Sustainable Management of Mega Growth in Megacities

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Key words: Megacities, Sustainability, Information Management, Urban Planning, Just in Time Mapping, Automated Data Extraction, Public Participation GIS

SUMMARY

World-wide, around 2.8 billion people currently live in cities. By 2015, this number will have risen to 3.9 billion. By 2007, more people will live in cities than in rural areas. The 21st century is the century of cities and urbanisation.

The majority of this urban growth will take place in developing countries. For example, Dar es Salaam in Tanzania has a growth rate of 6% per annum, which leads to a doubling of the population every 13 years. The number of megacities will rise from 39 today to 59 in 2015, involving around 604 million (Kötter, 2004).

This incredibly rapid growth of megacities causes severe social, economical ecological and problems. How can this growth be nurtured in a sustainable way when over 70% of the growth currently happens outside of the planning process ? Our challenge is to provide the megacity 'managers', both political and professional, with appropriate, up-to-date, city wide information in a very timely manner to support more proactive decision making that encourages more effective sustainable development.

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 can be measured through information derived from the land registration process, for example. However, in megacities within developing countries, where informal settlements are the norm, growth is rampant and administrative structures limited, this traditional source of change information is not readily available.

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 but be optimised to operate within the spatial data infrastructures as they are evolving today. This will lead to more proactive urban planning and land management.

Rather than megacities being 'overrun' by out of control growth, these new information sources and tools would help megacities to create spatial, development frameworks and to prioritise their scarce resources to tackle the most sensitive and risk prone areas within a megacity.

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1. INTRODUCTION

World-wide, around 2.8 billion people currently live in cities. By 2007, more people will live in cities than in rural areas and by 2015, this number will have risen to 3.9 billion.. The 21st century is the century of cities and urbanisation. (Hall & Pfeiffer, 2001).

The majority of this urban growth will take place in developing countries. For example, Dar es Salaam in Tanzania has a growth rate of 6% per annum, which leads to a doubling of the population every 13 years. The number of megacities will rise from 39 today to 59 in 2015, involving around 604 million (Kötter, 2004). This prediction is illustrated in the Figure 1.

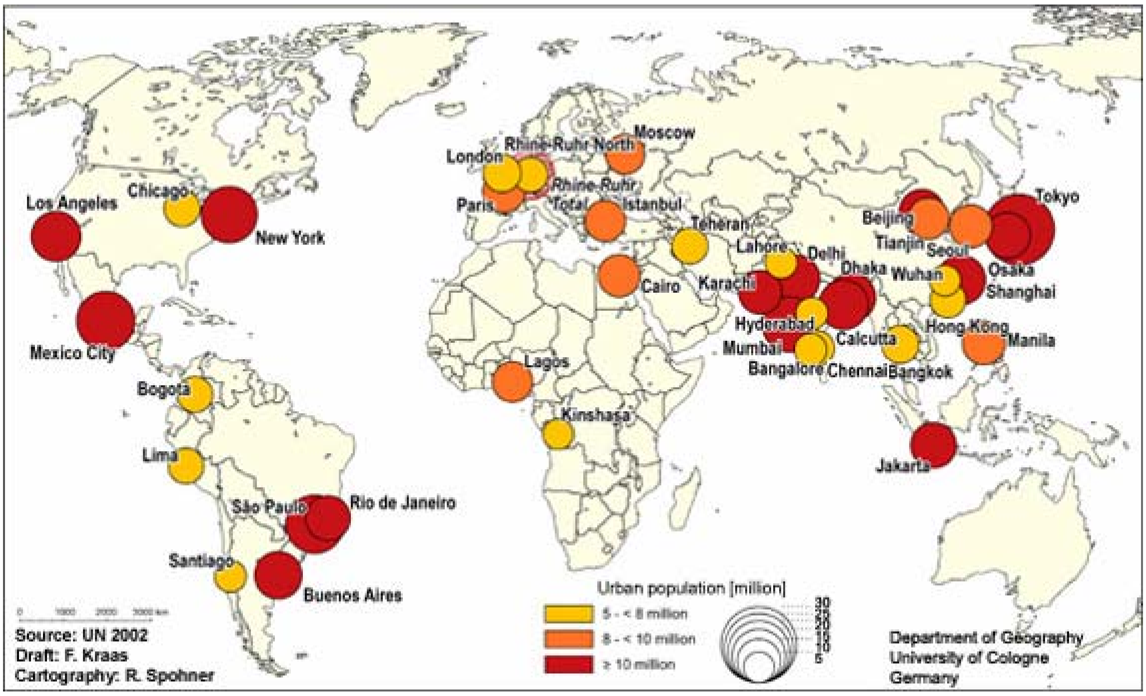

Figure 1: Megacities in 2015
[Source: www.megacities.uni-koeln.de]

This incredibly rapid growth of megacities causes severe ecological, economical and social problems. How can this growth be nurtured in a sustainable way when over 70% of the growth (Kötter, 2004) currently happens outside of the formal planning process ?

Our challenge is to provide both political and professional megacity ‘managers’ and citizens / communities with appropriate, up-to-date, city wide information in a very timely manner to support more proactive decision making that encourages more effective sustainable development. Unfortunately, institutional constraints and traditional approaches to large-scale mapping programs and development of urban information systems do not always lend themselves to providing decision-makers with such information in a timely manner.

In this paper, the authors argue there is a need for an information infrastructure that provides this new breed of “megacity managers” – and the citizens in these cities – with the information required to manage such sustained development. A new information collection / management paradigm should be developed in the context of the spatial planning of megacities and sustainable development. New tools, techniques and policies are required to baseline and integrate the environmental, economic and social 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.

2. CHARACTERISTICS OF MEGACITIES

Megacities have distinctive characteristics that make their growth management and associated information management requirements problematic. These include:

Dynamics: Megacities have phenomenal growth rates. Bangkok, for example mushroomed from 67 km^2 in the 1950s to 426 km^2 in the early 1990s and Beijing has more than tripled in size over the last four decades. Every day, hundreds, if not thousands of people move to each of the megacities from the surrounding rural areas of the country. This tremendous influx often undermines Local Government’s best efforts to provide adequate services to the inhabitants of the cities.

Scope of Economic, Environmental and Social Influence: Megacities have a major influence beyond the built up space of the city and there is a need to understand the relationship between the megacity and the corresponding economic region. Solving some of the underlying rural issues would help to stem the influx to the megacities.

Density: To accommodate the large growth of population, megacities sustain the highest density of inhabitants, industrial assets and production, social and technical infrastructures.

Settlement, Infrastructure and Land Tenure: Due to the significant dynamics of megacities, urban planning and public infrastructure provision tends to be reactive rather than a guide to development. Large portions of megacities grow outside of the legislative or development control framework. In the early 1990s, three out of every four housing units in Dar es Salaam were in unplanned and unserviced settlements (Rutsch, 2001). This has led to significant areas of informal housing that fall outside of the land tenure systems.

Governance: Good governance is one of the greatest challenges for megacities. São Paulo has a population of 10.8m, but it is merely the largest of 39 municipalities that comprise the metropolis of 18m (The Economist, 2005). There is an awareness that all must work together at a macro level and that local communities must also be engaged and empowered at the local level.

Scarce Resources: Within developing countries capacity building is limited and there are scarce human resources to support effective growth management across megacities.

Vulnerability: The concentration of inhabitants increases the risk of man-made and natural disasters. Informal settlements tend to encroach into areas of greatest risk: flood or mudslide prone areas, near areas of high pollution, or in areas of 'protected' natural resources.

Given these characteristics of megacities, one of the key challenges is to obtain up-to-date, city wide information in a very timely manner to support more proactive decision making that encourages more effective sustainable development.

3. INFORMATION TO SUPPORT SUSTAINABLE GROWTH MANAGEMENT

In cities where there is an effective Land Administration regime, change information associated with the ownership, value, use and condition of land and property can normally be obtained from the operational level, where services such as Land Registration and Cadastre, taxation and development control are provided. This assumes that an effective vertical information highway exists and that there is the means to technically and institutionally integrate these component themes of land and property information into a truly city wide information resource that can be disseminated to decision makers. Figure 2 (FIG, 2002) illustrates the information flows. In this situation, information is available to formulate robust land policies and to quickly monitor the effect of these policies.

However, in the context of megacities, this steady state, information management paradigm may not exist. The explosive growth of the city and the fact that a large proportion of development takes place outside the formal land management and administration process does not support the luxury of change information being fed from operational services. In addition, the participation of citizens in the decision making process is severely limited since 'communities' are informal and not integrated into the Municipal structures. Therefore, these traditional sources of information to support proactive planning decisions do not exist. A new information collection / management paradigm with new tools, techniques and policies is required to baseline and integrate the environmental, economic and social 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, but be optimised to operate within the spatial data infrastructures as they are evolving today. This will potentially lead to more proactive urban planning and land management than is possible within megacities today.

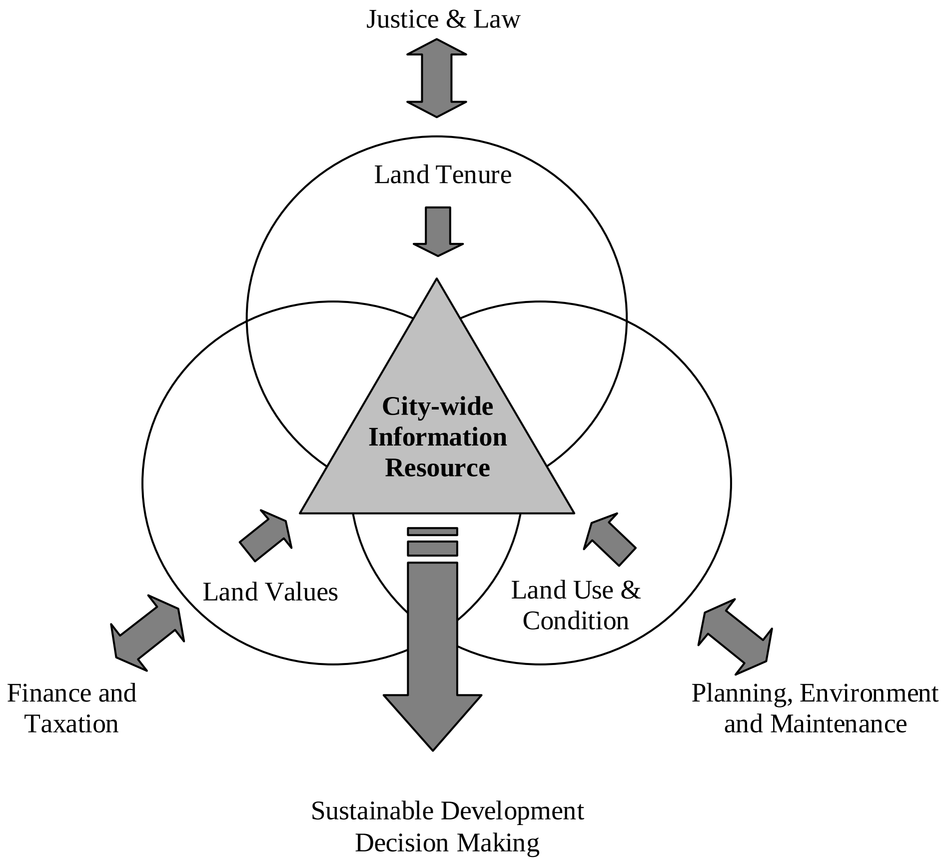

Figure 2: City-wide Information Resource Supporting Sustainable Development Decision Making

Therefore, if there is no reliable information being fed through the vertical information highway from operational services and the systematic, cyclical mapping of the entire city jurisdiction is not being performed then the limited information gathering resources available will have to be targeted on key, vulnerable parts of the megacity, with greater responsiveness that will result in more effective sustainable development.

Megacities should develop an overall Strategic Urban Development Plan that prioritises areas of the city that are most vulnerable and require on-going monitoring and proactive intervention. These priorities should be decided locally through an environmental planning and management process to ensure that the issues are pertinent to specific parts of the city rather than simply applying generic, city wide issues. This will result in a patchwork of different information collection and analysis requirements across the megacity – quite different from a consistent, city wide data gathering exercise. For example, priorities could range from all informal settlements, just encroachments on agricultural land within urban areas, areas at most risk to flooding, or areas at most risk to mud slides. It would be up to communities / local governments to decide on the priorities for information gathering to be applied to leverage more effective management of growth. The rate of change in portions of the megacities also varies significantly. Therefore, priorities for data collection could also be focused on those areas of the megacities with the highest growth patterns.

This requirement for highly responsive, information specific data capture and analysis within targeted parts of the megacity provides a new challenge for the Geomatics community. However, technologies to support change detection, ‘just in time mapping’ and more informed public participation are emerging that are cost effective and flexible enough to support more effective information management for growth management within megacities.

4. TECHNOLOGICAL ADVANCES IN RAPID-RESPONSE, “JUST-IN-TIME” MAPPING

More than 50 countries now have spatial data infrastructure initiatives underway (Onsrud, 2001). In the most advanced of these, professionals and the general public take advantage of a “data-rich”, wired environment. In this environment, people can locate themselves (and their assets) precisely and in real-time, can quickly obtain georeferenced digital imagery covering an area of interest, and can access on-line detailed mapping and attribute information on property ownership, valuation, land-use planning and even nearby hospitals and banking machines. Due to the wireless communications infrastructure available in these countries it is possible to both “pull” location information from sensors and “push” location-based attribute information – nearby service stations, for example – back out.

4.1 Rapid Response Mapping

Numerous authors have focussed on the development of applications that make use of existing data and services within a spatial data infrastructure. However, it is equally valuable to look at how researchers and professional practitioners are taking advantage of this wired, data-rich environment to change the way they produce traditional products and create new types of mapping products and services.

The advent of GPS/INS-controlled digital aerial cameras has reduced the need for time-consuming ground control and aerial triangulation operations. Taken in combination with existing digital elevation data from existing government mapping, Shuttle Radar Topography Mission (SRTM), and other sources that now exist around the world, medium-accuracy digital orthophoto mapping can be created in some areas within hours of a photo flight. As wireless broadband communications services improve and become commonplace, we will see more instances where the data is sent directly from the photo aircraft and orthophoto maps are completed back at the office by the time the plane has landed.

4.2 The Promise of Automated Feature Extraction

Automatic collection of spatial information from digital images is currently the most complex and challenging task faced by the computer vision and photogrammetry communities. Traditional photogrammetric techniques can be slow, expensive and require well-trained operators; for rapid urbanising and high-densely urban areas such techniques cannot suffice (Ruther et al., 2002). Numerous authors and agencies have promoted new mapping techniques based on generic mathematical models using digital aerial imagery [e.g. (Gulch, 2000); (Haverkamp, 2003)]. However, using generic mathematical models to define building shapes in areas where construction does not follow any building code cannot provide realistic results (Ruther et al., 2002).

The development of more robust feature extraction software now portends the promise of automated extraction of road and building information from digital imagery. Commercial software like *eCognition* by Definiens Imaging and *Feature Analyst* by Visual Learning Systems are both early examples of automated data extraction or (”ADE”) products now in the marketplace.

While certainly of interest to managers of mapping programs in more developed nations, such technologies are also being applied in the megacities of developing countries. Informal settlements (i.e., ”squatter settlements” or ”shanty towns”) are dense settlements comprising communities housed in self-constructed shelters under conditions of informal or traditional land tenure (Hindson and McCarthy, 1994). The formation of such settlements is caused by the continuing urban migration, which can result in a proliferation of small, makeshift shelters, degradation of local ecosystems, and serious social and economic problems. Professional managers are often unable to plan properly due to the lack of accurate and sustainable geo-spatial information concerning these settlements (Mason et al. 2001).

Over the past seven years, researchers have begun applying automated feature extraction techniques to the challenges of mapping informal settlements [(Barry and Rüther, 1999), and (Li et al., 1999)]. Mayunga et al. (2004) and others have argued that using the “active contour” (also called “snakes”) feature extraction model in conjunction with high-resolution satellite imagery (HRSI) has demonstrated real promise in meeting urban mapping requirements in informal settlement areas.

Mayunga’s research has applied a modified version of the snakes algorithm to extract buildings from an area of Dar Es Salaam, Tanzania (Figures 4a, 4b, 5a and 5b). QuickBird satellite images covering the project area were geo-rectified by the image vendor Digital Globe Inc. and have the following properties:

- Spectral resolution: four bands (R, G, B, NIR), 8 bits/pixel
- Spatial resolution: two metres/pixel (multispectral) and 0.6metre/pixel (panchromatic)
- Pre-processing: DigitalGlobe Inc. standard geometrically corrected (CEO) at position accuracy of 23m.
- Map projection: UTM Zone 39 WGS-84.

Figure 4(a). Shows input image

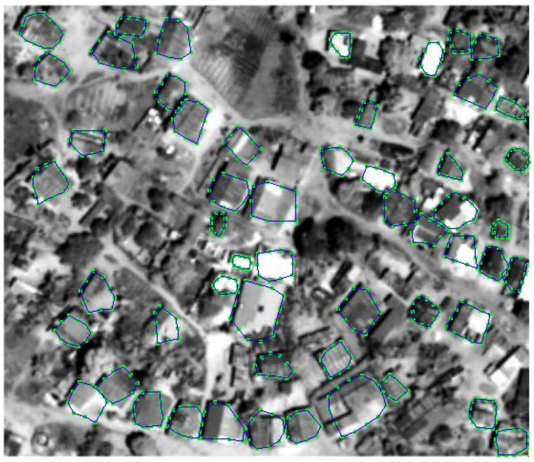

Figure 4(b). Shows extracted buildings

Figure 5(a). Shows input image

Figure 5(b). Shows extracted buildings

Although most of the buildings in Figures 4(a) and 5(a) have different shapes and orientation, the snakes contours correctly identified and extracted almost 94% of the boundaries of structured and unstructured buildings over three test areas. Results from this semi-automatic building extraction method were subsequently evaluated and compared with a 2D ground truth data manually plotted using photogrammetric techniques. In quantitative analysis, coordinates of individual building corner points were randomly selected and measured. The selected and measured points using the ADE approach were compared with their corresponding points from the ground truth data to determine the positional accuracy of extracted buildings. Based on 71 randomly measured points measured in the three different test areas, the results showed the mean standard deviation of 0.68m and 0.94m in x and y respectively and root mean square error of 1.16m in planimetry. Given the scale of the original imagery, limitations of the original rectification process, and the requirements of this application, these results were deemed to be satisfactory.

5. PUBLIC PARTICIPATION GIS

As mentioned earlier, decision-makers and megacity managers require information from a wide variety of sources in order to ensure appropriate and sustainable development over time. If they are to provide input to this process, then citizens require information as well. In societies where citizen input is considered important to the planning process, then mechanisms must be in place to encourage *informed* engagement.

“Public participation” encompasses a group of procedures designed to inform, consult, involve, and inform the public to allow those affected by a decision to have an input into that decision (Smith, 1993). Its ultimate aim is to facilitate and mediate consensus building. It is a process that requires access to information concerning the matters being addressed and intensive communication and discussion amongst the stakeholders. In the context of community planning, the stakeholders include, but are not limited to, the planners and the general public. The discussion focuses on the allocation of land-use resources and location-related issues, and maps are always used in such discussions.

Depending on the needs of the decision situation and the disposition of those in control of decision-making, the degrees of public participation in community planning vary from evasion to full empowerment. Arnstein (1969) used a ladder to depict the different levels of power given to the citizen in affecting the outcome of the participation process. More recently, Wiedemann and Femers (1993) have also used the ladder analogy to their consideration of environmental decisions about hazardous waste management and developed a six-rung participation ladder (Figure 6). This model is considered to be more applicable to today’s planning context. It assumes that as one moves up the ladder, each successive step embraces the lower steps on the ladder.

In the last decade, we have witnessed the growing application of Geographic Information Systems (GIS) in participatory community planning. GIS professionals concerned about community development have developed a framework, generally called Public Participation GIS (PPGIS), to help neighbourhood community groups and individuals use mapping and spatial analyses in community development and public participation (Wong and Chua, 2004). Recent efforts in PPGIS have concentrated primarily on making GIS and other spatial decision-making tools available and accessible to the general public. [See (Ammouri, 2002) for an extensive discussion of such efforts.] For example, many PPGIS systems are now available online to enable the general public to explore spatial data over the World Wide Web. While many Web-based PPGIS are very innovative in terms of the technology involved and have often done a great service in terms of informing the public, most serve only to move citizens in developed countries up to the middle of the “public participation ladder” at best.

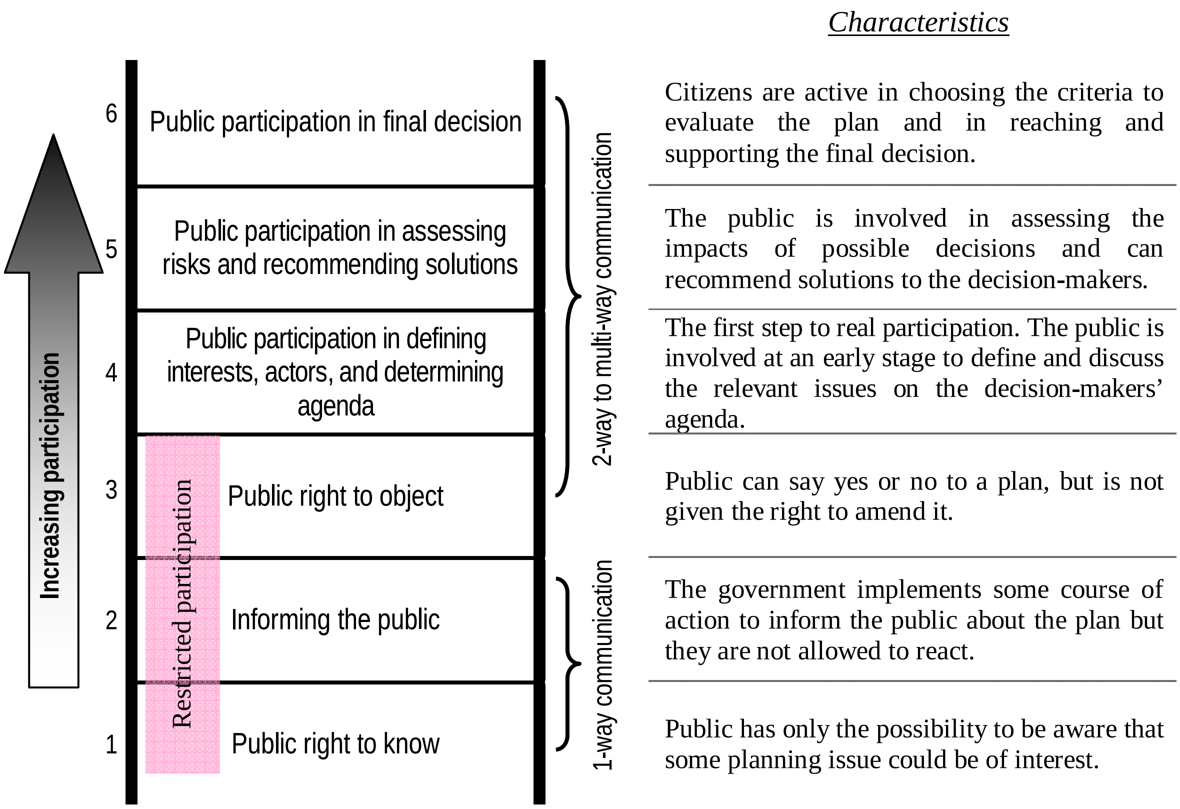

Figure 6: Wiedemann and Femers' Ladder of Public Participation
[Modified after (Wiedemann and Femers, 1993) and (Carver et. al, 1998)]

We should expect more – especially with the growing challenges posed by managing megacities. As PPGIS are intended for community participation, it is reasonable to expect them to satisfy the principles of participatory planning approach. One of those principles is to facilitate the transparent exchange of ideas because planning issues are often considered as ill-defined issues. Simply making such tools available and accessible does little to move citizens "up the ladder" of participation.

That said, a new generation of Web-based PPGIS initiatives is just beginning to provide users with tools to analyze existing proposals, suggest and evaluate alternatives, and frame an on-line discussion of alternatives within a geospatial context. See (Tang, 2005) for examples.

Deichmann and Wood (2001) observe that PPGIS research primarily addresses "concerns about GIS as an invasive and potentially divisive technology that benefits some people and institutions while marginalising others". They argue that PPGIS challenges include:

- Changes in local politics and power relationships resulting from the use of GIS in spatial decision making;
- The effects of differential access to GIS hardware, software, data, and expertise to analyse the information;

- The educational, social, political, and economic reasons for lack of access and exemplary ways in which communities have overcome these barriers;
- The ways in which socially differentiated communities and their local knowledge might best be represented within GIS;
- GIS as local surveillance; and
- Identifying public data policies that positively or negatively influence small-scale local businesses.

Most applications still focus on developed-country experiences. However, as Deichmann and Wood point out, PPGIS concerns are even more pertinent to poor communities – often informal settlements -- in the megacities now emerging in developing countries. Unfortunately, even as developments are made in terms of communications, computing and spatial data infrastructure in these nations, it is unlikely that the citizens in those communities will have the access to such infrastructure, much less the resources or education to understand and apply them effectively. This puts these citizens at a distinct disadvantage with respect to government, private developers and special interest groups when trying to respond to proposed new initiatives or development projects.

6. INCORPORATING THESE TOOLS INTO INSTITUTIONAL PLANNING AND ENGINEERING PROCESSES

This paper has identified emerging technologies to support just in time mapping and more informed public participation that appear to provide a significant source of timely information for the more effective management of megacities. However, can these new data collection techniques be effectively applied within the context of megacities or are there operational, institutional, cultural or even political barriers limiting their successful introduction?

Many urban mapping and GIS programs are still steeped in traditional approaches to data collection and update that impose restrictive specifications and may take many months to move from basic collection to final data dissemination. This does not provide the responsiveness required to manage the rapid changes characteristic of megacities. Although some project-based work, particularly for planners, may be completed more quickly, the existing mechanisms to incorporate *ad hoc*, project-based information, with varying specifications and accuracies into larger, *program-driven* databases is not always in place. There are examples of the transactional upgrading of Cadastral databases over time, but this approach is rarely applied to topographic mapping programs. Due to the wide variety of stakeholders involved in the data collection process, concerns are raised over data reliability and the engrained business processes of large institutions impose barriers to any innovation to data collection.

This could well be a “techno-political” issue where large mapping agencies / organisations are reluctant to incorporate any information into their databases that was not collected through their own, “tried and true” production workflow. This may be true even when the newer data is also more accurate geometrically. For example, higher-accuracy LIDAR

DEM's may be available over a given project area, yet the data are never integrated into the DEM's of the national mapping agency even when their collection was funded by the same government ! It is relatively easy to manage heterogeneous data, but the megacities need to compromise this ideal situation since they require the management of a patchwork of data at different specifications and accuracies; to ensure that timely data is available to manage the rapid change. To support the immediate introduction of rapid-response, just-in-time mapping technologies described in this paper, there is a requirement to develop the tools, processes and workflow necessary to incorporate these technologies into urban mapping programmes and the extension and/or updating of existing urban GIS databases. This will require the introduction of more effective data management and dissemination environments to manage this patchwork of data, the ability to fast-track priority data sources through the workflow process and to inform users of the corresponding data quality.

One of UN-HABITAT's prerequisites for achieving sustainable development is the effective engagement of communities in the management of their local environments. The use of PPGIS is potentially a tremendous tool to achieve this aim. However, its application is still in its infancy even in developed countries and there are technology and cultural issues to be considered in the context of developing countries and megacities. Firstly, the effective and appropriate usage of PPGIS as described earlier depends on the presence of mature communications and information infrastructures and people who know how to use them; this is certainly not the current situation in megacities in developing countries. The creation of that infrastructure in emerging nations will take time and doubtless be different to what has been developed elsewhere. Secondly, the effective uptake of PPGIS in any jurisdiction depends less on the technologies than it does on long-standing traditions of civic engagement in the planning and political processes. If people are not used to involvement, have not been allowed to participate, or do not know how to get engaged in such processes then any high-tech tools and processes introduced may never get past the demonstration stage before the next generation of technology renders them obsolete. A more appropriate, interim solution for introducing PPGIS in megacities may be the use of "mediators", skilled in the use of GIS in spatial decision making, who can act as intermediaries between communities and the managers / politicians of megacities. This approach could alleviate the 'digital divide,' all too apparent in megacities, and effectively channel the requirements of the communities into the megacity planning process.

Megacities require new, innovative, highly responsive and selective approaches to information collection to manage their rapid growth in a sustainable way. This paper has highlighted the potential of emerging technologies such as just in time mapping and PPGIS for delivering such timely information for the efficient management of megacities. However, the effective adoption of these technologies within the context of megacities will require a paradigm shift in how spatial information is collected and managed and our engagement with communities in the megacity planning process.

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BIOGRAPHICAL NOTES

Robin McLaren is a director of Know Edge Ltd a UK based, independent management consulting company formed in 1986 specialising in optimising the business benefits of land & property related information through the strategic design and implementation of Information Systems and Services. Robin has been at the forefront of the GIS revolution and is recognised as a world expert in Land Information Management. He has worked extensively in Eastern Europe and world-wide to strengthen land tenure to support economic reforms.

David Coleman is Dean of Engineering and a Professor of Geomatics Engineering at the University of New Brunswick, Canada. Prior to joining UNB in 1993, his career included engineering, consulting and executive management assignments across North America and on three other continents. He has authored numerous papers dealing with land information management and spatial data infrastructure. He is a Past President of the Canadian Institute of Geomatics, a former Canadian representative to FIG Commission 3, and is a member of the Board of Directors of the GSDI Association.

Selassie David Mayunga was born in Bariadi, Shinyanga, Tanzania. He studied Land surveying at Ardhi Institute -- now the University College of Lands and Architectural Studies (UCLAS) -- graduating at the age of 24. He then continued with post graduate studies in photogrammetry at ITC in the Netherlands and obtained an MSc. in photogrammetry at University College London.. He started working in the Ministry of Lands and Human Settlements as a Land Surveyor, district land development officer and then a provincial Land Surveyor in Shinyanga. He joined the Ministry of Lands and Human Settlements Headquarters in 1996, and became head of the photogrammetry section within the Surveys and Mapping Division. Selassie is currently a PhD candidate at the University of New Brunswick in Canada.

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