitious community mapping process, aiming at producing a representation of youth urban geography, that could provide to policy makers an updated and consistent knowledge for future urban policies. The mapping process was based on First Life (FL), a map-based social network, aiming at reconnecting digital and real spaces, using cartographic representations and crowdsourcing. The specific relational perspective allowed by the social networking functionalities of the application, specifically redesigned for this project on user-centered principles, favours a real shared representation of urban space. The purposes of FL developers are that the platform could be used “to visualize, integrate, share, comment urban data and make them useful for strengthening social communities in the real world” (Antonini et al. 2016, p.2). This chapter is structured as follows: paragraph 2 summarizes the key issues of teenagers’ geographies, basing on a literature review; paragraph 3 explores the idea of participatory mapping and volunteered geographical information (VGI), that guided the research; paragraph 4 describes the methods of the research; paragraph 5 reports the results of the spatial analysis of the more than 2000 points of interest (POI) mapped by teenagers; paragraph 6 provides some critical considerations of the teenagers’ urban geographies emerging from the research; paragraph 7 proposes some final remarks.

TEENAGERS AND URBAN SPACES

Does a “teenagers geography” exist? The existence of adolescence or teenage, as the transition between childhood and adulthood, is a cultural construction, historically and geographically characterized (Savage, 2009).

In this context, teenagers are acknowledged as a specific social group, characterized by psychological and behavioural specificities and playing a specific role in society (Avanzini, 2012).

Among the reasons for the “invention of adolescence” in Western society (Savage, 2009), we can identify historical factors, such as the abolishment of child labor and the extension of compulsory education; cultural factors, with the social

acceptance of the increased length of the period of dependence of teenagers by their parents (Berrini and Cambiaso, 1995); economic and market factors, in particular through the identification of teenagers as a consumer group particularly sensitive to marketing (Brooks, 2003).

Of course, despite some common traits, hardly teenagers can be treated as a unitary world, even within the cultures of the most economically advanced countries. The multiplicity of microcultures among teenagers is indeed one of the central themes of the sociological and cultural hub of studies on youth (Skelton and Valentine, 1998).

Adolescence is also associated with a specific spatial behavior, partly related to the affirmation of power relations, which define what are the acceptable spatial behaviors of different age groups (Massey 1998; Holloway and Valentine 2000; Holt 2011). The literature suggests though that the sociocultural and psychological characteristics of teenagers are actually translated into specific modes of frequentation, use and perception of urban spaces, which form the basis of teen geographies, distinct from general youth geographies (Weller, 2006).

Matthews et al. (1998) have proposed a useful systematization of some characteristics of the micro-geographies of adolescents, according to which the spatiality of teenagers would be characterized by specific elements such as: the need to create physical spaces of independence and exercise their recently gained and still limited autonomy; spaces where each juvenile microculture can perform its peculiarities and exercising an exclusive territoriality; ordinary and apparently marginal spaces, that play a very important role in teenagers' everyday geographies.

Lieberg (1995) identified two main typologies of places in teenagers' geography: a) "places of retreat" (e.g. backyards, basements, parking lots, etc.), where they can stay away from the adult gaze, which is always present at home and in institutional places (e.g. school) and b) "places of interaction", where they can perform their public character, seeing their peers and being seen by them (e.g. main streets, shopping malls, etc.).

The places of the individual and collective geographies of teenagers in the city, though, are planned and managed by adults, that perform their power of parents, educators, city planners or economic players. The public space is an adult space (Collins and Kearns 2001), where adults reproduce their authority in a hegemonic way and in which adolescents perform some sort of negotiation, or even resistance (Hil and Bessant, 1999), eventually bringing to a separation between the city *for* teenagers - which is planned and thought for them - and the city *of* teenagers, which is actually used, performed and represented by adolescents.

A typical trait of the teenagers' relationship with space is the limited capacity that they have to formally intervene in transformations, since they are seldom involved in decision-making processes and they do not have the legal power to own and manage private property. They can be described then as actors and producers of

“landscapes of powerlessness” (Matthews et al., 1998), which can change without them having the power to intervene, due to the action of adults or other groups of peers who exercise a stronger power.

If streets and outdoor public spaces were the typical space of action and interaction of teenagers in urban areas (Cahill, 2000), the progressive privatization of the public space in the contemporary neoliberal city and the emergence of public uses of private spaces (Mitchell, 1995; Nemeth and Schmidt, 2011) contributed to a growth of the control of behaviors in urban spaces and to a “moral panic” toward some groups of people, including teenagers (notably if non-white and male) (Evans, 2008).

As a consequence of the progressively bigger control on behaviors in public spaces, of families’ increased perception of unsafety in urban streets and of commercial strategies of private actors, teenagers partially lost the habit to hangout and spend time in squares, parking lots and streets and more and more moved to clearly stated private spaces that they use as public ones, typically shopping malls (Anthony, 1985; Matthews et al, 2000), not only in North American, British or Australian cities, where this trend firstly emerged, but also in Italy (Lazzari e Quarantino, 2010).

Even if research shows the still existing importance of material meeting places in the daily geography of adolescents (Martino et al, 2015), the pervasive diffusion of personal digital technologies contribute to change the approach of youth with urban space. The ability to decide in real time where to meet, with a phone call or message, has changed the way the meeting places traditional had for teenagers. Moreover, chat and social networks represent virtual meeting places unknown to those who were only teenagers a decade ago and that partly took the place of the “hanging around” places that characterize teen geographies (Vanderstede, 2011).

The research presented in this contribution aimed to explore teenagers’ geography in physical space starting from the creation of a virtual space, through a process of community participatory mapping, based on the idea of Volunteered Geographical Information (VGI), presented in the next paragraph.

PARTICIPATORY PRODUCTION OF GEOGRAPHIC KNOWLEDGE

In 2007, Michael Goodchild introduced the term Volunteered Geographic Information (VGI), categorizing those geographic information systems through which information is collected directly by users (considered as human sensors) on a voluntary basis.

Since then, the term VGI has become representative of a phenomenon that is spreading in the world of geoICT, fully responding to the web 2.0 paradigm where interactivity plays a key role in the development choices of computer platforms. The willingness and the ability to enter geographic information by users entails

different challenges and raises new research questions that require an increasingly interdisciplinary approach (Capineri, 2016)

The spread of systems for crowd mapping led to the emergence of a new figure: the neo-geographer (Haklay, 2013). The collection and dissemination of geographic information through digital cartography changes to the extent that the cartographer, in the age of geoWeb 2.0, no longer has to be “expert” in the construction of a digital map, but to be engaged in interacting with more and more user friendly platforms .

This passage, considered by Critical Cartography (Crampton et al 2006, Casti 2013), takes on the connotations of a substantial transformation of the very meaning of maps, which become the result of a collective gathering of information.

The awareness of the added value that the involvement of citizens, who do not necessarily have mapping skills, can guarantee to the processes of analysis and representation of territories and to geo-referencing processes dates back to well before the advent of the contemporary digital mapping revolution, which is based on concepts like neogeography, crowdmapping and volunteered geographic information. Although some methodologies have already been experimented with experiences such as the mental maps proposed by Kevin Lynch (1960) or the English Parish Maps, the first participatory mapping definitions, in the field of the analysis of the territorial processes, were produced by the FAO around the mid-1990s (Chambers, 1994).

The field of application of the first structured participatory mapping experiences is the evaluation and management of local resources by rural communities, particularly in developing countries (Chambers, 2006). In this context, the co-production of cartographic knowledge, often carried out under international cooperation projects, allows the emergence of territorial values that are invisible in the eyes of external experts, increasing the degree of legitimacy and acceptance of development projects by local communities.

The diffusion of digital technologies and automatic geolocation and geo-referencing systems has radically altered the concept of participatory mapping directly involving maps users in the production of geographic knowledge. The most used concept to describe this new perspective, of almost total disappearance of the rigid boundary between those who produce cartographic knowledge and those who use it (Rana and Joliveau, 2009) is the one of “crowdmapping” (Aitamurto, 2012), which transfers to the field of mapping the idea of information crowdsourcing, giving a role in the production of knowledge to large and diversified groups of people, not necessarily previously formed (Heipke, 2010). Each of us is increasingly subject to passive crowdmapping, and understanding how to become aware subjects of active crowdmapping essentially appears to be a project of political geography. The relationship between unintentional (data that users provide unintentionally) and voluntary (in a planned crowdmapping process) geographic information is a matter of great importance (Capineri and Rondinone, 2011).

The possibility to easily produce cartographic representations of the territorial complexity led the participatory digital cartography to gain a central role both in institutional participatory planning (through the so-called Public Participation GIS, PPGIS: Brown, 2013, Voghera, Ardissono and La Riccia 2018), and in many bottom-up and grassroots practices of active citizenship and community participation, as a tool of the so called “counter-cartography”, opposed to official cartography produced by experts and by the most influential actors (Parker, 2006, Schofield, 2014).

On the one hand, it seems undeniable the potential of participatory mapping in terms of information democratization, particularly with regard to the inclusion of the weaker actors, the transparency of information and the empowerment of population involved processes of self-reflection about themselves and their relationship with places, resources and other actors (Parker, 2006).

On the other hand, though, there are many critical voices on participatory mapping, which go far beyond doubts about the accuracy, quality and cleanliness of the data collected through the involvement of unskilled users without the application of appropriate filters (Flanagin and Metzger, 2008).

The main doubt raised in the field of the so-called critical GIS (Sheppard, 2005) is the actual involvement of the weaker population groups through participatory processes using GIS tools, whose technological character, especially in the early years of their dissemination, it is more likely to marginalize less digitally literate citizens (Elwood, 2002).

The weakest groups of population continue to be excluded from certain processes: it is therefore essential to observe the relationships between digital participatory mapping and democratization processes with a sufficiently critical analytical gaze (Haklay, 2013).

A study of Tabusi and Dumont (2012) on the relationship between societies and virtual spaces shows that the articulation of society and power in cyberspace passes for many actors and for many positions, not always immediately evident and never only virtual. It is unhelpful and unrealistic then to talk about virtual space as other than traditional space. The two authors propose to use the concept of “increased space”.

Recalling this inspiration we can therefore speak of increased spatiality and territoriality, highlighting how the whole of relationships with externality and alterity can be expanded through the use of ICTs (biometric sensors, satellite navigators, personal digital maps, etc.).

As a result of the incredible spread of geoICTs and the growing interest surrounding them, the new challenge is to exploit the multiple nature of the information, to reach a representation of space as a social product, focusing on those social phenomena that, even articulating in space, do not have with it an immediately apparent relationship. We can investigate the meaning that space assumes in a relational dimension between different social actors, thus focusing not so much on the “representation of space”

but on the “space of representation”. According to Lefebvre (1991), we can define the latter as the living space of sensations, imagination, emotions, and meaning that is part of our daily life practices.

The research described by this paper is based on a conceptual framework linked to the world of VGI that is constantly evolving. Use cases and technological development are increasingly characterized by a mutual dependence. Taking this perspective into account, it is necessary to emphasize the function of users off-line accompaniment. In particular, the digital engagement given by the usability of proposed technology and the definition of maps’ legends and categories should be the results of participated debate and discussion.

The ability to process large amounts of geolocalized information is only possible through the use of new technologies. As a result, the challenges we face today seem to relate to balancing off-line methodologies of participation with digital activities. On the other hand, the increase in the quantity and quality of computable information opens new perspectives in relation to the potential for processing and the creation of new information.

METHODOLOGY

The mapping activities of Teencarto³ were carried out through three two-hour classroom meetings for each of the 36 involved high-school classes (for totally 620 teenagers involved).

The first meeting aimed to engage students and share with them the aims and the spirit of the project. The main goal of this phase was to convey to teenagers the idea not to be just objects of research, but rather actors in a wider process of participation and knowledge co-production, aimed at dialogue with institutions. On the same day, students were introduced to concepts of knowledge co-production, participatory mapping, crowdmapping and web narrative. The theoretical part of the lesson was followed by two practical activities aimed at increasing the confidence of participants with the maps production and with the role of knowledge producers that the project intended to attribute to them. The first activity consisted in the drawing of mental maps of their neighborhoods or towns, with the purpose of introducing them to the production of maps and to the self-reflection about spatial behaviors.

The second activity focused on a sort of digital “treasure hunt”, during which students, divided into groups, had to find (on the web) the locations of some murals painted on the walls of Turin, of which only one photograph was provided.

In the second day of activity students were involved in the actual production of a map of the most significant locations in their daily geography. Participatory mapping work has developed around three main themes. At first, boys and girls were asked to

reflect on the places in the city that they mostly frequented (the “frequented city”), putting them on the map and attributing to them names, formal or informal ones, thus creating an interesting teenagers’ toponymy map), a detailed description and keywords. The same activity was carried out to map the “inaccessible city” asking them to indicate which places they avoid or which ones they cannot attend for various reasons (economic, perceived insecurity, prohibitions).

Thirdly, particular attention was given to the city that the boys and girls imagine for the future, asking them to imagine a transformation project for the city (“the imagined city”). These imaginative projects could involve the creation of new places or the transformation of existing and perceived places as degraded or unsuitable to the needs of adolescents.

The third meeting was devoted to this, with a discussion about the interest and feasibility of the proposed projects.

RESULTS

The project involved 17 schools located both in the city center and in the peripheries of the city and 620 teenagers. Activities which have been carried out during the project led to the collection of 2465 points of interests (POI), whose 2069 are within Torino’s administrative boundaries. This result is also due to the use we made of a user-friendly web-based application, called FirstLife, which allows to directly insert georeferenced points on a digital map. FirstLife is a civic social network, designed to be as a collaborative environment for citizens (Antonini et al., 2016). The application has been specifically set to fulfil the project’s goal: mapping teenagers’ geographies in the city of Turin.

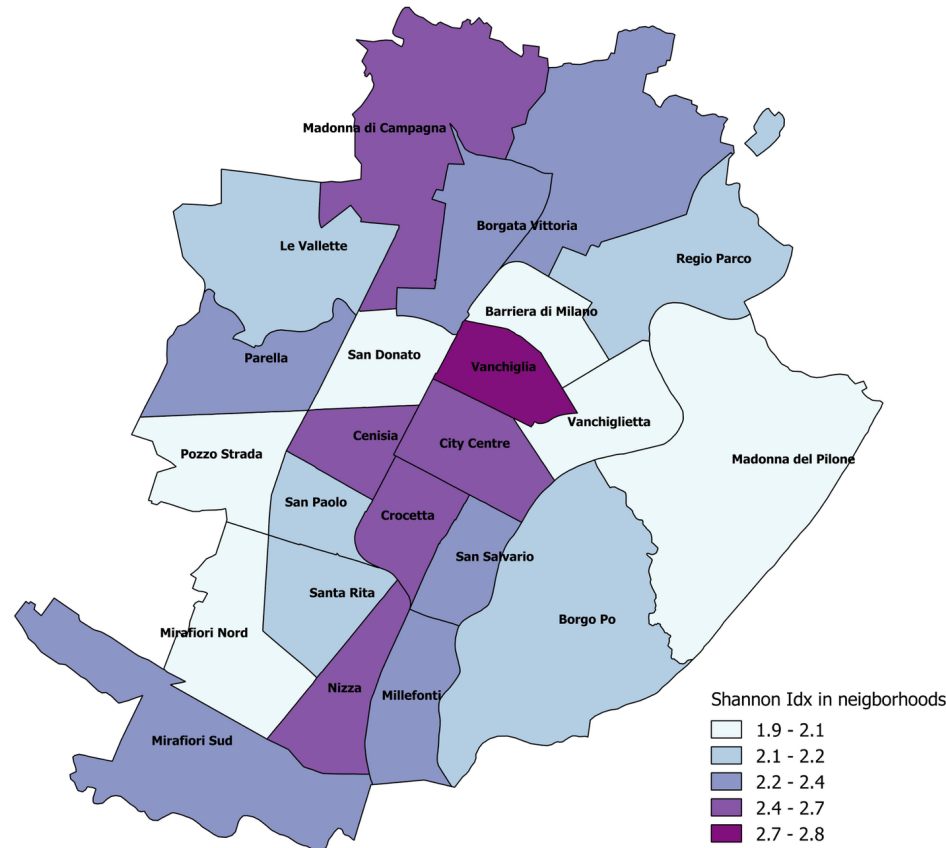
The dataset is composed of georeferenced POIs characterised by the following metadata description:

- **Name:** A text field where adding the formal or informal name of the POI;
- **Category:** A set of exclusive categories describing POIs (Art, Food, Education, Work, Nightlife, Meeting Spots, Shops, Sport, Services, I imagine);
- **Evaluation:** Two exclusive POI features describing its perceived quality (positive or negative)
- **Transformation:** Three exclusive POI features describing the perceived temporal like value (positive transformation, negative transformation or no transformation);
- **Description:** Free text of at least 140 character
- **Tags:** Recommended tags (frequent, suggest) and free tags.

In Figure 1, the frequency distribution of POIs for each category is shown. Besides the category “I imagine” which is a special one, the “Meeting spots” (MS) category is the most relevant for the teenagers, followed by “Sport” and “Food”.

The evaluation of each POI as a positive resource or a criticality of the area results in a great predominance of positive resources: 89% of the total number of POIs. We count only 271 places out of 2473 total on which a negative evaluation has been attributed, and they are located across all the study area with no significant spatial concentration.

Figure 1. Number of points per category



Spatial distribution

Regarding the spatial distribution of POIs we report that they are distributed throughout the city (see Figure 2). It can be seen that POIs are spread over the entire study area. The distribution of Meeting Spots displays a major concentration in the city centre (see Figure 3) while POIs collected under the category “Sports” concentrates in noteworthy places such as the three stadium of Torino and parks (see Figure 4).

Tags

Teenagers enriched the POI description with the use of tags. The most used tags are: 1) “divertimento” which is the Italian word for “fun”, and 2) “amici”, which means “friends” (see Figure 5). These two tags are associated to almost all the categories but work and services. This is rather explicative of the relevance teenagers give to entertaining activities and to sociality in general. Table 1 shows the ranking of the five most used tags by each category. Generally, tags refer to architectural types, activities and quality of spaces.

A more accurate natural language analysis of the tags will be object of future works. Extracting a folksonomy from the collected data, indeed, might allow going beyond the use of a predefined set of categories. However, crowdsourced data are particularly noisy and they need a long pre-processing phase.

Figure 2. Distribution of POIs

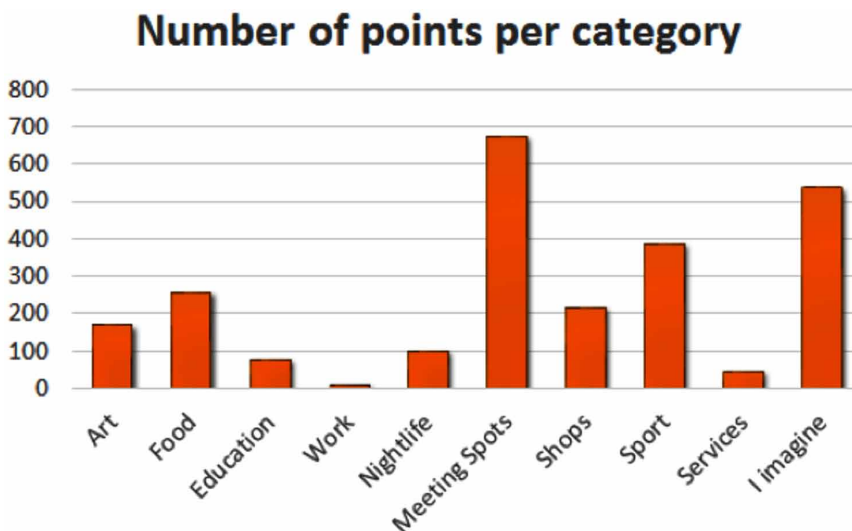


Figure 3. Distribution of meeting spots

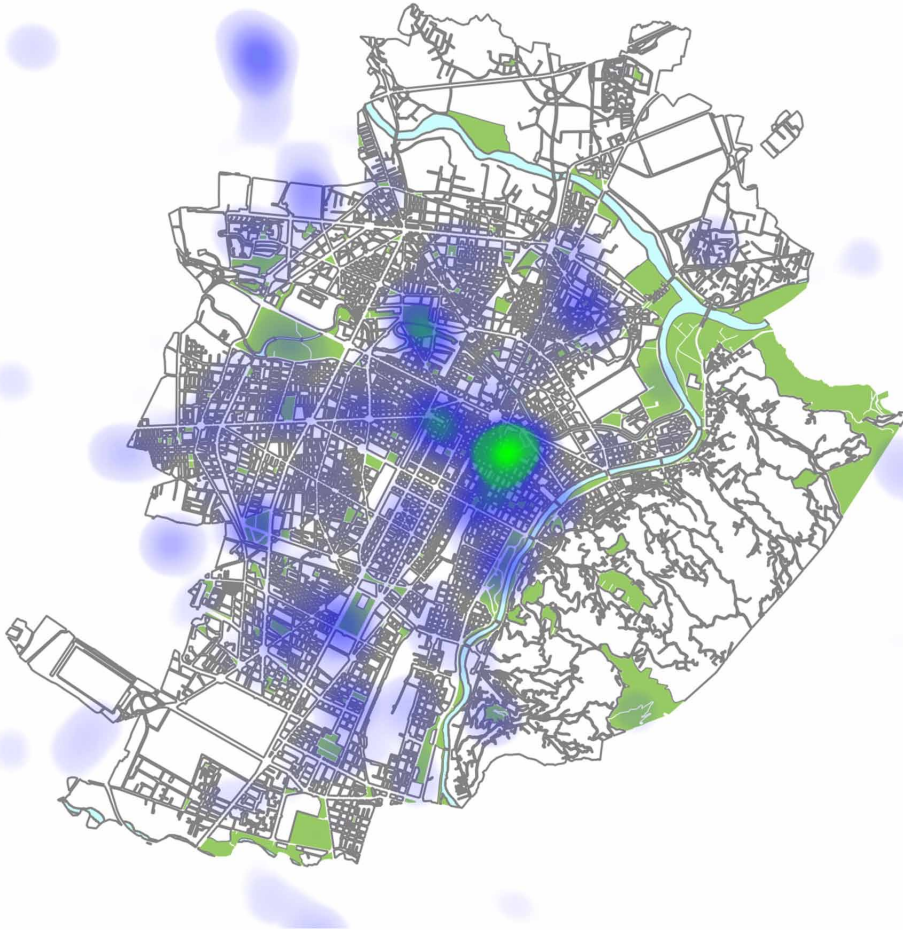


Popular Neighborhoods and Their Functions

Teenagers have been explicitly asked to use the tag “frequent” to pinpoint, among the places they have added, which of them are the ones where they generally go. Places tagged as such are of particular interest for our analysis. We have evaluated them considering how they distribute across the 23 neighborhoods of the city. Insights we wanted to extract to map teenagers geographies were: i) what the most popular neighbourhoods are, ii) how neighbourhoods are currently used by teenagers, iii) and to verify if there exists a relation between the diversity of a neighbourhood in terms of its functions, and its appeal for the young population.

Map in Figure 6 shows what the most popular neighbourhoods are. The city centre contains about 30% on the total POIs, while other neighbourhoods reach

Figure 4. Distribution of POIs collected under the category “Sports”



a maximum of 7%. It appears clearly that the city centre is considered the most attractive neighbourhood to young people; however, there are some peripheral areas, which are quite frequented as Santa Rita and Pozzo Strada.

To identify the specific character of each neighbourhood in terms of their actual uses we obtained POIs' relative frequencies dividing the number of POIs per category by the total number of points in neighbourhoods. Maps of Figure 7 and 8 present the relative distribution of the POI classified as Sport and Meeting Spots (MS), which are the most used categories. Mirafiori Nord and Pozzo Strada have the highest proportion of Sport's POI (see Figure 7). This is due to: the presence of a park and the Stadio Primo Nebiolo in the first case, and the Juventus Stadium in the second; only about 3% of the POIs are classified as sport places in the city

Figure 5. Tags cloud



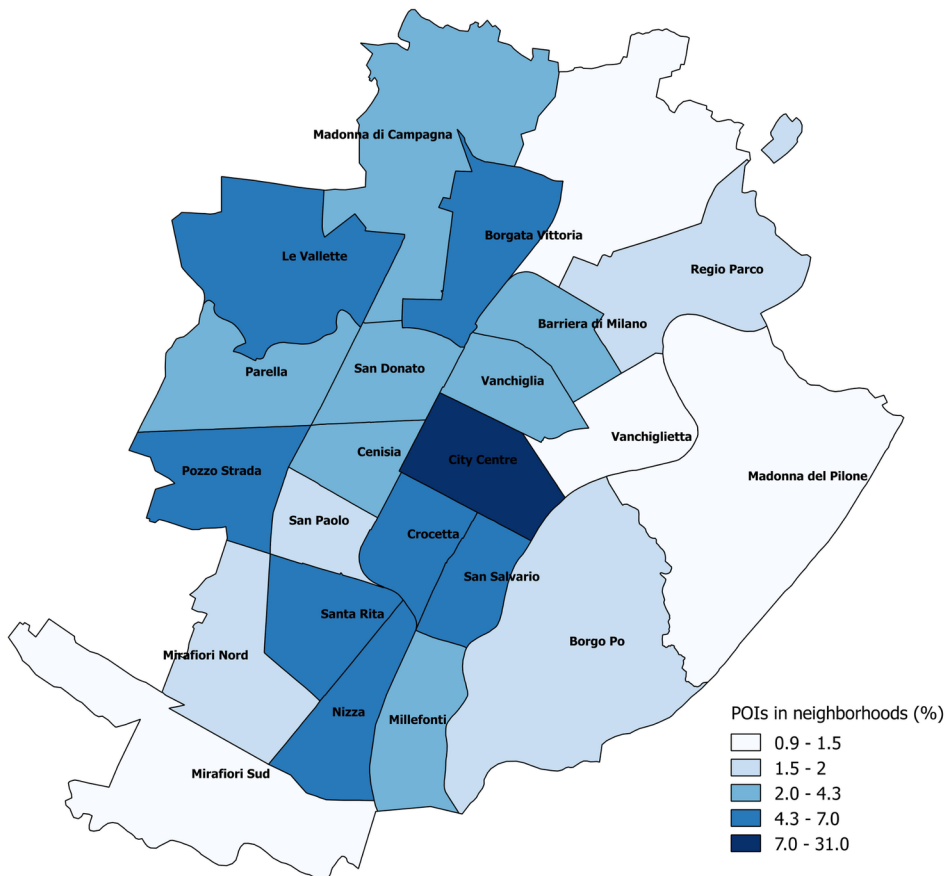
Table 1. Recurrent tags per category

Art	Food	Education	Work	Meeting Spots	Shops	Sport	Services
friends	eating	school	working	friends	shopping	fun	bus stop
cinema	restaurant	friends	looking for	fun	friends	playing	station
fun	friends	study	trains	park	fun	park	taking
film	fun	experts	going to	garden	clothes	football	passing
chiesa	ice-cream	fun	...no fun!	square	city centre	swimming pool	...no fun!

Figure 6. Density of POIs per neighbourhood



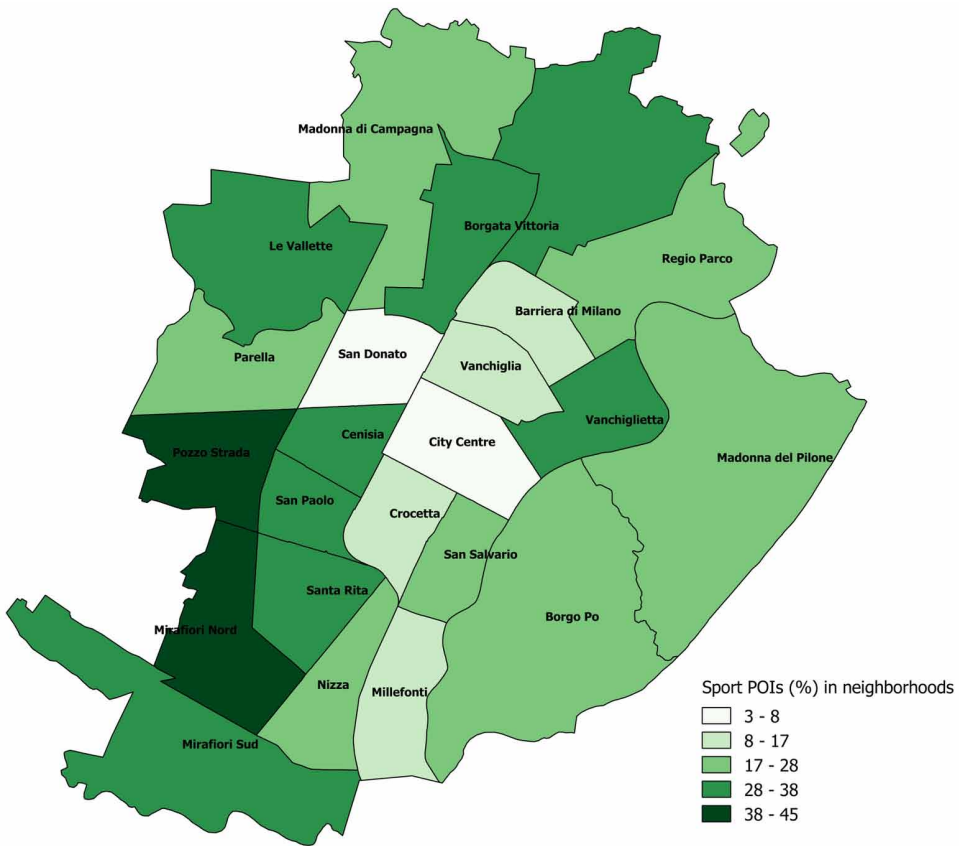
Figure 7. Density of sport related POIs per neighbourhood



center. It is interesting to see that the proportion of MS is particularly significant not only in the city center, but also in peripheral neighbourhoods such as Barriera di Milano, San Donato, Parella and Santa Rita (see Figure 8).

Finally, we calculated an index to estimate the diversity of uses for each neighbourhood in order to verify a possible correlation between diversity in neighbourhoods' functions and popularity. Indexes of diversity are generally used to measure biodiversity in natural ecosystems in order to get to what extent the species of a new individual can be predicted. The Shannon Index is one of those and it is more robust than merely count the number of species that are present in an area, since it also takes into account the population sizes of each species. The most distributed the population sizes are in the study area, the low the probability to predict the species of a new individual is. Applying the same method to the urban ecosystem we thought at urban functions, given by the categories used, as if they were biological species within a neighbourhood and at the urban diversity as

Figure 8. Density of meeting spot POIs per neighbourhood



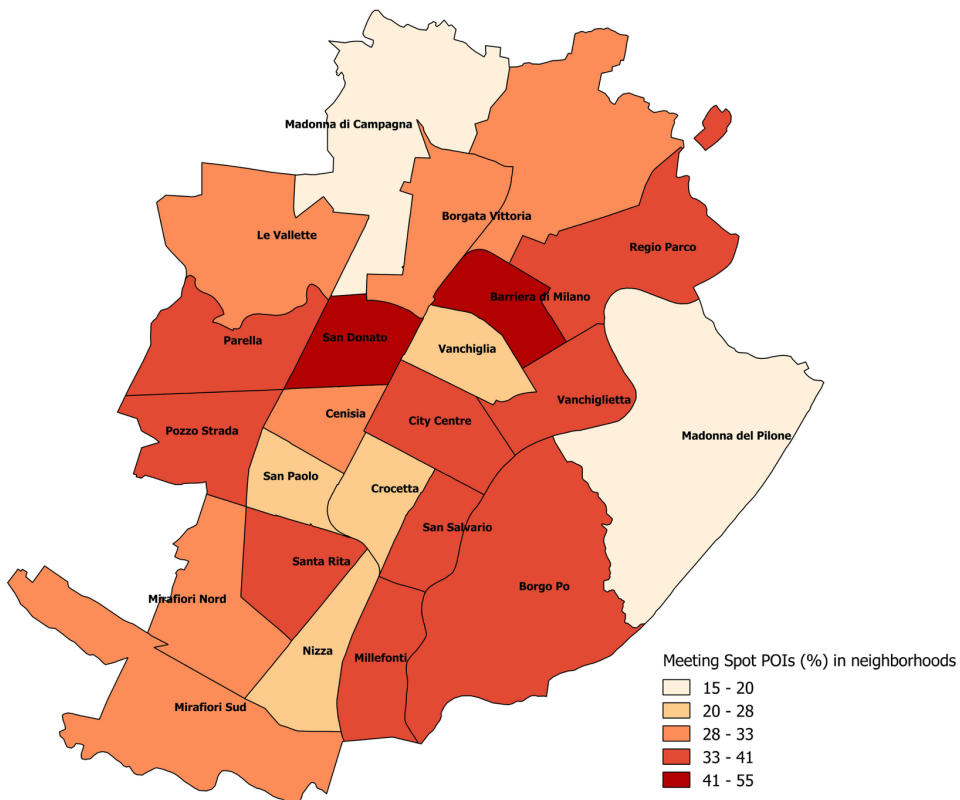
the probability to predict a new POI of which category may be. Therefore, the idea behind the index is that the more different categories are in a neighbourhood, and the more equal their proportional abundances is, the more difficult it is to correctly predict category of a potential new POI. It follows that when the uncertainty in classifying a new POI is high we can say that the neighbourhood is significantly diverse in terms of its functions.

The formula of the Shannon Index is:

$$H = -\sum (p_i \log_e p_i) / C$$

where p_i is the proportion of POI belonging to the i th category in the neighbourhood and C is the total number of categories. Figure 9 shows the index value mapped in each neighbourhoods. As it can be seen, we can distinguish highly specialized neighbourhoods such as Barriera di Milano, Pozzo Strada, Mirafiori Nord and San Donato (respectively as being characterized by places where doing sports and places

Figure 9. Shannon index values in Turin neighbourhoods



where meet, see Figures 7 and 8), from more diverse neighbourhoods such as the city centre and Vanchiglia.

Regarding point (iii) mentioned above, we tested the hypothesis that more diverse neighbourhoods are also popular. What emerged was that there is no statistically significant correlation between the calculated index and the neighbourhoods popularity, measured on the number of POI in each area ($R=0,27$).

THE GEOGRAPHIES OF TURIN TEENAGERS: VARIOUS TYPES OF “PIAZZA”

In Italian the expression “*fare piazza*” means to meet people in a public place, in order to chat and spend time together. In the youth slang, the term “*la piazza*” refers at the same time to the place where people meet to chill out and to the group of friends meeting there.

The real and the metaphorical *piazza* (literally, square) is a privileged space for the practice of teenagers’ geographies, that are strongly characterized by the tendency of spending time in public (or hybrid public-private) spaces, in order to interact with peers and be out from adults’ (parents) control.

According to Vanderstede (2011), one of the recurrent activities mentioned by teenagers while describing their activities is “chilling”, “it refers to quite diverse activities and atmospheres. Most often, it stands for meeting up with friends in a very ‘relaxed’ ambience (sitting, hanging and often lying on the ground) (p. 175).

The *piazza* (it can be a street, a shopping mall or a parking lot) is the typical “place of interaction” (Lieberg, 1995), where young people show themselves to their peers and establish direct relationships with them, even if more and more often with the mediation of digital devices, like smartphones, and virtual spaces (social networks) (de Souza e Silva, 2006).

This paragraph focuses on the need to identify, use and represent public spaces as places of interaction that clearly emerges from the self-reported teenagers’ geography mapped during the Teencarto project.

The way young people think and use urban public space is of specific interest because of the growing hybridization or privatization of publicly accessible space that characterize the contemporary neoliberal city (Nemeth and Schmidt, 2011).

From the Teencarto maps, five main types of squares (or *piazza*) can be recognized: a) the *real* squares of the city, mostly concentrated in the city center; b) the *invented* squares: other public places that teenagers use as squares, despite their original function (e.g. parking lots); c) the *green* squares of urban parks, where teenagers seem to seek public relationships, more than the typical benefits of green areas; d) the *hybrid* squares of commercial private places, especially inside shopping malls,

that are used as and confused with public places by teenagers, that spend there much time, unconsciously absorbing commercial messages, e) the *nightlife* squares of urban playscapes (Chatterton and Hollands, 2002), that characterize some central Turin neighbourhoods (Crivello, 2011).

The next sub-paragraphs describe more in detail these five typologies of “squares” emerging from the Teencarto mapping activities, directly reporting some of the descriptions, provided by the project’s participants⁴ (in the field “description” of the First Life form, see par. 5).

The Real Squares

The squares of the city center play a primarily important role in the use of public spaces by teenagers, as for the rest of the population in most Italian cities (Canniffe, 2008). Turin’s main squares are present in the mental map and in local geography representation of a large number of young people involved in the project, who attribute highly positive values to them and consider them as their main meeting places. Even if also semi-peripheral and peripheral neighbourhoods squares are mentioned and mapped, the map shows a strong centre-periphery unbalance. Many teenagers living in non-central neighbourhoods, in fact, regularly come to the city center in order to spend time and meet friends.

One of the clearest example is Piazza Castello, described by many teenagers as one of the favorite places to meet up with friends and spend free time. This emerges for example by the words of Alessandro, 16 years-old, living in the suburbs: *It is one of the most beautiful squares in Turin, it is a perfect place for tourists because there are Palazzo Madama and Palazzo Reale; in the center of the square there are also fountains and all day there are street artists. It is a suitable place to meet with friends and spend time in the company, in the square, the main meeting points for young people are the monuments and bus stops and a few steps from the square the royal gardens. I spend many Saturday afternoons here with my friends because it’s a place where there are a lot of guys and girls.*

The frequentation of the square by young people from all over the city, and beyond, also leads Piazza Castello to be the meeting place and clash among the many micro-sculptures that characterize the youth world: *We often go there with my friends or with single friends. I like going there because there is life, even if lately I like it a little less, because there are always a lot of vippini⁵ at you in a strange way. In Piazza Castello I go there just to go shopping because there are many shops* (Marilena, 17-years-old, living in the city center).

The square is also the location of one of the ritual moments of Turin’s high school students: the celebrations for the end of the school year characterized by games with the water jets of the fountains in front of Palazzo Madama: *Piazza Castello is*

a meeting place for many young people from Turin, and it is also the square where the last day of school hundreds of students take a “purifying” bath to definitively greet the school year. It is a regal and sumptuous square thanks to the two palaces of the Savoy age. I really like this square because it reminds me of many memories. (Giulia, 16-years-old, city-center)

The adolescent microgeography also structures the square in different places, dedicated to different activities and frequented by different groups. The most recurrent example is that of the great monument dedicated to Emanuele Filiberto Duca d'Aosta, that teenagers appropriate themselves physically, transforming it into an informal skate park.

The Invented Squares

Not in every neighborhood the existing squares become aggregation poles for young people. It is therefore frequent, especially by boys and girls who live far from the center the “invention” of places of aggregation, of informal squares, using parking lots, open spaces or unused spaces, which become meeting places, where dynamics of creation of micro-geographies and relationships between different social groups, similar to those already described regarding the main squares of the city, take place.

One of the most interesting cases is that described by a group of teenagers living in the western suburbs of the city, in reference to the common spaces (a *portico*) of a popular housing complex in the Borgata Paradiso district, in the Western outskirts of the city, which appears to have become a popular meeting place: *Usually we meet all around 5.00 and I'm here with my friends. I really enjoy myself and I feel at ease. I feel comfortable with my friends, whom I have known for many years (...) for me it is a second family* (Carlotta, 16-years-old).

Adolescents' fantasy and the need to carve out spaces of autonomy in a strongly regulated world supervised by adults lead to the identification of original meeting places, such as the roof of a building in the working-class industrial neighborhood of Mirafiori: *Here there is practically nothing special but you can really be in peace. Despite the constant conflicts with the typical “village-style” old people who live in the palace in front of them, one can lie down on the roof of a courtyard in peace. It is not dangerous of course* (Alessandro, 18-years-old).

The Green Squares

City parks and green areas are among the most frequented and mentioned places of the city, for various reasons, starting from their role as spaces dedicated to outdoor sports. In many cases, though, parks are described more as places of interaction and public relationships, than as places where practicing sport or enjoying nature.

A particularly relevant case emerged from the mapping is the Parco Dora, a new green area opened a few years ago in a former industrial area, that soon became a favorite place of adolescents in Turin, thanks to the free sport facilities designed for them (skate park, tennis, volley and basketball courts) and special events (e.g. music festivals), in an infrequent identification between the city *for* and the city *of* teenagers. Imane, a 17-years-old of Moroccan origins, living in the Madonna di Campagna neighborhood, describes it using a “Tripadvisor-review-style”: *Meeting place especially for young people. Fun is guaranteed. There are several facilities for various entertainment activities such as ramps for skateboarding, tennis, basketball or football fields, and children equipments. Also ideal for taking walks for example with friends or relatives, etc. Sometimes there are also events, such as concerts.*

The park, located in a very multicultural neighborhood, is the set of interaction between different ethnic, social and cultural groups of teenagers, characterized by interesting dynamics of integration as well as by conflicts: *It is an outdoor park, recently built, where you can find fields of various kinds of sports, including a basketball court, a volleyball court, a skateboard ramp, soccer field, tennis court. Many people come here to train, even for run only. I personally train in basketball with my friends or with the Filipinos that always hang out there. (...) I come to the camps at about once a week, or on Saturdays or Sunday. A critical aspect of this place is that it is also frequented by unpleasant people. In this park many events such as Street Food fairs and parties are organized* (Andrea, 18-years-old, Aurora).

Some green areas are also places perceived as potentially dangerous, especially in the evening hours. The park with the worst reputation seems to be the historical and very central Valentino park, more due to the influence of opinions transmitted by families, than to real bad experiences: *Valentino's park is a place that I do not frequent so much and I go there only during the day accompanied by someone. This place seems dangerous to me because there are many people who take drugs and drink in the middle of the park and since it is very large and there are so many hidden places it is not a recommended place for people to be well. Too bad for its beauty* (Denisa, 15, Santa Rita).

The Commercial Hybrid Squares

Commercial spaces represent a recurring point in the individual and collective geography of many teenagers. The role of shopping malls and commercial spaces as protected and presumably safe places where youngsters spend their time hanging out, often without buying anything, is widely discussed in the debate about youth geographies, mostly focusing on the contradiction between the real purpose of commercial spaces and the use of public space that people practice when they hang

out there (Anthony, 1985; Matthews et al., 2000; Vanderbeck and Johnson, 2000). The debate, that emerged with the “mallings” of American society in the mid-80s (Kowinski, 1985), has today new nuances, linked to the public role or private space in the neoliberal contemporary city, also in other parts of the world (Erkip, 2003; Németh and Schmidt, 2011).

The importance of shopping malls’ covered “squares” as meeting places for teenagers clearly emerges from Teencarto maps, especially in peripheral neighborhoods, less close to the city center and where the density of shopping malls is higher.

According to teenagers descriptions on the map, they find in shopping malls hospitable places, that appear as specifically designed for attracting them: *A place to be with friends and spend an afternoon together shops where you can find everything you need. In winter there is a small trail from ice skating. A place to shelter from the cold in winter* (Iara, 17, Grugliasco); *It is a meeting place for many young people both for an afternoon of shopping and for one afternoon of leisure with friends. Between the cinema and the shops it is a perfect place to forget of the school and everything for a couple of hours* (Giulia, 16, Mirafiori Nord); *It is a shopping center that becomes a meeting point for young people living in Mirafiori. It is a place to spend the afternoon in the shops or in the square in front of it. It is the first place where I could spend time with my friends during secondary school* (Lisa, 18, Mirafiori South).

In the city center the role of shopping malls is played by commercial streets, like via Garibaldi and via Roma, where teenagers spend their afternoons strolling, looking at shops’ windows and daydreaming about things they (almost) never actually buy: *I like spending whole days [in via Roma] observing the windows of the most expensive shops and trying to guess the price of fancy clothes. In some shops I try clothes just to see how they fit me. I also like to smell the perfume that every store gives off, everyone has a different scent. I have bought very few things in the shops of this streets, but it is a very important place to me* (Erika, 16).

A special, recurrent and symbolic role, as commercial spaces playing the role of meeting points, is played by some cafeterias and fast foods, where teenagers spend hours, meeting their friends. Busters Coffee, for example, is a local chain of american-style cafeterias (there are two in Turin city center), crowded of teenagers that consider them among their favourite places in the city: *Busters is a Starbucks style café. During summer I always go there for a snack and sometimes to have breakfast with my friends; in the moments we spend there we relax by chatting or listening to music while drinking a cappuccino and we eat donuts and pancakes. I have taken many photos that remind me of beautiful moments, every time I go there something unforgettable happens* (Cecilia, 16).

The Nightlife Squares

Turin's nightlife geography clearly changed in the last decades: the industrial working-class city has progressively been replaced (since the late 90s) by a vibrant city, nationally and internationally appreciated for its music and clubbing offer. The geography of Turin "playscapes" (Chatterton and Holland, 2002) is highly selective and "expression of urban segmentation, gentrification and spatial divides" (Crivello, 2011, p. 713), as well as linked to privately driven strategies of urban renewal based on entrepreneurship. As a consequence, bars, clubs and restaurants are concentrated in few neighborhoods, notably the gentrified San Salvario and Quadrilatero Romano and the central area of Piazza Vittorio Veneto.

Nightlife is largely present in the map of Turin adolescents' geographies. Some of the squares and streets of city's playscapes, mostly concentrated in the central area of Piazza Vittorio and in the gentrified neighborhood of San Salvario, are among the most mapped places of the city.

Many participants to the mapping activity described alcohol-based evenings, even if according to Italian law the sale of alcohol to minors of 18 is not allowed. This means two possible things: either the teenagers exaggerate their "night-time enterprises", boasting behavior that they do not put into practice for real, or bartenders sell alcohol to teenagers even under the minimum legal age.

Largo Saluzzo, in San Salvario neighborhood, is one of the more recently emerged hotspots of Turin's nightlife and location of conflicts among nighttime users and residents. Here every Friday and Saturday night, hundreds of teenagers meet in order to meet friends and drink alcohol: *[Largo Saluzzo] definitely is the best place to meet up with friends on Friday and Saturday night and it is the scene of the biggest parties in Turin. It has become the place of freedom for young people. We come from every part of the city and the province, to party in this place. [...]* *This fantastic situation lasts until three in the morning when a nice little car with blue sirens (the municipal police) stops in front of the church to face the problems with drunk people disturbing the society* (Riccardo, 18).

CONCLUDING REMARKS

The teenagers' geography that emerged from the Teencarto research confirms most of the aspects highlighted by the debate on the relationships between youth and space. The adolescents that participated to the research asked to be treated as citizens with an active role in society (Weller, 2006) and for services and places fitting their real needs. Many of them also described their city as made up of an

archipelago of places that they live in their own way, responding to specific cultural, social and power dynamics, much more than to the rules and the meanings that the adults' society attributes to those spaces and to the role that youngsters are expected to play in them.

Nevertheless, the conflictual component in the relationship between adolescent and adult territoriality emerges very weakly from the research, probably also due to the methodological bias of data collection, to the protected and controlled environment of data collection (school).

A discrepancy between the city *for* the adolescents, constituted by the places that the institutions dedicate to the youngest citizens (e.g. youth centers) and the city *of* teenagers, that they regularly frequent and that almost never includes places institutionally designed for them, neatly emerged.

The progressive confusion of the boundaries between public and private function of urban spaces is another constant issue. If streets and open-air public spaces were the typical space for adolescents' action and interaction in urban areas (Cahill, 2000), the progressive privatization of the public space in the contemporary neoliberal city and the emergence of public use of private space (Mitchell, 1995, Nemeth and Schmidt, 2011) have contributed to the development of new behaviors, taking place in controlled spaces (Evans, 2008). Teenagers seem to have reduced their propensity to use public spaces to spend their time in group, in favour of private spaces. As Teencarto shows, this not only occurs in North American or British cities, where this trend first emerged (Matthews et al., 2000), but also in Italy (Lazzari e Quarantino, 2010).

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ENDNOTES

- ¹ Some of the contents discussed in this paper were presented at the *AESOP* Annual Congress 2017 - Spaces of Dialogue for Places of Dignity: Fostering the European Dimension of Planning, that was held in Lisbon, in the period 11 - 14 July 2017.
- ² The chapter is the result of a common effort. Though, paragraphs 1 and 7 can be attributed to Egidio Dansero; paragraphs 2, 3 and 6 to Giacomo Pettenati; paragraph 4 and 5 to Alessia Calafiore.
- ³ The group of researchers directly involved in the activities in schools was composed by Giacomo Pettenati (project coordinator), Eloheh Mason, Agnese Migliardi and Cristina Pidello.
- ⁴ Places' descriptions were provided in Italian. Here we report authors' translations.
- ⁵ In the youth slang, *vippini* means something like “people striving to become VIPs and behaving in pretentious ways” or “wannabe VIPs.”

Chapter 11

A Territorial Dimension Can Be Useful for Managing Long-Term Regional Road Safety

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ABSTRACT

Analysis of road crashes at the local level is necessary for targeting and implementing effective countermeasures. This chapter presents a contribution to this task. It describes the research carried out in Piedmont, Italy, where an exploratory approach has been used to link road crash data with information about the spatial characteristics of urban settlements. The analytic strategy is developed in three steps. First, fine-grained spatial data for road crashes, land use, traffic counts, and population distribution are linked by GIS methods. Second, a selection of the data is implemented at the municipality level and processed through a cluster analysis to identify territorial accident profiles. Finally, to show their analytic potential, one case study is discussed that considers road segments as main observation units.

INTRODUCTION

A new mobility and transportation plan has been recently laid out in the Piedmont region of northwest Italy (Piedmont Region, 2018). The plan is oriented around sustainability targets, including a long-term time horizon that adheres to a “vision zero

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approach” to road safety (Belin, Tillgren, & Vedung, 2012). The plan focuses on the involvement of stakeholders and customized interventions at the sub-regional level.

The territorial lens leveraged by the plan helps to sharpen road safety problems in the local areas. On a conceptual ground, it stimulates a deeper understanding of the complex nature of these problems and refines the concepts originally proposed by Rumar (1999). This author suggested that road safety problems can be articulated according to three levels:

1. **First Order Problems:** Made apparent from the way we analyze accident and injury data. Examples of these problems include speed which are too high in built areas; alcohol and drugs are found too frequent in driving; road standards are inadequate; road safety for vulnerable road users is very low; accident risk for young drivers is too high. Adopting a more adequate territorial lens can help assess the severity of a situation in an area. The accident counts and their features have to be investigated, considering the geographical and spatial morphology of settlements.
2. **Second Order Problems:** Not immediately evident from the statistics they are revealed from a closer inspection of first order problems. These problems typically stem from the inadequacy of road traffic legislation, road safety education and/or control of road conditions. Solutions to these type of problems may make the countermeasures meant to solve first order problem redundant. Thus, the territorial dimension is more substantial for these types of problems. Since these problems are under the responsibility of several government institutions, addressing them requires attention at the extending and overlapping of the different spatial jurisdictions.
3. **Third Order Problems:** General in character and deal with the underlying conditions of road safety. These problems may concern the organization and management of road safety work and affect the values and knowledge of road safety for citizens. At this level, the territorial dimension also has a more encompassing role. It becomes a tool for supporting the exchange of information and sharing evidence about the social costs of road accidents, as well as the implemented countermeasures and their effectiveness. Additionally, local information about accidents helps raise awareness about the value of road safety by citizens and decision makers.

This chapter addresses the stronger role of using the territorial lens in managing road accidents. A methodological approach is suggested for profiling territorial situations of road accidents at the local level. The Piedmont region is used as a case study.

BACKGROUND

A road accident is an event involving at least one moving vehicle that may or may not lead to injury on a public road. It is unpredictable and results from the interaction, in a certain place and a certain time, of a number of factors, including human behavior, traffic situation, urbanization patterns and weather conditions.

Insights from the literature (Hermans et al, 2008, Ewing & Dumbaugh, 2009, Hughes et al 2015, Larsson et al 2010) show that these factors can be grouped into the following broad categories:

D1. Territorial context: includes local area features, such as geo-morphology and climate, functional level of roads, land-use pattern, traffic flows, transport services, socio-demographic and employment characteristics;

D2. Technology: accounts for the level of safety equipment of vehicles, e.g. passive safety systems (airbags, seatbelts, whiplash protection system etc.) and active ones meant to have a preventative role in mitigating accidents (Anti-lock Braking Systems, Lane Departure Warning System, Blind Spot Detection, etc.)

D3. Humans: includes factors about road users' demographic profile, driving behavior and competence, life-styles, etc.

Humans are at the very core of road safety. The acknowledgment that humans are prone to error is the main premise of a safe system approach, which aims at preventing serious outcomes from accidents in the first place (Itf, 2008, 2016). Four principles underpin the safe system approach (Itf, 2016, p. 24):

1. People make mistakes that can lead to road accidents;
2. The human body has a limited physical ability to tolerate accident forces before harm occurs;
3. A shared responsibility exists amongst those who design, build, manage and use roads and vehicles and provide post-accident care to prevent accidents resulting in serious injury or death;
4. All parts of the system must be strengthened to multiply their effects, and if one part fails, road users are still protected.

At the foundation of these principles is an enhanced understanding that the intertwining effects of the factors mentioned above do have a role in road safety. Therefore, investigating road accident phenomena and designing countermeasures is key for long-term regional road safety.

The issues are overtly addressed in a recent European project, SafetyCube (Thomas & Talbot, Eds. 2018). This project developed a database, an analytic approach and a design protocol as a decision support system to deal with road safety in European countries. The investigation framework developed in the project makes reference to

the conceptualization by Elvik (2004) which posits that road safety outcomes result from two mechanisms: one related to factors which are beyond the road user control (“generic”) and one related to accident-specific conditions (“circumstantial factors”).

The project reflects the advances in the safe system approach which shifts attention from a reactive to a pro-active view for preventing accidents. The latter is concerned not solely with the causes of the actions of those at the scene, but also considers the conditions which, while present at the scene, were created in the distant past (Hauer, 2016).

In such an undertaking, the analysis of the territorial context (D1) becomes more prominent than in the past when attention mainly focused on road characteristics (Eksler & Lassare, 2008; Eksler, 2008, 2010; WHO, 2004, 2006).

This study develops a meso-level approach for investigating territorial profiles of road accidents in the Piedmont region.

Situated in north-western Italy, Piedmont has more than 4 million inhabitants. The region consists of 8 provinces, and 1206 municipalities, the majority of which are small towns in rural and mountainous areas. The ratio between vehicle density and road total length is among the highest in Italy.

Since the early 2000s, several road safety programs, including education, enforcement and road improvement countermeasures, have been carried out by the Transportation and Health Care Departments. The number of casualties has decreased significantly over the years. In 2016, there were 15800 persons injured in road accidents (Regione Piemonte, 2017). The number of deaths per one million persons (56.2) was higher than the Italian average (54.2).

MAIN FOCUS OF THE STUDY

The meso-level approach adopted in this study is an intermediate level between:

- A macro-level overview of the phenomenon, meant to account for the level and severity of accidents in a city, region or country, as it comes out from the official statistics (the report, by Regione Piemonte, 2017 and ETSC, 2018, are examples of this approach);
- A micro-level examination of accident events, (in-depth analysis) which investigates their on-site circumstances, e.g. the dynamics of driving behaviour and vehicles (Larsen & Kines, 2002, Beanland et al, 2013).

It builds upon the findings of a longstanding research activity carried out at IRES to support regional road safety policy in Piedmont (Boero et al, 2010, Grieco et al. 2014, Landini, Occelli, & Scalzotto, 2017). It showed that road accidents differ

considerably across the sub-regional areas. Not only are accident counts and severity different for urban and rural roads, but they also vary across municipalities. These findings gave ground to the questions addressed in this study:

- How and to what extent road accidents taking place in an area are associated with the settlement features and socioeconomic characteristics of the area?
- Is it possible to identify territorial-based profiles, in order to better qualify sub-regional areas according to road accidents?

To tackle these issues, an approach is suggested to integrate GIS methods with existing regional databases accounting for road accident determinants at the fine-grained spatial level. To identify territorial accident profiles, a Cluster Analysis is then carried out at the municipality level which exploits the information in the integrated database. Finally, to show its analytic potential, the individual road segments and their accident situations are examined.

METHODOLOGY

To investigate the territorial variety of road safety in Piedmont, the working method involved two steps:

- **Step 1:** Building an integrated information base by means of relational DB and GIS tools
- **Step 2:** Defining territorial types through a cluster analysis algorithm,

The analysis considered road accidents that occurred in the Piedmont region between 2013 and-2016.

Building the Information Base

A crucial prerequisite is the availability of an exhaustive information basis containing data about:

- Infrastructure and traffic (e.g. traffic counts, speed, road functional level and geometric characteristics)
- Settlement (e.g. population density, built environment and land use)
- Accidents (e.g. crash distribution by intersection types, number of casualties by road users).

Table 1. The databases for the territorial analysis of road safety in Piedmont

Database	Focus	Main Information Contents	Spatial Elementary Unit	Source
DbAccidents	Accidents	Location, circumstances, vehicles and casualties	Spatial Coordinates	Regional (CSI – Twister)
DbCensus	Settlement	Population and employees, building types, built surface	Census tract	National (ISTAT)
DbRoadNetwork	Traffic	Length, traffic flows, speed, capacity, municipality	Road segment	Regional (5T - CSI)
DbMunicipalities	Mixed	Group of DBs providing diverse information at municipal level on, e.g., mobility, land use, budget, public transport, etc.	Administrative Units	Local/ Regional/ National

To build this information basis required two main tasks: 1) identifying the information sources and processing their data and 2) choosing the relevant information in each database and merging them.

Data Gathering and Processing

Four main institutional information sources have been identified at local, regional and national levels. Table 1 gives an overview of their contents and spatial granularity.

A necessary preliminary operation was to complete the DbRoadNetwork. In the original dataset, only one road segment out of five (108,205 of 484,494), had information about traffic flow and speed. To assign traffic flow value to all road segments an estimation procedure was devised, which tries to best exploit all the available data. It is based on the following assignment rules:

- *Rule 1* = segments belong to a road R_i that has at least one segment with traffic flow values. These values (or the average, in case of more than one edge valorized) are assigned to all the Ei_{R_i} edges belonging to a road R_i .
- *Rule 2 (if rule 1 is not applicable)* = segments belong to a road R_i of type TR_i in the municipality M_i for which flow data exist. The Ei_{R_i} segments associated with R_i are given the average traffic flow value for TR_i in M_i .
- *Rule 3 (if rules 1 and 2 are not applicable)* = The Ei_{R_i} are given the average traffic flow value computed at the regional level for the road type TR_i given the territorial features that characterize municipality M_i (land use, density, altimetry).

Merging Data by GIS Tools

Beside its conceptual strength, the territorial perspective has the practical advantage to enhance the possibility of data integration. Applications of GIS methods permit to greatly improve the possibility of information sharing across databases. In conventional applications of relational databases, a common information key, usually the record identifier, is defined for all the datasets to be merged. This was the case in a previous study on the spatial distribution of accidents in the Piedmont region (Landini, Occelli & Scalzotto, 2018), where the common information key was obtained by merging road and municipality codes

For the databases considered in this study such a key could not be created and specific GIS functions were used, as all the databases listed in table 1 are georeferenced.

Through GIS tools, each accident (DbAccidents) is assigned to a specific road segment (DbRoadNetwork) and to a specific census tract (DbCensus). After the merging, appropriate links to the information stored in the DbMunicipalities were also created.

Two GIS geoprocessing methods have been used in the merging procedure¹:

- *Intersection* to merge DbAccidents with Db Census.

Function *intersection* merges two layers by their geographical overlapping: the input layer (DbAccidents) and the intersection layer (DbCensus). The result is a new layer (DbAccidentsXCensus) which contains all the information already stored into DbAccidents and, for each record (accident), all the attributes of the census tract, where it occurred, as described by in the DbCensus.

- *Minimum distance* to merge DbAccidents and DbRoadNetwork

Since the layers in these two databases don't overlap, it was necessary to compute the minimum distance between the points (representing the record of DbAccidents) and the lines (representing segments *s* of DbRoadNetwork)² in order to assign accidents to the segments. Given two existing layers (*origin*, DbAccidents, and *destination*, DbRoadNetworks) the result of the *minimum distance* function is a new layer, AccidentsXRoadNetworks. This new layer is linked to a database with all the information of DbAccidents and, for each accidents, two additional information: the ID of the nearest road segment and the distance between the two elements. As the application of the *minimum distance* function performs much better between two layers of points rather than between a layer of points and a layer of lines, a transformation of the destination layer was carried out. This required huge

computational resources and resulted in the conversion of the 484,494 lines linked to the DbRoadNetwork in 15 million points.

The result of the data-linkage is the Road Safety Data Base (RSDB). Conceived as a scalable knowledge base, RSDB is expected to be further refined in the future, by integrating more detailed data about accidents, settlements and traffic, and additional information about road accidents phenomenon (e.g. work zones, maintenance actions, peak hour flows, transit services, road projects, return on investments, etc.).

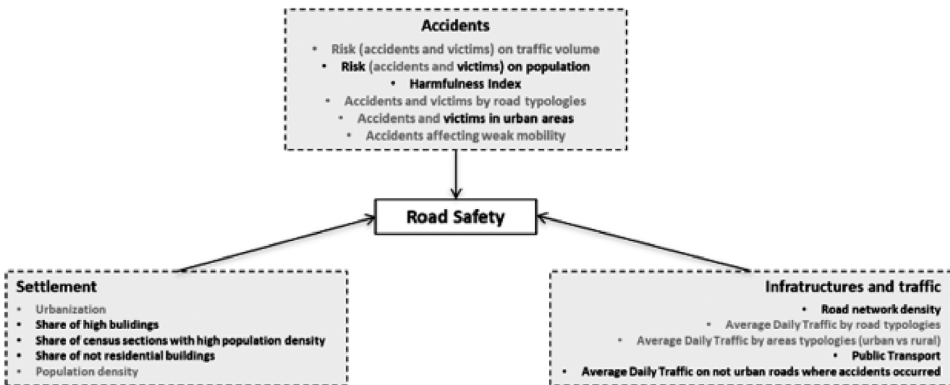
Defining Territorial Types

The RSDB is used to identify road safety territorial types, i.e. groups of geographical areas in the region that are similar with respect to road accidents phenomenon. In the study, these areas are the 1202 municipalities of Piedmont region and the similarity is defined on the basis of information about infrastructure, traffic, settlement and accidents.

Types have been defined by applying a k-means Cluster Analysis (CA) algorithm. Cluster Analysis is a statistical technique which groups individual elements on the basis of the similarities of a number of features selected by the researcher. In road safety studies, cluster analysis has been used to identify the *blackspots* of an infrastructure network, i.e. the most critical points in terms of accidents (Anderson 2009, Ng et al 2002). The present study aims to identify accident territorial types considering a wider set of variables than those about accidents.

Figure 1 shows the list of variables considered in the CA application, distinguishing those used for feeding the algorithm (*clustering variables*, in black) and the variables used to describe the similarities within and the differences among the groups (*descriptive variables*, in grey).

Figure 1. Cluster Analysis: clustering (black) and descriptive (grey) variables



All the variables refer to the municipal level and resulted from the aggregation of the individual data stored in RSDB. Table 2 presents the *clustering variables* in more detail.

RESULTS

The analysis provided meaningful insights aimed at qualifying the distribution and the intensity of road accidents in Piedmont by taking into account territorial factors that may influence their occurrence.

The following sections present the main results in detail. First, the road accidents territorial profiles that resulted from the clustering algorithm are described, i.e. the type of municipalities grouped according the selected variables .

Second, a use case for the exploitation of the RSDB is presented. Beyond the objective of this study, RSDB has a great potential for investigating individual road segments and assessing their accident situations, depending on the accident profiles, traffic conditions and spatial characteristics of the area. .

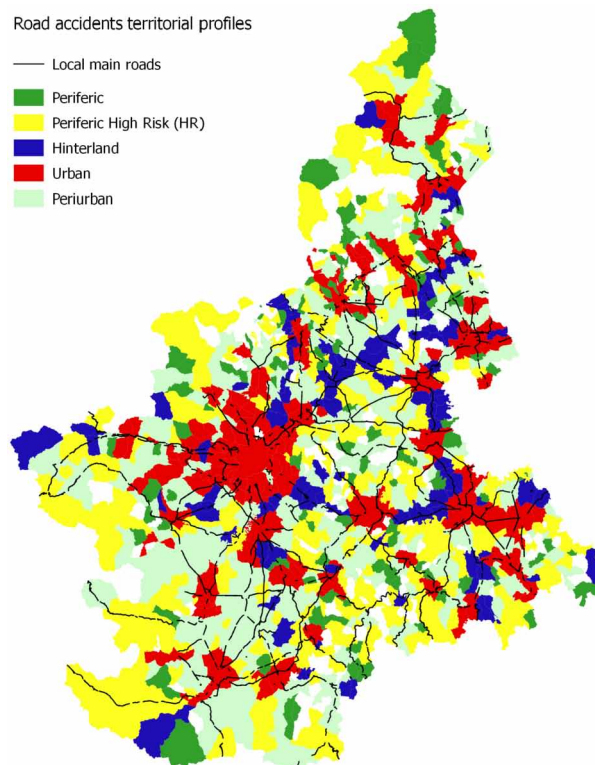
Road Accident Territorial Profiles

Five territorial profiles (clusters) have been identified. Their spatial distribution in the region (Figure 2) gives ground to the expected relationship between accident occurrence and the urban spatial pattern in the region.. In the figure, each cluster overlaps an area characterized by a specific land use typology ranging from the

Table 2. Clustering variables: dimension and detail

Dimension	Variable	Indicator
Accidents	Accident risk ³	n of casualties / population
	Severity level	n of casualties / n of accidents
	Casualties in urban areas	n of casualties in urban areas / total casualties
Infrastructures and Traffic	Road network density	roads length / municipality surface
	Traffic volume ⁴ on extra-urban roads where accidents occurred	% of total traffic volume
	Public transport	n of trips by PT/ total trips
Settlement	Share of not residential buildings	n of non-residential buildings /total buildings
	Share of high buildings	n of buildings with (above 3 floors) / total buildings
	Share of census tracts with high population density	high density tracts (>1500/ km2) /total tracts

Figure 2. Road Accidents territorial profiles: spatial distribution in Piedmont region



most populated to the less urbanized mountainous and hilly areas. The names of the clusters reflect this distribution.

When looking at the distribution of accidents and casualties (deaths + injured), tab 3, the *Urban type*, distinguishes the most critical situations. Even if the number of municipalities in this group is small (15% of total municipalities), they concentrate almost 80% of total number of accidents and above 50% of the fatalities.

The *Peri-urban* type shows some criticalities, in particular for the gravity of the accidents: they account for 25% of the total fatalities, while having only 12% of accidents. A similar, but relatively more critical profile, is revealed by the *Periphery High Risk type*: this is the largest cluster with more than 30% of municipalities. While accounting for less than 5% of total number of accidents, the number of deaths are almost 15% of the regional total s. The *Periphery* and *Hinterland types*, include 11% of municipalities; they are less critical areas with the lowest share of accidents and casualties.

To sharpen the description of these profiles, table 4 presents some additional variables selected from those listed in figure 1.

Table 3. Distribution of municipalities, accidents and casualties by road accident territorial profiles

	Municipalities		Accidents		Casualties		Fatalities	
	N	%	N	%	N	%	N	%
Periphery	112	11,1	583	1,4	851	1,4	16	2,1
Periphery HR	320	31,8	1792	4,4	2900	4,9	109	14,1
Hinterland	112	11,1	1342	3,3	1973	3,4	60	7,8
Urban	158	15,7	31780	78,5	45481	77,3	397	51,3
Peri-urban	305	30,3	4975	12,3	7613	12,9	192	24,8
Total	1007	100,0	40472	100,0	58818	100,0	774	100,0

Urban type accounts for the most populated municipalities where traffic volume is highest and urbanization pattern densest. Although they concentrate the greatest number of accidents,, casualties and fatalities, the accident risk with respect to the traffic volume is low. Vulnerable road users (cyclists and pedestrians) are a significant share of the total number of injured people. Rather unexpectedly the share of people using public transit is lower than the regional average.

Peri-urban municipalities are located in proximity to the major regional cities. Their settlement and infrastructure profiles are similar to the regional ones, the accident risk is higher, particularly in urban areas.

Municipalities belonging to the *Periphery High Risk* type have a low population density. They are well infrastructured but the values of the risk and harmfulness indicators are above the regional average. Traffic, accidents and casualties mainly concentrate in extra-urban areas.

Municipalities in the *Periphery* type are located in areas far away from the main regional cities or in between less urbanized areas. High values of accident risk (on population) and harmfulness are observed only the roads with accidents. The accidents occur mainly in urban areas and the share of pedestrians and cyclists involved is relevant.

Finally, the *Hinterland* type includes municipalities situated above all along the main regional transport axes. Coherently traffic speed is higher than in other groups.

A Case Use for RSDB: Analyzing Critical Road Segments

Designing and building the RSDB has been an effort whose relevance goes beyond the aim of this study, i.e. the definition of the road accidents territorial profiles described above.

A Territorial Dimension Can Be Useful for Managing Long-Term Regional Road Safety

Table 4. Insights into the road accidents territorial profiles: clustering (C) and descriptive variables

		Road Accident Territorial Profiles					
		Periphery	Periphery HR	Hinterland	Urban	Peri-Urban	Total
Accidents profile							
% Casualties in urban areas (C)		93,1	6,7	37,1	73,5	45,6	42,0
Accident risk on population (C)		1,5	2,9	2,2	2,5	2,6	2,5
Severity level (C)		1,4	1,6	1,5	1,4	1,5	1,5
N of accidents / traffic volume (total)		0,11	0,11	0,09	0,20	0,13	0,13
N of Accidents / traffic volume (roads with accidents)		11,1	4,5	3,2	1,7	2,4	3,8
N of Accidents/traffic volume (urban areas)		11,32	4,43	3,96	2,55	5,33	5,12
N of Casualties / traffic volume (total)		0,16	0,18	0,13	0,28	0,20	0,19
N of Casualties / traffic volume (roads with accidents)		14,4	7,5	4,7	2,3	3,3	5,5
N of Casualties/traffic volume (urban areas)		14,91	5,22	4,73	3,55	8,26	6,85
Share of injured cyclists and pedestrians (% on total accidents)		19,1	6,6	9,8	16,9	10,7	11,1
Settlement profile							
Share of high buildings(C)		0,66	0,51	0,38	0,76	0,54	0,56
Share of non-residential buildings (C)		8,1	7,1	8,5	11,3	8,7	8,5
Share of census sections with high population density (C)		16,6	16,0	24,2	55,1	22,3	25,0
Infrastructure and traffic profile							
Road Network density (C)		3,2	2,9	3,3	5,0	3,5	3,5
Public transport (C)		15,0	15,1	13,6	12,5	13,7	14,1
Average speed (all roads) (C)		45,2	49,4	51,4	48,3	50,5	49,3
Average speed (km/h) roads with accidents)		46,7	58,8	59,0	53,9	58,0	56,1
Traffic volume on non-urban roads where accidents occurred (C)		9,3	96,6	70,0	44,2	71,1	68,0
Traffic volume (% on total)	Municipal roads	15,5	5,9	9,5	23,5	8,6	10,9
	Local roads	79,2	85,5	84,5	65,1	78,9	79,5
	Natioanl roads	5,2	8,2	5,3	11,0	12,1	9,1
	Urban roads	90,7	2,9	29,2	55,5	28,5	31,6
	Extra-urban roads	9,3	96,6	70,0	44,2	71,1	68,0
	Total	100*					

(*) The values do not sum exactly to 100 because the modality 'other roads' is not shown in the table.

As it was built on the basis of datasets containing individual information on accidents, segments and census sections,

Use of RSDB can help investigate road accidents at a low spatial level and better target road *interventions*.

In the following RSDB is used to identify the most *critical segments* of the road network. Here critical means that on that segment accidents are more frequent and have the worst consequences in terms of injuries. These road segments, therefore, should have a priority attention by decision makers.

We consider the number of accidents which occurred *on each road segment* in the between 2013-2016. Two types of situations can be preliminary distinguished: *high and low critical situations*, depending on whether the number of accidents per year is at least 1 or less .

The following questions guide the analysis:

1. *How many road segments are highly critical?*
2. *Where are they located?*
3. *How do they differ from the rest of the segments where accidents occurred with respect to the three dimensions of analysis?*

Table 5 answers the first question. It shows that whereas these segments account for less than 3% of the total number of road segments, they concentrate more than 12% of accidents and casualties and around 8% of the total fatalities. By considering the distribution among the territorial profiles, table 5 also confirms that th *urban* municipalities are more critical.

Table 5. Number of high critical road segments and shares on the respective totals by territorial profiles

Types	Number of Road Segments	Shares on the Respective Regional Totals			
		Road Segments With Accidents	ACCIDENTS	Casualties	Fatalities
Periphery	5	1,0	4,8	5,7	0
Periphery HR	13	0,9	4,7	4,7	4,4
Hinterland	3	0,3	1,2	1,3	0
Urban	695	3,5	14,4	15,3	12,3
Peri-urban	23	0,6	2,8	2,9	3,7
Total	739	2,8	12	12,6	7,9

Figure 3 and 4 answer the second question concerning the location of the critical segments. As expected, critical segments concentrate in urban areas and close to the main nodes of the road regional network (figure 3).

Besides this regional perspective, the RSDB, and specifically The connection between DbRoadNetwork and DbAccidents, allows us to zoom in the situation at the municipal level. For example, figure 4, presents the results for the city of Biella,

Figure 3. Road segments with accidents in the period between 2013-2016

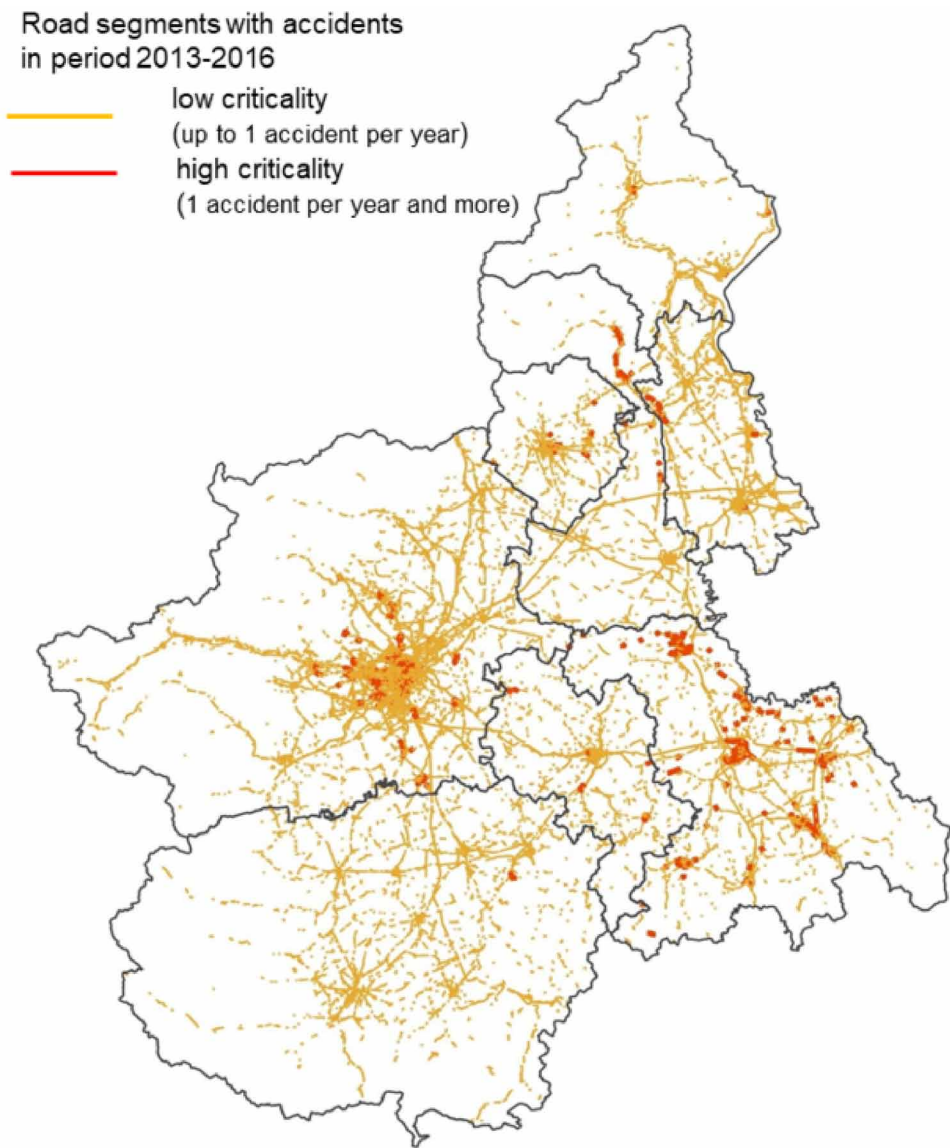
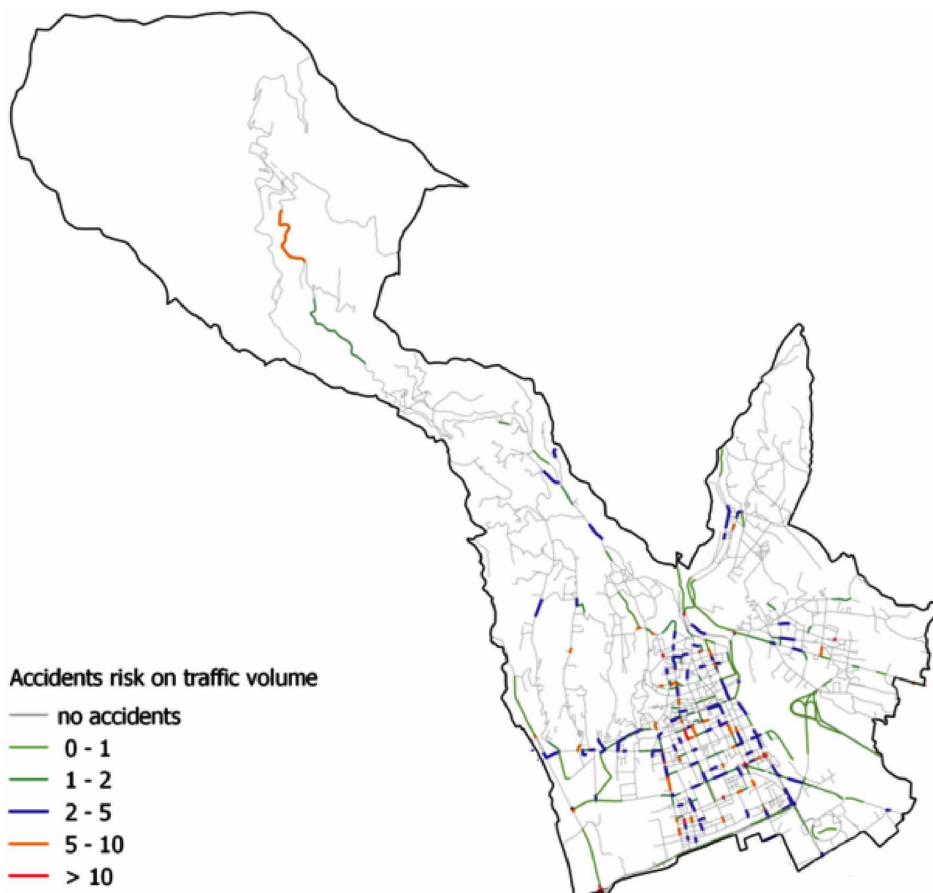


Figure 4. Accident risk on road segments for the city of Biella



a province chief-town. The figure reveals that the majority of critical road segments with high accident risk are in the urban area, even if a specific risky segment is located in the countryside.

Finally, table 6 highlights the differences between high and low *critical segments* by considering a subset of the variables in the RSDB.

Critical segments have a higher volume of traffic with vehicles driving at higher average speed. They cross dense urbanized areas with a relatively higher share of both non-residential buildings (industrial areas) and high residential buildings (blocks). Distribution of accidents and casualties by circumstances is similar between the low and high *critical segments*. However, *critical segments* also show a relatively higher share of accidents due to frontal-side crash and collision.

Table 6. Differences between high and low critical segments along the three dimensions of analysis

		Road Segments With Accidents			
		Low Criticality Less Than 1 Accident/ Year		High Criticality More Than 1 Accident /Year	
		Accidents	Casualties	Accidents	Casualties
Accidents (% by circumstances)	Frontal crash	5,0	6,6	3,9	5,1
	Frontal-side crash	35,7	38,2	39,7	43,8
	Side crash	9,2	8,5	7,5	6,4
	Collision	15,8	18,3	19,6	21,5
	Pedestrians	14,5	11,1	13,7	10,1
	Standing vehicle or other obstacle	9,0	8,1	7,0	6,0
	Driving fails	10,8	9,2	8,5	7,1
	<i>Total</i>	<i>100,0</i>		<i>100,0</i>	
Traffic	Average Daily Traffic	6110		12294	
	Average speed	54,9		56,3	
Settlement model	Share of high buildings	11,3		18,9	
	Share of non-residential buildings	23,4		36,2	

CONCLUSION

By linking information about road accidents, infrastructure, traffic and settlement models, this study has built an integrated database for improving the accounting of the territorial context of the accident phenomena in the Piedmont region. It can be considered as a kernel of a scalable regional road safety database. Eventually it will allow analysts to identify what has been called “generic factors of accidents” (Thomas & Talbot, Eds. 2018).

A twofold possibility for exploiting this integrated database has been explored.

First is the identification of road accident profiles at the municipality level, by means of a (K-means) Cluster Analysis. Its findings help qualify the spatial distribution of accident counts and severity in the region. Eventually, they improve the evidence about road accidents in the region.

The second is the exploitation of the integrated database to refine the analysis and is done by moving down the observation level to road segments. This is expected to provide practical support to road analysts and decision makers, and for managing road safety, e.g. investigating critical situations and better designing countermeasures at a local level.

Of course, the research undertaken in this study can be refined in several ways.

On a practical ground, a strategy worth being pursued for developing a regional road-safety integrated database is to directly involve its users and investigate with them the likely most useful scenarios. This strategy can also help promoting a more shared responsibility to road safety (McAnrews, 2013).

On a methodological ground, two possibilities for refining the clustering approach should be highlighted:

- Taking into account the changes of the clustering variables over time (Kotsakos et al 2014). This would help assess the stability of the clusters over a longer period of time, and of the associated road accident risk in the regional sub-area;
- Exploring automatic techniques for classifying accident risk situations of road segments by applying a machine learning technique based on neural networks (Bleščic et al, 2018). This would help investigate more thoroughly the situations considered as most critical by analysts and identify the spots deserving from road experts' safety audits.

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ENDNOTES

- ¹ *Layers* are the specific types of geographical information and can be composed of polygons, lines or points. Descriptive data are linked with the polygons, lines or points and are stored in a linked database file (i.e. the databases listed in table X). By primarily merging layers, GIS tools also merge the linked databases.
- ² Of course, here the assumption is that the nearest edge is the one where the accident occurred.
- ³ *Accidents risk* has been computed on the basis of population and traffic volume to estimate risk of accidents and casualties (Hakkert and Braimaster 2002).
- ⁴ Traffic Volume is computed as: Number of Vehicles * road lengths (km)

Chapter 12

Defining Urban Planning Strategy Through Social Media Application

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ABSTRACT

Social networks in the public sphere support the process of innovation that aims to make the action of the municipalities more efficient and participatory. Due to their characteristics, social media seem to be able to contribute significantly to the development of e-governance and e-democracy as tools based on dialogue and on the enhancement of the contribution of users-citizens or, more generally, of users-local stakeholders. Web 4.0 and social media are progressively taking on a role of primary importance in the contemporary socio-economic context, contributing to change not only the processes and methods of communication of individuals, citizens and businesses, but also the organization and business management itself. In the new dimension of the Web 4.0 the user's behavior is not predetermined, but the user can derive and autonomously build the services, as the web is decentralized and enriched by the experiences of the users who participate in the definition and improvement of content.

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INTRODUCTION

During the XX century, several authors gave them contribute to the study of urban planning management and of citizen's behavior pointing out different key points for a theoretical definition (Goulding, 2003; Gruen et al., 2007). In particular, it was highlighted that the behavior includes not only the use of the area but also its fruition and exploitation (Bertot et al., 2012). It referred not only to the green urban area itself, but also to the services, ideas, events and all the other entities that may be fruition, and used in a way that may potentially generate value, satisfaction and reach the target (Fritz et al., 2004). During the years, theory has become more and more complex and diversified, developing different trends and approaches. Seen the great number and variety of international approaches (Baskerville & Dulipovici, 2006; Brown et al., 2007) concerning citizens' behavior in the process of urban areas utilization, it was decided to follow the postmodern trend (Waters et al., 2009), that manages to catch the specific aspects of the society (Sturiale & Scuderi, 2011) of the new millennium (Garrigos-Simon et al., 2012). This approach also pointed out the reasons that have made consumers refer more and more to new information and communication technologies, ICTs, web and social networks. In particular, this study has approached deeply the purchasing attitudes and behaviors of citizens of metropolitan area of Catania, focusing on the influence of social networks on the decisions of green areas fruition. Such information has turned to be interesting for policy and management of city to develop suitable strategies of social media marketing, aiming at a better citizen interaction, which means higher satisfaction for the citizens (Gronlund, 2009). The exploratory research on which the article is based aims at evaluating the effect of the message and of online and off-line communications in order to evaluate the reactions by citizens of management policies.

PLANNING OF URBAN GREEN AREAS

In the urban project, nature has almost always been introduced with decorative purposes, often underestimating the beneficial effects it has on the city and its inhabitants. In recent years the social, economic and climatic scenario, in urban environments, has strengthened the importance of the green component, especially of social place available to contributing for health quality (Scuderi et al., 2017). The advantages the urban green contributes to debate and original design choices, in the scientific and technical fields, as well as in the public opinion using both traditional and innovative channels offered by social media.

The theme of the renaturalization of the city, through initiatives of structural integration of the green with the built environment, well-established practice, in the

countries of Northern Europe, represents in Italy one of the new frontiers of urban and territorial planning. Although, for some years, interesting indications are present in the building regulations of the cities most sensitive to environmental issues, in Italy the regulatory apparatus and the forms of financing and public facilitation that have allowed countries such as Germany, the rapid diffusion of the use of hanging green.

Green must be able to recognize functions that meet real needs and insert it as a priority element in the city's investment plans. In fact, if the Gray Infrastructures (roads, railways and bridges) constitute the built capital of our cities and are necessary for the economic development of a territory, the Green Infrastructures (parks, rivers, trees and meadows) represent its natural capital and are necessary to ensure environmental sustainability. Ensuring that the two types of infrastructure work properly ensures healthy and sustainable urban environments, as both play a vital role in maintaining the quality of life in our cities. Moreover, in the case of the compact city, where the urban form is now largely established and difficult to create significant green spaces, the Green Infrastructure represents a creative approach to the problem. Road shafts, green building along the railway lines, roofs and green facades, are configured as easy-to-implement solutions and suitable for creating links with the nearest green spaces. The need to change the current trend in the construction of municipal urban planning tools, which rarely include actions aimed at combating the effects of climate change and developing new tools suitable for introducing the climate into the process of forming the plan, are translated, translating these information and results, in climate guides, addressed to politicians and urban planners.

"Green Infrastructure", appears frequently in the debate related to the themes of the environment, the landscape and sustainable urban development. Its role and importance in the management of environmental resources are concepts, now acquired internationally. Coined in America, by Edward T. McMahon, former vice-president of the Conservation Fund, the term was used in a May 1999 report, "Towards a sustainable America: promoting prosperity: opportunities and healthy environment for the 21st century" "by the President of the Council for Sustainable Development. In the report, the Council describes the Green Infrastructure as:" An interconnected network of protected land and water that supports native species, supports natural, ecological processes, supports the air and water resources and contributes to health and quality of life for American communities and people "

McMahon and Benedict defined the practices and principles of Green Infrastructure, in the book "Green Infrastructure: Linking Landscapes and Communities", describing it as "An interconnected network of green spaces that preserves the natural values and functions of ecosystems and provides multiple benefits to the human population "and also emphasize the difference between traditional conservation practices

and the need to change popular perception, in relation to green spaces and their conservation and protection”.

While the term is relatively new, the concept, however, dates back to the beginning of the last century and is attributable to Frederick Law Olmsted, founder of the American landscape school and convinced assertor of the benefits that parks systems and green areas, connected to each other are able to offer, compared to isolated green areas; an example is the “Emerald Necklace” in Boston. It is believed that the drawings of the parks and the thinking of Olmsted and Howard were fundamental for the elaboration of the idea that led to the development of the Green Infrastructure (Davies et al., 2007) and while the idea of combining the ecological aspect to the social opportunities of a territory have been attributed to the landscape planning, the work of Olmsted and Howard was an anticipator in the exploration of this relationship. In fact, many researchers believe Olmsted’s work in New York and Boston is among the first examples of promoting the integration of form and function that leads to the multifunctionality of the landscape (Little, 1990; Fabos, 2004; Williamson, 2003). These, today, are considered the fundamental themes in the thinking of the Green Infrastructure. In the United Kingdom, the work of Howard and Olmsted is also attributed to the ability to suggest the planning of green spaces near residential areas, in order to improve the physical and psychological health of the local population (Howard, 1985).

Howard tends to control the spread of urban form in cities to avoid the continuous urbanization of rural territory, promoting the creation and maintenance of spaces that offer a constant diffusion of green infrastructures and services to support the communities that live there. Thus lowering the continued urban expansion and discouraging the conversion of the green belt territories into housing or industries. Howard’s ideals show a series of similarities with the current values attributed to the themes of “Smart Growth”. The garden city of Howard has promoted the use of building and sustainable transport systems that are all strongly taken up and promoted in the “Smart Growth” literature that is very widespread in the United States.

The Green Infrastructure applies the same concept of connection to trees and the natural system that must be connected in order to function and provide greater benefits.

The “nodal sites” (sites), the “vast areas” (hubs) and the “corridors” (links) are the constituent components of the infrastructural network, which embraces a wide variety of natural ecosystems and characteristic landscapes.

Hubs, are vast portions of territory that serve as anchor of the network. They are reserves, national parks, forests, private farms, regional parks, and local parks and other sites at the local level where natural features and ecological processes are protected or recovered.

Links are the connections that hold the system together and allow the Green Infrastructure network to function. They differ in size, function and properties and include: large protected areas that connect existing parks, rivers and waterways. Greenways, greenbelt and natural conservation corridors

Sites are similar to hubs, but they are much smaller and localized. They include local parks and arboretums. While the Americans are focusing on large structures, consisting of large nodal areas and large connecting corridors, leaving out the smallest components and therefore the green network inside the city, the English approach pays attention to even the most modest urban green areas. In England, the Green Infrastructure is one of the emerging themes of the debate that sees the environment and the landscape as protagonists. At the moment there is no univocal and shared definition. However, there are documents and proposals that can be used to draw a Green Infrastructure profile.

The United States Environmental Protection Agency (2009) describes Green Infrastructure as a wide range of products, technologies and practices that use natural systems or engineered systems that mimic natural processes to improve overall environmental quality and provide utility services. As a general principle, green infrastructure techniques use soil and vegetation through infiltration, evapo transpiration, and rainwater runoff.

The experiences under way, already for some years, although differentiated in the conceptual and operational strategies show to recognize that the Green Infrastructure must be considered fundamental component of the network of the cities requiring the identification within the urban plans, from the territorial to the municipal, with specific functions and contents when the scale of intervention changes

The role of Green Infrastructures in mitigation strategies includes:

- Absorption and storage of CO₂ in the soil and in the vegetation;
- Supply of sustainable transport corridors;
- Supply of local food production to reduce “food miles”;
- High temperature management;
- Management of tourist pressure.

E-GOVERNMENT AND WEB 4.0 CITIZENS: A NEW SOCIAL INTERACTION

The target of this work is to understand the evolution of citizen behavior, in order to perceive the new attitudes that have evolved in the new context, especially with the advent of internet and the new communication modalities among citizen and between citizen and municipality, which in the last few years have started social

networks. And, it aimed at defining the bases of such changes not only concerning citizens but also municipality that have been offering new activities to meet the new citizen demand (Goulding, 2003; Gruen et al., 2007), and have to join the new virtual contexts (Arnone et al., 2009). Starting from the analysis of citizen behavior, we noted an active debate within the different subjects here involved concerning different theoretical approaches. Web 4.0 and social media are progressively taking on a role of primary importance in the contemporary socio-economic context, contributing to change not only the processes and methods of communication of individuals, citizens and businesses, but also the organization and business management itself. Social media is at the heart of the Web 4.0 and consists of means of communication oriented to social interaction. The Italian cities, in recent years, have begun to enter the Web 4.0 environment, understanding its potential, using it for the story of their products and themselves, for the selection of staff or for the management and sharing of knowledge and information (Smith & Kidder 2010; Sturiale & Trovato, 2016). The decision of the citizens to invest in social media is therefore transforming the way of constructing one's own image, of managing communication with the outside world and partly implying changes in the internal management of institutions. In the new dimension of the Web 4.0 the user's behavior is not predetermined, but the user can derive and autonomously build the services, as the web is decentralized and enriched by the experiences of the users who participate in the definition and improvement of content. Social media initially are web 2.0 based communication tools that allow the creation and exchange of user-generated content, the so-called user generated content (Klijn & Koppenjan 2000; Kaplan & Haenlein, 2010). These tools are stimulating because they allow you to easily share information and materials and receive real-time comments and suggestions on what is shared. Among these Facebook, coherently with what happens in the rest of the world, is the most widespread social network in Italy, the other most popular social networks in Italy are LinkedIn, Twitter with about active users. In the public sphere, social networks in particular can support that process of innovation which, also through the use of new technologies, aims to make the action of the Municipalities more effective, efficient and participatory (Pollitt et al., 2007). Due to their characteristics, social media seem to be able to contribute significantly to the development of e-Governance and e-Democracy, as tools for defining are based on dialogue and on the enhancement of the contribution of users-citizens or, more generally, of users-local stakeholders (Raghavan, 2002; Kluemper & Rosen, 2009). These tools offer considerable opportunities in terms of involvement of citizenship, and today, however, they are able to reach a significant part of the population. in Italy the number of internet users has grown considerably in recent years, reaching 73.2% of the population. However, the digital divide still remains significant because, as the Report indicates, 92.2% of young people (14-29 years old) against 19.3% of the elderly (65-80 years) and the 76.1% of the most educated

against 34.2% of those less educated. In recent years, municipal administrations have been the subject of a vast reform and modernization movement, largely inspired by New Public Management (Ferlie et al., 1996), Public Governance, which emphasizes the systemic dimension and governance of the administrations, and to the Network Management, which highlights the importance of the network organization in the effective management of the public sector (O'Neill, 2009). Even if the results of the reforms inspired by New Public Management change from specific country, we can identify some regularities and common elements among which stand out besides the adoption of principles and tools typical of private management, orientation to the citizen-user, the devolution of authority at the local level, the empowerment of public employees and, above all, of the citizens, the propensity to adopt the new information and communication technologies (ICT - Information and Communication Technology) to the end of modernizing, reforming, improving internal organization, offering more effective and efficient services, encouraging the direct involvement of citizens and other recipients of public administration services, as well as other relevant actors in a territory (OECD). The new technologies were then adopted with the aim of improving both the internal and external performance of the public sector, the quality of services, and the trust and collaboration with the administrations, both in the communication and involvement of the citizen and other local stakeholders (Torres et al., 2006). Literature and practice agree that new technologies can play an enabler role in carrying out processes of change in the public sector (Bertot et al., 2012). However, change in the public sector does not appear to be totally "technology driven", but can be influenced by other factors both endogenous, such as people and their skills, available resources, climate and organizational culture; exogenous, like the socio-economic conjuncture, the current regulatory system, the choices made within the public system (Kickert et al., 1997). Intensive use of ICT in the performance of political and public administration functions to improve both the management of information and the effectiveness, efficiency and economy of the administration and public services offered to citizens and other stakeholders, to deny information and services, to transform administrations and to achieve better public governance is generally referred to as e-Government. E-Government can also be defined as the result of the interaction between new technologies, the public sector and individuals using the technologies themselves. This is a complex phenomenon for which it is therefore difficult to offer a univocal and exhaustive definition, as it usually involves both technical, managerial, relational and institutional changes. In the logic of e-Government, the adoption of new technologies, however, requires a real revolution in the way of working within administrations, as it requires the use of tools, procedures and skills that were previously non-existent or poorly valued.

The interactions with the stakeholders of interest identified in the matrix of Hiller and Bélanger are therefore those: with the other PAs (G2G government to

government); with its employees (G2E - government to employee); with citizens, seen both as voters (G2IP - government to individual political), and as recipients of services and information (G2C - government to consumer); with companies, both as recipients of public services and information (G2B - government to business), and as suppliers of goods and services to the Public Administration (G2BMKT - government to business market) (Hiller and Bélanger, 2001).

According to many authors (Snellen & Van de Donk, 1998; Hiller & Bélanger, 2001), there are three roles that ICT can assume in e-Government: assisting the economy and efficiency of administrative activities, supporting the provision of public services and supporting democracy. From this point of view however, e-Government has sometimes created more the illusion of a new approach to public sector government than a real change, because, despite the introduction of new technologies, political, legal and constitutive structures, as well as government relations, have often remained unaltered. The formula of change is often consisted, therefore, in doing things differently, rather than doing different things. In particular, the e-Government matrix considers these two dimensions: the level of sophistication in the adoption of ICT for the provision of online services; and the type of stakeholders we turn to, we offer services and interactions are made. Crossing these two dimensions, the model identifies five stages in the process of adopting new technologies: (1) information (mono-directional from Public Administration to its stakeholders); (2) two-way communication; (3) transaction; (4) integration; (5) political participation. Going from one stage to the next, we tend to use more and more technologies and progressively more complex and moreover we are going to involve more users, be they citizens, businesses, public employees or other public administrations.

METHODOLOGY AND RESULTS

The analysis carried out in Catania metropolitan cities aimed at investigating the interaction among web consumers, measuring citizens' intention to tell others about their experience concerning a five green areas of urban planning, and the intention to use (Jang, et al., 2008; Lipsman et al., 2012; Kickert et al., 1997). In particular, in order to highlight the activity of citizen as source of messages that integrate or replace the emitting cities, it is important to differentiate the intention (Persaud et al., 2012) to talk about a personal experience with friends or other persons known, in a traditional offline environment, or with unknown people in virtual communities (Kozinets, 2002). Besides, it was this study intention to verify how such will may vary according to the opinion of citizens to be referred to others, whether it was positive, negative or ordinary.

By means of an ad-hoc 5 questions, 1.000 followers with Social Media.

The research adopted a quantitative methodology (Goulding, 2003) through the experiment and the adoption of an inductive method, the systematic analysis, which experimented the phenomena under study including organization and interpretation (Heinon, 2011; Gatautis et al., 2012).

Such relation between one or more independent variables ($x_1, x_2, \dots, x_n$) and one dependent variable (y) was random and the scientific method did only disturb without proving it. The limits of it, in fact, were the long time to obtain the requested results, the high costs to pay out the control units, and finally the complex management that led to results.

Questions were randomized in a experimental design aiming at building up the questionnaire as much realistic as possible, showing simple scenarios and adopting widely used green area, both by frequent and non-frequent citizens, including them in a daily context of the style of interviewees.

The supply side was given three scenarios characterized by three experiences: positive, negative, neutral, for 5 green areas of Catania.

Each interviewee answered to questions for green area, while the value of the experience was randomized. On the demand side each interviewee answered to one question and the experimental design was built by crossing the three value conditions of the online experience, with the three offline ones (awful/ok/great) for one area. In order to understand the very efficacy of the experiment, as far as the demand is concerned, the “treated” interviewees, that is, those who were given questions with different randomized opinions, were studied together with a control group of “untreated” ones, who were asked to tell their opinion about use green area without receiving any comments or suggestions from other citizens. The questionnaire aimed at evaluating from one side the will of people to tell others of the experience: to a friend for traditional purchasing or writing a online comment. It was then asked 65% of interviewees to indicate the level of probability, from 0 to 100%, to tell others about their experience concerning a product by telling a friend, while the other 35% by online posting. Randomized statements were given for the supply side, deriving from the union of the three values, positive, negative, neutral, and for the 5 green infrastructures area of category (Green Belt, Green Corridor, Green Network, Green Patch, Green Matrix); 10 randomized statements were given to the demand side by joining the 3 level of values for green area from the offline environment (awful/ok/great) and from the online one, and one case where the interviewee did not received any kind of opinion .

This study utilized the statistics R package, to implement data analysis and verify the hypotheses. Estimation of parameters was carried out by minimizing the distances between data included in the model and those observed. Functions of estimation were different, LM, linear mode was used to study the relation between a dependent variable (y) and a series of independent ones ($x_1, x_2, \dots, x_n$), in order to understand

the impact of such variables on the subject under examination. Concerning the “supply side” the dependent variable y was the probability to tell others about a personal experience concerning a green area, both to friends of an offline context, and to online communities.

It was possible then to explore about the existence or not of a relation among the variables observed as well as the strength of the relation among the dimensions, that is, its statistics significance.

This study also allowed to understand the capacity of this model to represent the phenomenon under examination as much realistic as possible, by reading the coefficients of the independent variables, that is, the variation of the dependent variable according to the varying of the independent ones.

This model highlighted the logic scheme of variables that were related with the dependent variable USE –WOM prob, that is, the probability of telling others about the personal experience of the purchase. USE-WOM prob was function of a series of independent variables, such as, GREEN AREA CATEGORY in other words, the category of products that in this case were five, the experience value, POS (positive), NEG (negative), MED (neutral).

Here after is the base model with all the variables analyzed:

$$\text{SOCIAL prob}_i = \beta_0 + \beta_1 \text{AREA} + \beta_2 \text{POS} + \beta_3 \text{NEG} + \beta_4 \text{MED} + \beta_5 \text{GENDER} + \beta_6 \text{POST}_i + \beta_7 \text{WHY}_i + \beta_8 \text{AGE}_i + \beta_9 \text{EDU} + \beta_{10} \text{PERS.f} + \epsilon_t$$

where “SOCIAL prob_i” is the probability to report others about the experience of purchase, where i stands for individuals, while AREA stands for the typology of urban green area, POS for the positive experience, NEG for the negative experience, MED for the neutral experience, GENDER for the sex, POST for the online posting activity by interviewees, WHY for the motivation of the online posting activity, AGE for the age, EDU for the education, and pers.f the variable that collected the individual characteristics of each interviewee, and finally ϵ_t is the error of prediction/residue.

Models of linear regression were elaborated are 10 for the “Demand side”. As far as the main results of the supply side are concerned, they are summarized in tables 1 and 2.

In the second column of below tables are the coefficients of the different variables chosen to verify a possible influence of the same on the dependent variable, or the will to tell others about the personal experience of purchase, that measured in percentage terms varies from 0 to 100 percent. Such links were detected for the sample’s will to spread the experience of purchase in the community (off-line) (table 1) and online (table 2).

Table 1. Estimated structural parameters for the sample concerning the will to spread tradition ally WOM for green infrastructure (offline)

	Estimate	Std. Error	t value	Pr (> t)
(Intercept)	82.5897	5.5812	6.358	0,008743
med	-11.2378	5.2897	-4.121	0,028914
pos	17.6912	1.6987	5.258	0,018974
Green Belt	17.3598	2.2391	1.358	0,009578
Green Corridor	12.7715	2.6347	3.981	0,005178
Green Network	13.1289	2.2251	2.225	0,005987
Green Patch	11.9864	3.3318	3.912	0,000927
Green Matrix	11.2597	2.1581	3.128	0,000602

Table 2. Estimated structural parameters for sample concerning the will to eWOM for green infrastructure (offline)

	Estimate	Std. Error	t value	Pr (> t)
(Intercept)	63.235	5.2145	3.5874	0,006358
med	-15.239	3.2359	-3.2487	0,055871
pos	17.2512	2.8745	4.2984	0,065890
Green Belt	4.2597	3.2341	1.128	0,008745
Green Corridor	23.2571	3.1287	5.263	0,002687
Green Network	12.2987	2.1289	4.128	0,004589
Green Patch	11.2141	5.3587	4.127	0,002689
Green Matrix	12.1287	3.1289	3.214	0,002699

Specifically, there was a significant statistics link as far as the green urban area category is concerned and the relative will to tell others about the purchase experience. In the traditional channel (offline) all categories, which does not weight online, showed a significant and positive coefficient for the will to spread USE-e-WOM relative to such category.

Considering the variables that referred to the value of the purchase experience, neg, med, and pos respectively, or to the relation that occurred between the typology of the citizens' experience for a specific green area and the intention to tell others, there was a significant relation for all typologies of value for the sample in both cases, traditional and virtual.

The positive experience generated more whom than a negative one, and the latter caused on its turn, a bigger will to transfer such experience than an ordinary one, for which, for both samples considered, we obtained all negative coefficients statistically

significant. This means that, the presence of a med experience negatively affects the will to tell others information relative to an urban green area.

The same trend, where the will to tell others about the experience prevailed, was for the sample of the traditional environment. Another aspect that was considered in the different models of regression adopted for the analysis of the Supply side, was the possible impact of the online posting activity, that is, to post comments and reviews inside the virtual context in the different communities relatively to an area, the will to tell others about the personal experience both online and offline. A significant relation was noted for the POST variable, exclusively for the destined USE-WOM of the virtual store, while it was not individualized a significant link between the online posting activity and the offline USE-WOM one. In particular, it was also asked the reason that pushed interviewees to do it.

Passing to consider the series of regression models concerning the experiment called “Demand side”, the study focused on some models, that related the opinions deriving from the traditional offline environment and the online context on the possible impact they may have had on the intention to buy of citizens that received such information.

The first aim was that of verifying the existence of a significant statistics link among the different opinions, suggestions and comments relative to area proposed to the interviewees and the will to purchase it. Both offline opinions and online reviews were considered. The first ones had three dummy variables, respectively of_med=offline opinion with mediocre value, of_pos=offline opinion with positive value, both related to the variable of_neg=offline opinion with negative value. The second ones had two: on_med=online opinion with mediocre value, on_pos=online opinion with positive value.

Such relations were significant with the dependent variable concerning the category of opinions with a positive value, both that they derive from a traditional environment and from an online context. However, the relation among all the other opinion categories and the dependent variable did not result statistically significant, confirming then the lack of correlation between the two dimensions. The positive mark of the relation showed a potential direct relation, so that in case the interviewee receives more information, her/his intention to use may rise.

This investigating shows the possible different influence of the information deriving from the two case, and above all understanding whether the value of such information “weighted” differently on the purchasing intention. As it may be observed on above table, there is a statistically significant link for a combination of information, that is, whether the information deriving from the online context and the traditional environment were both positive.

It was noted, finally, a positive relation of the POST variable, that is, the posting activity of online reviews from interviewees and the intention to use the green area.

Table 3. Estimated structural parameters of opinions deriving from traditional (of_med of_pos) and virtual (on_med. On_pos) and how they affect citizens and their intention for green infrastructure

	Estimate	Std. Error	t value	Pr (> t)
(Intercept)	23.187	9.187	2.158	0,004587
med_off	4.698	4.823	1.258	0,231643
pos_off	12.131	5.321	2.215	0,023898
med_on	5.239	4.587	1.426	0,292321
pos_on	19.351	4.418	3.258	0,000905
no.rev	7.125	7.125	1.239	0,117370
post	5.691	1.358	2.218	0,000472
gender	3.012	1.268	2.369	0,197481
age	2.369	1.785	2.581	0,202610
edu	3.112	2.369	1.258	0,217954

More specifically, there is a significant positive link between the positive experience (pos) and the dependent variable SOCIALprob, even if with a different intensity whether it was considered by a male or a female sample and the kind of SOCIAL network it is destined to.

CONCLUSION

The research represents a contribution tending to demonstrate the possibility of interacting between citizens and institutions in urban green planning policies. Comparative assessment of the use of the traditional channel compared to the online channel has shown a different level of interaction. The traditional off-line channel was more objective and direct, while the on-line channel automatically generated a comparison on the net from which the will of the individual subjects arose. Social media represent an instrument of future application that will allow to act on different levels, either directly with direct contacts, or at a second level of comparison through online discussion. This last aspect is the most interesting because it generates proposals, evaluations such as spontaneous movement of citizens exalting the civic sense. The involvement of several subjects, indirectly involved, generates a flow of data, which become strategic and confirm the possibility of interaction between citizen and institution.

The interactions that can be activated in metropolitan cities with the use of social media in the more general framework of e-Government, while not directly addressing the issue, seems to suggest that social networks can improve the dialogue of Municipalities with citizenship and territory both for the offer of services, both

for the dissemination and understanding of the policies implemented. As regards the stage of maturity in the e-Government of Italian Municipalities, which have decided to invest in social media, it can also be assumed that the Municipalities that have invested most in these instruments are at an intermediate stage, if not sometimes mature., in the development of e-Government, as the adoption of social media implies a certain sophistication from the technological point of view and an effective investment in these tools presupposes the adoption of other technological tools. In general, Italian metropolitan cities can not fully speak of a massive evolution because the activities and services of e-Democracy and e-Governance are often still at an embryonic stage. On their whole, the metropolitan cities have late understood the opportunities offered the social media (Sturiale & Scuderi, 2013), in order to refer directly to final citizens who are here involved actively. It is necessary, however, to avoid failing, to point at the right target and build up specific supports then, such as events and advertisement, that involve municipality more and integrate their activities (Liu-Thomkins, 2012). Italian city should catch the opportunities offered by social networks considering that 2/3 of Italian internet users (more than 36 millions) belong to a social network. It may be a privileged tool for a privileged relation with customers (Menduni et al., 2013). Internet spreading has helped modifying significantly citizens' behavior and their attitude towards new green area of metropolitan city, purchasing process and information. In particular, the virtual environment has strongly influenced the purchasing process' phases introducing innovative elements. Firstly, by guaranteeing a wide range of information on the web at sensibly reduced costs, which have allowed citizens to compare competitive green urban areas and know users' opinions. It is necessary for municipality, then, to start a suitable route to guarantee new forms of collaborations for citizens, with particular reference to the online environment, whose logic passes three levels: connection, conversation and building of new relationships (Lipsman et al., 2012; McAlexander et al., 2002). Without considering the specific results, this study allowed obtaining the following results for the urban green areas offered directly to citizens:

- The wish to tell others about the personal purchasing experience varies whether this refers to a different level of past knowledge;
- The intention to refer others of one's own personal purchasing experience varies whether the message is sent in an offline or online context;
- The will to tell others about one's own personal experience varies whether the message is from an offline or online context;
- The value of the purchasing experience affects differently the will to refer others about one's own experience;
- The will to tell others about one's own personal experience varies whether it concerns area already known;

The direct evaluation of citizens' behavior has allowed demonstrating its utility for green urban areas, to orient towards a strategy of communication in the different place, traditional and virtual (Jang et al., 2008), understanding firstly what's the impact of social media through citizens' word of mouth about the purchasing decisions referred by others, and also how such experience relative to the power of messages in the two considered environments, affects differently the purchasing decisions.

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Chapter 13

A Planning Model for Cognitive Cities: Spatial Cognition Through a Participatory Approach

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ABSTRACT

A city is a real-time function with constantly changing variables. Rapid urbanization of the cities and increase in a number of mega cities has made the entire urban management complex. With many parameters involved in it, urban data has started to resemble the characteristics of big data. The nexus between spatial cognition and the frequency of data collection of an urban system explains the role of big data analysis in performance monitoring of the urban systems. Urban data collection and analysis can be possible through participatory planning and participatory citizens. This chapter focuses on understanding the correlation between spatial cognition and participatory planning.

INTRODUCTION

A system has a definite task of doing a set of things, receiving an input, processing of inputs and generates both output and waste. These systems can be broadly classified into two types based on the pattern of output generated; bio-systems and machines. The major difference between bio-systems and machines is, bio-systems are dependent on nature (i.e. dependent on parameters like time and processes or cycles

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of nature). It has many subsystems which are why the result or output can never be same. Machines, on the other hand, are very less dependent on other systems and the result is always the same as designed. So when you look at a city as a system with many interdependent sub-systems, from a scale of individual human being to ever-growing megacities; an urban system is a complex web of different systems at different scales influencing each other.

To regulate and manage the performance of these urban systems with their performance history gives the basic understanding and nature of the system. The complex data has become a challenge but with the advanced technology and intelligent systems, big data analysis has become possible.

To regulate and manage the performance of these urban systems with their performance history, gives the basic understanding and nature of the system. The complex data has become a challenge but with the advanced technology and intelligent systems, big data analysis has become possible. The big data revolution has shown the possibility of cognitive cities, a step ahead of smart cities. In cognitive cities, the data from their past experiences predicts the needs of the city and its people based on pattern of resource consumption and performances of different systems of a city. Urban diagnosis in planning procedure, is a cognitive phase where the urban data is collected to cater the *urban needs* and to generate the relevant information. The objective of this chapter is to understand the importance of participatory planning in enabling quick data collection to read the systems' performance, the urban diagnosis in assessing the urban needs which enables spatial cognition.

Background

Every system has a set of cognitive skills which is not null. Any system, at some point or the other of its cycle, has to take a decision based on the loop framed. A simple 'if - else' loop does take a decision through which the attribute or the input has to pass. Similarly, the planning procedure or the methodology we are practicing today does have a cognitive stage and every urban system or sub-system does have a set of cognitive skills, though the decision-making tasks are taken by a human being, they are considered as a part of the system too. With advances in information technology, big data analysis has enabled to program a system with both historical data and continuously changing data; to compare systems behavior in similar situations and analyze system's past with current scenario for decision making. This study focuses on the components of urban cognition and understands the planning framework for an urban system a step closer towards cognitive cities.

COGNITION AND URBAN SYSTEMS

Nature and Characteristics of Cognitive Systems

As a part of nature, man just like every other creature has his everyday game of survival. His ability to think and understand the environment he lives in, helps him evolve. He learned from his experiences in this unknown world and developed a script to read the environment. This ability to think, which is nothing but to analyze his experiences, understand and develop his own formula to deal with issues of his life and his ecosystem is called cognitive thinking. Today's technology has made artificial intelligence possible, where man-made cognitive systems have the ability to solve real-life problems of its own system or any other system which are interdependent on each other for their existence.

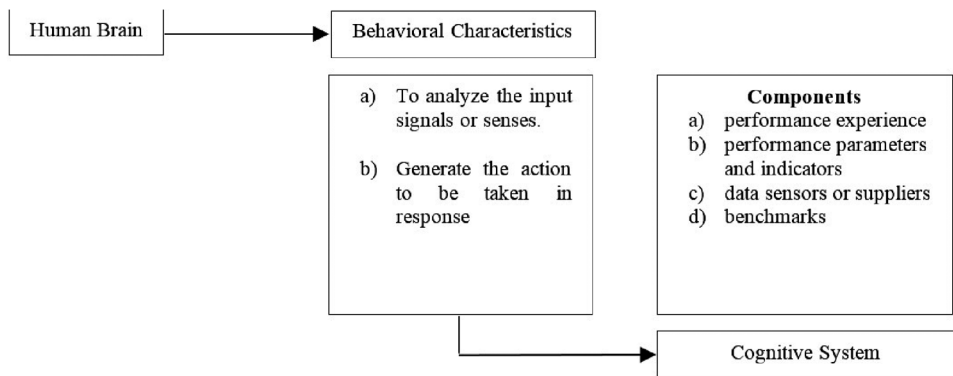
The human neural system has been one of the major inspirations for artificial intelligence in our daily lives. Brain's function can be decoded broadly into two steps which are, to analyze the input signals or senses and generate the action to be taken in response. The analyzing skills and the required intelligence to make a decision is based on how our brains are trained. The training here refers to the process of learning, a system trained to gain the knowledge of experience. Thus the analyzing capacity of a system is based on the experience data of the system. Hence cognitive systems are those systems that produce intelligent actions and are able to view scenes in more than one way.

Based on the above behavioral characteristics considering human brain as a prototypical cognitive system, the four essential components of any system are data of its own performance experience, performance parameters and indicators for constant monitor of systems performance to analyze the needs of a system as early as possible to reduce the gaps between projected data and real data, data sensors or suppliers and benchmarks to judge the any particular situation, nothing but to detect a need or a problem of the system.

Urban Systems and Their Ability to Think

Cities are part of human ecosystems, where the inputs of the systems are natural resources. Urban metabolism can be compared to system's processing, which results in urban transition as an output plus waste. The four essential components necessary for the cognitive system are compared to characteristics of an urban system. The system's performance history or experience which is considered as knowledge of the system is compared to the chronological growth of the city and urban transformation. Performance indicators of urban transformation guide us in analyzing the status

Figure 1. Components of a cognitive systems in correlation with human brain



of performance of urban systems. Data sensors or data suppliers of urban systems have always been the citizens, though the mode of data collection was different. Surveys, interviews etc. those in practice currently are lengthy and take years to collect data and extract the information. Hence the frequency of data collection has made these systems reluctant to the immediate diagnosis of systems' performance and implementation of planning measures. This disability to constantly monitor urban systems is a major drawback for enabling cognitive thinking in urban systems. Thus the ability of urban systems to think effectively is possible with the increase in the frequency of data collection and update of system's performance status.

SPATIAL COGNITION

A city is a system with many interdependent sub-systems. There are different systems at different scales influencing each other, which justifies that a city has become a complex web of systems and managing these complex systems is impossible. These huge complex systems can be simplified based on the spatial hierarchy. Spatial cognition is the cognitive ability of an urban space with its spatial character and boundaries. Many other systems of urban services fall within these boundaries. Since the study attempts to understand how cognitive skills of an urban system can be strengthened to a level that the system can diagnose its issues and needs on its own, the components and characteristics of a cognitive urban system are discussed in clear on how they aid to system learning in the context of urban systems.

Components of Urban Cognition

Urban cognition doesn't stress the spatial character of the system, it refers to the cognitive ability of any system that serves citizens. The concept of spatial cognition is built on certain assumptions based on definitions and understandings of cognitive systems. Systems that serve citizens across the city and deliver their services will have the spatial character making spatial cognition, a part of urban cognition. When you try to map the cognitive character of a system and characteristics of an urban system, the basic components of urban cognition has the ability to recollect knowledge and ability to judge. Thus the four basic components identified in any urban system requires for system learning are knowledge, performance indicators, data collectors, and benchmarks

Knowledge

Knowledge of a cognitive system refers to the information collected from past experiences about the system and its environment. Knowledge to an urban system or any of its sub-system explains how the system works, its interdependency with other sub-systems and systems' environment. For example, how a city ward or a zone is maintained, dependent on other wards/zones and its role in the hierarchy of the whole urban system. The parameters to be considered as knowledge in the context of defining spatial cognition are:

1. The hierarchy of an urban module selected since the spatial character of any urban system cannot be ignored.
2. The planning model in practice where different players involved in planning procedure and their roles gives us the framework of the system's management.
3. Existing scenario and the setup of an urban system, existing issues, and needs, etc.

Performance Parameters and Indicators

Urban systems are complex and have multi-dimensional functions that depend on many variables. These variables are dependent on time and other parameters. To understand the nature and change in any function, it is studied in terms of its variables or indicators, they help to measure the function. Any urban issue or any goal is always deconstructed mathematically into a quantitative form, to measure the change and to set the vision for a time period. Thus, a city can be expressed with a set of indicators and with which the performance of the city can be measured. These

indicators help in the situation monitoring of the system. A continuous monitoring is essential to ensure the efficient and effective performance of the systems. There might be ‘n’ number of parameters to read the situation of an urban module. But to understand the cognitive character and creative use of system’s knowledge, few of major parameters are given below the table.

We cannot solve our problems with the same level of thinking that created them.
Albert Einstein

Data Sensors and Collectors

Data collection helps in monitoring a system, its performance or any particular situation. Data collection and recording is an important aspect of data quality and knowledge of the system. Data collectors and sensors help in the collection of data based on identified parameters and indicators, without which it is impossible to manage a system. Urban systems need data to assess and to manage its sub-systems. The concept “survey before plan” by Sir Patrick Geddes explains the importance of knowledge while planning a city. He compares survey before the plan to diagnosis before treatment, where the importance of data collection and management is clearly understood for better understanding.

The brief of contemporary planning, as a continuous process models consist the following stages; problem identification, determination of goals and objectives,

Table 1. Parameters and Indicators to assess the cognitive ability of an urban system

Parameters	Indicators
Knowledge	Size of Data
	Density of data along timeline
	Variety of data
Policies and reforms implemented	Gaps between plans and achievements
	Frequency of performance monitoring of implemented policies
Urban Governance	Transparency
	Percentage of civic participation in Planning procedure
Infrastructure	Self-situation monitoring
Telecommunication and Innovation	Availability of Open data sets to citizens
	Data Accountability
Finance	Government funds to build an open data society
Science & Technology	Ease of civic participation in urban planning

survey and data collection, analysis and synthesis, policy and plan formulation, implementation of the plan and monitoring & evaluation. Survey and data collection is a crucial stage which helps the plans in really hitting the targets. The quality of data is ensured by the size of the data and the frequency with which data is collected.

Benchmarks

Benchmarks are necessary for performance monitoring of any system. The indicators measured during situation monitoring are compared to the benchmarks. They measure progress in achieving specific results in relation to implementation of various plans. The indicators measured when compared to the benchmarks help in the evaluation of the performance of the systems. The benchmarks are the outputs planned for a system, thus indicators have to meet the planned benchmarks.

COGNITIVE CITIES AND URBAN SENSORS

A cognitive character of a system is nothing but the ability of a system to make its own decisions and develop knowledge through experience. Developments in Information technology has made it possible to install the character of cognition in machines. Every existing system has some positive capability, whether a system's decision-making ability ranges from a set of preloaded options or the system's ability to develop its own knowledge and options. Similarly, urban planning procedure is the critical factor that is responsible for the performance of urban systems. Planning procedures are frameworks that guide an urban system's behavior and how cities work. Every planning model has different measures for its cognitive character. Cognitive components and indicators of a cognitive system can help us to compare the cognitive ability of urban systems which run on different planning models.

Urban Planning Models and Their Ability to Think

Planning models and frameworks are highly correlated with the cognitive behavior of urban systems. The planning models give an idea how planning situations, behaviors, and outcomes are diagnosed, predicted, and assessed. They explain the reaction of cities to change and the decision-making ability in relation with functionality. Planning procedures are read differently with the components of a cognitive system. Planning models used today and with the developments in Information Technology made it possible to increase the cognitive behavior of urban systems.

Rational-Comprehensive Planning

“Banfield’s (1955; 1959) Rational planning model focuses to maximize the achievement of desired goals by careful consideration of potential consequences. Harris, 1967 describes its framework as Desires, Design, Deduction, Decision, and Deeds. A fundamental aspect of planning in the rational mode is the disjuncture between individual rationality and collective rationality.” (Hudson, 1979)

An urban system functioning based on the framework of rational planning, the decision making clearly shows the individual rationality which implies that the systems needs aren’t the priority and the goals framed are based on very little data shows that the knowledge of the system is poor. Goals framed were given importance but those goals aren’t framed based on the system’s performance, though the goals act as benchmarks for the plans implemented.

Incremental Planning and Strategic Planning

Lindblom’s alternative, Incremental planning calls for the simultaneous selection of goals and policies and the preference for results of social experimentation over theory as the basis of the analysis, unlike rational planning. Urban issues are usually targeted at incremental levels. The decision making here is based on social experimentation and the goals aren’t finalized. The incremental approach towards the urban issues indicates that the systems issues are identified and are targeted shows that a comparatively better understanding of performance indicators of urban systems. Amitai Etzioni’s (1967) strategic planning or mixed scanning model tries to involve the positives of rational comprehensiveness and incrementalism (Hudson, 1979).

Transactive, Advocacy Planning and Radical Planning

Advocacy planning was a successful means of blocking insensitive plans and challenging traditional views of a unitary public interest. In theory, it calls for the development of plural plans rather than a unit plan. It gave the reason for a legal framework since these are plural plans targeting public. Radical planning is guided by the pragmatic vision of self-reliance and mutual aid. It believes in departure consists of specific substantive ideas about collective actions (Hudson, 1979). The planning theories are more focused on the goals or targets of plans and legal framework that they don’t concern much regarding the framing of a goal.

Communicative, Progressive and Participatory Planning

Communicative planning by Forester asserted that through communicative strategies complementing their technical work, planners can alert citizens to the issues of the day, arm them with technical and political information, and otherwise encourage community-based planning actions. Forester suggested that ensuring widespread availability of data and understanding of public decision processes would help to enfranchise the underprivileged. Where progressive planning theory focuses on the methodology or the procedure of decision making and implementation of plans where the progress of plans implemented and the progress is monitored. Participatory planning emphasizes the role of citizens in planning procedure. Participatory planning takes the government towards a transparent system (Hudson, 1979).

Data Sensors or Collectors, an Important Component of Spatial Cognition

Planning models have evolved through time according to the need of urban ecosystems. Today planning models are more towards participatory approach and public are involved in decision-making activities. The data collection through surveys in planning methodologies is to access the urban performance and identify urban issues by measuring urban performance indicators. Plans being time bounded and planning is a continuous process, data collection and urban assessment are done

Table 2. Components of a Cognitive system are compared for different planning models

Planning Models	COMPONENTS OF A COGNITIVE SYSTEM			
	Knowledge	Performance Parameters & Indicators	Data Sensors & Collectors	Benchmarks
Rational Planning	Poor	Poor	Poor	Average
Incremental Planning	Poor	Average	Poor	Poor
Transactive Planning				
Strategic Planning				
Communicative Planning	Poor	Average	Average	Poor
Progressive Planning				
Participatory Planning				
Inclusive Planning	Average	Good	Good	Good

periodically during plan formulation. Though plans require a time frame, cities have become increasingly complex that these urban systems need a continuous scrutiny of their performance for better decision making.

A cognitive system needs a constant understanding of its performance and needs to be able to think. Data collection is an important aspect of cognitive thinking since cognitive skills without knowledge are impractical. The frequency of data collection, data collectors and the methodology in which data is collected is crucial to develop required knowledge for a system to think. Data collection and analysis for urban systems has always been a lengthy task. A scale at which the sensors can be distributed all over the city may collect the urban data quickly when compared to physical and primary surveys. Thus data collector is an important component of spatial cognition, and a cognitive city needs a data collection pattern and data sensor which can collect entire urban data frequently for better performance monitoring.

Urban Sensors

Different players, stakeholders, and institutions are being responsible for data collection for urban planning in most of the countries. With the transition of spatial politics more towards participatory planning, the general public is involved in decision making. Many concepts like the social innovation of planning techniques, commoning as an approach to community planning emphasize the need for public participation in planning and decision making.

The complex nature of urban systems makes it difficult to practice traditional methods and practices. Developments in Information and Technology has made management of complex and big data easier. Though big data analysis has become easy, data collection of such a complex system huge in its physical extents is a tough task, particularly when the frequency of data collection is more. Since cities are part of human ecosystems and the ultimate goal of any system or any urban service is to serve human being, which justifies that the end point of these systems is a man. So, man is the smallest yet most accurate data supplier than any other level, i.e. data collection at ward level, zonal level etc. With an idea of public participation in data collection has made to collect huge data on such huge urban extents makes it easy. With people as data collectors, developments in Computer Science and Technology has helped people connect on common platforms and submit their surveys. To collect data with high frequency for systems like cities since they are part human ecosystems, the fastest approach to collect data over such systems is through public as urban sensors. The pattern in which urban sub-systems and people are connected is truly interesting. A human being the lowest possible scale within a city to the largest scale possible, which is the urban system itself are connected

beautifully. Data collection is a huge task for the complex urban system to collect the entire performance data. When a citizen becomes the data collectors, man being the smallest in the hierarchy and distributed across the city the task is broken down into smaller ones which give the possibility for more frequent data collection or data collection can become a continuous task. A cognitive city has citizens as urban sensors, public participation not just in decision making but also in data collection and developing systems knowledge (Ali Mostashari, 2011).

SPATIAL COGNITION THROUGH A PARTICIPATORY APPROACH

The need for cities to develop knowledge for better decision-making abilities based on performance history of the system and developments in Information technology has made urban systems develop the ability to think. With urban sensors that provide data with a higher frequency that can keep tracking the performance of the city in a better way than current planning models can strengthen spatial cognition. A participatory approach that involves people not just in decision making but also in data collection has a non-zero probability to collect entire system's data within hours. Human sensors where citizens become data collectors of the city is the next stage of transition for smart cities towards cognitive cities. A participatory approach that involves citizens in data collection and decision making of a planning model slowly transforms the thinking ability of the system, where the system itself will develop certain thumb rules and scenarios how it has performed based on its performance history. Big data generation with high frequency can be possible only with human sensors through a participatory approach which justifies the statement that a participatory approach is the in an immediate step to any city towards spatial cognition.

Role of Individual Citizens and Social Institutions

A city as commons to its citizens, every citizen has a set of rights and responsibilities towards the city. With urban systems growing complex every day, it gets difficult for governing bodies to manage these complex megacities. A participatory approach in managing complex urban systems is an easy approach to the governing bodies where civic participation in planning procedure allows citizen can participate in assessment and management of everyday services in their neighborhood. An algorithmic approach to govern urban services where a function aimed at certain results or benchmarks framed in terms of indicators is measured through civic participation where information technology becomes a powerful tool for community engagement.

Participatory Methods: An “Inside-Out” vs. an “Outside-In” Method

Advancements in Information and Communication Technology has influenced human life to a great extent, they reduced human efforts in every possible sector. Participatory planning, an approach to urban planning where public participation in decision making for urban systems has also been influenced by ICT. The conventional public participation in the context of urban planning is in the form of consultation or a collaborative activities, where citizens are asked for feedback on particular issues either through public hearings or online consultations.

An Inside-out method in civic participation is nothing but the conventional method where various stakeholders are brought together for a communicative exchange which is nothing but staged participation which aims to reflect a common understanding for different planning scenarios and resolution of disagreements. Boonstar and Boelens in 2011 refer staged participation as an inside-out approach based on the methodology in which it is performed. The participatory approach is initiated by the government institutions which then involves civic participation. An Outside-in approach is where citizen-led initiatives are that originate in civil society based on networks of citizens which are independent of government procedures of urban planning but the knowledge and the information from these self-organized initiative are utilized for urban planning procedures. The concept of self-organization is borrowed from complexity theory (Saad Sulonen, 2013).

The influence of Information and communication technology in participatory activities is seen in the transition from an inside-out approach, where government institutions play a major role has slowly shifted to outside-in approach where citizens are in the center and government institutions are dependent on civic contribution to urban data. The transition achieved is the result of open data network where public are accessible to the performance data of their city and the transparency brought to the governance system.

Participatory Mapping

Developments in technology made people available to huge data of the city and the environment they live in but with the primary source of performance data of a city as its citizens, participatory mapping is the great source of data formation of different urban systems. Kevin Lynch in his work *Image of the city*, explains how local citizens view and perceive cities and how it relates to mapping. He introduces the concept of cognitive mapping into urban planning, explaining how people perceive spaces and the image they frame regarding urban spaces can be mapped which are easily readable than the city street maps and other city maps. Participatory mapping in a way

differs from any other survey since participatory mapping is involved with citizens who are intimately connected to the space than any other who goes to that place to survey. Participatory mapping can give a high resolution maps in comparatively less time period than a group of surveyor mapping the entire city (Warner, 2015).

Algorithmic Civic Participation

Civic participation resulted through algorithmic functions within a system, i.e. harnessing civic participation through data science refers to algorithmic civic participation. Algorithmic functions are nothing but mathematical functions with a problem-solving capability. They are typically defined by Gillespie, 2014 as a set of “encoded procedures” or “a logical series of steps for organizing and acting on a body of data to quickly achieve the desired outcome.” An algorithmic approach to an issue or a target can involve collecting, classifying, structuring, aggregating and analyzing data. All these stages study the data through different algorithms. Citizens become data collectors and participate in developing knowledge to the urban system by feeding decision-making algorithms the data required. Thus data science indirectly harvests civic participation towards the urban performance. So when public participation in data collection and urban governance to an extent where open data is used for better decision making provides transparency of urban performance. So for a cognitive city, the challenge is not just in decision-making abilities but also the way the city is governed since the public has become one of the important stakeholders of urban governance where technology-enabled paths for participatory governance of the city (Matthew & Renee, 2016).

Chicago's Open Data Management

Chicago's policies are building towards an open and transparent government to transform Chicago into a see-through society. A new administration started on May 16, 2001, under Chief Data Officer during the period of Mayor Emanuel works towards establishing an open data administration that uses city's rich data as a tool for policy making which involves open civic data and a participatory approach of public towards a transparent government. Chicago's open data program has changed the way data is produced and used across the city while increasing transparency on how urban system works and its performance history to its citizens. The major reforms implemented right after the administration was set up and how these reforms attracted citizens to use the open data platform established by the administration regarding Chicago's open data which transformed the city's governance through a data-driven civic participation are as discussed below.

Socrata's API was city's data portal through which Chicago successfully experimented its open data governance. The first dataset of the city released by the administration in the name of the new open data program was Chicago's crime incident dataset. The data was collected by the administration from Chicago's Police Department's CLEAR path website which offered ninety days of historic incident-level crime data via mapping interface. The open data set was designed as incident-level crime data obtained from January 1, 2001, to the date of release of the dataset to the public which will be the largest automatically updating set of incident-level crime data released then (Goldstein, 2013).

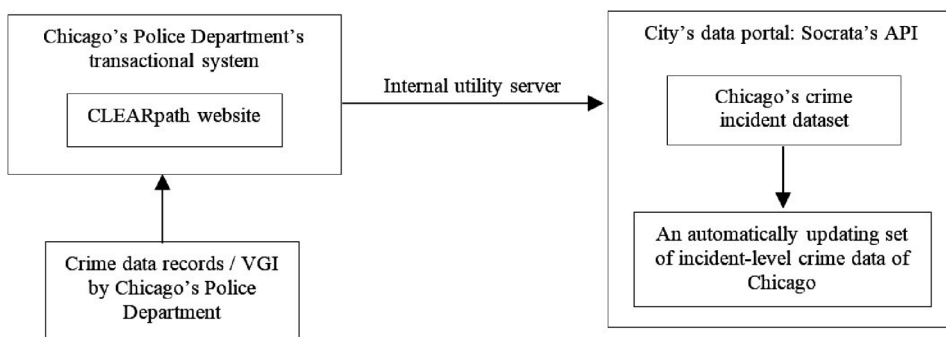
The second of the reforms is regarding the apps for Metro Chicago, the dataset released by the administration is city's street sweeping dataset for Metro Chicago contest window. Metro Chicago was a competition for app development initiated prior to the administration and open data program. The competition was a great help to launch the new open data program in Chicago, it helped citizen participation and access to open data of the city helped the open data program by the admiration gain momentum quickly. Kicking off the Apps for Metro Chicago competition soon after the start of the new administration was consistent with the strategy of rapidly expanding the existing open data program. Street sweeping schedule existed, but it was not published in easily used by software engineers. A website sweeparound.us was developed which assisted being mindful of city's cleaning schedule a night before. The administration under Chief Data Officer, Chicago has transformed the government into a platform which provides raw city data to the public in machine-readable formats, by providing API to this data, the data can be accessed, used or can be integrated for any purpose by its citizens. A standards-based data portal allows the administration to be a platform for Chicago's open data (Goldstein, 2013).

A UTOPIAN MODEL FOR COGNITIVE CITIES

Any plan or reforms are designed with targets to be generated as output, so there is an expected result or output for every input to a system. Every system is designed for a set of tasks to produce expected output, similarly, every urban sub-system does. Since an urban system is a subset of human ecosystem, every system developed by man is to serve him, thus every urban system also has an expected output or expected the supply of service to its citizens. When citizens submit the feedback about their experience, the Volunteered Geographic Information (VGI) generated is captured.

Any urban service supplied to its citizens has to be referred with geographical location thus hierarchies of urban services can be classified based on spatial extents, ex: municipal level, Zonal or sector level, ward or block level. Thus, when service

Figure 2. A flowchart showing the transition towards open data system achieved in Chicago through different reforms, 2001



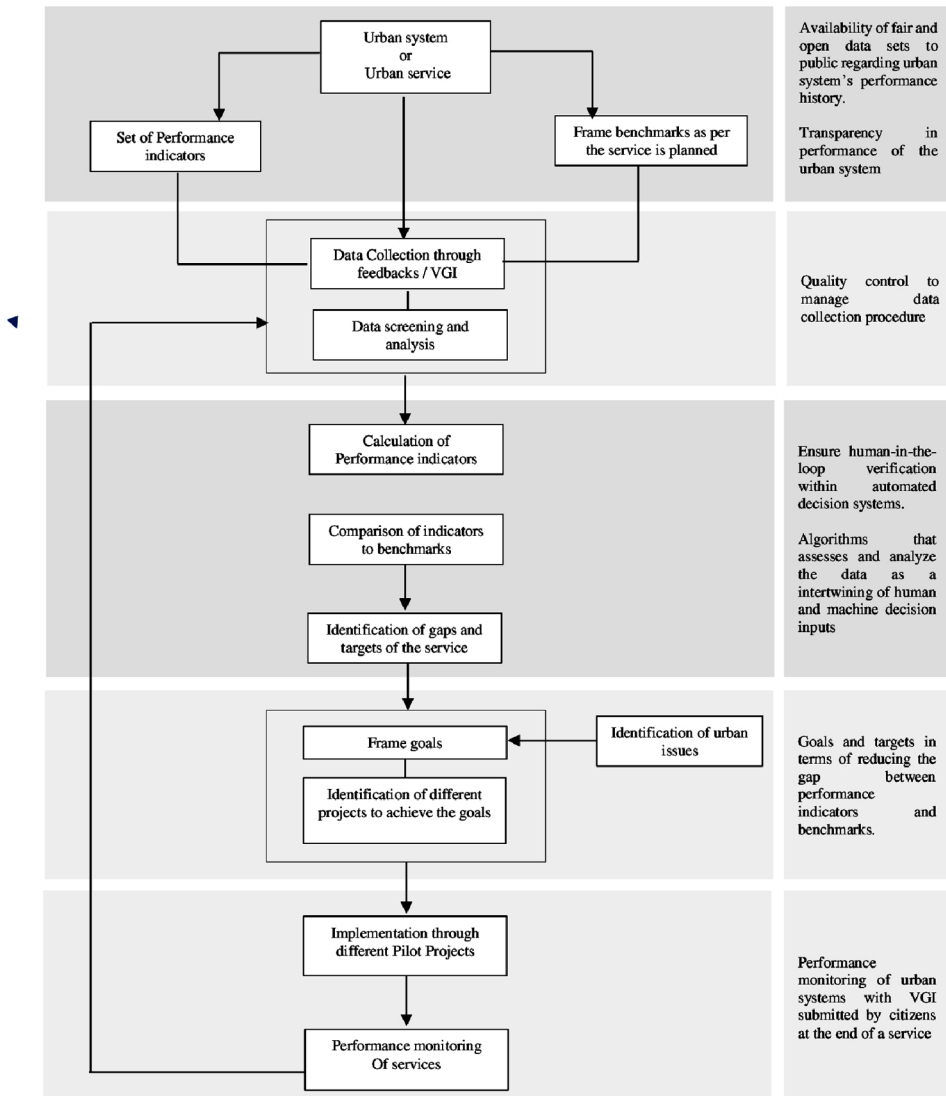
feedback or system's performance data is collected from citizens at lower scales of urban services, things can be managed easily.

For every citizen to submit their feedback on any urban service they use, urban services should be defined in terms of indicators which can be measured. Based on the socio-economic feasibility of the service provided, benchmarks of the service are set and with the data collected in terms of feedback, where indicators are rated by users or citizens is compared with benchmarks. Unlike conventional planning procedures where data analysis starts after entire data is collected, with VGI, data analysis doesn't need data collection to finish, data collection can be a continuous task. Data collection and analysis are performed with the help of algorithms, with various levels of transparency also the indicators of services. This open data is a fundamental cultural shift that goes beyond sensor technologies and machine learning.

CONCLUSION

Man is in the never-ending search for a comfortable lifestyle. He has been evolving over time, where his lifestyle, his approach to deal with nature and culture has been changing constantly. Technology has a great influence on human lifestyle. Advances in technology have been used to achieve what man wants in an easier way. Since cities are part of the human ecosystem, change in human lifestyle and culture to change the how the city functions. Today we see smart devices everywhere in cities, where data is being created and used in multiple ways, for to track vehicles, current road traffic analysis, election campaigning, and many other. So without any idea technology is playing a great role in urban management. It has become easy to produce data,

Figure 3. A flowchart to explain an ideal methodology for urban planning towards a Cognitive City



collect and analyze it. Cities are in a transition phase towards cognitive cities, where big data analysis plays a major role in urban diagnosis.

Change is inevitable but the change that a system experiences should not disturb the equilibrium of the system and its performance. With citizens as data collectors and participatory approach towards spatial cognition not just changes the way city works but also how the city is governed, as citizens become data collectors the transparency

that a city provides will increase. Thus transformation to cognitive cities is a cultural shift, where not just the urban planning procedure but also the function of the entire system and the culture of the city changes entirely. Thus a steady transition must be planned for urban systems where its equilibrium isn't disturbed since the transition involves cultural change on how the city is governed.

With citizens as data collectors produce enormous urban data and with techniques of big data analysis. Volunteered geographic information generated has a spatial character which when plotted can produce fractals. These big data fractals from VGI represent urban fractals. Thus data collection pattern for urban data can be framed by analyzing urban fractals of that particular city. There is a high positive correlation between urban volunteered geographic data and urban fractals.

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Conclusion

WHAT DID WE LEARN?

Trying to conclude from a series of contributions that have addressed some of the many dimensions of the big data phenomenon in the urban planning perspectives is certainly a difficult task. In this field of study, the task of examining the possible lessons learned and indications on the future trajectories of the important and varied relationships that dealt with this topic is even more ambitious.

We can then identify some questions, to which the contributions of the authors have explicitly or implicitly given the answers, not always convergent but suitable to draw useful repercussions for working in an operative and effective way in territorial and urban planning. In the different disciplinary fields emerge convergent answers on the criticalities deriving from the extensive application of the big data theory in planning. Instead, it nevertheless appears a useful catalyst for the development of transdisciplinary studies and researches.

In the chapters, albeit with different methods and disciplinary depths, we can identify at least three questions of interest:

1. Will the big data theory help us to deal with the complexity of the themes and problems of spatial and urban planning from an analytical and planning point of view?
2. What are the impacts (positive and negative) on which depends the success of its extensive application in many different disciplines?
3. Which, then, the conditions that can favour its success in those sectors in which big data is already widely used, but also in those in which it has not yet been included?

If it is true that the big data paradigm has become a widespread methodological tool in all sciences, it is legitimate to try to recognize a minimum common denominator, starting from disciplinary fields ranging from pure data analysis, evaluation, public participation, urban and territorial planning.

Conclusion

Certainly, all contributions more or less explicitly suggested that researches are developing new approaches and using new tools: the discipline of planning, in particular, needs to review its conceptual and methodological bases in order to better deal with the evolution of complex territorial systems and with the needs posed by the most recent consolidated paradigms (smart and resilient city).

Let us try then to outline some answers to these questions.

1. Will the Big Data Theory Help Us to Deal With the Complexity of the Themes and Problems of Spatial and Urban Planning From an Analytical and Planning Point of View?

The contributions presented in the volume seem to agree on accepting a first common commitment: to succeed with the big data paradigm not only to explain the processes, but also to predict the behaviour of territorial systems, and to build scenarios; besides, to better simulate where possible (and not for all systems it is) future evolutions (perspectives).

We recognize a prevalent purpose very focused on analysis and interpretation, but also projected intervention. Many use cases discuss that actions find reference in the practices of evaluation, analysis and definition of scenarios, also based sometimes on the community involvement (FirstLife, Territorial Integrated Evaluation, OnToMap, etc.).

All contributions confirmed their confidence in the ability to apply big data theories not only to support the progress of territorial, social, environmental and economic systems; but also in the need for these studies to be promoted because they are fundamental to face the changing and complex territorial dynamics and citizen everyday life problems.

Nevertheless, all contributors agree on the difficulty of these scientific paths and on the critical transfer towards the practices. In fact, the tools currently in use within spatial analysis and knowledge that use big data theories are at the high levels of complexity and too often require transversal skills.

So what can we aim for to get closer to the important goal of helping us not only in understanding the territory, but also in decision and action? How can we make smartness and resilience goals effective, strongly linked to big data? In line with these questions and objectives, the contributions seem to refer to key aspects on which depends the success of the operational effectiveness of knowledge and of the territorial action based on big data:

- Interdisciplinary;
- Geographic-territorial intelligence;
- Semantics;

- Participation;
- Social media;
- Adaptation;
- Co-evolution.

2. What Are the Impacts (Positive and Negative) on Which Depends the Success of Its Extensive Application in Many Different Disciplines?

Through the sections of the book not only are the interpretations of the big data phenomenon explored, but proposals are discovered that intend to support the possibility of determining new, unpredictable and original behaviours linked to the structure of technological, environmental and social systems. It is precisely in the study of these technologies that great advances in the field of artificial intelligence are also exploited through neural networks and new algorithms. The significant element seems to be the high computing power of computers (e.g. HPC) and the critical aspects of the new computational methods that should allow rapid and effective models to describe complex phenomena to be applied especially in the field of spatial planning.

If it is difficult to hypothesize possible scenarios it is even more difficult to identify exactly the effects, often unexpected or uncontrolled, arising from the application of big data theories in planning choices. It is very difficult to predict how these researches can be used to improve and increase the interaction between users who are increasingly attracted to the active use of e-participation and PGIS tools.

Studies on social trends in virtual interaction can probably facilitate the understanding of social action on the territory and change the cognitive approaches to spatial planning. It is evident that the effects of these issues are complex and difficult to face and aggregate in common and transversal elements to the many disciplinary strands. In fact, all contributions report in a different way and with different strength the critical issues related to the separations and dichotomies between the disciplines.

Regarding the skills, an effective big data scientist aimed at contributing to spatial planning must be a subject capable of reaching out to the various disciplines and making use of the cognitive, analysis and evaluation tools of all sectors of territorial studies. Cooperation, support, interaction, adaptability between studies and experts from different disciplines is therefore essential.

Conclusion

3. Which, Then, the Conditions That Can Favour Its Success in Those Sectors in Which Big Data Is Already Widely Used, But Also in Those in Which It Has Not Yet Been Included?

Also in this regard, a summary of how much the contributions agree in pointing out some conditions for the operation of big data theories for the planning and construction of the new generation city: information/meta-information, representation, awareness and empowerment. The possibility to find suitable answers to the question of information and meta-information (sometimes few, sometimes too many and in any case always difficult to deal with, integrate, monitor, especially for georeferenced data and databases, or real-time dynamic data) and connected to it, information technology and calculation tools are not sufficient to solve the problems of feeding models and forecasting schemes with adequate inputs.

The ability to represent, displaying graphs, networks, etc. to describe the relationships between the elements of the territorial system is too often related to the use of GIS tools, but fails to fully return the complexity of the real. In this direction, the semantic tools of conceptual representation of the territory based on ontological systems/relationships (e.g. OnToMap) are innovative and effective.

The ability to promote and exploit self-organization processes (bottom-up information, online participation) of territorial system, with VGI and PGIS to build knowledge and scenarios, make actors cooperate and respond to the needs emerging from communities and local authorities (co-planning, co-production, co-design).

CONCLUSION TOWARDS THE NEXT-GENERATION CITY

In order to outline some synthetic conclusions, we can try to grasp some advantages from the main approaches to working with data for architects, planners and urban designers:

- Using data to help designers to meet user needs;
- Developing experimentation to model data;
- Analysing data to improve local and large scale policy making and their implementation;
- Improving data transparency to speed up development processes;
- Using data to face risks and to accompany socio-ecological evolution of cities.

Besides, we need to consider some recommendations:

- A better coordination between government departments to work together to realise a smart future (prevent data duplication and identify gaps in data provision);
- A deep integration of big data within the so-called open data initiative: it is important to consider the potential benefits of digitalising all planning information and making this data available to the public;
- A strong promotion of public participation of different working groups and societies (including professional and academics with local and regional governments);
- A promotion of co-designing with citizens: using big data to better match user needs (e.g. how people use public spaces and infrastructures, or how can people contribute to the need of city auto-organizing);
- An experimentation of models that could allow designers and planners to test designs before they enter the construction process (and help identify objections, model solutions, etc.);
- A transparency: reducing search and processing time through sharing data.

Consequently, big data theories and applications can outline the following challenges for the next-generation cities (such as smart and resilient cities):

- Analysing and understanding the relationships or better the interdependence between the community and the environment;
- Reading the effectiveness of public policies and governance and the adaptive capacity of socio-ecological systems;
- Considering the place-based impact of social, economic and environmental changes in the short and long term, making “virtual communities” and “real communities” interact;
- Interpreting and supporting the creativity and innovation potential of socio-economic actors and institutions on a local and wide scale;
- Preventing, studying solutions, carrying out interventions with knowledge and monitoring actions (GIS, PPGIS, VGI, etc.) to give effect to the blurry concepts of smartness and resilience, which too often reflects the difficulty of finding specific significant indicators, capable of make planning actions more effective.

As recognized by the literature and the many contributions of the book, institutional leadership and collective learning skills are increasingly dependent on the digital technologies of the next-generation city. In this sense, it is necessary to make synergy between public policies and self-organized processes, in order to propose actions of regeneration and enhancement towards smart and resilient innovation.

Conclusion

There is also a strong need for innovation in the institutional governance of the system in which citizens' communities play a vital role in active learning, robustness, adaptability and innovation with respect to change, to which these technologies can effectively contribute.

These perspectives point to a substantial change in seeking effectiveness in the contemporary paradigms of spatial planning, which must know how to use the territorial knowledge derived from the availability of data to face: the traditional dimensions of uncertainty, of the continuous transformation of the social use of the territory, of the fluent/dynamic community engagement, the search for adaptability and a better quality and health of the city and territory. The spatial knowledge on which the next-generation city is based is the opportunity to redefine a smart, sustainable and resilience future.

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