The Role of Urban Sensing in Strengthening SDIs

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Abstract:

Many megacities are growing at an annual rate of over 6% and some will double their populations in the next decade. This incredibly rapid growth of megacities causes severe social, economical ecological and problems. 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.

M-government is an extension or supplement to e-government and provides information and services through mobile devices, e.g. cellular phone, laptops, and is mobile and wireless. For developing countries with no infrastructures of wired Internet technology, this is the only low cost infrastructure option available. Despite cellular phones having disadvantages in the delivery of information and services, e.g. size of screens and some security aspects, M-government opens up additional channels for citizen participation and has a significant potential to increase the constituent participation.

This paper explores the role of 'urban sensing' that uses cellular phones, sensor technologies, GIS related technologies. Web 2.0 and crowdsourcing (mass collaboration using Web 2.0) to support the creation of a public infrastructure, a 'data commons,' that will allow the citizen to increasingly participate in politics, civics (including land administration and management), aesthetics and science. These emerging techniques have the potential to strengthen the Spatial Data Infrastructures and urban change information available to megacities.

Key words: Mobile Government; Public Participation Geographic Information System; SDI, Citizen Participation; Crowdsourcing, VGI, Urban Sensing.

1. INTRODUCTION

Urbanisation is a major change that is taking place globally. The urban global tipping point was reached last year when over half of the world's population was living in urban areas; around 1.6 billion people. Although this depends on the definition of 'urbanisation', as outlined in the World Bank's 'World Development Report 2009, Reshaping Economic Geography' (World Bank, 2009). 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% (Kelly, 2008).

This rush to the cities has generated 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 (Kelly, 2008). 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 and it is recognised that over 70% of the growth (Kötter, 2004) currently

happens outside of the formal planning process and leads to 30% of urban populations living in slums.

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 world-wide (Kelly, 2008). Cities are where climate change measures will either succeed or fail.

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 (Coleman et al, 2005). 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.

This paper explores a new generation of urban sensors, both ubiquitous surveillance and citizen initiated sensors, which have the potential to provide "megacity managers" – and the citizens in these cities – with more effective and timely information required to manage such sustained development. This environmental, economic and social information will be integrated to create a public infrastructure, a 'data commons,' that will allow the citizen to increasingly participate in politics, civics (including land administration and management), aesthetics and science. These emerging techniques have the potential to strengthen the Spatial Data Infrastructures and urban change information desperately needed by megacities.

2. CURRENT APPROACHES TO URBAN INFORMATION MANAGEMENT

Land management underpins the distribution and management of a key asset of any society namely its land. For western democracies, with their highly geared economies, land management is a key activity of both government and the private sector. Land management, and especially the central land administration component, aim to deliver efficient land markets and effective management of the use of land in support of economic, social, and environmental sustainability (Enemark et al, 2005). The land management paradigm, as illustrated in Figure 1, allows everyone to understand the role of the land administration functions (land tenure, land value, land use, and land development) and how land administration institutions relate to the historical circumstances of a country and its policy decisions.

In cities where this land management paradigm exists and is fully functional, 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 there is the means to technically and institutionally integrate these component themes of land and property information from a variety of agencies and local authorities into a truly city wide information resource that can be disseminated to decision makers; this is rarely the case even in the western world. 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 most megacities, this steady state, information management paradigm does 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 through 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 sustainable development decisions do not exist (Coleman at al, 2005). Robust land administration and management institutional structures will not be introduced into the majority of megacities in the short term. Therefore, new and innovative sources of information and its management must be found; urban sensing provides a potential source of some of this essential information.

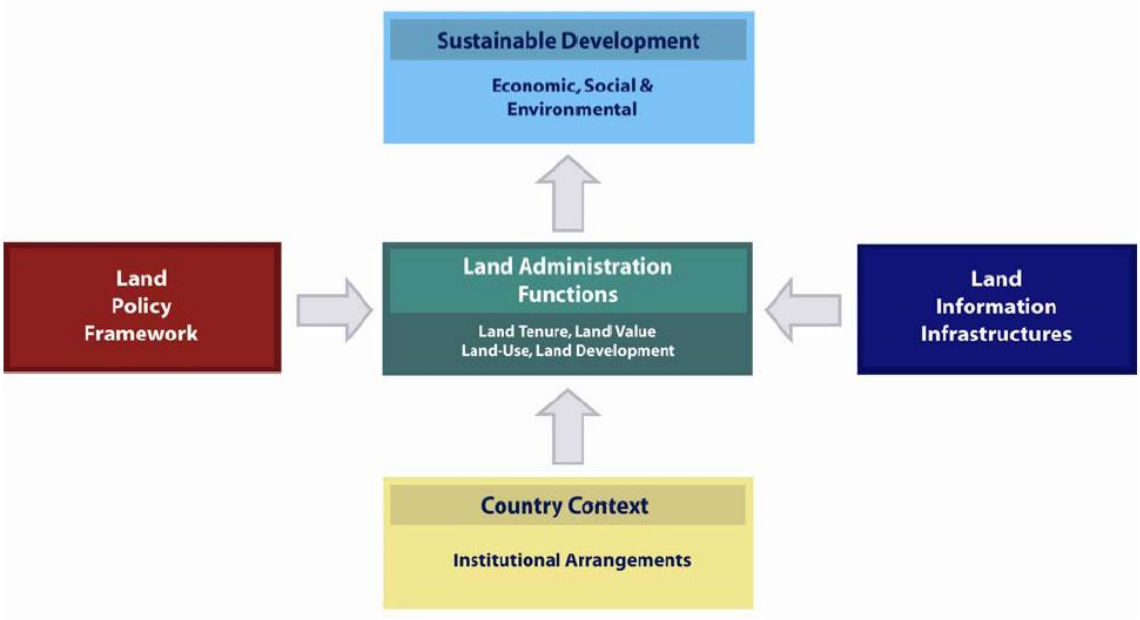

Figure 1: The land management paradigm (Enemark et al., 2005)

3. URBAN SENSING

Rather than using embedded network sensors, a new generation of citizen activated sensors in the urban environment is creating opportunities for collecting and managing a wide range of urban information. This is termed 'urban sensing' (Cuff et al, 2008) and uses a wide variety of sources including cellular phones, RFID tagged items, GIS related technologies, Web 2.0 and crowdsourcing (mass collaboration using Web 2.0) to support the creation of a public infrastructure, a 'data commons,' that will allow the citizen to increasingly participate in politics, civics (including land administration and management), aesthetics and science. These emerging techniques using pervasive computing (Weiser, 1991) have the potential to strengthen the Spatial Data Infrastructures and urban change information available to more effectively manage megacities.

This section explores the roles of ubiquitous sensors, citizen initiated sensors and direct citizen contributions as potential sources of urban information.

3.1 Ubiquitous Sensors

Radio Frequency Identification (RFID) tags have been likened to barcodes that broadcast their information and have been primarily used to identify parts and inventory as they make their way through the supply chain. However, over the past decade there has been a shift to embed them in an increasing number of personal items and identity documents, including transport and toll passes, office key cards, school IDs, "contactless" credit cards, ski passes, clothing, phones and even groceries.

A good example of this transition to having RFID tags in our pockets is in the USA where new drivers' licenses (on a voluntary basis) incorporate RFID tags that can be read right through a wallet from as far away as 10 metres (Albrecht, 2008). Each tag incorporates a tiny microchip encoded with a unique ID number. This is designed to make border crossing more efficient. As the bearer approaches a border station, radio energy broadcast by a reader device in the border station is picked up by an antenna connected to the chip, causing it to emit its unique ID number. This unique ID is picked up by the customs information system and by the time the driver reaches the border agent, their photo and other information are displayed. Another example is in hospital environments where staffs' RFID tagged ID cards are constantly tracked around the hospital to allow the current location of staff to be determined to more efficiently support emergencies.

Because the RFID tags were designed to be powerful tracking devices and typically incorporate little security, especially those conforming to the EPCglobal Gen 2 standard (Albrecht, 2008), people wearing or carrying them are vulnerable to surreptitious surveillance, tracking and profiling. Anyone can purchase an RFID reader and have access to this information without the owners' knowledge or consent and existing laws offer people scant protection from being surreptitiously tracked and profiled while living an increasingly tagged life, e.g. unscrupulous marketers, government agents, thieves or snoops. However, RFID-based contactless ID cards and e-passports are based on the ISO 14443 standard that includes rudimentary encryption and require tags to be closer to a scanner to be read – around 10 cms. This type potentially provides a much higher level of security for users.

IBM has a patent (US Patent 7076441) for 'Identification and Tracking of Persons Using RFID-Tagged Items in Store Environments.' In this store application, a person can be tracked using networked RFID readers called 'person tracking units' and times of visitation across the store recorded. On check out with a credit card, the link between the unique RFID number of the tag and the personal information can be made. Any tags based on the EPCglobal Gen 2 standard would allow this to happen now.

This store tracking infrastructure could be expanded to be city wide and incorporated virtually everywhere people go – shopping malls, airports, restrooms, libraries..., to closely monitor peoples' movements. A good example of how this might work is already in operation at Alton Towers, a theme park in England. (*http://www.altontowers.com*) where visitors can opt to participate in and purchase a 'YourDay' DVD souvenir. On entering the theme park, visitors are provided with a RFID tagged wrist band. This is used to track the location of the visitors throughout the theme park and triggers the recording of video footage of the visitors on and in the proximity of the attractions. At the end of their visit, they take home a unique personalised DVD movie featuring 'you and your friends and family having a great day out' as a keep sake.

In the context of megacities, it is not inconceivable for RFID based tracking devices to track the movements of all citizens across the city; to some extent this already happens with toll passes used to track vehicle movements and travel passes to track public transport movements. This information would help to understand the daily and on-going migration patterns across the city and support better planning of the transport infrastructure requirements. However, this scenario also has great surveillance potential and may provide some countries with a way of potentially controlling their population in the future – China, for example, is currently spending 6$B to roll out RFID-based national IDs to nearly one billion citizens and residents.

3.2 Citizen Initiated Sensors

It is not scalable or feasible to set up a centrally controlled solution where scientists deploy the sensors within the context of a megacity. Instead, we can implement ubiquitous

surveillance through the use of cellular phones, for example. Cellular phones are not just a communication device, but are also a passive sensor that silently collects, exchanges and processes information all day long. As well as recording sounds, cellular phones are increasingly recording images and locations (cellular phones are progressively being spatially enabled through integration with GNSS technology, cell phone triangulation or wifi positioning). In the future, cheap sensors will be added to cellular phones to detect aspects of the environment, e.g. air and noise pollution.

The cellular phone is generating a move to distributed citizen / participatory sensing and supporting Mobile(M)-government as an extension or supplement to e-government and providing information and services through mobile devices, i.e. cellular phones, laptops and is mobile and wireless (Trimi and Sheng, 2008). For developing countries with no infrastructures of wired Internet technology, this is the only low cost infrastructure option available and opens up new channels for communication with citizens. M-government has the following advantages (Enemark & McLaren, 2008):

- It avoids the digital divide since the use of cellular phones is becoming ubiquitous [70% of the USA population and 93% of the EU own one (Wikipedia, 2007)] and is evenly distributed across society;
- Use of cellular phones is fastest growing in developing countries (in 2007, 90% of phone subscriptions in Africa were cellular phones);
- Services are available anywhere, anytime;
- Cellular phones are increasingly being spatially enabled;
- Supports 2-way communication, including real-time alerts to citizens, e.g. terror and severe weather alerts;
- Can be used for e-payments for services. This can reduce the potential of corruption; and
- Cellular phones are single user devices, allowing services to be personalised, e.g. license renewal reminders.

Despite cellular phones having disadvantages in the delivery of information and services, e.g. size of screens and some security aspects, M-government opens up additional channels for citizen participation and has a significant potential to increase the constituent participation. Within the context of managing megacities, M-government through cellular phones has the potential to considerably increase the type and currency of information gathered from citizens based monitoring of their environment. For example, the location (postal address or GNSS derived co-ordinates) and images (including video) of new informal settlements and illegal developments, pollution incidents, traffic congestion hot spots, crowds waiting for local government services and crimes could be submitted by citizens. This information could become part of a public information infrastructure (Cuff et al, 2008) that would need to be authenticated, managed, prioritised and acted upon by the megacity authorities to encourage the citizens to continue to engage and provide this type of information.

The constant surveillance of peoples' locations can be perceived as highly sensitive information. However, the convergence of Location Based Services and social networking where location connects virtual social networks with real live social interactions has triggered the controlled sharing of location information with designated people. People appear to be comfortable sharing their location information either with known sources or where there is an incentive. An example of this incentive based exposure is in Northern Ireland where males under 25 were finding it impossible to obtain reasonably priced car insurance. One innovative car insurance company offered an insurance deal only if the driver fitted GPS to their vehicle to allow the constant monitoring of speed to ensure conformance with the speed limit. The driver also agreed for their location information, in the form of traffic flow data, to be sold on to third parties by the insurance company. In another project called 'CarTel', the

Massachusetts Institute of Technology (Cheng 2008) is attempting to free up the traffic jam using mobile sensors. The project has developed a system to capture massive amounts of traffic data and has outfitted a fleet of limousines and taxis with mobile sensors that pick up real-time information on the location and speed of the vehicles as well as the condition of the roads. The data are fed back to a central computer that calculates the traffic patterns and can predict the optimal route. In the future, this could be deployed through and distribute to smartphones programs that can perform similar functions, relying on regular commuters who can download the programs online or sources such as Apple Inc.'s App Store. The incentive to provide location information is in route optimisation. In megacities, maybe citizens will provide their location information in return for reduced transport costs, travel times or road tax.

3.3 Direct Citizen Contributions

Rather than gathering information from citizens through surreptitious surveillance, citizens also directly volunteer information for use by government. This section discusses citizen tracking, formal e-government based sources as well as informal sources through crowdsourcing.

3.3.1 Direct Tracking of Citizens

Citizens could also volunteer to have their movements around the urban environment tracked; just like the research of endangered animals in the wild! Positions obtained through GNSS would be transmitted and logged. The robustness of these positions may be improved further by supplementing GNSS solutions with extra sensors known as Inertial Measurement Units (IMUs), able to supply relative motion changes. IMUs are able to assist GNSS in difficult environments, e.g. indoors, urban canyons and can be placed on the user's foot to exploit human walking kinematics and therefore to estimate the user's position (Radoczky, 2007) in between GNSS updates.

3.3.2 e-Government

In countries that are fortunate to have mature infrastructures of wired Internet technology and a moderate to high uptake of Internet users, e-government has allowed public sector organisations to engage on-line with citizens to better deliver their services and improve their efficiencies. For example, many governments have established e-planning portals (Enemark & McLaren, 2008) that allow citizens to access on-line the land use control information, including:

- Access to zoning development plans; planning regulations; and general land-use information;
- Submission of development applications;
- Access to proposed developments, associated drawings and their current status;
- Submission of comments associated with proposed developments to be used as material evidence in the decision making process; and
- Access to the results of development control decisions.

These e-planning portals normally support a one way dialogue, with the responsibility on the citizens to access the information and to participate. However, a new generation of Geographic Information System (GIS) based tools are now available, supported by maturing Spatial Data Infrastructures, which are being used to enhance the interaction experience and effectiveness with the citizen. Examples of these new tools are

- GIS is being applied to participatory community planning (Coleman et al, 2005). 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. A new generation of Web-based PPGIS initiatives is beginning to provide users with tools to analyse existing proposals, suggest and evaluate alternatives and frame an on-line discussion of alternatives within a geospatial context. See (Tang et al., 2005) and (Zhao, 2006) for examples.

- Using Google Earth, for example, allows communities, citizens or pressure groups to increasingly create an easy to access simulation of the proposed development. This environment can then form the basis for a dialogue amongst the stakeholders.
- For many citizens the use of PPGIS environments is either too advanced for their use or they are on the wrong side of the Digital Divide. However, there are emerging virtual reality techniques that allow citizens to access sophisticated GIS and visualisation technology through mediators. One such example is the 'Virtual Landscape Theatre,' (The Macaulay Institute, 2006) developed by The Macaulay Institute in Scotland, that uses cutting edge virtual reality technology to recreate landscapes and provide a forum for people to visualise and assess impacts of proposed change.

For megacities in developing countries, this e-government source of information is at an early stage of development and hindered by the lack of infrastructures of wired Internet technology. However, e-government extended into M-government has a greater potential to deliver within these megacities.

3.3.3 Crowdsourcing / Distributed Citizen Sensing

The difference between crowdsourcing and ordinary outsourcing is that a task or problem is outsourced by an open call to the public (undefined group of people) rather than another body (www.wikipedia.org). Citizens volunteer to collect and sometimes maintain information for a variety of initiatives. These on-line communities self organise into productive units and have produced some excellent results, including:

- The Great Backyard Bird Count in the USA involves volunteers recording bird sightings in their backyards;
- Geo-tagged images and videos are voluntarily uploaded to sites like Flikr and Panoramio;
- The Dutch navigation company TomTom has introduced a facility called 'MapShare' that is basically Crowdsourced map maintenance;
- OpenStreetMap is a free editable map of the whole world – the free WIKI world map – created and maintained by volunteers (watch out for your local 'mapping party'!).
- 'Explore' is a new application from Ordnance Survey GB that allows you to create and share routes with the world, and join in with ones that already exist.

The ease and increasing use of GPS for data capture, adoption of data standards, the availability of Web 2.0 tools and the efficiency of mashups for managing and distributing the information are accelerating the growth of crowdsourcing and distributed citizen sensing. A good example within the context of megacities where this approach has been very successfully used is in disaster and crisis management. During the Hurricane Katrina disaster in New Orleans, two software engineers created www.scipionus.com to let thousands of New Orleans citizens post emergency information on a visual wiki in the wake of hurricane. This became much more important than the official sources of information. Another example happened during the recent forest fires in California, a wide range of information was integrated from GIS professionals and distributed citizen sensed information, much of it real-time, to provide fire fighters and the public with crucial disaster management decision making information. This included:

- Topographic mapping;

- Forest compartment boundaries;
- Meteorological information;
- Models and predictions of fire fronts speeds and directions;
- Actual locations of fire fronts from GPS feeds aboard helicopters;
- Real-time feeds of IMAGE imagery;
- Evacuation routes;
- Closed highways; and
- Information from witnesses on the ground.

Another recent example is a web-based reporting tool called Ushahidi, "testimony" in Swahili, (Marwaha, 2008) that allows Africans caught up in political unrest to report incidents of killing, violence and displacement. It is an open source tool (see www.ushahidi.com) to crowdsourced information in times of crisis and its goal is to create a simple way of aggregating information from the public for use in crisis response. It taps in to mapping 'backends' like Google Maps, Virtual Earth or OpenStreetMap and has been used in Kenya after the recent violence following elections and more recently in the Democratic Republic of Congo. The approach involves people providing information through the web, email or text messages (either directly sending text messages or posting information for those who don't have access). There is also a process whereby NGOs confirm events and provide a credibility score. As Lyn Lusi, founder and programme manager of an NGO called HEAL Africa, puts it, “It is also very important that this information should be verified because this is also an information war.”

It is conceivable that citizen groups within megacities will form crowdsourcing communities to collect and maintain timely urban information that will supplement and possibly replace some out-of-date information obtained from official channels. However, the whole relationship between officially sourced information with specified levels of quality and crowdsourced information with unknown quality is still developing and not fully understood. The quality of large scale, citizen initiated information can potentially benefit from its ubiquity and scale, leading to redundancy that can identify, interrogate and correct faulty data. In addition, because these data are open and available to anyone to review, this offers a kind of ‘social data analysis’ (Cuff et al., 2008) that interactions and inferences can improve (see the 'ManyEyes' initiative from IBM at http://services.alphaworks.ibm.com/manyeyes/home).

Another key issue associated with large scale, citizen initiated information is its management. What model should be adopted and who should be responsible for its management? There are two main management models:

- A central authority maintains terms and conditions of data collection as well as a central repository who ‘employs’ us to voluntarily and idiosyncratically collect data, e.g. the Great Backyard Bird Count; and
- A fully decentralised model with no central authority beyond some actor to provide basic storage and search capability – more in line with Web 2.0 ethos which values unconstrained user participation (Cuff et al., 2008).

In the urban context, the initial management model adopted may be the central authority approach to focus data collection on specific geographical areas and types of information, e.g. informal settlement growth and damage to sensitive environments in the peri-urban areas. However, overtime, this model could migrate to the decentralised model and accommodate the urban sensing of a wider range of information across the megacity, creating a public infrastructure, a ‘data commons,’ that will allow the citizen to increasingly participate in politics, civics, aesthetics and science (Cuff et al., 2008). An example of this wider urban sensing has occurred in the city of Doetinchem, Netherlands. A 12 metre tall D-

tower (see figure 2) maps the emotions of the inhabitants. The tower changes the lights according to emotions reflected from the D-tower website, (www.d-toren.nl) .

On the website there is a questionnaire, where the inhabitants can respond to respectively love, hate, happiness and fear, determining the intensities of their feelings. Each evening the tower transmits the colours as “the State of the Town” as a large interactive system of relationships.

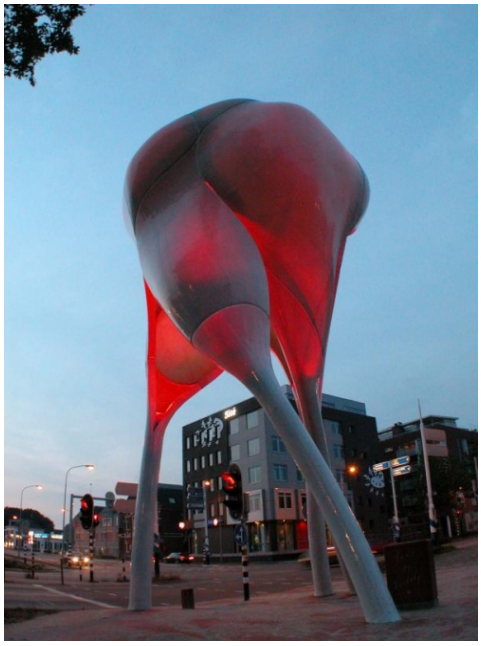

Figure 2: Interactive D-Tower in the Netherlands (Photo: Henk Vlasblom)

4. WHAT ARE THE SECURITY, LEGAL, POLICY ISSUES WITH THIS TYPE OF URBAN SENSING?

We are all increasingly living a tagged life as the use of RFID tagging on clothes and devices we carry on a daily basis proliferate. Many of these devices, especially the EPCglobal Gen 2 standard tags, have little security to stop illegal reading of the information. In addition, there is little legislation to prevent the misuse of this RFID tagged information either in the USA or European Union and on the manufacturing / retailing side, there is just a voluntary code of practice that cannot be enforced (Albrecht, 2008). This currently leaves citizens significantly open to the abuse of this technology in terms of monitoring, identity theft and stalking, for example. Accordingly, action groups have been formed against RFID; more can be found in Albrecht and McIntyre, 2005.

The explosion of spatially enabled cellular phones and the corresponding take up of Location Based Services provides the citizen with new navigation tools and better understanding of local services. However, the technology does permit the tracking of the movements of individuals that are not always apparent to the user. For example, the locations of cellular phone calls have been used in court to prove the whereabouts of individuals at specific times and vehicle tracking systems provide constant locations of all vehicles within an organisation’s fleet of vehicles.

Increasingly, technology is being widely used to monitor people's lives. However, if this information is made available to everyone then the ‘Big Brother’ element could be negated. A report from the Leading Edge Forum 2008 (CDC, 208) predicts that “You'll still be able to have secrets, but only if you can keep them off the Net. Privacy will be available, but only to

those who can afford to pay for it. For most people, privacy will end in 2013, or a little beyond that."

At the National Spatial Data Infrastructure 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. This paradigm shift has yet to be understood and absorbed at this level.

5. FINAL REMARKS

The new generation of urban sensors has significant potential in providing the managers of megacities with unparalleled access to a comprehensive range of current spatial and environmental information about the evolving workings of the megacity. Peoples' movements can be monitored; their use and modes of transport determined and people can voluntarily provide information about changes to their environment. All this information would potentially be much more up-to-date than equivalent information obtained through official channels and provide essential change intelligence in a highly dynamic environment. However, for megacities to gather and mine this valuable source of information, a number of prerequisites are required, including:

- Legislative and policy frameworks governing this type of surveillance;
- An agreement with citizens over what type of surveillance information can be captured and how it can be used. This will allow citizens to opt out, directly volunteer information or provide information through incentives;
- Structure appeals for crowdsourcing around focused topics to help manage the city more effectively, e.g. new informal settlements, environmental damage;
- An information infrastructure to manage, analyse and distribute this urban sensed information to facilitate its widespread use in solving urban problems; and
- A communication strategy to provide transparency of the process of urban sensing and to ensure that citizens understand the benefits of urban sensing.

This paper argues that people will participate more when provided with smooth almost ubiquitous access to information and the ease of providing information through m-government applications, for example. The increased levels and quality of participation will most likely take time to evolve as citizens gradually realise tangible evidence of urban improvements related to their participation. One initial consequence may be that City Authorities just receive hundreds of trivial requests for services. However, the communication traffic generated by this technology has to be managed effectively and acted upon in a beneficial manner by City Authorities to build trust with the citizens.

The successful introduction of urban sensing will involve considerable cultural and behavioural change of politicians, government officials, the business community and citizens and will be incrementally introduced as policies and legislation evolve. However, it has a great potential in filling the urban information gap we currently have in understanding the dynamics of megacities.

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