URBAN MANAGEMENT: AVAILABILITY OF TECHNICAL TOOLS

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ABSTRACT

The research identifies the basic social, economic, and environmental impacts of the current global urbanization rates and the results of this research are illustrated by examples and statistics derived from various countries. It is emphasized that the current situation and its impacts bring new challenges for planners, surveyors and government administrators.

Simultaneously with the rapid global urbanization process, mainly in the second half of the 20th century, major technological developments occurred and their impact on the surveying, mapping and geographic information communities is extremely significant. During the last decades new advanced hardware systems and sophisticated geospatial processing algorithms have been developed, thus affecting dramatically the traditional methods for data collection and data processing and providing surveyors, planners and administrators with new methods and techniques to improve the systems and tools used for land management.

A review of the available technical tools for spatial information collection, integration and management is given mainly according to their applicability for better urban management. Proposals are given about the most appropriate tools that facilitate usage of the diverse spatial information derived from various sources (such as photogrammetry, field surveying, radar, LiDAR, cartographic digitization and scanning) to facilitate current urban planning and management needs (such as city modeling, informal development detection, environmental monitoring, risk management, disaster prevention).

Key word: Urbanization, Spatial Management Tools, Data Collection, Data Integration, Data Processing

1. INTRODUCTION

Homo sapiens did not start as an urban citizen; it took about 120,000 years until the end of the last ice age when the very first "human settlement" appeared, and about 6,000 years more until the classical antiquity when people established large cities to live together for security and prosperity, for trade, but also for worship or for other specific purposes like the organization of the Olympic Games. Generally, living together meant security and provided the opportunity to exchange goods and ideas. During the 5th

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century B.C. several Greek cities had populations of several thousand people. By example, it is estimated that in those days the city of Athens in its greater jurisdiction of a total area of 2650 Km^2 had about 40,000 citizens, the city of Argos had 20,000, and the city of Samos, the capital of an Aegean island, of 450 km^2 had 15,000 citizens (Mega, 1990; Tassios, 2009).

The 5^{th} century BC brought an innovative element in the history of the cities, the initiation of city planning by Hyppodamos from Mellitus; however, the "rectangular road network" had already been applied in Egypt and Babylon (Mega,1990; Lavedan, 1926; Martin, 1956). Location and topography played a major role in the development and structure of the cities. Most ancient cities had structural similarities: built near water (sea, lake, or river) the lower city had a public square (Agora) of a mean size of 20x40 m^2 and an Acropolis built on the top of the hill; the area in between was used for constructions such as theaters and stadiums that required a natural ground inclination (of about 23^o-27^o).

As some cities developed through the centuries, they became known for their specific attributes. By example, in the classical era Delphi, Delos, Epidauros and later on Rome, Jerusalem and Mecca were known for their religious role, Alexandria for the library, Constantinople as the capital of the empire, and Beijing as a center of administration. In modern days culture and market have in a way "replaced" religion; visitors, but also investors and large international corporations, are attracted by the largest cities worldwide for the museums, exhibitions, cultural events, fashion, theaters, art galleries, etc. Cities became centers of learning, innovation and sophistication.

However, already since the very early years there was much concern about the size and the density of the cities and about their expansion. Plato (in his "Republic", 49B) advised "*as long as the city expands without loosing its connectivity let it expand, but no more*".

It is true that technological improvements in transportation, and some primitive services provision, like fresh water and sanitation, in the Roman times have facilitated the increase of urban population. However, all over the world, many city-dwellers' health is still threatened by inadequate provision of fresh water and sanitation.

During the Byzantine era, Constantinople had a population of 500,000 citizens (6^{th}-7^{th} century AD) and was considered to be the second largest city after Baghdad. Today, the same city, Istanbul, has become a mega-city of approximately11 million citizens. It is obvious that the location and topography of the area, together with other major factors like economy, conquest, good or not so good government, disease, etc, have played a major role for the longevity and expansion of several cities through centuries.

Initially the industrial revolution didn't actually improve the quality of life in the urban areas, but because it offered a plethora of jobs, a new urban era began. The twentieth century witnessed the rapid urbanization of the world's population. By 1900 13% of the world's population became urban. During the next years, improvements in medicine and science allowed larger city densities. According to UN reports, the urban population increased from 220 million in 1900 to 732 million in 1950 (29% of the world's population). By 2007 50% of the world population live in the cities; further improvements in technology, medicine and prevention of disease allowed even larger urban densities; according to latest predictions, 4.9 billion people, or 60% of the world's population, are expected to be urban dwellers in 2030 (Table 1).

Table 1. Global proportion of the urban population increase (source: UN Population Division)

Year	**Urban population** (million)	**Proportion**
1900	220	13 %
1950	732	29 %
2005	3,200	49 %
2030	4,900	60 %

Investigations show significant differences in urban population change between the more developed regions and the less developed regions. The majority of the inhabitants of the less developed regions still live in rural areas, but in the more developed regions the population is already highly urbanized. As urbanization tends to rise, as development increases, urbanization is expected to rise as well, in future (Table 2). However, despite their lower levels of urbanization, less developed regions have more than double the number of urban dwellers than the more developed (2.3 billion vs. 0.9 billion). By 1968, the urban population of the less developed regions surpassed for the first time that of the more developed regions and continues to do so thereafter; furthermore, the rapid growth of the population of the less developed regions combined with the near stagnation of the population in the more developed regions implies that the gap in the number of urban dwellers between the two will continue to increase (Table 2) (UN, 2006).

Table 2. Differences in urban population rates (source: UN Population Division)

Year	**More developed regions**		**Less developed regions**	
	Population (billion)	Per cent	Population (billion)	Per cent
1900	0.15		0.07	14 %
2005	0.90	74 %	*2.3*	43 %
2030	1.00	81 %	3.9	56 %

Eight out of the nine countries with more than 50 million rural residents (Bangladesh, China, Ethiopia, India, Indonesia, Nigeria, Pakistan, Viet Nam), are all located in the less developed regions. Additional population is expected to migrate to these cities in future.

The 20^{th} century is related to the emergence of mega-cities (cities with population greater than 10 million). Never before had such large populations been concentrated in cities. Since 1950, the number of mega-cities has risen from 2 to 20 in 2005 (UN, 2006). Moreover, 17 out of the 20 mega-cities in the world are located in the less developed regions. Ancient Megalopolis, built by Epaminondas in 371-368 B.C., was the capital of the Arcadian alliance in Greece, and was considered to be a model of a prosperous, happy and peaceful city; most current mega-cities (that actually share the same name with the ancient city) but also metropolitan cities (cities up to 5 million) do not experience a similar quality of life, since global population growth is becoming an urban phenomenon mainly in the less developed regions (UN, 2006).

2. IMPACTS OF RAPID URBANIZATION

According to the research results, impacts may be briefly classified as following:

- High urban densities, lack of green areas and buildings reflecting local cultural heritage, of local historic or architectural value
- Transport, traffic congestion
- Energy inadequacy
- Unplanned development and lack of basic services e.g., public transportation, fresh water, parking areas, waste management, sanitation, public toilets
- Illegal construction both within the city and in the periphery; dilapidated city centers
- Unclear or informal real estate markets
- Creation of slums
- Poor natural hazards (floods, fires, earthquakes, etc) management in overpopulated areas
- Crime
- Water, soil and air pollution; environmental degradation
- Climate change
- Inefficient administration, bad governance (Potsiou, 2008)

Almost all big modern cities, due to over-increased population, worry about pollution, creation of dilapidated city centers, energy inadequacy, increased criminality, garbage treatment, etc. It is ironic that much of what was once considered as the major advantages of life in the city, like security, better housing conditions, and services provision are now transformed into the city's major disadvantages, like criminality, slums, lack of services.

In 500 BC the city of Athens organized the first municipal dump in the Western world. Citizens were required to dispose their waste at least one mile from the city walls. Today, Athens is in the grip of a garbage crisis. Six thousand tons of trash is produced daily in this city of more than 4.5 million people.

Until 2005 Greece was operating 1102 open landfills. Greece has successfully managed to close most open landfills (only 410 are still operating) and avoid high EU penalties. However, the costs for the regeneration and mechanical recycling procedure are also high (~145 million €) (Potsiou, 2009).

The Public Power Corporation's (PPC) plant in Kozani, Greece has been found to be one of the most polluting in Europe. PPC will pay up to 2,2 billion euros a year for carbon emission licenses unless it shifts away from its dependence on lignite. Consumers could expect a rise in electricity bills of 45% by 2013 (Figure 1) (Potsiou, 2008).

When it comes to transportation in mega-cities, statistics show that Mumbai (a city of 14-18 million citizens) has low level of car ownership with 29 cars per 1,000 residents; 55.5 % of Mumbai's population walk, 21.9 % go by train, 14.4 % use the bus, and only 1.6 percent drive their car. However, more than 20,000 people have been killed on Mumbai's notoriously overcrowded train system over the past five years — many of them crushed, run over or electrocuted — according to official data. No other city in India has so many people traveling by one mode of transport. There are a minimum of 10 deaths daily on the railways (The Boston Globe, April 18, 2008).

As cities expand beyond their administrative boundaries they lack the financial or jurisdictional capacity to provide the necessary services (planning, water, electricity, sanitation, etc) to all inhabitants. The administration of the city becomes more complicated and bureaucratic in the less developed countries, where new technology and necessary digital tools are not implemented.

Fresh water becomes expensive. Most cities in the developing world discharge their sewage untreated into the rivers (from where they also draw their drinking water) or into the sea, together with farm chemicals and industrial effluents. Some 20 years ago, for example, a large quantity of Delhi's sewage was used for irrigating the agricultural lands. Today much of the agricultural land has been converted into residential colonies. Delhi alone contributes around 3,296 MLD (million liters per day) of sewage to the local water bodies.

Figure 1. PPC plants in Greece

Figure 2. High urban densities in countries in transition

Most of the world's current urban expansion is caused by the poor migrating in unprecedented numbers. This situation usually results in the overwhelming of capacity in certain places. This is also the case in most eastern European countries in transition (Tsenkova et al., 2009). Accelerated development, pro-poor or affordable housing needs, and economies of scale often lead to high urban densities (Figure 2) by tearing down the stock of old buildings, including buildings of character, built to a human scale, that reflect local architecture and history. Affordable housing often seems to mean identical constructions, of more than 25m height, built of concrete. By example, for achieving economies of scale in Skopje the capital city (of only 571,040 citizens) of FYROM, this has recently become the minimum required height prescribed in the building regulations, while in the past planners were accustomed to work with maximum permitted height standards. Furthermore, due to pressure to reduce government deficits, many developing economies apply flexible or poor environmental regulations for their productive units in order to achieve competitive advantages in production, and attract international investment.

Safety standards are frequently overlooked, for the sake of increased commercial profits, with terrible results (Sahapira, 2009 & Altan, 2009). Such was the case of L' Aquila, Italy in April 2009, following a strong earthquake. Humanity has lived with floods for centuries but the impact of floods was not felt to the same extent in the past as it is experienced now. Construction in the stream and river routes or close to the coast, or in areas where extensive deforestation has taken place due to accelerated development, presents greater risk of flooding. The results are similar whether in the favelas of Sao Paulo, or in the unplanned settlements of Eastern Europe, or in New Orleans, or in Asia. Natural disasters, floods, earthquakes and fires are more difficult to deal with in highly urbanized areas, and affect both rich and poor (Figure 3).

Figure 3. Floods in Mumbai

Figure 4. Fires in Attica, the greater region of Athens, Greece in 2009

Rapid population increases lead to rapid informal urban development (Tsenkova et al., 2009). As cities get crowded and polluted and new technology enables people to work in rural areas at the urban fringe (where rural and non-serviced land is cheaper) on home computers, or makes commuting easier, an inverse process, the so called sub-urbanization takes place mainly around large cities. The spread of low or middle-income population to the cities' outskirts and surrounding rural lands for better living conditions in single family self-made houses results in informal or unplanned development of relatively good construction quality, expansion of municipal areas, illegal changes in the spatial organization of land-uses, informal real estate markets and loss of state revenue, and increased pressure on water resources and green areas (Potsiou, 2009).

Due to the failure of the state to ensure modern and effective zoning and planning regulations and the multiplicity of administrative agencies involved in forest and public protection, uncontrollable fires in the greater region of Athens metropolitan centre becomes an ever-more-regular phenomenon (Figure 4) threatening people's lives and properties scattered on the periphery of the city.

Figure 5. Left: Dharavi, Mumbai, India. Right: Informal settlement in Albania

Another type of informal development is caused by the poor who seem to prefer urban squalor to rural hopelessness. According to UN statistics, one of every three of the world's city residents lives in inadequate housing with few or no basic services (fresh water, sanitation, schools, hospital, and security). The world's slum population is expected to reach 1.4 billion by 2020. Informal settlements, whether of good or bad construction quality have a common characteristic all over the world: they do not officially exist! And for that reason government provides nothing or very little in the best cases. Slums in the less developed areas whether in Latin America, Africa, Asia (Figure 5 left), Ex-Soviet Asia, or even in Europe (Figure 5 right) have a few similar characteristics: unclear land tenure, poor quality and size of construction, no or poor access to services and violation of land-use zoning.

Unfortunately the slum situation is not going to change easily because both the city administrations and the slum dwellers enjoy some benefits:

- Frequently, many people make money from such informal housing sector
- Slums provide cheap labour that enables city to operate
- The situation suits the authorities nicely, since the economy of the city is supported and at the same time is an alternative to the missing social housing policy
- Several politicians and civil servants are reputed to be landlords in slums areas
- Poor rural people or immigrants are offered hope for employment in the formal economy of the city
- Slums are usually well placed, near the city: if the poor do find jobs they can walk to work (Potsiou, 2008).

As shown above, rapid urban development leads to a series of problems, the most important threat of which may be the global climate change. World greenhouse gas emissions, one of the major factors responsible for climate change, have increased 70% between 1970 and 2004. Much of that is due to growth in the sectors of energy (+145%), transportation (+120%) and industry (+65%), and to the reduction of forest land and land use changes (40%) (Wilbanks et al., 2007). Current sustainable development policies are directed at practices leading to climate change, and much research is being carried out to provide appropriate policy options for the sectors of energy supply, transportation, buildings, industry, agriculture, forestry and waste management.

Restrictions on private rights in the use of land in terms of air, soil and water pollution have to be defined clearly and accepted by all market participants (state, individuals, funding institutions, entrepreneurs, etc) and applied equitably. All must assume the costs of the natural resources they consume, knowing that their competitors do the same (Economic Studies Division of Alpha Bank, 2007).

Urbanization can still be seen as an indicator of development, generally related to industrialized and technologically advanced economies. The concentration of major economic activities in the urban areas produces economies of scale and leads to various social and economic benefits, like employment, higher quality of health and education services, trade and cultural activities. It is a matter of human rights that people are free to choose where they will live. However, nobody wants to live in a city which is congested, suffers constant blackouts and frequent floods, has few parks, poor schools and clinics, is devoid of any buildings of charm, and is governed by an incompetent public sector.

Legislation and regulations for water supply, sewage treatment, control of air, water and soil pollution from industry and traffic, control of radioactive and toxic substances storage, garbage management, garbage burial and studies for the environmental impact of each large development project, are in the agenda of the authorities in most countries. Such legislation however, cannot always be efficiently applied and relevant services cannot be appropriately planned without the necessary legal framework for the provision and dissemination of reliable and updated relevant spatial information. Markets cannot function efficiently without reliable systems to secure land tenure and zoning and planning systems to define the regulations concerning private rights for the use of land and natural resources. In Europe, spatial information infrastructure is usually provided by the cadastral, planning and land development permitting authorities and it is a fundamental tool for sound decision making, providing for the management of land in a holistic way (Enemark, 2007 & 2009).

It is obvious that humanity has never experienced such problems in the past. It is a matter of good governance to achieve sustainable urban growth, and this brings new challenges for planners, surveyors and Governments. The new tools that are now available, in comparison to the past times, are reliable advanced technology and spatial data for better decision-making. In the following, the resolutions of a research made on the current technical tools that support spatial data collection, management and dissemination for the purpose of good governance and sustainable urban development will be reported.

3. TECHNICAL TOOLS

Following the rapid urbanization processes, the need for updated, precise and continuous representation of our natural environment in general, and urban areas in particular, is nowadays one of the more urgent and major tasks the surveying and mapping community has to answer and give adequate solution to. During the last decades major technological developments in data collection, data integration, data analysis and building of sophisticated GI databases were introduced. These new data acquisition technologies on the one hand, and methods, algorithms and software packages on the other hand, yield that the surveyors, computer experts and the mapping community has to give answer to rapid and frequent updating, integration and analysis of existing GI databases, and moreover - deal with data volumes, resolution levels, and accuracies that were unknown until recently. These technological developments can be divided into two groups: (i) data collection; and, (ii) data integration, processing and analysis.

3.1. Data Collection Technologies

As to data collection, until recently it was basically acquired and measured by one of the following three different techniques (Zhilin et al., 2005):

a. Photogrammetry, which utilizes stereo pairs of aerial or space imagery covering approximately the same area;
b. Field surveying that utilizes total station and Global Positioning System (GPS) receivers for a direct field measurements;
c. Cartographic digitization and scanning, which utilizes raster vectorization techniques to convert existing maps.

Recent technological developments feature two new techniques in addition to the existing ones:

d. Radar based systems, utilizing radargrammetry techniques as well as Interferometric Synthetic Aperture Radar (IfSAR) imaging;
e. LiDAR (Light Detection and Ranging) that produces 3D point cloud representing the scanned region.

3.1.1. Photogrammetry

Photogrammetry utilizes a pair of stereo images (covering approximately the same area from two different directions and positions), i.e., stereoscopic model. The geometric properties of objects are determined from the acquired images by a metric measurement of 3D coordinates. Usually, large regions are covered by an aerial strip or a block containing a large number of photographs (and stereoscopic models). As a result, aerial imagery is probably the most common and most effective source to map a region (usually acquiring a digital geospatial dataset or database of the region), as well as to update existing maps (or GI databases).

Figure 6. Operational Photogrammetric Systems (Habib, 2009)

Similar to aerial imagery, satellite imagery are common today and is being used in photogrammetry, usually only for production of maps at smaller scales. Though satellite imagery resolution is becoming denser, aerial images still present higher resolution - and are relatively more accurate. The horizontal/vertical accuracy is a variable figure that is a function of the sources and photogrammetric equipment utilized to collect the data. It is worth noting that with the development of digital aerial cameras since the 1990s and small digital metric (aerial) cameras in last few years, high quality digital imagery is increasingly available (Figure 6). Additionally, with the progress in high performance computer hardware and software, automation of part of the photogrammetric processes becomes feasible and techniques from image processing and computer vision have successfully been employed (Habib, 2009).

3.1.2. Field Surveying

Traditional field surveying techniques acquire the precise location (position) of certain points on earth, i.e., coordinates, by direct measurement. This can be done by measuring distances and angles while utilizing total-station, or GPS receiver for the task. Though the accuracy of a position acquired here is very high (in respect to other techniques), this type of equipment deliver much fewer data and is usually used to measure and map only small areas (especially when high level of accuracy is required, i.e., in dense urban areas). Field surveying is usually being used to measure ground control points as a basis for the photogrammetric process.

3.1.3. Cartographic Digitization and Scanning

Digitization and scanning can be performed on maps in order to "transform" existing graphical paper maps to a digital dataset (probably as input to a digital geospatial database). This can be achieved by: i) *vector-based* line following, and; ii) *raster-based* scanning. Though manual digitization is still performed, semi-automated and automated algorithms are becoming more available nowadays, and many on-the-shelf GIS (Geographic Information System) software packages are equipped with tools delivering these tasks. Manual quality assurance was widespread when applying theses tasks, though with new automated developments it is becoming less common - and eventually will disappear soon. Until recently, producing a digital database via these techniques while using medium-scale to small-scale maps was very common. Nowadays, these techniques are being used mainly to "digitize" graphical map of underground infrastructure networks (i.e., water and sewage networks) where direct field surveying might be non-possible or too expensive.

3.1.4. Radar Based Systems

SAR technology (based on Doppler frequency shifts principle) is utilized mainly to acquire images, and it was proved that these images are very sensitive to terrain variation. Until recently, SAR images were utilized mainly to produce DTMs (describing the terrain) either by radargrammetry algorithms by parallax measurement (principally similar to traditional photogrammetry only here it utilizes intensity data for measurement), or by inteferometery algorithms by phase shifts extracted from two acquired epochs.

In the last few years, based on the remote-sensing satellite technology, small and compact high-resolution radar systems have been developed, systems that can monitor land and buildings from air as well as from space. These radar systems monitor structures such as dams, harbours, canals and buildings, leading to mapping of urban areas, for example: planning, cadastral updating, etc. Several flights over the same location enable us to discover changes between pictures, revealing ground movements that could affect structures. This technology can be used for accurate mapping, deformation monitoring (at the range of millimeters), change detection and many more.

3.1.5. LiDAR

Since the mid 1990s, LiDAR technology has been becoming an applicable and available tool for surveying and processing of geospatial data. This system provides a dense and accurate 3D points cloud of the scanned area. The LiDAR system integrates three sub-systems: laser scanner, Global Positioning System (GPS) and the Inertial Navigation System (INS). The general concept of this system is precise measurement of the time that the pulse generated by the scanner travels to and from an object it hits on the scanned area (i.e., from the launch epoch to the receive epoch). Combined with the GPS and INS sub-systems, accurate calculation of the spatial location of the object becomes feasible.

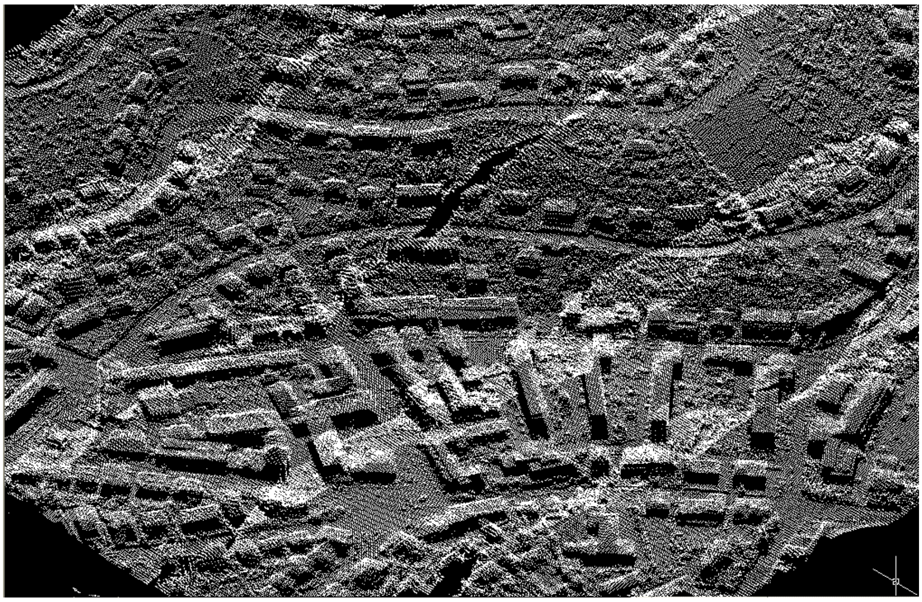

Figure 7. Sample of LiDAR data: A 3D view of urban neighborhood

Although the LiDAR system provides a dense 3D points cloud that describes accurately objects within the scanned area, it is not an explicit representation. This is due to the fact that points cannot be classified automatically and semantically as terrain, trees, vegetation, objects (such as buildings), etc. Moreover, the amount of data is relatively large, and in respect to file size can reach up to several gigabytes. Therefore, an automatic or semiautomatic technique is required to analyze the acquired data. Different strategies to differentiate between the ground point and the non-ground points (i.e., buildings) have been developed in the last few years (Vosselman and Dijkaman ,2001; Morgen and Habib, 2002; Filin and Pfeifer, 2006; Abo Akel et al., 2009). These approaches enable to automatically (or semi-automatically) reconstruct the buildings and other natural as well as man-made objects and receive a 3D map of the measured urban area (Figure 7).

3.2. Data integration, processing and analysis

During the last decades the digital mapping community is facing major and significant developments of algorithms, methods and software packages dealing with data integration, data processing and data analysis. These developments have improved our abilities to handle and process geospatial information. In the following sub-chapters a few of these abilities will be presented.

3.2.1. Data integration

Digital maps are collected by various institutions and different means, representing different disciplines, kept in different databases, and maintained separately. Urban areas are in particular covered by diverse geographic information sources. These facts lead to partial different representations of the same world reality. In order for one to efficiently using the information, it should be obtained from the different sources and merged together (by applying an integration process).

Mechanisms for overcoming spatial and semantic heterogeneity in diverse information sources are critical components of any interoperable system. In the case of diverse geographic information sources, such mechanisms present particular difficulties since the semantic structure of geographic information cannot be considered independently of its spatial structure. The issue of integration is even more complicated due to the fact that the different digital datasets (or databases) can contain data in vector format (a discrete data structure, where entities in the world are represented by objects) as well as raster format (a continues data structure, build of a two dimensional array of pixels, where each pixel represents a characteristic of an equal area rectangular of the world). Moreover, a simple solution of overlaying the different digital datasets (by using the straightforward "cut and paste" algorithm) is not applicable due to different geodetic projections and datum.

Integration of heterogeneous datasets has received a lot of attention in the last 1-2 decades. Diffrent approaches to the issue have been proposed by many reserachers. Wiederhold (1999), Neiling and Lenz (2000) and Boucelma et al. (2002) suggested an architecture of wrappers and mediators for integration systems. According to this approach, wrappers extract data from heterogeneous sources and transform the extracted data to a uniform format. A mediator receives data from the wrappers and integrates it. Integration of spatial datasets by finding correspondences between schema elements was proposed by Devogele et al. (1998). It was shown that interoperability can be achieved in applications that manage spatial data. This aspect of integration - how to provide interoperability - was also suggested by Parent and Spaccapietra (2000) and Laurini et al. (2002).

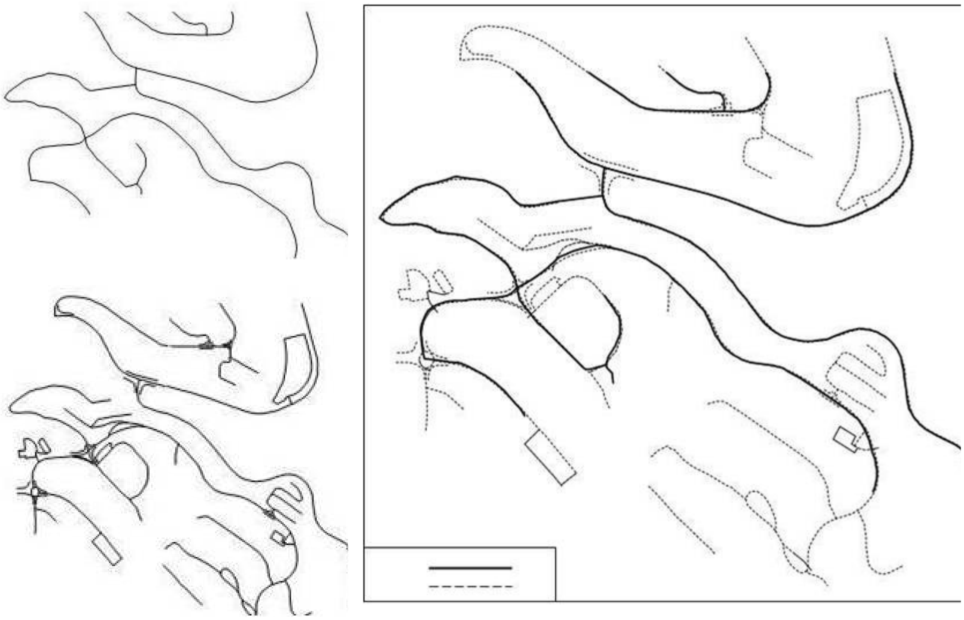

Figure 8. Two digital road maps of hilly urban area on the left (top and bottom) and the conflated (integrated) map on the right

Generally, there are two different types of applications for integration of geo-spatial datasets, namely, map conflation and data fusion. Map Conflation is the process of producing a new map (digital dataset) by integrating two existing digital maps (Saalfeld (1988); Cobb et al. (1998); Doytsher et al. (2001); Samal et al. (2004)). Map conflation of two geospatial datasets starts by choosing some anchors. The anchors are pairs of points, from the two datasets, that represent the same position in the real-world. A triangular planar subdivision of the datasets with respect to the anchors (for example by using Delaunay triangulation) is performed and a rubber-sheet transformation is applied to each subdivision. In Figure 8 a conflated map based on two different road layers from two sources is depicted.

3.2.2. 3D DTM/raster data integration

Digital terrain models that cover very large regions are usually stored as grid (raster) datasets, in which for each grid-point (cell) a height value is given. The main advantages of this method are data handling simplicity and fast data access (needed for various analyses procedures - mostly real-time ones). Usually, datasets that were sampled with high accuracy (and hence are usually dense) will cover smaller regions than the ones sampled with lower accuracy. Simple overlay integration of these separate datasets - can produce model errors, discontinuity and incompleteness. For applications, such as visibility maps, terrain analysis and others, utilizing models that are incomplete and discontinuous will eventually lead to wrong outcome. Direct comparison of different datasets representing the same area can be utilized for morphologic tasks, such as change detection. By super-imposing the two models the height difference value of the two models will give a qualitative analysis of topographic changes occurred between the two epochs of collecting the data. In the past, common techniques such as "Cut &

Paste" and "Height Smoothing" were in use. These techniques are characterized by not preserving the spatial morphology and topography of the terrain (Laurini, 1998).

In the last few years, in order to avoid these complications when integrating terrain relief models, new approaches and new algorithms were suggested. These algorithms serve as the basis of establishing reliable and qualitative environmental control processes. As opposed to the previous common techniques, which did not or only globally analyzed the corresponding topography of both datasets, in the new algorithms a local thorough investigation of the relative spatial correlations that exist between the datasets is achieved, and consequently, preventing distortions as well as an ambiguous and ill-defined modeling analysis. These algorithms are aimed at achieving a continuous topological representation and correct structures of the terrain as represented in the merged DTM, while taking into account the differences in both height field and planar location of terrain entities (see Figure 9).

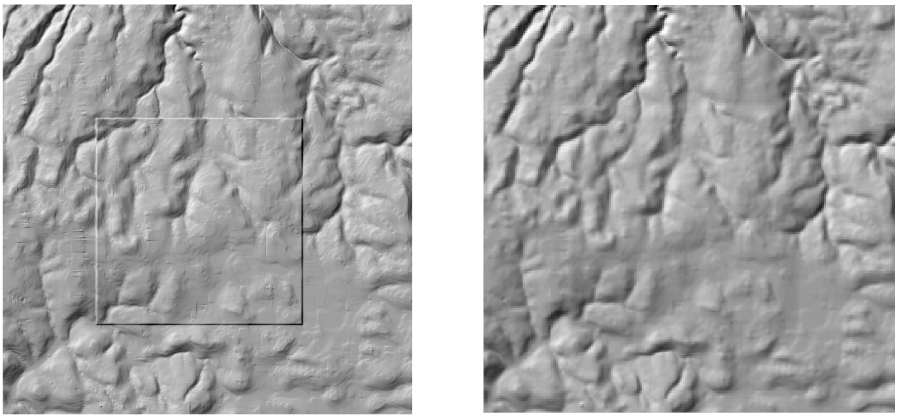

Figure 9. Integrated DTM: a non-continuous dataset based on the common Copy & Paste mechanism (left), and an improved continuous dataset (right) (source: Doytsher et al. 2009)

It is worth noting that similar approaches are being implemented when raster datasets (images) are to be merged. A more detailed description regarding raster integration can be found in (Shragai et al., 2005).

3.2.3. Constructing a seamless geospatial database

One of the common procedures in establishing geographic databases is constructing a seamless database based on separate adjacent separate maps. The conversion of paper maps, i.e., cadastral blocks, into digital data (through processes of digitizing or scanning and vectorization) is usually performed separately, map by map, and only at a second stage are all the separate maps combined into one continuous database. Between adjacent digital maps, gaps and overlaps can be found due to various factors. Among those may be included the accuracy of digitizing or scanning processes; inaccuracies inherent in the original drawings; non-homogeneous interpretations by different operators during the input process of boundary lines of adjacent maps, etc.

Edge matching process means the determination of common boundaries of the adjacent maps, thus annulling the gaps and overlaps, and achieving continuity of details passing from one map into another (such as roads, power lines etc.). During this process only points lying on the external boundaries of the maps are corrected, thus obtaining a unique definition of those boundaries. During this process we do not normally correct or change features or points that fall within the map itself, and therefore relative distortions and discrepancies occur between the contents of the map and its boundaries.

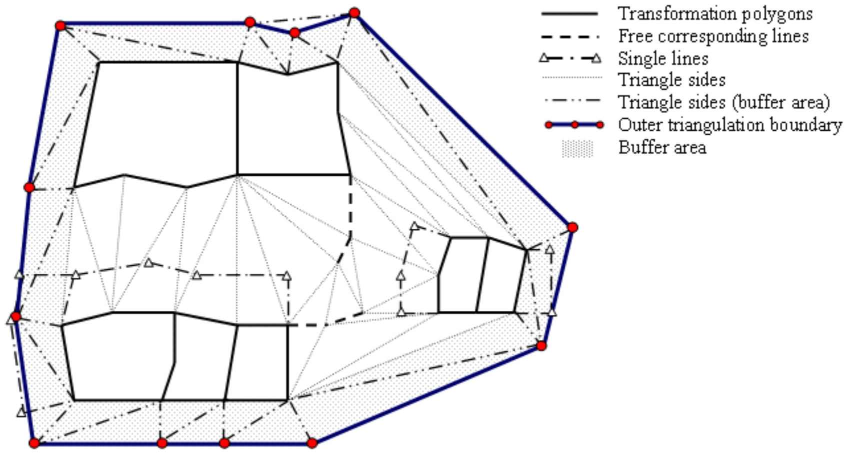

Figure 10. A triangulated rubber-sheeting map sub-division

It is possible to ignore this phenomenon of relative "disorders" between the boundaries of the maps and their content in cases of low accuracy data and/or maps at a small scale. Nevertheless, when handling geospatial data of urban areas in general and cadastral information in particular, these disorders and distortions cannot and should not be ignored. In these cases, edge matching is insufficient and it is recommended to apply non-linear transformations to solve existing disorders and distortions. Non-linear transformation or rubber-sheeting refers to a process by which a digital map or a layer is "distorted" to allow it to be seamlessly connected to adjacent maps or layers, and/or to be precisely super-imposed to other maps or layers covering the same area. In the last few years various approaches to rubber sheeting have been developed with various proposed solutions, inter alia, a polygon morphing technique associated with a Delaunay triangulation (Cho et al., 1996), a non-rectangular bilinear interpolation (Doytsher, 2000), a triangulation and rubber-sheet transformation for correcting orthoimagery (Chen et al., 2006), and others. Figure 10 depicts a typical triangulated rubber-sheeting sub-division. In Figure 11 a group of cadastral maps are depicted in their original situation (pre-processing) and in their final seamless cadastral definition (post-processing).

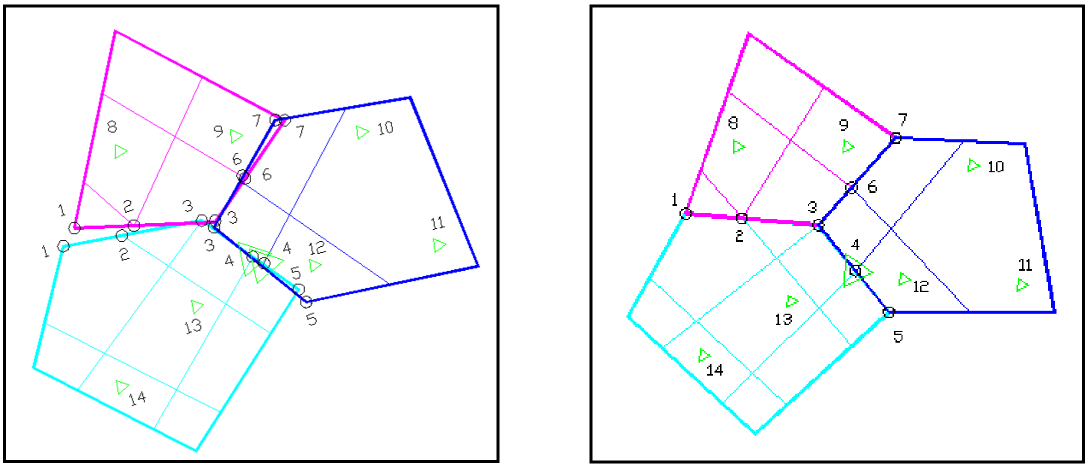

Figure 11. Original separate pre-processing cadastral blocks (left); Post-processing homogeneous seamless cadastral continuity (right)

3.2.4. 3D City Modeling

Generating 3D city models is a relevant and challenging task, both from a practical and a scientific point of view (Gruen and Wang, 1998). This type of data is extremely important in many areas of the urban environment such as municipal management, planning, communications, security and defense, tourism, etc. Most of the input data for these systems was until recently collected manually ("point by point") on Digital Photogrammetric Workstations (DPW) or analytical streoplotters. In the last two decades, extensive research dealing with 3D building extraction from aerial images on the one hand and from LiDAR points cloud on the other hand has been carried out by the photogrammetric and computer vision communities. However, full automation of object space extraction by "autonomous" systems is still far from being implementable. There is a great variety of algorithms for automation in building extraction both from aerial images as well as from LiDAR data, algorithms depending on the type of building, level of required detail, usage of external and a priori information, and level of automation and operator interference (Gruen, 1997).

As to aerial images, most of the 3-dimensional algorithms are based on processing at least two solved images (a photogrammetric model) and the assumption that roofs are composed of several spatial polygons, and that they can be obtained by extracting all or even only some of them (when the model is known). The algorithms can be divided into two types: those that extract a contour and height (2½D) of flat roof buildings (e.g.: Gerke et al., 2001; Ruther et al., 2002; Oriot and Michel, 2004) and those that extract the detailed roof (3D) of the buildings (e.g.: Gulch et al., 1999; Gruen and Wang, 2001; Rau and Chen, 2003, Avrahami et al., 2008). In Figure 12 the steps of automatic extracting 3D buildings are depicted.

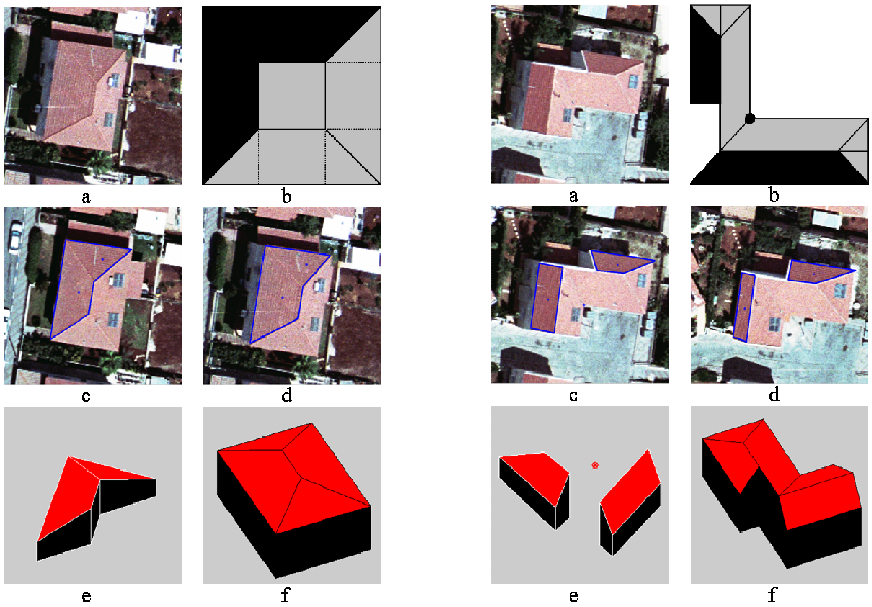

Figure 12. Steps in automatic extraction process of 3D building from aerial photographs (G-Model roof – left; L-Model roof – right)

Since the LiDAR technology provides a dense and accurate 3D points cloud of the scanned area only as an explicit representation of the ground surface (terrain together with all connected man-made objects), algorithms has to be developed in order to extract 3-dimensionally the buildings. The extraction of buildings from LiDAR data is usually divided into two parts where the first involves their detection within the points cloud, and the second the reconstruction of their 3D shape. For their detection, different approaches have been suggested. Within these approaches can be mentioned: edge operators to localize buildings (Wang, 1998); morphological opening filters to identify the non-buildings (Oda et al., 2004); local segmentation to identify detached solid objects (Alharthy and Bethel, 2004); using of external data in the form of ground plans to localize the buildings (Schwalbe et al., 2004) and many others.

As for the reconstruction of the 3D shapes of buildings, the extraction of the roof primitives, in almost all cases, is based on segmentation of the points cloud that will seek partition into a set of planar faces (Voegtle et al., 2005; Rottensteiner et al., 2005; Rottensteiner 2006, Abo Akel et al., 2009). While a large body of research has been devoted into building reconstruction, many challenges still remain unanswered. One such challenge concerns the general planar roof-face assumption that is common to almost all reconstruction models. While planar roof-face buildings are still the majority, buildings with general roof shape can be found in almost every scene. In Figures 13 and 14 the reconstruction results of buildings are depicted. In Figure 13 it is a complex building with a free-form roof surface that is constructed, while in Figure 14 three complex buildings with flat faces is constructed.

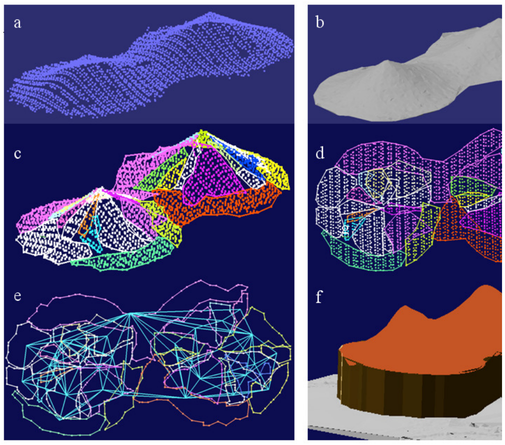

Figure 13. Reconstruction of a building with a free-form roof surface: (a) point cloud; (c) segmented point cloud; (d) segmented point cloud in down-looking view; (e) connectivity graph ; (f) reconstruction results

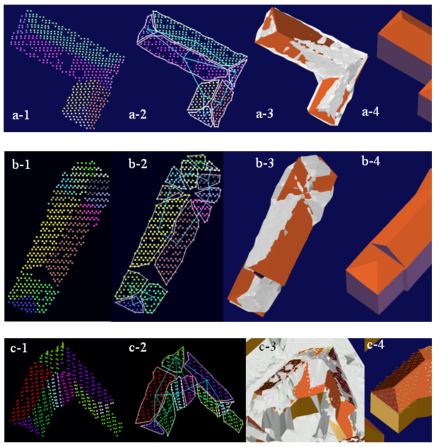

Figure 14. Reconstruction results of three complex buildings. Left to right: segmented point cloud; segments boundaries; roof topology; final reconstruction results

A sample of extracting the buildings of an urban neighborhood from LiDAR data is depicted in Figure 15. Even though the LiDAR information in this scene is a non-dense points cloud (only 0.6 points per square-meter), the results of extracting the complex buildings, as depicted in the figure, is impressive. It is noteworthy mentioning that new LiDAR systems are capable to measure nowadays up to 18-20 points per square-meter, and the potential for extracting very detailed urban scenes and build accurate and precise 3D city models is very high.

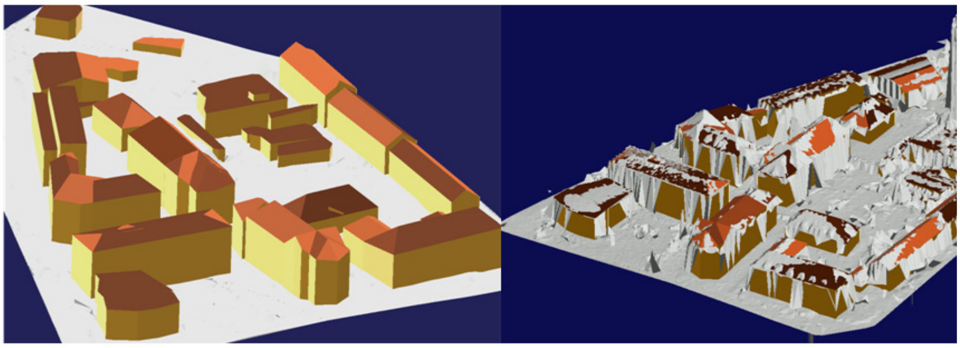

Figure 15. A 3D view of an urban neighborhood showing the LiDAR data (right) and the complete reconstruction results (left)

There are two types of laser scanners, namely, airborne and terrestrial. Even though the characteristics of the two types are similar, they are dissimilar in terms of the measuring range; density of the measured points cloud, precision, etc. Using terrestrial laser scanners are being used to construct realistic 3D building facade models of urban scenes. These models are beneficial to various fields such as urban planning, heritage documentation and better decision-making and organization of the urban environment. Laser data and optical data have a complementary nature when extraction of 3-

dimensional feature is required. As efficient integration of these two data sources will lead to a more reliable and automated extraction of 3D features, automatic and semiautomatic building facade reconstruction approaches and algorithms have been developed in last few years, approaches which efficiently combine information from terrestrial laser point clouds and close range images (Sester, 2009; Pu and Vosselman, 2009). The result of a terrestrial laser scanning (a points cloud containing several hundred thousands points) presented in Figure 16 depicts the inherent potential of this technology to construct realistic 3D building facade models of urban scenes.

Figure 16. Results of a terrestrial scanning of a complex facade

4. CONCLUDING REMARKS

Human beings have been congregating in cities for several thousand years, for common defence, the development of commerce and the practice of religion. The benefits of this urbanization of peoples include development of public security, culture, education and the many systems of civic, political and religious organization. But not all the results of urbanization have been favourable either for the quality of life of people, or for the environment in which we all live. As people gather in ever greater numbers in their cities, the consequent impact on land and resources is multiplied. Large congregations of people in relatively limited spaces threaten to exceed the natural supplies of potable water. As large populations of people use water for various vital purposes an opposite problem of disposal results in the form of sewage and waste water in many forms, in an irony of supply shortage versus a disposal overburden. The same is true of the very air that we breathe: We come together in our cities to find employment in the activities that result in air pollution with direct impacts on the enjoyment of our surroundings, and with an ever-greater degradation of public health.

The less direct results of urban settlement include floods that result from construction in stream paths and tidal areas; mud slides that are the result of deforestation; crime that flourishes in crowded areas with insufficient job opportunity; slums that are the result of inadequate affordable housing; and an exhausted supply of land, not only for housing, but for the quality of life of the city's residents. Most of the causation for these well-documented problems may be traced to an over-use – or abuse – of the land and its resources. The quantification of these problems, then, is a challenge to the surveying/mapping/data processing community. Fortunately, the technical tools required for this process that includes both discovery and quantification, are in the hands of our community. From surveying in the field to photogrammetry, radar-based systems and LIDAR, and digitization and scanning, we possess the needed tools in the discovery phase. The quantification phase is the integration, processing and analysis of the collected data for presentation to the policy-makers of government and the problem-solvers, planners, etc of the commercial community.

It is noteworthy that the work of the surveying/mapping/data processing community is not done when the policy-makers take over. The process of data collection and monitoring of the physical systems put in place, as the many problems of the city are addressed, must continue. The tools are available for all these efforts and the professionals of our community will continue to apply their skills as the policy-makers seek solutions to the problems of the urban environment. The vision and goal of this research has been to demonstrate, not only to government policy-makers, but to planners, economists, scientists, environmentalists, sociologists and all others with an interest in the life of our cities, the technical tools for environmental urban management applied by the surveying/mapping/data processing community.

5. REFERENCES

Abo Akel N., Filin S., Doytsher Y., 2009. "Reconstruction of Complex Shape Buildings from LiDAR Data Using Free Form Surfaces". Photogrammetric Engineering and Remote Sensing, 75(3):271-280.

Altan O., 2009. "Role of Geospatial Professionals in Risk and Disaster Management and Preventing Natural Catastrophies". Proceedings of the FIG Working Week 2009, Eilat, Israel, http://www.ortra.com/fig/

Avrahami Y., Raizman Y., Doytsher Y., 2008. "A Polygonal Approach for Automation in Extraction of Serial Modular Roofs", Photogrammetric Engineering and Remote Sensing, 74(11):1365-1378.

Boucelma O., Essid M., Lacroix, Z., 2002. "A WFS-Based Mediation System for GIS Interoperability". Proceedings of the 10th ACM international symposium on Advances in geographic information systems (ACM-GIS), pp. 23–28.

Chen C., Knoblock C.A., Shahabi C., 2006. "Automatically Conflating Road Vector Data with Orthoimagery". GeoInformatica 10 (4): 495–530.

Cho M.G., Li K.J., Cho H.G., 1996. "A Rubber Sheeting Method with Polygon Morphing". Proceedings of the Seventh International Symposium on Spatial Data Handling, Advances in GIS Research II, pp. 395-406.

Cobb M.A., Chung M.J., Foley H., Petry F.E., Show K.B., 1998, "A Rule-Based Approach for Conflation of Attribute Vector Data". GeoInformatica, 2, 7–33.

Devogele T., Parent C., Spaccapietra S., 1998. "On Spatial Database Integration". International Journal of Geographical Information Science (IJGIS), Special Issue on System Integration, 12, 335–352.

Doytsher Y., 2000. "A rubber sheeting algorithm for non-rectangular maps". Computers & Geosciences, 26(9-10):1001-1010

Doytsher Y., Filin S., Ezra, E., 2001. "Transformation of Datasets in a Linear-Based Map Conflation Framework". Surveying and Land Information Systems, 61, 159–169.

Doytsher Y., Dalyot S., Katzil Y., 2009. "Digital Terrain Models: a Tool for Establishing Reliable and Qualitative Environmental Control Processes". In GeoSpatial Visual Analytics:

Geographical Information Processing and Visual Analytics for Environmental Security, Raffaele De Amicis, Radovan Stojanovic, Giuseppe Conti (Eds.), Springer Science and Business Media, pp. 215-234, ISBN 978-90-481-2897-6

Economic Studies Division of Alpha Bank, 2007. "Environmental Protection: For a Long-term Sustainable Development". In: Economic Report of Alpha Bank, vol. 103: 3-21, URL: http://www.alpha.gr/files/infoanalyses/oikon_deltio_103.pdf (in Greek).

Enemark S., 2007. "Integrated Land-Use Management for Sustainable Development". Proceedings of the Joint FIG Commission 3, UN/ECE Working Party on Land Administration and UN/ECE Committee on Housing and Land Management Workshop, Sounio, Greece.

Enemark S., 2009. "Facing the Global Agenda-Focus on Land Governance". Proceedings of the FIG Working Week 2009, Eilat, Israel, http://www.ortra.com/fig/

Filin S., Pfeifer N., 2006. "Improved Segmentation of Airborne Laser Surfaces Using Adaptive Distance Based Neighborhood". ISPRS journal of Photogrammetry and Remote Sensing, 60(2):71–80.

Gerke M., Heipke C., Straub B.M., 2001. "Building Extraction from Aerial Imagery Using a Generic Scene Model and Invariant Geometric Moments". Proceedings of the IEEE/ISPRS joint Workshop on Remote Sensing and Data Fusion over Urban Areas, November 8-9th 2001, University of Pavia, Rome (Italy), pp. 85-89.

Gruen A., 1997. "Automation in Building Reconstruction". Photogrammetrische Woche. pp. 175-186. www.ifp.uni-stuttgart.de/publications/phowo97/gruen.pdf.

Gruen A., Wang X., 1998. "CC-Modeler: A Topology Generator for 3D City Models". ISPRS Journal of Photogrammetry & Remote Sensing, 53(5): 286-295.

Gruen A., Wang X., 2001. "News from CyberCity Modeler". Automatic Extraction of Man-Made Objects from Aerial and Space Images (III), Balkema Publishers, Lisse, The Netherlands, pp: 93–101.

Gulch E., Muller H., Labe T., 1999. "Integration of Automatic Processes into Semi-Automatic Building Extraction". International Archives of Photogrammetry and Remote Sensing, Vol. (32) 3-2W5, pp: 177–186.

Habib A., 2009. "Integration of Photogrammetric and LIDAR Data for Accurate Reconstruction/Visualization of Urban Environments". Proceedings of FIG COM3 Workshop on Spatial Information for Sustainable Management of Urban Areas, Mainz, Germany

Laurini R., 1998. "Spatial Multi-Database Topological Continuity and Indexing: A Step Towards Seamless GIS Data Interoperability". International Journal of Geographical Information Science, 12(4):373-402.

Laurini R., Yetongnon K., Benslimane D., 2002. "GIS Interoperability, from Problems to Solutions". Encyclopedia of of Life Support Systems (EOLSS) (Eolss Publishers).

Lavedan P., 1926. "Histoire de l' Architecture Urbaine", t.1, H. Laurence, Paris.

Martin R., 1956. "L' Urbanisme dans la Grece Antique", A & J. Picard, Paris.

Mega V., 1990. "Topography and Development of Ancient City-States in Greece". Journal Arxaiologia, http://www.arxaiologia.gr/assets/media/PDF/migrated/588.pdf (in Greek).

Morgan M., Habib A., 2002. "Interpolation of LiDAR Data and Automatic Building Extraction". Proceedings of 2002 ACSM Annual Conference.

Neiling M., Lenz H.J., 2000. "Data Fusion and Object Identification". Proceedings of the SS-GRR2000.

Oda K., Takano T., Doihara T., Shibaski R., 2004. "Automatic Building Extraction and 3-D City Modeling from LiDAR Data Based on Hough Transform". International Archives of Photogrammetry and Remote Sensing, 35(B3):277–281.

Oriot H., Michel A., 2004. "Building Extraction from Stereoscopic Aerial Images". Applied Optics, 43(2): 218-226.

Parent C., Spaccapietra, S., 2000. "Database Integration: The Key to Data Interoperability". Advances in Object-Oriented data modeling (MIT Press).

Potsiou C., 2008. "Unplanned Urban Development and the Need for Good Spatial Information Infrastructure". Proceedings (CD) of the FIG Commission 3 Workshop on 'Spatial Information Management toward Environmental Management of Mega Cities', Valencia, Spain.

Potsiou C., 2009. "Tools for Legal Integration and Provision of Environmental Improvements in Informal Settlements in Europe – A case study from Albania and Greece". Global Land Tool Network, UN HABITAT, (to be published)

Pu S., Vosselman G., 2009. "Building Facade Reconstruction by Fusing Terrestrial Laser Points and Images". Sensors, 9:4525-4542

Rau J.Y., Chen L.C., 2003. "Robust Reconstruction of Building Models from Three Dimensional Line Segments". Photogrammetric Engineering & Remote Sensing, 69(2): 181-188.

Rottensteiner F., 2006. "Consistent Estimation of Building Parameters Considering Geometric Regularities by Soft Constraints". International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 36(3):13–18.

Rottensteiner F., Trinder J., Clode S., Kubik K., 2005. "Automated Delineation of Roof Planes from LIDAR Data". International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 36(3/W19):221–226.

Ruther H., Martine H., Mtalo E,G., 2002. "Application of Snakes and Dynamic Programming Optimisation Technique in Modeling of Buildings in Informal Settlement Areas". ISPRS Journal of Photogrammetry & Remote Sensing, 56(4): 269-282.

Saalfeld A., 1988. "Conflation-Automated Map Compilation". International Journal of Geographical Information Science (IJGIS), 2, 217–228.

Samal A., Seth S., Cueto K., 2004. "A Feature Based Approach to Conflation of Geospatial Sources". International Journal of Geographical Information Science (IJGIS), 18, 459–489.

Schwalbe E., 2004. "3D Building Model Generation from Airborne Laserscanner Data by Straight-Line Detection in Specific Orthogonal Projections". International Archives of Photogrammetry and Remote Sensing, 35(3):249–254.

Sester M., 2009. "The Potential of Geosensor Networks for Sustainable Management of Urban Areas". Proceedings of the Workshop on Spatial Information for Sustainable Management of Urban Areas, Mainz, Germany

Shragai Z., Barnea S., Filin S., Zalmanson G., Doytsher Y., 2005. "Automatic Image Sequence Registration Based on a Linear Solution and Scale Invariant Keypoint Matching", BenCOS - ISPRS Workshop in conjunction with ICCV 2005 on 'Towards Benchmarking Automated Calibration, Orientation and Surface Reconstruction from Images', Beijing, China, International Archives of Photogrammetry and Remote Sensing. 36(3/W36): 5-11.

Tassios T., 2009. "The Archaeological Park of Samos", TO BHMA online, 23rd August 2009 http://www.tovima.gr/ default.asp?pid=2&ct=122&artid=284737&dt=23/08/2009

Tsenkova S., Potsiou C., Badyina A., 2009. "Self-Made Cities – In Search of Sustainable Solutions for Informal Settlements in the United Nations Economic Commissions for Europe region". United Nations Economic Commission for Europe (UNECE), United Nations Publications, ISBN 978-92-1-117005-4, Geneva, p. 113.

Voegtle T., Steinlle E., Tovari D., 2005. "Airborne Laserscanning Data for Determination of Suitable Areas for Photovoltaics". International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 36(3/W19):215–220.

Vosselman G., Dijkaman S., 2001. "3D Building Model Reconstruction from Point Clouds and Ground Plans", IAPRS - the International Archives of Photogrammetry and Remote Sensing, 34(3/W4)

Wang Z., 1998. "Extracting Building Information from LIDAR Data". International Archives of Photogrammetry and Remote Sensing, 32(3/1):279–284.

Wiederhold G., 1999. "Mediation to Deal with Heterogeneous Data Sources". Proceedings of the Interoperating Geographic Information Systems, pp. 1–16.

Wilbanks T.J., Romero Lankao P., Bao M., Berkhout F., Cairncross S., Ceron J.P., Kapshe M., Muir-Wood R., Zapata-Marti R., 2007. "Industry, Settlement and Society". Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 357-390.

Zhilin L., Qing Z., Qung Z., and Gold C., 2005, Digital Terrain Modeling – Principles and Methodology, CRC Press, ISBN-13: 9780415324625.

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