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ORIGINAL RESEARCH PAPER

Explanation of Urban Morphology Evaluation methods and Tools in Sustainable Energies Approach*

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ABSTRACT: The concept of sustainability in the last age has become amplified. Its beginning can be traced far back in the fields of economics and natural resources, relating to the content of natural stocks, the Malthusian concept of resource exhaustion due to population increase. The theory that the spatial form of factors in an urban region influences ecosystem dynamics is based along the estimate that the spatial forms of the urban setting alter the biophysical structure and habitat and act upon the flows of resources. Just recently the relationship between urban patterns and energy efficiency, energy saving or renewable energy local exploitation is getting more and more significant. The much important challenge in this matter always is connected to how we can evaluate different views of the main subjects and can be aware of proper results to have best conclusion. Anyway, for this evaluation new methods need to have adopted by newest technologies that extract accurate data and data. All of new approaches such as, City as a system, Urban metabolism VS Pattern Oriented, integrated PSR-POM approach for urban - energy systems and etc. lead to present newest models and tools like Pixel by pixel analysis, Pixel by pixel analysis, Ranking system, Multivariate statistical analysis, LIDAR system and other tools, nevertheless in this paper the methods will be presented to know how can measure with this standard in urban morphology field in the approach to energy sustainability.

Keywords: Energy efficiency, Urban morphology, Evaluate methods, Newest technologies, Methods and tools

RUNNING TITLE: Urban Morphology Evaluation methods in Sustainable Energies

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INTRODUCTION

The starting hypothesis, backed by this inquiry, is that in urban settlements a strong relationship exists between "urban morphology" and "sustainable energy performances" of settlements. This dissertation proposes to make this relationship survives and to propose a method to conceptualize and spatially visualize it. The used re- lookup method is the inductive reasoning based on empirical observations. Man can now formally be named an urban species (Oliver, 2007) More than half of the global population now live in cities and the United Nations (UN, 2007) estimates that by 2030, 60 percent of us will survive in them. despite only representing 2 percent of the world's surface area, urban settlements are responsible for 75 percent of the world's energy consumption (IEA, 2008) Almost 100 percent of this energy is imported in cities from outside. According to U.N. Habitat (UN-Habitat, 2009) the world's cities emit 80 percent of worldwide carbon dioxide as well as "significant quantities of other greenhouse gases". The conclu-

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sion is easy: if you want to tackle the energy issue, tackle the cities. According to the IEA (IEA, 2008) cities planning influence, directly and indirectly, significant energy using areas. Improving the energy performances of cities can cut energy use. In the past, to improve energy efficiency in cities, the solutions have been concentrated on the micro scale and segmented interventions, mainly on the improvements of buildings' and vehicles' energy performances. Very rarely the researches were focused along the urban morphology at urban and territorial scales. The "pioneer" Owens, in 1986, wrote "Energy, planning and urban form" (Owens, 1986) This book, that could be defined as "milestone" in the research of sustainable urban morphologies from the energy point of view, suggested that city's spatial structure and built form affect the efficiency in the usage of energy and the potential production of energy from renewable sources in urban centers. Unluckily, her great work was presented in the form of guidelines completely lacking of:

1- Tools to assess the state of energy performances of existing resolutions;
2- Tools to produce the urban-energy data sets;
3- Conceptual models to be applied in the definition of assessment methodologies.

The much important challenge in this matter always is connected to how we can evaluate different views of the main subjects and can be aware of proper results to have best conclusion. Anyway, for this evaluation new methods need to have adopted by newest technologies that extract accurate data and data. In this paper the methods will be presented to know how can measure with this standard in urban morphology field in the approach to energy sustainability.

MATERIALS AND METHODS

Sustainable energy development of urban morphologies

The concept of sustainability in the last age has become amplified. Its beginning can be traced far back in the fields of economics and natural resources, relating to the content of natural stocks, the Malthusian concept of resource exhaustion due to population growth (Hollander, 1997) and fundamental economic principles on the relationship between use of goods and services and wealth. The prevailing modern usage of the word sustainability finds its recent roots in the environmental movement, for example, the 1972 UN Conference on the Human Environment and Meadows et al (Meadows and Acts, 1978) Limits to Growth, which served to promote environmental concerns onto the planetary agenda. A follow-up to Limits to Growth, Alternatives To Growth includes papers from a broad range of disciplines, presented a conference aiming to chart routes to potential "sustainable futures", which are connected with a "steady state" economy and a "just" social club. Rees (Rees, 1997) credits the World Conservation Strategy of 1980 with the first explicit use of the term "sustainable growth". By the late 1980s the idea of (environmental) sustainability became formally incorporated into mainstream development concerns with the departure of the well-known Bruntland Report (Brundtl and Commission, 1987) which formalized the concept of sustainable development, recognizing the primal need to exist inside the earth's means and the implications for passing on the same, or greater, amount of total resources to future generations. By 1992, sustain- able development hits center stage when the United Nations convened the Conference on Environment and Development in Rio de Janeiro organized around the principal themes "environment and sustainable growth" (Zegras, 2005) interactions that have survived throughout time? Sustainability regards, in fact, the interaction between human activities (economic and societal) and nature (environment). Cities, according to UN, are the seat of most of these interactions so urban settlements can be defined "the office of sustainability challenge". According to Wheeler and Beatley (Wheeler and Beatley, 2004) in urban settlement context, the foremost one who contemplated the discipline was probably Ebenezer Howard, and urban planner, in tomorrow (Howard, 1808) Regarding sustainable development, probably the most famous definition comes from the Bruntland Report: "to insure that development conforms to the needs of the present without compromising the ability of future generations to satisfy their own needs". Rather than an operational definition of sustainability the Brundtland definition offers more a general affirmation of rules. The economists' perspective offers some other approach to get at this definition of sustainable development: "maintain the capacity to furnish non-declining capital utility of infinity". [This definition introduced the concepts of solid (SS) and weak (WS) sustainability. The former requires that the amount of natural resources should not decline, over-time as this may shorten their entire supply. It postulates that natural re- sources should not be employed at a rate which exceeds their rate of renewal. The latter principle of sustainability requires that the quality of natural resources should not decline, over-time as this may dilute their value. According to Neumayer the capacity to provide utility is conceptually embodied in four kinds of capital: produced, natural, human and societal. According to Pearce (Pearce and Atkinson, 1993) Much of the ecological literature denies this substitutability, at least across some categories of natural capital. Of special interest are the "life support" functions of eco- schemes, e.g. maintenance of carbon balance, hydrologic cycles, nutrient cycles, etc. Ac- cording to Pearce (Pearce and Atkinson, 1993)

Urban morphologies with sustainable energy performances

According to Alberti "The theory that the spatial form of factors in an urban region influences ecosystem dynamics is based along the estimate that the spatial forms of the urban setting alter the biophysical structure and habitat and act upon the flows of resources. Just recently the relationship between urban patterns and energy efficiency, energy saving or renewable energy local exploitation is getting more and more important (IEA, 2009) Summarizing the state of the art of the debate it is possible to say that from an urban morphology prospective, urban development affects settlements' configurations (i.e. Compact VS sprawl) influencing their dimension, shape, location, interconnection and composition, determining, then, different morphologies of settlements (structures, textures, shapes). Several forms of the urban structure textures and forms imply alternative energy uses, and affect efficiency, conservation and energy production capacities. Some important implications of this kinship, as reported also by Alberti are:

- That spatial structure and land use patterns directly influence urban energy flows, for example by redistributing solar radiation;
- That the energy demands of human activities are indirectly determined by spatial configurations of small towns;
- That spatial structure is an important determinant of future energy supply, distribution arrangements, and exploitation of ambient energy sources.
-

Then, since different settlement configurations, modify the urban energy flows through: physical changes, induced consumptions and feasibility of using alternative systems to supply resources and services, alternative urban morphologies (structure, shapes, forms) are looked to generate different "energy performances of settlements". According to the previous assumptions, it is possible to define the "energy performances of an urban settlement" as:

- The stock of services that it needs to operate (functions that require energy);
- The stock of energy that it needs to provide the required stock of functions;
- The amount of energy that it needs to import from outside systems.

Getting into that urban settlements could be modeled as desired, as Lynch stated,
"We must learn what is desirable so as to study what is possible" it is possible to define the "urban morphologies with sustainable energy performances" those morphologies that are optimized to:

- Maximize the energy conservation: use less energy to attain a lesser energy function (reduce needs);
- Maximize the energy efficiency: use less energy to supply the same level of function (quantitative and qualitative);
- Maximize the exploitation of on-site and renewable energy sources to match local energy demand. (Fig. 1)

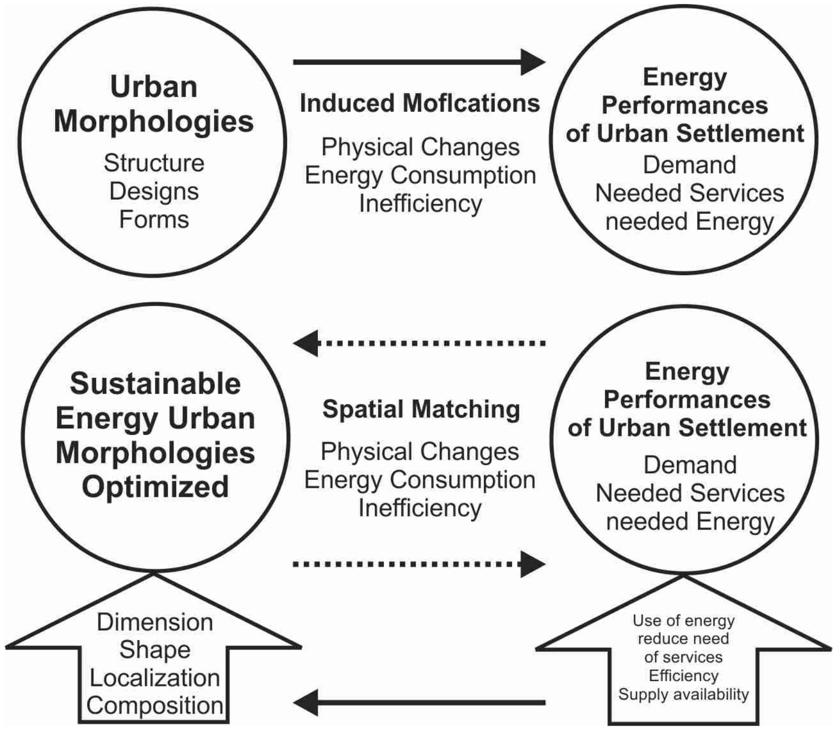


Fig. 1: The relationship between urban morphology and energy performances

RESULTS AND DISCUSSION

Urban Morphology Evaluation methods and Tools in Sustainable Energies Approach

City as a system: A complex system approach to human-nature interactions

The development of a model to estimate the energy performances of urban morphologies is required by emerging environmental and economic problems (i.e. Climate change, oil peak, etc.). Although present in the environmental debate since the early times, the interest in natural resources in the broad sense came to the head of the global scene in the Rio Conference in 1992 and the adoption of Agenda 21. This has encouraged the development of economic-environmental accounting. In OECD countries the dominant framework for reporting on the body politic of the environment are the linear Pressure-State-Responses (Rapport and Friends, 1979) and the more detailed variant Driver -Pressure-State-Impacts-Responses introduced by OECD in 1993 [3.4]. As reported also by (Weber, 2010) our understanding of the universe has changed since that time, partly because the achievements of the period (recognition of environmental statistics, production of indicators and regular publication of state of environment re- ports) have highlighted what has yet to be answered and the limits of the used environ- mental accounting approach to resolve, for example, the energy and climate change issues. Rapport and Singh reported that the in PSR approach:

- The focus on isolating "pressures", "states", and "responses" tends to provide a static representation of the environment, ignoring the important dynamic processes that integrate the interactions between these components;
- Lacks a 'bottom line' that would supply the policy community and the public with an overall appraisal of environmental movements.

Humans generate spatial heterogeneity as they transform land, extract resources, intro- duce exotic species, and modify natural agents of disruption. In turn, spatial heterogeneity, both natural and human-induced, affects resource fluxes and ecological processes in urbanizing ecosystems

Landscape ecology is, perhaps, the first consistent effort to study how human action (i.e., changing spatial patterns) influences ecological processes (e.g., fluxes of organisms and materials) in urbanizing environments. In this fabric it is possible to study the energy system in cities as an ecological process or an ecosystem service, an ecological function that have value to individual or society (IPCC, 2001) that like other ecological processes is sensitive to spatial configurations. Spatial configurations affects the magnetic fields of energy resources that ultimately hold the underlying urban energy patterns and public presentations. Vice versa in this setting it is possible to hypothesize that, in cities, changes in spatial configurations of urban morphology can modify the magnetic fields of energy resources and then control urban energy patterns and public presentations. But as Lynch (Lynch, 1961) suggested in A Theory of Good City Form "we must determine what is desirable so as to meditate what is possible". A gap exists between the "optimum" urban morphology that provides the best energy patterns and performances and the existing urban morphologies. This crack is the touchstone of the distance between what is possible to obtain from urban re-design, renewal, reconversion of an existing urban settlement and the existing conditions. Uniting all the consideration explained above the research proposes a Pressure State Response conceptual model for Urban-Energy systems with focus on urban morphologies. The theory is that focusing on the State, considered as the state of the interaction between energy system and urban morphology (quantity, character, structure and operation of the physical portion of an urban settlement) it is possible to synthesize all the pressures and changes in spatial practices that determine energy conditions in urban villages. Afterward linking this resulting potters to expect "sustainable energy performances" it is possible to evaluate the state of "urban morphologies energy performances" from a sustainable energy point of opinion. The Pressure State Response conceptual model for Urban-Energy systems will be introduced. The PRESSURES are determined by the interaction between, on the one hand Population growth and urbanization process, and on the other hand by the energy needs for urban uses, mainly for mobility and built environment (buildings and open spaces comfort). The STATE is explained on the one hand by the interactions between the resulting urban morphologies (structures, textures, forms) and on the other hand by the energy use for urban functions that influence the energy balance. The RESPONSES are, from the energy point of view, the "sustainable energy targets" that determine actions for energy saving efficiency and conservation, and production of renewable energy, and from the urban morphology point of view the design of morphologies that can maximize the positive interactions and minimize the negative interactions with sustainable energy targets. Presuming that the pressures cannot be diminished because this should limit the (population) growth the iterations between statements and responses will determine, in the urban design context, sustainable energy performances of urban morphologies.

Modeling: Urban metabolism VS Pattern Oriented (POM)

Cities are complex, self-organizing systems that develop through a large number of mainly bottom-up decisions and activities. Nevertheless, the spatial organization that emerges profoundly affects how efficiently the organization as a whole uses energy and process materials. Complex systems typically go on the modelers from building models that are too simple in structure and mechanism, or too complex and changeable. Exciting progress has been built in modeling urban metabolism, including energy dynamics, and building up an integrated hypothesis of how cities develop. These approaches, that proposes to model the urban dynamics thought a very detailed representation of the "real word", similar to a "virtual reality" approach uses very complex mathematical models that require a great deal of data as input and are very difficult to be done. Their purposes, for example, to model the city object by object, building by building, road by road, tree by tree, person by somebody.

These examples are very comprehensive but also very expensive in terms of data needs and computational resources. Recently a new theory to address the complex-systems analysis applied to ecosystem modeling. This is called Pattern Oriented Modeling (POM) strategy and it has been introduced to the scientific community and published in the Science Magazine. The POM is presented as a means to concentrate on the most substantive data around a complex system's internal organization. POM follows the basic research program of science: the explanation of observed pat- terns (Grimm, 2005) Patterns, in the POM model, are intended as observations of any kind showing nonrandom structure and therefore containing information on the mechanisms from which they issue. Complex systems contain patterns at different hierarchical levels and plates. In the words of Grimm et al."Ecosystems, for model, contain rules in primary production, species diversity, spatial structure, dynamics of component species populations, behavior of individual organisms, resource dynamics, and response of all these to disturbance events and stress. Useful patterns need not be striking; qualitative or "weak" forms can be potent in combination. For instance, we can easily identify a person in a crowd even without a strong pattern (e.g., a photograph) by applying a set of weak pasterns: sex, rough age, hair color, size, etc. Each of these characteristic patterns excludes many individual". Patterns are defining characteristics of a system and often, therefore, indicators of essential underlying process and structures. Patterns contain information on the internal organization of a system, but in a "coded" form. The purpose of POM is to "decode" this information. The motivation for POM is that, for complex systems, a single pattern observed at a specific scale and hierarchical level is not sufficient to reduce uncertainty in model construction and parameters. Therefore, in POM, multiple patterns observed in material systems at different hierarchical levels and plates are applied consistently to optimize model complexity and to reduce un- sure thing. Determining the optimal point of resolve in a bottom-up model's structure is a central problem. If a model is too simple, it neglects essential mechanisms of the real sys- tem, limiting its potential to extend understanding and testable predictions regarding the problem it addresses. If a model is excessively complex, its analysis will be sticky and likely to become bogged down in detail. The way to find an optimal zone of model complexity is defined in the POM theory as the "Medawar zone". "Payoff of bottom-up models versus their complexity. A model's payoff is determined not only by how useful it is for the problem it was developed for, but also by its structural realism; i.e., its ability to produce independent predictions that match observations. If model design is guided only by the problem to be addressed (which often is the explanation of a single pattern), the model will be too simple. If model design is driven by all the data available, the model will be too complex. But there is a zone of intermediate complexity where the payoff is high. We call this the "Medawar zone" because Medawar described a similar relation between the difficulty of a scientific problem and its playoff. If the very process of model development is guided by multiple patterns observed at different scales and hierarchical levels, the model is likely to end up in the Medawar zone."

Modeling has to start with specific questions. From these questions, it is possible to formulate a conceptual model that helps us decide which elements and processes of the real system to include or ignore. With complex systems, however, the question ad- dressed by the model is not sufficient to locate the Medawar zone because they include too many degrees of freedom. Moreover, the conceptual model may too much reflect our perspective as external observers, with our specific interests, beliefs, and scales of perception. A key idea of POM is to use multiple patterns observed in real systems to guide design of model structure. Using observed patterns for model design directly ties the model's structure to the internal organization of the real system. To develop a Pattern Oriented model the question to be answered is: "What observed patterns seem to characterize the system and its dynamics, and what variables and processes must be in the model so that these patterns could, in principle, emerge?" This use of patterns might force us to include state variables and processes that are only indirectly linked to the ultimate purpose of the model and are not part of our initial conceptual model. Ideally, the patterns used to design a model occur at different spatial and temporal scales and different hierarchical levels, because the key to under- standing complex systems often lies in understanding how processes on different scales and hierarchical levels are bound to each other. Again, according to Grimm et at all(Grimm, 2005) when designed to reproduce multiple patterns, models are more likely to be "structurally realistic". In particular, model components correspond directly to observed objects and variables, and processes correspond to the internal organization of the real system, so that the model "not only reproduces the observed real system behavior, but truly reflects the way in which the real system operates to produce this behavior" . The method proposed in this research apply the POM to the complex system "urban morphology – energy performances" assuming the model components as the urban morphology spatial patterns and the processes as their sustainable energy performances.

Sustainable energy and urban morphologies: an integrated PSR-POM approach for urban - energy systems

In the following paragraphs I included different aspects of sustainable energy that, according to the literature, become important in the design of urban morphologies with sustainable energy performances.

- Energy Saving and Conservation
- Micro climate design of urban morphologies
- Passive solar design of urban morphologies
- Proximity design of urban morphologies
- Density design of urban morphologies
- Energy efficiency
- Transport modalities and urban morphologies
- Renewable Energy source exploitation

Scales

According to the sustainable development debate the three components of sustainability in the city are Economic, Social, Environmental and have to be considered together. The challenge of finding a sustainable urban morphology has induced to propose new frameworks for the redesigning and restructuring of urban places to achieve a higher level of sustainability These approaches have been addressed on different spatial scales:

- The regional and metropolitan scale;
- The city/urban scale;
- The neighborhood/community scale;
- The building scale.

A critical review of these approaches demonstrates a lack of agreement about the most effective analytical scale in the context of sustainability. From the sustainable energy point of view some critical analysis can lead to the same considerations. According to [3.48] different aspects of spatial structures of settlements become important, if related to energy, as we move across various scales. In geography anyway, the notion of scale can be a source of ambiguity. It is always used in the sense of spatial resolution, but it can just as well refer to cartographic representation or levels of observation and analysis.

The Interaction matrix

Driving from the considerations presented in the preceding paragraphs about analytical scales and interactions between sustainable energy and urban morphologies, an inter- action matrix that systematize these relationships is presented. The aim of this tool is to prepare the analytical framework for the analysis of the spatial relationships between urban morphologies and sustainable energy performances. The matrix is based on the PRESSURE-STATE-RESPONSE conceptual model . In the X axes we find the STATE represented by different urban morphologies ordered by scale (regional, urban and neighborhood) and by urban function (urban comfort, mobility, energy production). In the Y axes we find the RESPONSES, represented by three aspects of sustainable energy (saving and conservation, efficiency and renewable energy). The output of the matrix is then used to define the set of spatial indicators to describe the spatial patterns of energy performances of urban morphology. the complete interaction matrix is presented in Tab. 1

Tools

The Indicators set: energy performances of urban morphologies

From the interaction matrix a set of spatial indica-

	RESPONSES				
STATE			Energy saving and conservation	Energy Efficiency	Renewable energy production
	Regional scale		INTERACTIONS		
		Comfort			
		Mobility			
		Production of energy			
	Urban scale				
		Comfort			
		Mobility			
		Production of energy			
	Neighborhood Scale				
		Comfort			
		Mobility			
		Production of energy			

Table 1. Multi-scale structure of the interaction matrix

tors is derived. These indicators are given in form of spatial patterns metrics. Every spatial pattern metric can finds in literature several ways to be calculated. For ease of presentation the procedures to obtain the indicators are not described in this section.

Pixel by pixel analysis

Spatial indexes are rendered in raster images of a standard resolution to permit the use of the pixel-by-pixel comparison approach . Each pixel refer to a land unit, according to the spatial resolution of the grid, and represent the value of the spatial index. The pixel composition renders the spatial patterns of the indexes. Traditional pixel-by-pixel comparisons involve overlaying mappings to evaluate the similarity between two or more maps.

Multivariate statistical analysis

Once the locations have been characterized, the intensity and the types of spatial differentiations have been determined, and the similarities and contrasts have been brought to light, the next task consists of finding the relationship between these features of spatial organization and to determine the exchanges these locations maintain among each other, as well as the mutual influences they have on each other: the inter- actions driven by spatial organization. Multivariate Statistical Analysis applied to raster images (MSARI) is selected to examine relationships among the spatial pattern metrics that are treated as variables. The MSARI technique allows exploration of relationships between many different data layers or types of attributes (Jiang, 2002) The Multivariate statistics is a form of statistics encompassing the simultaneous observation and analysis of more than one statistical variable. In particular the Principal Component Analysis (PCA) involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. It is mathematically de- fined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on . In particular the correlations matrix is used to verify the relationships between the variables and to identify positive and negative correlations between them.

A ranking system

Finally a ranking system is used to assign scores to each aspect of "sustainable energy performances". In particular, arbitrary thresholds derived by literature are used to as- sign a score to each pixel for each spatial index. The scores are then summed for each pixel and for each spatial index belonging to a sustainable energy performance aspect (Saving and Conservation, Efficiency and Renewable energy production). The resulting maps are used to visually appreciate the differences in sustainable energy performances for the urban settlements areas.

Remote sensed datasets: new frontiers for the construction of a dataset for urban-energy planning and design

Remote Sensing is a powerful tool to assess environmental phenomena. The process of collecting geographic data to describe environmental phenomena over the past thirty years has seen the mapping industry moves from brute force approaches (e.g., field surveying) to passive sensing approaches (e.g., photogrammetry and passive remote sensing) Today the integration of Aerial Photography, Multispectral Images and low resolution Digital Elevation Models (DEMs) represent the core of most environmental process modeling (Schumann and etc. , 2008) This technique proved to work very well at the regional scale but local environmental phenomena exists that call for a deeper scale analysis. Urban Environments' phenomena are between them. In Urban Environments it is very difficult to automatically distinguish the objects by using traditional classification methods because of the high complexity of the urban pattern. A Three-dimensional urban model is necessary as a base for many urban energy analysis such as urban morphology energy efficiency, solar energy source potential estimation and urban heat island assessment . Recently, the panorama of mapping industry for geographic data collection moved to active sensing approaches: e.g., LiDAR and Radar

Airborne LiDAR sensor for 3D representation of urban morphology spatial patterns relevant for energy

The LiDAR Technology The LiDAR (Light Detection and Ranging technology) is an optical remote active sensor that measures properties of scattered light to find range and/or other information of a distant target. The method to determine distance to an object or surface is to use laser pulses. Using accurate timing, the distance to the feature can be measured. By knowing the speed of light and the time the signal takes to travel from the sensor to the object and to come back to the sensor, the distance can be computed using the basic relationship:

$$D = vt/2$$

where D is the distance from the aircraft to the object (this is one-half the total distance that the laser signal actually traveled), v is the velocity or speed of light, and t is the time between emitting and receiving a particular signal (Burtch, 2000) (Fig. 2)

The LiDAR technology has been in existence for 30 years but became commercially available only recently .Airborne LiDAR is relatively new technology complementary to traditional field surveying, multispectral and photogrammetric approaches. This system collects data from the first

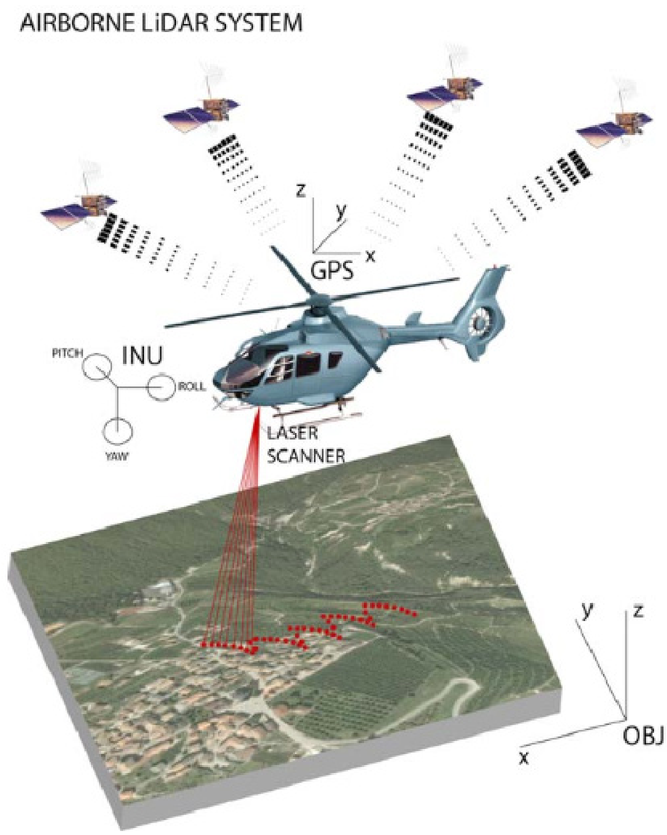


Fig. 2 Airborne LiDAR system

surface hit by laser beams. The resulting DEMs are representative of the elevation of that surface composed of both the "bare earth" surface and above ground features. Used in combination with an aircraft the LiDAR provide laser-based measurements of the distance between an aircraft carrying the sensor and the ground . On a functional level, airborne LIDAR is typically defined as the integration of three technologies into a single system capable of acquiring data to produce accurate ad high resolution DEMs in physical applications. These technologies are: Lasers, Global Positioning System (GPS), and Inertial Navigation Systems (INS). Combined, they allow the positioning of the footprint of a laser beam as it hits an object, to a high degree of accuracy. The integration of LiDAR with airborne GPS facilitates the wider use of high resolution DEMs in physical applications .Advancement in LiDAR technology have al- lowed 3D information of environment to be remotely obtained over large areas. LiDAR produces fine scale 3D data from which environmental structural attributes can be de- rived. It can operates during the day and the night and it is not affected by shadows, dark soils, and different light conditions, unlike conventional aerial photography or multispectral images (Dowling, 2003)The resulting measurements can be post-processed to pro- vide a DEM with a precision up to 15cm .The method of survey with an airborne LiDAR is rapid, relatively economic, allows survey over difficult terrain, and large areas providing information simultaneously of both surface and topography. It was estimated that LiDAR allows a quick collection of topographic data for large areas, up to 90 km2 per hours (Marks and Bates, 2000) and while first-pulse LiDAR measures the range to the first object encountered, such as the vegetated surface the last-pulse LiDAR measures the range to the last object represented, for example, by un vegetated surface. By acquiring such first and last pulse data simultaneously, both object heights and the topography of the ground beneath can be addressed in a single pass. The 3D point cloud could be then filtered and classified as ground, vegetation, structures etc., in order to obtain Digital Terrain Model (DTM) (Fig. 3) depicting only the ground and Digital Surface Model (DSM), which also includes all other objects like for example buildings and trees. The difference be- tween DSM and DTM produces the Normalized DSM, nDSM, (Fig. 3) (Fig. 4)

Accurate 3D digital models of urban environments are required for a variety of applications. Using the proper operational parameters, airborne LiDAR offers the ability to accurately map urban environments without shadowing. Detailed DSM can be extracted from the LiDAR data and enhanced

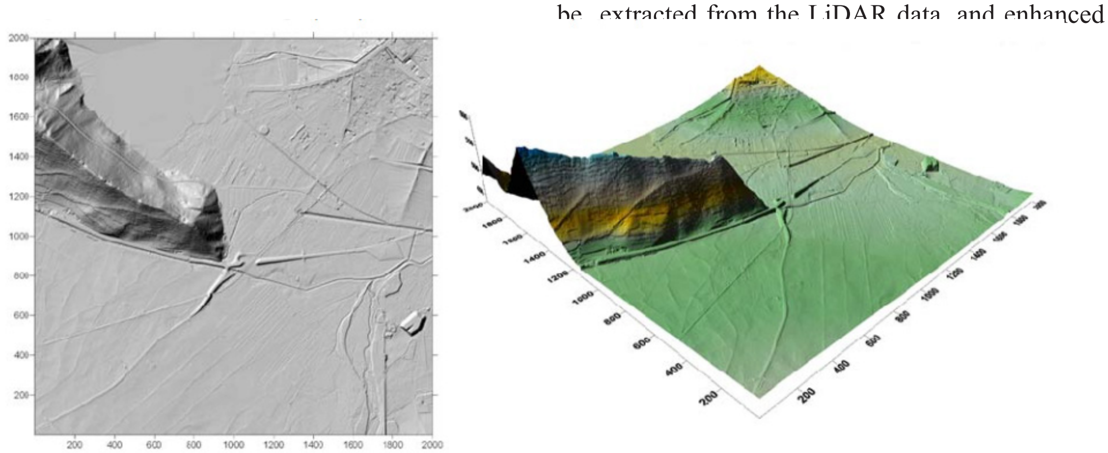


Fig. 3. Digital Terrain Model (DEM derived from Last-pulse LiDAR) 1m resolution, depicting only the ground, the “bare earth”. Levico lake area – Province of Trento, Italy: shaded relief map (left), surface render (right).

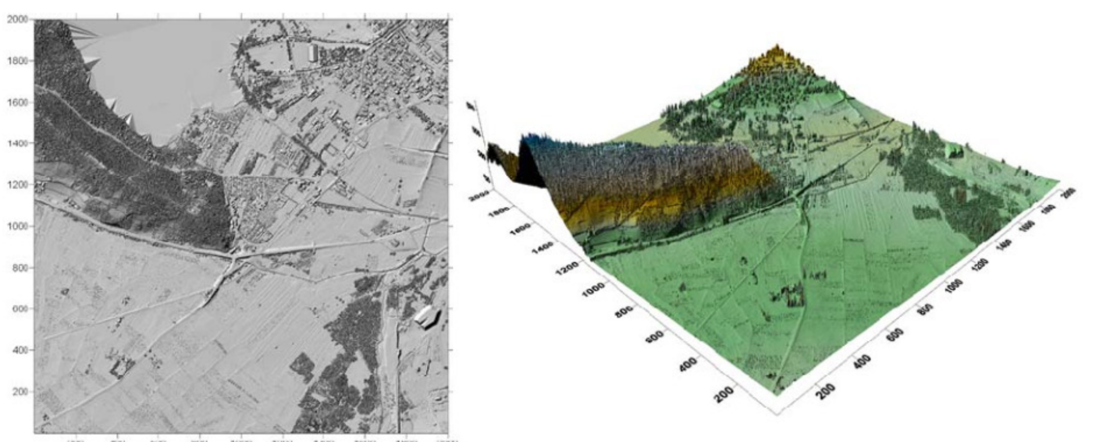


Fig. 4. Digital Surface Model (DEM derived from first-pulse LiDAR), 1m resolution, includes buildings and trees. Levico lake area – Province of Trento, Italy: shaded relief map (left), surface render (right).

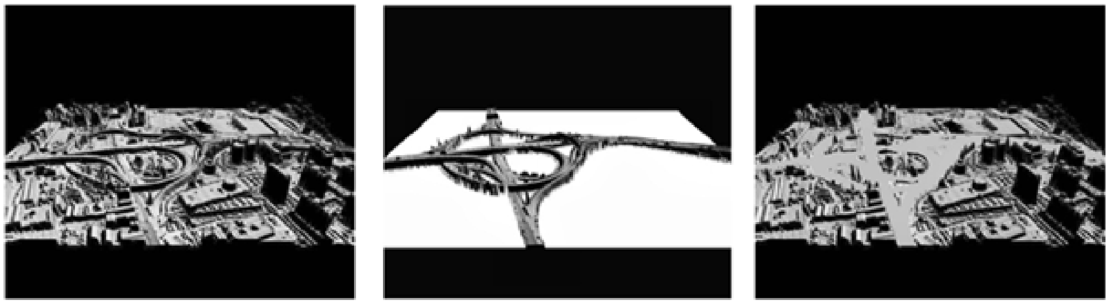
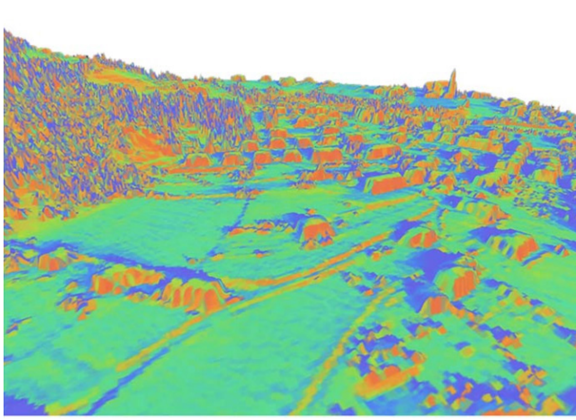


Fig. 5. DSM, DTM and nDSM. Trento northern area.

for applied analysis using specialized 3D rendering software. By adapting a set of appropriate geometric primitives and fitting strategies, the system can model a range of complex buildings with irregular shapes. The amount of information contained in such high-density 3D point clouds is enormous. A number of natural and manmade features, such as bare topsoil, trees, roads, buildings, waterways, power line, bridges and ramps are all easily discernable to the human eye in cross sections and range and intensity images . The panorama of application that LiDAR data can support in urban environment modeling is very wide. The first uses of airborne LiDAR in urban modeling includes telecommunications, law enforcement and disaster planning, but there are still many application to be explored. Vettorato and Geneletti. for example demonstrate the effectiveness of LiDAR data in the estimation of potential solar energy applied to building roofs to produce energy by thermal or photovoltaic solar panels. Fig. 6, Solar Irradiation Model applied to LiDAR data in a urban context. Ron- cegno Terme – Trentino, Italy.

However, there are also drawbacks and limitation related to the use of LiDAR sensor. Some difficulties, for example, were reported when determining the level of precision of LiDAR measurements for some surveys. The post-processing of data seems to be, so far, the main problem of LiDAR. While



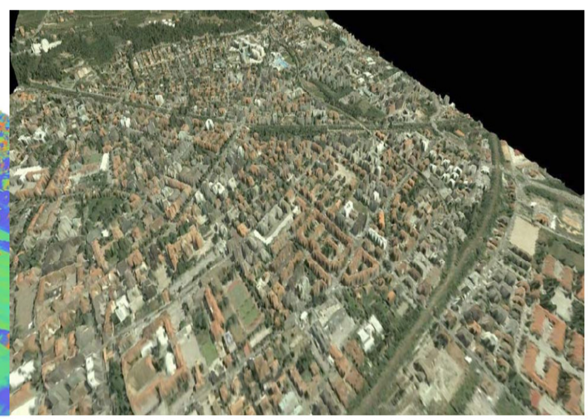
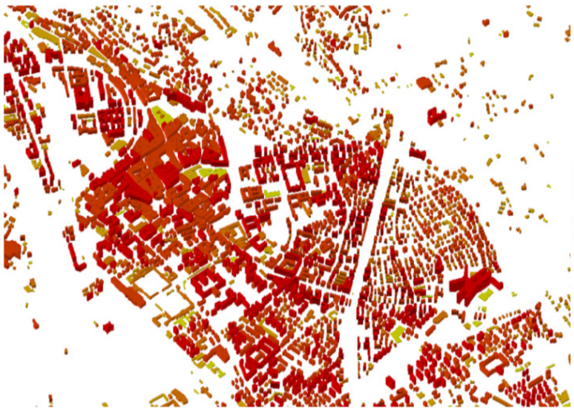


Fig. 6. Trento area: 3D render of LiDAR survey and Orth photo, Fig. 7 Trento center area: 3D render of buildings (height), extracted by the LiDAR survey.



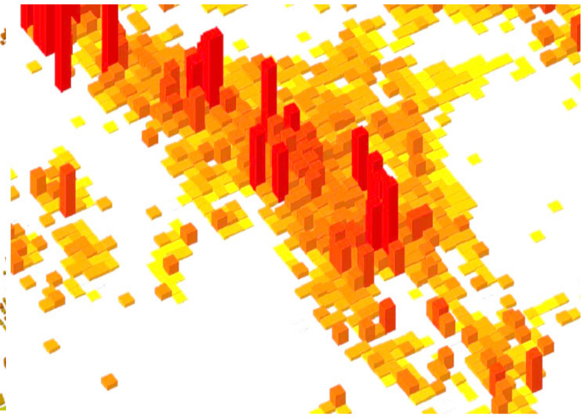


Fig. 8. Trento southern area: 3D render of Floor to Area Ratio (FAR) Fig. 9. Trento southern area: 3D render of Floor to Area Ratio (FAR).

the LiDAR technology continues to advance, the algorithms required and the amount of data that they have to process is significantly more. A better development of soft- ware to keep up with the demand for new application is necessary. 3D urban modeling, automated classification and vegetation mapping are three sectors to be deeply developed yet. The LiDAR market is growing all around the world, but LiDAR handling software is not.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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