Spatial Information Management, an Effective Tool to Support Sustainable Urban Management

Hartmut Mueller

Foreword

The International Federation of Surveyors (FIG) is an international, non-government organisation whose purpose is to support international collaboration for the progress of surveying in all fields and applications. FIG has undertaken a study about trends in the use of spatial information and technology in supporting the management of eight of the world's largest cities. The study has included:

- Management of spatial information about land, property and marine data;
- Spatial Data Infrastructure, including policy, institutional and technical frameworks;
- Management and transfer of knowledge and skills in using spatial information;
- Impacts on organisational structure, business models and public-private partnerships; and
- Spatial information management supporting good city governance.

Some important results of the study will be reported in the following sections.

1 Introduction

Urbanisation is a major change that is taking place globally. The urban global tipping point was reached in 2007 when for the first time in history over half of the world's population was living in urban areas; around 3.3 billion people. It is estimated that a further 500 million people will be urbanised in the next five years and projections indicate that the percentage of the world's population urbanised by 2030 will be 60%.

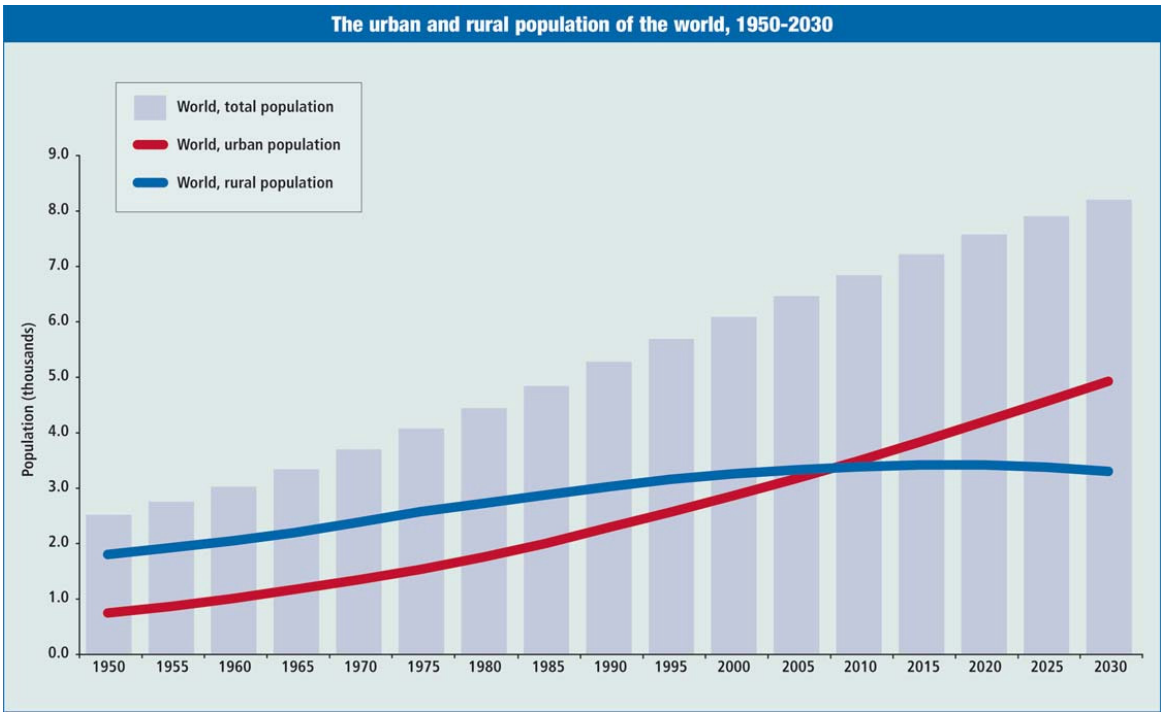

Figure 1 The urban and rural population of the world (source: UN Population Division, 2006)

This rush to the cities, caused in part by the attraction of opportunities for wealth generation and economic development, has created the phenomenon of 'megacities' that have a population of over 10 million. There are currently 19 megacities and there are expected to be around 27 by 2020. Over half this growth will be in Asia; the world's economic geography is now shifting to Asia. This incredibly rapid growth of megacities causes severe ecological, economical and social problems. It is increasingly difficult to manage this growth in a sustainable way. It is recognised that over 70% of the growth currently happens outside of the formal planning process and that 30% of urban populations in developing countries living in slums or informal settlements, i.e. where vacant state-owned or private land is occupied illegally and used for illegal slum housing. In sub-Saharan Africa, 90% of new urban settlements are taking the form of slums. These are especially vulnerable to climate change impacts as they are usually built on hazardous sites in high-risk locations. Even in developed countries unplanned or informal urban development is a major issue. Urbanisation is also having a very significant impact on climate change. The 20 largest cities consume 80% of the world's energy use and urban areas generate 80% of greenhouse gas emissions worldwide. Cities are where climate change measures will either succeed or fail.

Rapid urbanisation is setting the greatest test for Land Professionals in the application of land governance to support and achieve the Millennium Development Goals (MDGs). The challenge is to deal with the social, economic and environment consequences of this development through more effective and comprehensive land administration functions, supported by effective Spatial Data Infrastructures, resolving issues such as climate change, insecurity, energy scarcity, environmental pollution, infrastructure chaos and extreme poverty.

2 Problems to be Managed within Megacities

Administrations in large cities are often confronted with a multitude of key problems, like high urban densities, transport, traffic congestion, energy inadequacy, unplanned development and lack of basic services, illegal construction both within the city and in the periphery, informal real estate markets, creation of slums, poor natural hazards management in overpopulated areas, crime, water, soil and air pollution leading to environmental degradation, climate change and poor governance arrangements.

The inevitability of further population growth is a common issue. Some cities reported that their administrations have little control over population growth; it was a regional or national issue and needed to be addressed at that level. However, monitoring population change effectively and being able to respond through planning and infrastructure development will be major challenges. Informal settlements are a problem in many cities. An increasing number of citizens do not have either permanent or temporary access to land and adequate shelter. This exclusion is caused, in many cases, by structural social inequalities, inheritance constraints, conflicts, non pro-poor and pro-gender land policies and land administrations systems that are ineffective and expensive for the end user. Without a range of appropriate interventions being applied within the broader context of economic growth and poverty reduction policies, social exclusion and poverty will continue to spiral out of control; already 90% of new settlements in sub-Sahara Africa are slums. Natural hazards and emergency management are high on most cities' issues lists. Risk profiles from floods, fires, earthquakes and other hazards differ between cities, but capacity to plan, prepare, respond and recover from disasters is a common issue.

Many cities appear to have problems with unclear and overlapping responsibilities amongst internal and external agencies, leading to operational dysfunction such as a multitude of agencies holding non-accessible spatial information. For example, Sao Paulo comprises component cities all with their own governance arrangements.

Table 1 Key Problems Facing City Administrations (Source: Spatial Strategies Pty Ltd Australia)

Reported Problem	***Hong Kong SAR***	***Tokyo***	***Seoul***	***Istanbul***	***London***	***New York City***	***Lagos***
(Q): Questionnaire **(V):** Visit	**(Q)** ***China***	**(Q)** ***Japan***	**(Q)** ***Korea***	**(V)** ***Turkey***	**(V)** ***United Kingdom***	**(V)** ***USA***	**(Q)** ***Nigeria***
Informal settlements (land tenure, development approvals, building control)	N	Y	N	Y	N	N	Y/High
Traffic management	Y/Med	Y	Y	Y	Y	N	Y/High
Natural hazards (floods, earthquakes, fires)	N	Y	Y	Y	Y	Y	Y/High
Unclear responsibilities and mandates (within or between administrations)	N	N	N	N	N	N	Y/High
Uncoordinated planning	N	N	-	N	N	N	Y/High
Water management (fresh water supply and waste-water disposal)	Y/Med	Y	N	Y	N	N	Y/High
Provision of continuous electrical power	N	Y	N	N	N	N	Y/High
Visual pollution and garbage disposal	Y/Med	Y	N	N	N	Y	Y/High
Air and water pollution control	Y/Med	Y	Y	N	Y	Y	Y/High
Population growth	-	-	-	Y	Y	-	-

It is clear that solutions to problems facing megacities require concerted response from many internal units and regional and national agencies in areas such as planning, infrastructure,

development and land use controls, transportation, environmental management and water management. Mandates might be clear, but rationalisation of functions and more effective levels of cooperation and information sharing are needed. Even if city planning is centrally coordinated, often city administrations have little control over the implementation (i.e. land use and building controls) of their policies and plans. For example, in France the greater Paris region, Île de France, has a regional planning authority that sets planning policies for the highly decentralised 1,280 communes. Political differences create tensions in the consistent implementation of these planning policies.

The influence of megacities reaches out well outside their administrative boundaries to the peri-urban and regions beyond. It is essential that the greater region be managed holistically to maximise the economic benefits of the city. Regional planning places even greater emphasis on effective governance of the larger region, even across international boundaries, with cooperation in planning, development control and sharing information being essential. In many cases, infrastructure providers are not a direct part of the city administration's planning and development process, being privatised or at another level of government. This causes problems with the proactive planning and strengthening of utility services.

Most megacities support some level of civil society participation in the planning and design of their services, such as citizen involvement in the urban planning process. However, spatially enabled web based services are providing new opportunities to more closely involve citizens in consultations and land administration functions.

3 Spatial Information to Manage Megacities

The Need for Spatial Information Management

The incredibly rapid growth of megacities causes severe social, economical ecological and problems. How can this growth be nurtured in a sustainable way? The challenge for land professionals is to provide the megacity 'managers', both political and professional, with appropriate 'actionable intelligence' that is up-to-date, citywide and in a very timely manner to support more proactive decision making that encourages more effective sustainable development.

Spatial information has become indispensable for numerous aspects of urban development, planning and management. The increasing importance of spatial information has been due to recent strides in spatial information capture (especially satellite remote sensing and positioning), management (utilising geographic information systems and database tools) and access (witness the growth in web mapping services), as well as the development of analytical techniques such as high resolution mapping of urban environments. These more efficient techniques can lead to a wider diversity of information that is more up-to-date.

In some circumstances, a wealth of existing map, image and measurement data can already be found in areas such as land administration, natural resource management, marine administration, transportation, defence, communications, utility services and statistical collections. The challenge is for users both within and outside these areas of activity to break down the information silos and to discover, to access and to use this information to improve decision-making, business outcomes and customer services.

The study has found that spatial information and technology is being recognised widely as one of the tools needed to understand and address the big urban problems, but there is still a general lack of knowledge amongst communities of practice about what spatial solutions exist and how they can used and prioritised.

Information to support the management of cities is traditionally channelled and aggregated up the vertical information highway from a local, operational level to a policy level. In developed countries, urban growth and its characteristics can normally be measured through information derived from the Land Administration functions. However, in megacities within developing countries, where informal settlements are the norm, growth is rampant and administrative structures limited then this traditional source of change information is not readily available.

Table 2 Use of Spatial Data in City Administration (Source: Spatial Strategies Pty Ltd Australia)

Inputs

Base Maps	Imagery	Demographics	Natural and Built Environment Data	Infrastructure/Network Data	Sensor Webs

Spatial Data Tools

Data integration	Information access	Visualisation	Spatial Analysis and Modelling	Spatial Planning

Service Delivery Using Spatial Data

Urban Design Planning codes Land zoning City-wide environmental plans Smart growth Sustainable neighbourhoods	**Utility Services** Telemetry SCADA Micro-tunnelling Asset management and inventory Disaster preparedness, response and recovery
Urban Management Development and building permits Electronic lodgement of applications Automated valuation/taxes	**Transport Planning** Trip analysis Scenarios Integrated public transport networks Real-time monitoring of movements
Environmental Justice Siting impacts Best use of land resources Placement of public facilities	**Economic Development** Find available and suitable land Workforce demographics
Community Involvement Scenario and impact analysis, option development 3D visualisation Fly-throughs	**Public Safety** Emergency response management Crime modelling Emergency dispatch and routing
Environmental Services Optimising waste collection networks Water storage, allocation and distribution Environmental monitoring	

Outcomes

Performance Monitoring, Evaluation and Reporting

Spatial Data Infrastructures (SDI) for Megacities

The visionary concept of using a SDI to more efficiently manage, access and use spatial information across megacities is evolving and megacities are at different stages of their implementation. The EC INSPIRE Directive has provided welcome impetus across Europe and beyond. However, most cities have no strategic framework to guide and create their SDI. This reflects the difficulty of the task to create an SDI within megacities that are organisationally complex and involve a large number of stakeholders with diverse sets of spatial information; a microcosm of the national problem.

All cities have different interpretations of what constitutes a SDI, but most reported that they had at least some elements of an SDI. Cities like Paris and New York have a more mature and comprehensive implementation of a megacity SDI, managed by dedicated resources. However, most cities reported that they had only small "central GIS units", under-resourced and generally incapable of providing a comprehensive citywide SDI. Missing capabilities included no spatial data policies and standards, common metadata, formal data sharing arrangements between units or agencies, or shared data access mechanisms. It could be many years until mature and fully populated SDI emerge in megacities. However, it is important for megacities, especially in developing countries, to develop SDI capabilities in areas that will deliver the most benefits to their current pressing needs.

Table 3 Examples of use of spatial data and products in city administration (Source: Kelly, 2007)

Issue	***Use of spatial information***	***Examples***
Environmental		
Land use planning	Describe spatial extent of allowable land uses	Land zoning maps
Impact of development	Describe land capability and sustainability	Terrain maps showing vulnerability to land slippage
Impact of climate change	Vulnerability to rising sea level and tidal surges	Flood prone land mapping and real-time weather mapping
Access to water	Location of dams and fresh and waste water reticulation networks	Catchment terrain maps
Pollution and hazards	Location of broad and point specific pollution and hazardous wastes	Inventory of properties where hazardous wastes are stored
Governance		
Land allocation	Describe pattern of current land use	Digital cadastral database
Access to serviced land	Current location of serviced land	Cadastral map overlaid by current aerial photography and utility service networks

Table 3 continued

Issue	***Use of spatial information***	***Examples***
Secure property rights	Spatial extent of existing property rights	Land titles register containing all rights, restrictions and obligations for each property
Community participation	Public access to cadastral, planning and environmental information affecting individuals and the community	Public display of proposed developments, land suitability and other maps
Fiscal sustainability	Comprehensive and accurate records of the extent of existing property rights and land use	Land valuations shown on cadastral maps
Public safety	Comprehensive data about roads, properties and hazards	Emergency dispatch system; bushfire models
Slum reduction	Location of vacant or under-utilised land and population growth predictions	Current aerial photography, predictive modeling of land use
Measuring performance	Land change over time	Land change mapping
Social and economic infrastructure		
Employment	Location of existing enterprises and land zoning for future business use based on predicted population growth	Maps showing land zoned for business use
Communal facilities	Location of land set aside for communal facilities	Street map showing location of communal facilities
Utility services	Location and attributes of fresh water, sewer, storm water, electricity and telephone networks	Cadastral maps showing utility services
Transport	Location and attributes of public roads	In car navigation device using up-to-date road network and GPS
External effects		
Rural sustainability	Location, size and productive capacity of rural properties	Satellite images of rural areas overlaid by cadastral boundaries
Access to raw materials	Location of sources of food and mineral production and transportation corridors for their movement to the city	Topographic mapping series

Most do not have a formal "spatial information strategy" across the whole administration. However, most countries covered by this project have national (and in some cases regional) SDI strategies. At this stage it is not clear what connection there is between national and local strategies or how national strategies will meet the needs of cities.

Some cities, for example New York, have developed an intranet that could be used to access spatial data held across multiple units. Other cities, for example Buenos Aires, have invested in providing access to spatial data as part of their public websites, reporting information about aspects of city administration such as land tenure, use, planning, environmental and disaster management information. Approaches like these should be used as exemplars by other cities.

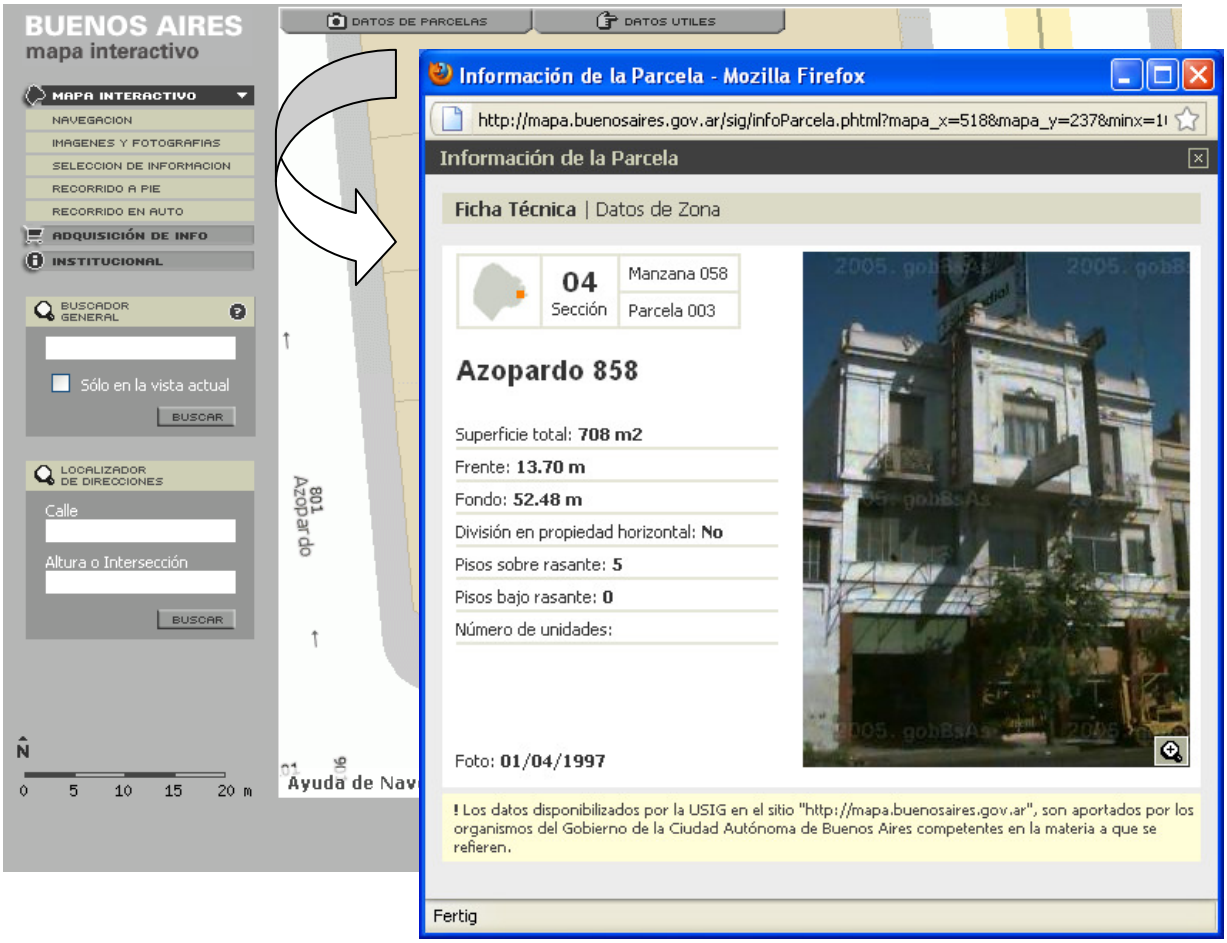

Figure 2 Public access to parcel information of the City of Buenos Aires, Argentina (Source http://mapa.buenosaires.gov.ar/sig/index.phtml

Innovative Uses of Spatial Information Tools to Manage Megacities

New tools, techniques and policies are required to baseline and integrate the social, economic and environmental factors associated with megacities, to monitor growth and change across the megacity and to forecast areas of risk – all within shorter timeframes than previously accepted. Moreover, they must be flexible enough to meet traditional needs such as land development, tenure and value applications, but be designed to be interoperable and integrate within the city wide SDI as it evolves. Access to integrated spatial information from

the SDI will lead to more joined-up, proactive decision making allowing the prioritising of scarce resources to tackle the most sensitive and risk prone areas within a megacity.

These tools must support the operation of land administration functions, but should also support the management of key problems such as disaster management, flooding control, environmental management, health and transportation, for example, but also encourage economic development and reduce social inequalities.

These spatial information tools include:

- Data collection & maintenance – high resolution satellite imagery (< 0.5m) is now commercially available at an affordable rate from a number of sources with repeat coverage at a frequency greater than required for this application. This opens up the possibility to efficiently generate topographic and thematic mapping (at a scale of at least 1:5,000) and to better understand changes across the city, such as sporadic creation of informal settlements.

- Data integration and access – international interoperable information and services standards allow the possibility of the real-time merging of data and services (plug and play) from a variety of sources across the city. This will be achieved through the creation of shared, web information services to allow users access to the wide range of information held by different agencies across the city. This will be instrumental in breaking down information silos. This will lead to the innovative re-use of spatial information.

- Data analysis – data mining and knowledge discovery techniques allow the integration of a wide range of spatial information and associated attribute information. This creates the opportunity to perform more effective forms of analysis, decision-making and leads to more cost effective solutions, such as targeting of limited city resources for health care and maximising the economic benefits of investments in transportation.

- 3-D city modelling – many applications are enhanced by the use of 3-D spatial information, such as visualisation of planning development proposals, flood predictions, modelling population growth, tourist visit simulations and the design of transportation networks. 3-D spatial information of the natural and built environments are increasingly available, through use of technologies like terrestrial radar, making many of these applications operationally viable.

- Citizen centric urban sensing - The new generation of urban sensors, including cellular phones, plus crowdsourcing has significant potential in providing the managers with unparalleled access to a comprehensive range of current spatial and environmental information about the evolving workings of their megacities. Peoples' movements can be monitored; their use and modes of transport determined and people can voluntarily provide information about changes to their environment. This has the potential to substantially increase the levels of citizen participation in the governance of megacities and to fill the current gaps in urban information needed to understand the dynamics of megacities. At national level, few if any countries have generated data management policies that truly integrate and utilise this new, valuable resource of large scale, citizen initiated information.

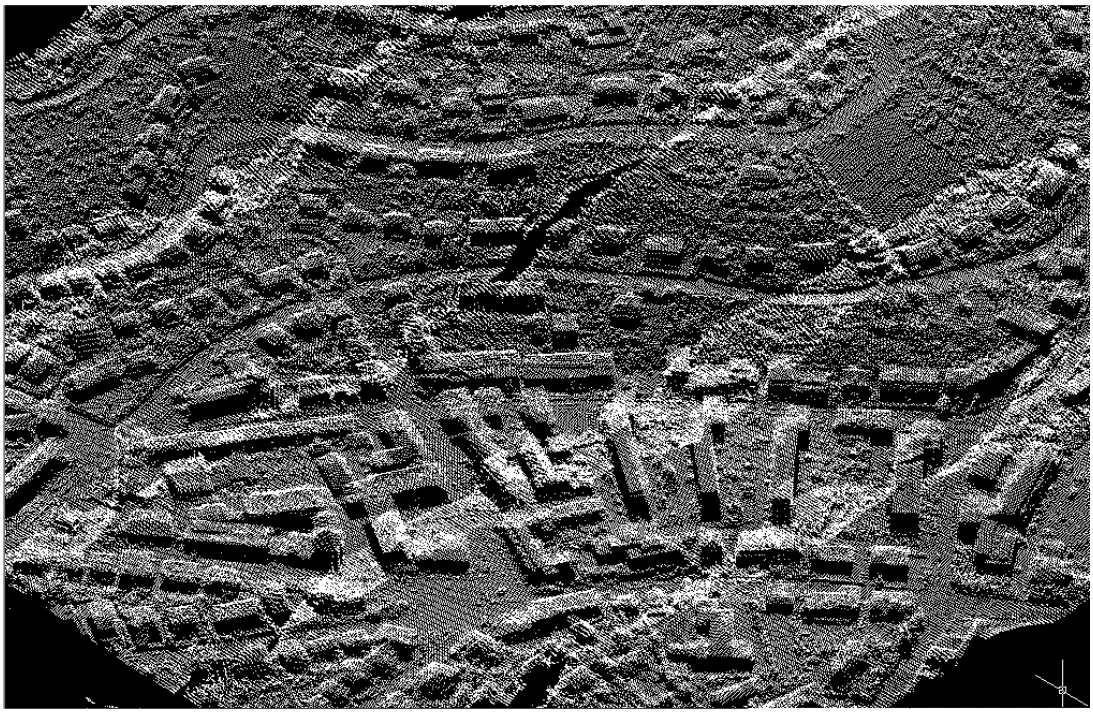

Figure 3 Sample of LiDAR data - a 3D view of urban neighborhood (Source: Doytsher et al., 2009)

Spatial Information Policy Constraints

The advances in developing megacity SDI will only occur when senior management within megacities are convinced of the benefits, through robust business cases based on evidence derived from experience, and the SDI implementation is guided by a supportive megacity information strategy. This support is difficult to achieve in the complex and multi-layer governance structures that exist around megacities.

The more that spatial information is used and exposed to the citizen there is a danger that they will be concerned over privacy issues and start to mistrust its use. It is therefore essential that both legal and policy frameworks are established to guide this use of spatial information.

4 Conclusions

Urbanisation is a major change that is taking place globally. There are currently 19 megacities (population of over 10 million) and there are expected to be around 27 by 2020. Administrations in large cities are often confronted with a multitude of key problems, like high urban densities, transport, traffic congestion, energy inadequacy, unplanned development and lack of basic services, illegal construction both within the city and in the periphery, informal real estate markets, creation of slums, poor natural hazards management in overpopulated areas, crime, water, soil and air pollution leading to environmental degradation, climate change and poor governance arrangements.

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Authors of the reported FIG study*:

Prof Dr Yerach DOYTSHER, Dean of the Faculty of Architecture and Town Planning, Technion Israel Institute of Technology, vice chair of FIG Com3, Israel
Paul KELLY, Director, Spatial Strategies Pty Ltd, chair of FIG WG 3.2, Australia
Rafic KHOURI, Senior International Relations Officer, Ordre Des Geometres Experts, France
Robin McLAREN, Director of Independent GIS Consulting Company KNOW EDGE LTD, United Kingdom
Prof Dr Hartmut MUELLER, Mainz University of Applied Sciences, co-chair of FIG WG 3.2, Germany
Dr Chryssy A POTSIOU, Lecturer at the School of Rural and Surveying Engineering of the National Technical University of Athens, Chair of FIG Commission 3, Greece

*Authors' names are listed in alphabetical order

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Prof Dr Hartmut Mueller
Mainz University of Applied Sciences
Germany