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UNITED NATIONS INITIATIVE ON
GLOBAL GEOSPATIAL
INFORMATION MANAGEMENT

Future trends in geospatial information management: the five to ten year vision

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Acknowledgements and disclaimers

This paper has been authored on behalf of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) by John Carpenter and Jevon Snell of Ordnance Survey, the national mapping authority of Great Britain. However, the content is based entirely on the contributions received in written form and the views expressed and trends identified at the discussion forum held in April 2012. Hence it does not necessarily reflect the views of the authors, or their employer. Whilst different and, at times, conflicting views were inevitably expressed by contributors, consensus on a number of major trends were forthcoming.

A first draft of this paper was presented to the UN-GGIM at its Second Session in New York in August 2012, for its consideration. This version has been developed to take into account feedback received at that Session and subsequent submissions.

A full list of those who have contributed can be found at the end of this paper. We are grateful to every person and organisation for giving their time; either to provide written contributions or to attend the discussion forum held in April 2012 and for allowing us to include their contributions in this paper.

Background

At the inaugural meeting of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), held in the Republic of Korea in October 2011, the Committee decided that there was a need to document the thoughts of leaders in the geospatial world as to the future of this industry over the next five years and, looking further out, its development over the next ten years.

A number of experts and visionaries across a wide range of disciplines of the geospatial community – from data collection experts, academics and major users of geospatial information, through to leading figures from the private sector and the volunteered geographic information (VGI) movement – were invited to contribute their views on the emerging trends in the geospatial world. In addition, all Member States were invited to contribute.

A number of written responses were received from individuals across the broad spectrum of the geospatial community and a follow-up discussion forum was held in Amsterdam in April 2012 to elaborate on these contributions and to try to find consensus on major trends. A first draft of this paper, building on both the written contributions received and on the discussions held in April 2012, was presented to the UN-GGIM for consideration at their Second Session in August 2012. This paper has now been updated to reflect the feedback received at that meeting and subsequent submissions.

Foreword

As a community, those involved in the geospatial world have seen significant change over the past decade. Understanding of the value of geospatial information among senior decision-makers in both governments and businesses around the world has increased significantly in recent years. The Internet, mobile devices and the explosion of location-based services, which bring everyone directly into contact with location information on a daily basis, have ensured that people, the world over, are beginning to appreciate the need for geospatial information.

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) was established to ensure that Member States can work together, share knowledge and support the development of strong geospatial information bases. The work is all based on a common recognition of the value geospatial information can play in developing our economies, in providing critical services, in underpinning sustainable development and, in doing so, enhancing people's lives the world over.

At the First Session of the Committee of Experts, it was agreed that it would be beneficial to document major trends we expect to impact on those of us involved in geospatial information management in the coming five to ten years.

A cross-section of recognised experts from all regions of the world was approached to provide initial written contributions, and requests were also made to all Member States to provide contributions. This was then followed by a forum in Amsterdam in April 2012, which offered the chance to build on those contributions and seek to find consensus.

A draft of this paper was presented to the Committee of Experts for discussion and feedback at its Second Session, which took place in New York in August 2012. This document seeks to reflect the feedback and comments made by Member States at that meeting and any submissions that have been sent in subsequently.

One of the comments at that Session related to uses of geospatial information. Relatively few of the initial responses received focused on uses and, as such, the paper reflected this. Nevertheless, raising awareness of the many uses to which geospatial information can be applied, and the value of doing so, will be a critical activity of UN-GGIM. As such, and as discussed at the Second Session of the Committee of Experts, Member States have been requested to provide case studies that demonstrate how geospatial information can be and is being used, and the benefits that its use has brought.

A number of case studies have now been received. These case studies demonstrate how countries the world over are already relying on geospatial information to underpin their development and the effective and efficient delivery of public services. From Egypt's use of detailed geospatial information to help grow its economy and increase the efficiency of its tax collection, to Spain's use of such information to underpin the economic aid management of its agricultural sector; from Brazil's use of geospatial information to reduce crime rates to the Republic of Korea's use of such information to update its cadastral maps and better manage land ownership issues, geospatial information is increasingly being relied on as a core part of a country's infrastructure.

The uses mentioned above are but a small sample of the many crucial uses that rely on geospatial information. Such uses will increase and diversify in the coming years, as governments increasingly come to recognise the importance of geospatial information to their everyday decision-making.

A wide range of case studies from all regions of the world are now available from the UN-GGIM website – **ggim.un.org** – as a complement to this paper. These will continue to evolve and be added to and updated over time and will hopefully help to demonstrate to senior decision-makers and stakeholders in your own country 'why location matters'.

It was noted by many respondents that there are many different challenges facing the members of UN-GGIM in the creation and maintenance of a trusted and accurate geospatial information base for their country; these challenges vary in both size and scope. However, the challenge to demonstrate the value of developing and maintaining a geospatial infrastructure base and the benefits that such information can bring to a nation is a constant one, and one that will

continue to require effort and commitment across the globe.

Nevertheless, where countries are battling to deal with the effects of famine, of widespread disease, or of access to basic resources such as food and water, convincing the government of the importance of maintaining an accurate geospatial information base is recognised by many as a huge challenge. Yet, potentially, it is in such countries where most value can be gained by society from an authoritative and maintained geospatial information base.

Hopefully this paper and the accompanying user case studies can help to demonstrate to all countries and all governments that location matters; that geospatial information is an essential building block of a country and that investment in such information is worthwhile and will generate returns beyond the investment made in it.

Whilst inevitably different Member States may face different challenges at different times, I am also confident that many of us will face a significant amount of similar challenges and opportunities in the coming five to ten years; many of which I hope are identified in this paper. The UN-GGIM is, I believe, already showing itself to be a valuable forum where we can meet and discuss these challenges and opportunities and support each other, sharing the valuable experience and expertise that we all possess.

Dr Vanessa Lawrence CB
Director General and Chief Executive, Ordnance Survey
and
Co-Chair, United Nations Committee of Experts
on Global Geospatial Information Management

July 2013

Executive summary

The use of geospatial information is increasing rapidly. There is a growing recognition amongst both governments and the private sector that an understanding of location and place is a vital component of effective decision-making. Citizens with no recognised expertise in geospatial information, and who are unlikely to even be familiar with the term, are also increasingly using and interacting with geospatial information; indeed in some cases they are contributing to its collection – often in an involuntary way.

A number of important technology-driven trends are likely to have a major impact in the coming years, creating previously-unimaginable amounts of location-referenced information and questioning our very understanding of what constitutes geospatial information. These developments offer significant opportunities but also present challenges, both in terms of policy and in terms of law. Meeting these challenges and ensuring that the potential benefits can be realised by all countries will be important in ensuring that the full value of geospatial information can be maximised in the coming five to ten years.

It is recognised that different countries are at very different stages in terms of the development, sophistication and use of their geospatial information infrastructures. There is a risk, inevitably, that not all countries will be in a position to invest in and realise the full potential of geospatial information for governments, businesses and citizens. International institutions such as the United Nations have an increasingly important role in helping to minimise this risk, communicating the value and importance of investing in and developing an authoritative and maintained geospatial information base and reducing the prospect of any 'digital divide' emerging.

Ensuring that the full value of geospatial information is realised in the coming years will also rely on having the necessary training mechanisms in place. New and changing skills will be required to manage the increasing amount of geospatial information that is likely to be created and to ensure that the maximum value is secured from it.

The number of actors involved in generating, managing and providing geospatial information has increased significantly in the last ten years, and this proliferation will continue and indeed is likely to accelerate in the coming five to ten years. The private sector and the public will continue to play a significant role in providing the technologies and information required to maximise the opportunities available. They are likely to provide valuable, and in many cases unique, elements of geospatial information and the technologies and services required to maximise it, in addition to offering a growing understanding of the end-user base for geospatial information.

Governments will continue to have a key role in the provision of geospatial information and be substantial users of geospatial data; however, governments' role in geospatial information management may well change in the coming five to ten years. Nevertheless it will continue to be vital. Building bridges between organisations, collaborating with other areas of the geospatial information community and, most importantly, providing complete geospatial frameworks with trusted, authoritative and maintained geospatial information, will be crucial to ensuring that users have access to reliable and trusted geospatial information and have confidence when using it. This information is vital to inform decision-making, from long-term planning to emergency response, and to ensure that the potential benefits of a fully spatially-enabled society are realised.

As with all technology-driven sectors, the future is difficult to predict. However, this paper takes the views of a recognised group of experts from a wide range of fields related to the geospatial world, together with valuable contributions from the national mapping and cadastral authorities (NMCAs) and attempts to offer some vision of how this is likely to develop over the next five to ten years.

Based on the contributions received, trends have been broken down into broad themes covering major aspects of the geospatial world. They are as follows: trends in technology and the future direction of data creation, maintenance and management; legal and policy developments; skills requirements and training mechanisms; the role of the private and non-governmental sectors; and the future role of governments in geospatial data provision and management.

1 Trends in technology and the future direction of data creation, maintenance and management

1.1 'Everything happens somewhere' – the new wave of data creation

1.1.1 We are witnessing an exponential growth in both the number of data capture methods and, perhaps more significantly, in the amount of data being generated and captured. Geography has long been 'mobile'; indeed, one of the most significant trends of the last five to ten years has been the number of devices in use that have Global Navigation Satellite System (GNSS) functionality and an Internet connection and that, as a result, both use and create location information.

1.1.2 This trend will continue over the next five to ten years – we can envisage a scenario in which many objects will be, in some sense, a geospatial beacon; referencing to or generating location information. The proliferation of low-cost, low-tech, network-enabled sensors – be it in mobile phones, computers, energy meters or any other everyday device – will mean that previously unimaginable amounts of data will be created.

1.1.3 Data creation will be both active but also increasingly passive. Users of social media such as Twitter® and Facebook® are likely to generate vast amounts of spatially-related information, without ever being particularly conscious of the fact they are doing so, as detailed information is collected as a by-product of everyday activities. Tweeting from a place where you have gathered with friends or posting a picture on Facebook from your phone may not be a conscious effort to create or provide geospatial information but this is still, in essence, what is taking place.

1.1.4 New layers of data will increasingly be generated as a result of these activities, leading to what can be described as 'modelled geospatial actor data'[1], whereby information generated by individuals using websites and social media is overlaid on top of spatially-accurate geospatial information. The information generated through use of social media and the use of everyday devices will further enable the detection of patterns and the prediction of behaviour. This is not a new trend – many online companies and resources already analyse and interpret information in this way and the proliferation of location-based services (LBS) has been one of the major trends of the last five to ten years – but the extent to which this takes place is likely to continue to grow over the next five to ten years as yet more and more data is generated through such channels.

1.1.5 There is a diverse range of existing demonstrable benefits that suggest this trend will continue – from life-critical information in the aftermath of a disaster to lifestyle information such as finding a restaurant. In the coming five to ten years, more are likely to emerge, from lowering insurance premiums, to being able to see on a mobile device the nearest source of fresh water or the owner of a parcel of land. Individuals will continue to 'opt-in' to a lifestyle that is enhanced by an ever-growing number of geospatial beacons and sensors, in turn providing 'analytical superfood'[2] that can and will, if used effectively and appropriately, improve people's lives across the globe.

1.1.6 Nevertheless, the significant growth in deployment of geospatially-enabled devices and the increasing use of geospatial information in everyday life will bring with it a need for stronger policy and legal frameworks to manage privacy concerns and protect the interests of those who are providing this data. The way the above information is used, and the privacy concerns that may manifest themselves as a consequence of this, will be discussed in greater detail later in this paper.

1.2 Managing a world of data

1.2.1 The creation of such huge amounts of data will bring with it a requirement for the ability to make sense of this data, which, in and of itself, will drive demand for geospatial information as people look to location to help to make sense of and identify patterns within the sea of data that is being created.

1 This phrase was used by one of the contributors in their submission to the UN-GGIM Secretariat on *Future trends in geospatial information management*
2 This phrase was used by a contributor in their submission to the UN-GGIM Secretariat on *Future trends in geospatial information management*

1.2.2 We are currently suffering from a data overload; our ability to create data is, in general, ahead of our ability to use that data effectively to solve problems. There is no doubt that there is a huge amount of value to be gained from the information contained within all this data that is being generated. However, the growth in the amount of data brings with it an ever-growing requirement to be able to find the *right* information at the *right* time.

1.2.3 The huge quantities of data now generated, and the increasing amounts of data that are likely to be created, will bring a requirement for enhanced data management systems. With approximately 2.5 quintillion bytes of data created every day[3], a significant amount of which will have some kind of location reference, the challenges of data management and data integration will be significant.

1.2.4 The need to address this problem will drive one of the main trends in the next five to ten years – an increasing use of and reliance on '*big data*' technologies – technologies that enable the analysis of vast quantities of information within useable and practical timeframes. Currently, many of the *big data* solutions being generated are custom-crafted. Technology is already available to deal with *big data*, but the reliance on this kind of technology will grow in the next five to ten years.

1.2.5 The demand for real-time information and real-time modelling seems certain to increase in the coming years and presents major challenges. Nevertheless, techniques such as graphical processing units (GPUs), NoSQL and powerful in-memory SQL databases are becoming available, which will meet the demand for integrated spatial and non-spatial analytics in orders of magnitude less elapsed time.

1.2.6 Looking forward over the next five to ten years, new massively-scalable, distributed systems for processing unstructured and semi-structured data will emerge, and will become widely accepted and relied upon in the management and interpretation of geospatial information. Use of these technologies will facilitate the effective use of the reams of raw data being generated by the increasing number of geospatial sensors, eliminating 'the white noise of excessive data'[4] enabling us to locate the right information at the right time, thus driving effective and well-informed decision-making.

Source: cgartist/Shutterstock.com

1.2.7 Whilst the proliferation of devices generating such information may reach most corners of the globe, the funds necessary to collate and manage such data in an effective way may not be so well distributed. There is, therefore, a risk of a digital geospatial divide emerging. Technologies, and the financial resourcing required to access such technologies, are not available equally across the globe. Although many developing nations have leapfrogged in areas such as mobile communications, the lack of fibre-optics and core processing power may inhibit some from taking advantage of the opportunities offered by some of these technologies.

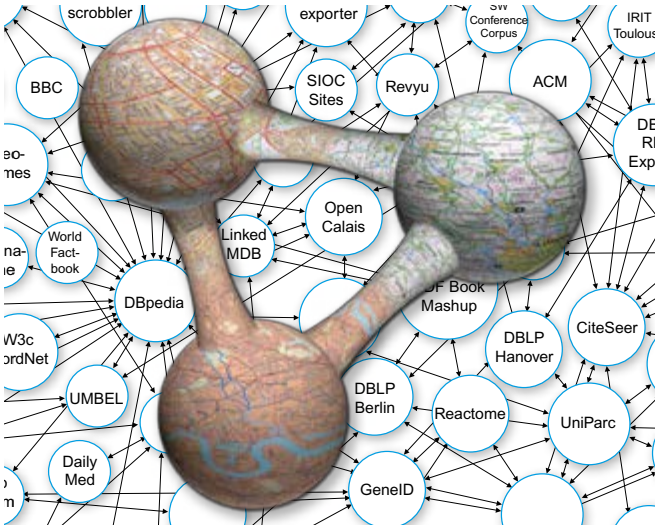
1.2.8 Whilst some of the technological developments highlighted have the potential to reduce costs and increase efficiencies, there is a danger that a lack of funds prevents some countries from benefitting from these opportunities, thus creating or increasing the division between those who are able to make use of such resources and those who are not. Furthermore, in countries where securing funding to develop a base geospatial infrastructure is still the primary challenge, prioritising the collection of basic geospatial data is likely to remain the primary focus. The potential trend towards greater outsourcing and offshoring of processing and analysis, as well as technological developments such as greater use of the cloud – discussed in greater detail below – could go some way to mitigate this risk.

3 http://www-01.ibm.com/software/data/bigdata/
4 This phrase was used in one of the submissions to the UN-GGIM Secretariat on *Future trends in geospatial information management*

1.3 Linked data and the 'Internet of Things'

1.3.1 Given the vast amount of data being generated, particularly through use of the Web, and the need to make sense of this data, the ability to link information on the Web will be increasingly important in the coming years. To this end, we may see data increasingly being distributed as 'linked data' in the coming five to ten years. Linked data offers the opportunity to connect data to other pieces of data on the Web, contextualising and adding value to the information that already exists.

1.3.2 Semantic technologies will play an important role when it comes to publishing and making sense of this data, offering the opportunity to create rich machine-processable descriptions of data. This will enable knowledge sharing and re-use in addition to data sharing and re-use. It is expected that data will really start to show its true value when it is combined with other data sources. Location will provide a key underpinning framework to the Web of linked data, providing an essential information hub that brings many datasets together.



Source: Ordnance Survey/linkeddata.org

1.3.3 The network of tomorrow, built on an increasing number of sensors and thus increasing data volumes, will produce a hyper-connected environment or '*Internet of Things*', with estimates of over 50 billion things connected by 2020. The 'omnipresence' of geospatial information[5] in our lives, whereby almost all pieces of data have some form of location reference, will continue, with location providing a vital link between the sensors that will generate the *Internet of Things* and the Uniform Resource Identifier (URI) assigned to a thing or object within that connected world of things. In order to maximise usability this will drive the demand for informative standardised metadata as part of geospatial data.

1.3.4 We are increasingly likely to see geospatial information needed to assist the evolution of this connected ecosystem over the next five to ten years. The emergence and use of precise location information in this way offers great opportunities and will see it form a core part of information technology infrastructure. Nevertheless, use in this way will also present geospatial management challenges over the coming years.

1.4 Cloud computing

1.4.1 Managing, hosting and serving the vast amounts of data witnessed today, and likely to be seen over the coming years, requires significant investment in infrastructure and software. These costs are not always viable for those managing geospatial information. Use of the 'cloud', however, either Private – hosted on your premises, or Public – hosted elsewhere in a shared manner, provides a means to host and serve significant volumes of data without the accompanying investment costs required to own the technologies necessary to do so independently.

Source: SCOTTCHAN/Shutterstock.com

5 This phrase was used in one of the submissions to the UN-GGIM Secretariat on *Future trends in geospatial information management*

1.4.2 To meet this demand in the coming five to ten years use of, and reliance on, the cloud by those in the geospatial community will continue to increase significantly, particularly as volumes of data and demand for real-time, real-world data grows. Over the next five to ten years, infrastructure as a service (IaaS), platform as a service (PaaS), software as a service (SaaS) and data as a service (DaaS) all offer technological opportunities to those in the geospatial management world to enable us to meet the requirements of users better.

1.4.3 As mentioned previously, users will want to receive the right information at the right time. In order to achieve this, and in light of the increase in the volumes of data available, the geospatial computation required to do this will increasingly be non-human in nature, with accurate results generated automatically and provided directly to end-users.

1.4.4 As well as expecting to receive the right information at the right time, users will increasingly expect to receive the desired information on their device of choice. Use of the cloud will also facilitate this and is likely to become the standard over the next five to ten years, making geoinformation resources accessible to anyone, anywhere, anytime.

1.5 Open-source

1.5.1 Open-source solutions are likely to grow significantly as a viable alternative to proprietary suppliers. The open source geospatial community already has a well-established 'infrastructure' through the Open Source Geospatial Foundation (OSGeo) and a vibrant and relatively tight-knit community who champion its potential. The drive by governments towards greater acceptance of open-source solutions may remove many of the perceived barriers to wider adoption, as the value will grow as more users adopt these solutions and feed back improvements. A number of NMCAs – those government bodies responsible for the provision of authoritative geospatial information within a country – have already adopted open-source solutions into some of their services.

1.5.2 Three trends seem likely to drive this adoption. Firstly, in countries where resources are particularly scarce, the availability of free-to-use software clearly has upfront economic benefits. Secondly, the ability to share and modify software relatively easily also helps to facilitate knowledge exchange and the building of common user communities. In countries where the development of geospatial infrastructures is in its early stages, the availability of open-source solutions offers a genuine alternative to previous operating methods. Finally, the next generation of geospatial graduates will have been exposed to open source during their academic studies and potentially in their personal lives, and hence will be technically as well as culturally attuned to using it. Significant education will be required on the total cost of ownership of open-source technology, recognising that – even when the core software may be free – open source technology development and maintenance costs can attract labour costs.

1.6 Open standards

1.6.1 There are a number of organisations, at both national and international levels, responsible for the development of standards for use in acquiring, implementing, maintaining and using geospatial data. At an international level these are led by the Open Geospatial Consortium (OGC®) and the International Organization for Standardization (ISO®) in partnership with many broader technology standards organisations to ensure interoperability. The standards developed by these organisations will continue to enable interoperability throughout the industry and improve access to data across the world.

1.6.2 Development of additional standards and complementary tools to best use these standards will be required to keep pace with changing technologies and practices. The growing compliance with OGIS Geospatial and GeoSPARQL standards, together with the use of standard SQL, will make it possible to develop interoperable technologies for maintenance of geospatial data, as well as complex semantic analysis of both spatial and non-spatial data.

1.7 Trends in 'professional' data creation and maintenance

1.7.1 A number of primarily technology-driven trends in the professional world of geospatial data

collection will continue to improve both the quality of data collected and the efficiency with which it is collected.

1.7.2 The trend of moving from two dimensional (2D) mapping through to three dimensional (3D) and on to four dimensional (4D) visualisations is both user- and technology-driven and will accelerate in the next five years. Users are likely to expect ever more complex and realistic 3D models, particularly of cities, to enable effective planning and management and to optimise resources. Increasingly, 3D will be an intrinsic part of the core geospatial data, rather than a distinctive add-on as it is now. Much of the influence for the developments in these areas comes from outside of the traditional geospatial sphere, with 3D software and developments in the gaming industry offering insights and possibilities that 2D 'maps' cannot provide.

1.7.3 There also will be an integration of 'external' 3D information with business information management systems that will use 'internal' and below-ground 3D to create integrated walk-through models. Development of both the technologies and the data models to exploit this potential will continue in the coming decade.

1.7.4 The use of the fourth dimension is also likely to increase over the coming five to ten years in geographic information systems (GIS), with GIS companies increasingly providing 'time' functionality as an additional dimension alongside conventional x, y and z coordinates. This is likely to provide the ability to view the past, in order to understand change that has already taken place, but will also enable predictive modelling of future trends. Effectively managing real-time information, but also effectively archiving time-referenced data, will become an increasingly important technique in the management of data over the coming years.

1.7.5 The quality of aerial imagery will continue to increase in the next five to ten years. However, with the existing availability of very high-resolution imagery at centimetre levels in many areas of the globe, focus in this area is likely to be more on the speed with which the imagery can be provided to users and what analysis can be undertaken with those images.

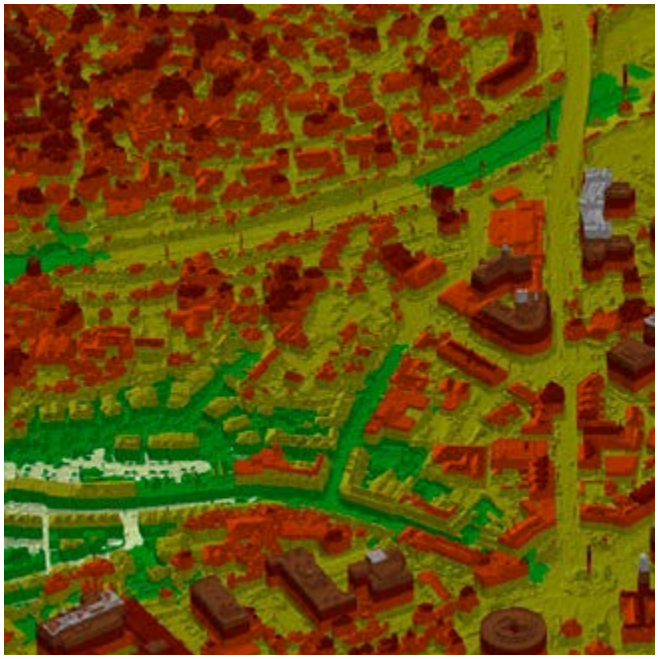
1.7.6 The proliferation of low-cost launch systems and affordable satellites, with increasingly-powerful multi-band sensors, will both lower cost and greatly increase the volume of high quality imagery. As well as providing greater coverage, increased frequency of data collection will allow more dynamic analysis of remote areas, for issues such as canopy loss and land use.

1.7.7 Unmanned aerial vehicles (UAVs) in the civilian sector are likely to be used increasingly as an additional method of data capture and will complement satellite remote sensing and aerial imagery. Data from these devices will be useful to supplement both everyday data collection and in emergency response situations, where near-real-time information is of particular value to those on the ground.

1.7.8 The ability of UAVs to access areas that would otherwise be inaccessible offers the chance to enhance the information available to decision-makers on the ground, providing a more comprehensive operating picture to those involved in an emergency response. The use of this kind of near-real-time data capture tool could be invaluable in an incident such as a fire on an industrial complex or when crowd control is required following an event, where additional information further increases effective command and control, and analysis.

1.7.9 The accuracy of optical imaging sensors will continue to improve significantly over the coming years, bringing with it the ability to identify features on the ground better. Spatial, spectral and radiometric resolutions will improve drastically, enabling better identification of features. In this regard, stereoscopic

high-resolution hyper-spectral imagery could also become more widely available.



1.7.10 Mobile mapping systems will be upgraded for capturing and processing both street-level visual information, points of interest (POI) and attribute data in more detail. We are likely to see further use of 3D LiDAR and optical sensors which will facilitate the generation of more comprehensive and complete datasets.

1.8 Positioning ourselves in the next five to ten years

1.8.1 GNSS technology is now mainstream, but the major step change across the spectrum of user equipment is likely to occur within five years, with the launch of both new and next-generation GNSS. By 2015, there will be over 100 GNSS satellites in orbit. This will enable faster data collection in very challenging environments, with higher accuracy and greater integrity. User equipment will see greater integration with other technologies to produce a more complete and ubiquitous positioning solution.

1.8.2 Improvements in satellite gravimetry missions are starting to challenge the way that vertical reference systems are defined. Some nations are already taking the step to move away from traditional schemes defined using large-scale terrestrial observations and base the national vertical reference system on purely gravimetric geoids instead.

Source: eteimaging/Shutterstock.com

1.8.3 Reference frames are becoming more accurately defined with each iteration as technology and techniques improve. This is further aided by long-term GNSS and other space observation, for example, satellite laser ranging (SLR), very long baseline interferometry (VLBI) and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) datasets. National reference frames are increasingly becoming more aligned to globally-standardised geodetic reference frameworks – an example being the International Terrestrial Reference Frame (ITRF) – as well as GNSS reference frames. This fosters interoperability and unification of geospatial information datasets across the globe and will be of increasing importance in the coming five to ten years.

1.8.4 Indoor positioning is also an emerging frontier, but one that still presents major challenges. Whilst a number of technologies exist that can be used to improve data in this area, including ultra-wideband, accelerometers and radio frequency identification (RFID), no single source is able, as of yet, to provide the widespread coverage that may be expected in years to come. Whilst solutions are likely to be forthcoming in time, it is more likely to be closer to ten years than five years when we will see the greater availability and widespread use of indoor geospatial information. It is expected that some of these new technologies will lead to new industry standards, conformant with current standards development processes.

2 Legal and policy developments

2.1 Funding in a changing world

2.1.1 Governments and governmental bodies involved in the collection and management of geospatial information have traditionally been reliant on public money to fund their activities. Whilst variations to the way such funding is provided have emerged in the last ten to twenty years, the majority of countries still are reliant, in one way or another, on funding from public appropriations. Convincing governments of the value of geospatial information, the benefits it brings and the need for sustainable funding to maintain the accuracy of the data will therefore continue to be one of the most vital challenges for NMCAs.

2.1.2 The availability of some information free at the point of use inevitably leads to questions about the cost at the point of use for other sources of information. Content is, in general, not cost-free, either to collect or to manage, yet the increasing availability of geospatial information free at the point of use increases the challenge of articulating the costs of data collection, management and maintenance and securing the necessary funding to ensure this happens. This challenge is likely to remain for NMCAs, regardless of the funding model under which they operate – for example, whether they are fully funded by public appropriations, whether they receive funding by charging users for a licence to use the data or whether under any other funding model.

2.1.3 In general, there are significant costs involved with collecting, managing and maintaining geospatial information, even when that data is then made available free of charge for others to use. Private-sector companies may choose to provide certain information free at the point of use, because the value they get from other information overlaid on that data, and the revenues they can generate from other sources linked to that information, make it economically worthwhile, especially in areas of high economic activity. Conventional volunteered geographic information (VGI) – that is, geographic information actively and voluntarily collected by members of the public (the best known example being OpenStreetMap) – may be provided free at the point of use. Such information is reliant on the significant amount of time and energy currently being spent by a relatively small number of individuals collecting and managing that information or incorporating information from other sources. The sustainability of its supply and update is yet to be proved over an extended period of time. Governments may choose to provide information to their citizens free of charge either out of principle, because they believe doing so will improve public life, or because they believe doing so will stimulate economic growth. Nevertheless, whilst new technologies may reduce associated costs, there are, and will continue to be, costs involved in the creation, management and maintenance of this content.

2.1.4 Most government providers of geospatial information today typically rely on funding, either from the taxpayer or from mixed sources of income. The funding of NMCAs to perform their task remains a controversial topic in some countries and will evolve over this period. In terms of the provision of geospatial information, one of the major challenges of the next five to ten years for governments will be demonstrating the value and securing the necessary funding to ensure that this information will be maintained. In a world where information, including geospatial information, can easily be accessed free of charge, this will be challenging.

2.1.5 In countries with less-developed mapping resources and spatial data infrastructures (SDIs), the vital role of high-quality data to support economic and social development will become better understood. Relatively higher proportions of national capital are likely to be spent on capture and maintenance programmes, as awareness and understanding of the value of having accurate and maintained geospatial information to other policy priorities increases.

2.1.6 Currently, balancing the costs needed to obtain the equipment and skilled resources necessary

to collect and maintain geospatial information against other priorities, particularly in those countries where basic health, sanitation and access to food are dominant policy issues, means that it may be particularly hard to convince governments of the value of investing in geospatial information. However, as more case studies emerge demonstrating the value of geospatial information in addressing such important issues, understanding of the importance of such information to facilitate a nation's development will grow. As this understanding grows, it is likely that more governments will start to view accurate geospatial information as an essential building block of a country and will decide to invest in such information, seeing it as both a necessary and worthwhile allocation of resources.

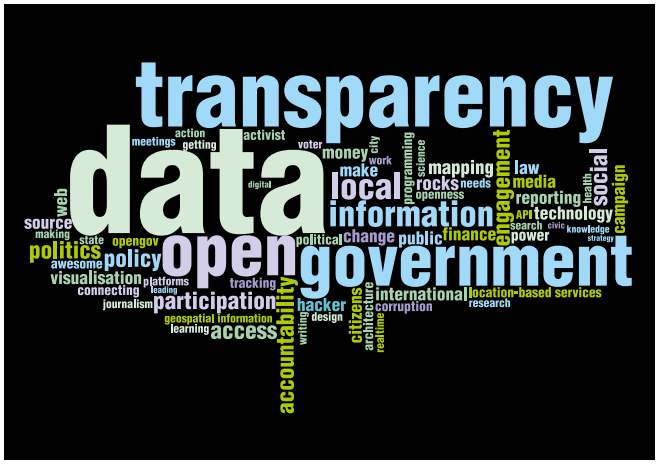
2.1.7 Because of the fundamental nature of the data, funding will come from central government sources, supported in some cases by additional funding from global or national development funds. This is likely to be the predominant model in certain regions, particularly those where the process of establishing reliable geospatial information bases is in its early stages.

2.1.8 In many countries the difficult economic climate has already seen reductions in central government funding. The accompanying increasing pressure and expectation for free availability of core datasets will also provide a challenging environment. Undoubtedly this will cause some of the NMCAs affected, and their governments, to look closely at the sustainability of their business models. The technological developments outlined earlier in this paper are likely to reduce some of the data capture and maintenance costs, which may therefore go some way to easing funding issues. Nevertheless, there will continue to be a need for initial investments. Other sources of income may be sought to supplement public appropriations – for example, fees for use of the infrastructure, charges to those utility providers that make greatest use of the data or, in some countries, development aid.

2.1.9 As such, one of the major challenges of the next five to ten years will be finding the funding and business models required to maintain accurate and quality-assured geospatial information, whilst growing the user community for high-quality, accurate and maintained geospatial information.

2.2 Open data

1.1.1 The drive for access to government-generated geospatial information free at the point of use is likely to continue, albeit in an uneven way, in the coming years. A number of trends will drive this. The most significant force behind this is simply the widespread availability of other mapping information free at the point of use. The Internet has shaken the foundations of a huge number of content-based industries. The creative industries, particularly music and movie, have been arguably the highest profile of the industries affected by this trend. However, geospatial content providers, particularly NMCAs, are not immune from this trend.



2.2.2 One of the greatest policy challenges over the coming years in the global geospatial community will be how countries can meet the increasing demand for free content that the Internet and the presence of organisations, such as Google® and Microsoft®/Bing®, has brought. This may particularly affect those who still require significant funding to improve the quality of core geospatial information in their country. However, in the next five years the drive for open data is likely to face two main counter-pressures; funding, especially where making the data open carries a cost and/or where it is currently charged for; and security/privacy issues.

2.2.3 Key to securing this funding is likely to be advocacy and education on the value that can be gained from use of high-quality, authoritative and trusted geospatial information and the

value it can bring, both economic and social, to effective decision-making.

2.2.4 Collecting and managing geospatial information is not without cost. As users increasingly come to rely on the accuracy and detail of geospatial information and base their decisions on it, any subsequent degradation in quality will be noticed, so the need to continually and reliably fund investments must be communicated and realised. If funding is not forthcoming in a sustainable model that results in data being maintained and made available – either free of charge or for a fee – then the implications and costs to society must be duly recognised and considered.

2.2.5 Privacy issues are also considered in greater detail below; however, as data becomes more accurate and timely, there will be a desire in some countries to control access, or at least know who is accessing the data. The development of online access controls will evolve to enable this, but given the ease with which such controls can often be circumvented, in those countries where such concerns exist, questions will potentially arise about who is accessing the information.

2.3 Licensing, pricing and data 'ownership'

2.3.1 Existing pricing and licensing models for those who charge for access to geospatial information are often seen as too complex, costly and rigid for many users. Indeed, part of the motivation for the development of VGI was to provide data that could be used relatively free of licensing restrictions. Nevertheless, for those who are required to license data in order to fund collection and management activities, the expectation of easy access to geospatial information for little or no cost or restriction will continue to challenge NMCAs.

2.3.2 The ongoing drive for cheaper access to information and the increasing richness of the information available means that there may be increasing pressure to monitor and license information at the feature level rather than at local, regional or national database level, bringing with it new challenges.

2.3.3 Data ownership issues will evolve in challenging ways in the coming years. At present, intellectual property issues around geospatial data are 'relatively' simple, as the role of data creator, processor and publisher are generally definable due to the discrete nature of these processes. The growth in the amount of data, the number of actors in the data creation processes and the interconnectivity of these parties can pose greater challenges regarding knowledge of data ownership, though some of this could be addressed through effective use of metadata and adherence to standards.

2.3.4 Nevertheless, the licensing of data in an online world is proving very challenging. The entertainment industry has sought to protect its rights over content with mixed results. The issues in the geospatial world may well follow those in the entertainment industry, with many users assuming that all data is freely available and can be shared widely. There are attempts to provide simple machine-readable licences for valuable content – sometimes referred to as digital rights management – but these have not, as yet, resolved the problem. Data piracy will grow significantly over this period to the extent that, combined with open data, *consumer* use of geospatial data may become effectively free at the point of use in virtually all circumstances. To counter this, it will be important to continue to communicate effectively that licensing, where used, is generally in place in order to ensure the quality of information can be maintained.

2.3.5 Again, however, the lack of a multi-national legal or policy framework in place to deal with these issues will need to be considered, as data acquired in one country will likely be processed in a second country by a corporate organisation domiciled in a third country, while the data itself will be held 'in the cloud' – hence determining the legal framework, liabilities and warranties and so on will be unclear without some attempt at a global accord. These issues, it should be made clear, are not unique to geospatial data.

2.4 Privacy

2.4.1 The rapid growth of mobile technology and social media has transformed attitudes towards privacy in many societies. Many people have a desire *not* to be private, particularly in the online space, and are comfortable with broadcasting information about themselves and their activities. The rise of the '*Internet of Things*',

where all devices that we use can be constantly online, will make most individuals visible most of the time – in fact it is likely to become increasingly difficult to opt out and hide oneself from other individuals or agencies.

2.4.2 This will challenge the individual's right to privacy. Given the amount of devices emitting and recording information that will exist, even if individuals choose not to use many aspects of modern technology, they will be visible as they move through the landscape. Aside from the moral aspects of a 'surveillance society', individuals will be the focus of targeted messaging, much of which will be driven by combining personal and locational data. Consequently, consumer protection and marketing laws and policies will need to evolve to enable the citizen to enjoy appropriate protections.

2.4.3 The ability of the state to track and monitor individuals is already a subject of controversy – this is witnessed by the debates on the use of closed-circuit television (CCTV) and the monitoring of voice and text messages. As all devices become location-enabled broadcasters available 24 hours per day, 7 days per week, the state will have the capability to hugely enhance its ability to observe the location of these devices. While bringing huge potential benefits in terms of national security and disaster management, national laws and oversight bodies will have to evolve to ensure the data is maintained and used appropriately and that personal privacy is not sacrificed.

2.4.4 Cybersecurity is a growing threat to privacy, where malevolent 'hackers' are not respecting privacy policies, and are stealing/manipulating/destroying private information. Such activity is further enabled by the availability of location information about individuals and organizations. Powerful encryption technologies and other security software/hardware protection will, therefore, increase in importance.

2.4.5 The issues described above are exacerbated when the citizen moves across the globe. In most cases the information they broadcast and which is acquired about them does not change, but the rights over the use of that data and the legal protections may change radically. There is likely to be a clear and growing demand over the next ten years that the lack of a global framework be addressed by multi-national bodies, such as the UN.

Source: jannoon028/Shutterstock.com

2.5 Standards and policies

2.5.1 The geospatial community is, relatively speaking, an exemplar industry in the development and maintenance of open standards. Over the past two decades this has been led and coordinated by OGC in partnership with many organisations. These partnerships often result in OGC standards being adopted by other standards organisations such as the ISO. Open and common technology standards and languages are now well established and adoption is increasing in both policy and practice throughout the industry, including the government, commercial, academic and research sectors.

2.5.2 New technology and development techniques drive the continued need for open standards. However, the majority of experts engaged with the standards development process have historically come from North America and Europe, with an emerging membership in Asia and the Middle East. If truly global representation in standards development is to be achieved, we will see a requirement in coming years for sponsorship in the adoption of open standards in a more formal way. In regions where uptake and adherence to such standards is in relatively early stages, there will be increasing focus on engaging with organisations such as OGC in the coming years.

2.5.3 A number of supranational organisations, including units of the UN, have supported the development and uptake of such principles. The need to share data will drive further adoption of these standards, although there is a clear risk that the more formal government-sponsored approach may stifle the creativity and rapid development approach of the more volunteered-based models. Demand may increase therefore over the next five years to further bring together the best of both models under the sponsorship of a body such as the UN.

2.6 Liability and the issue of data assurance

2.6.1 The issue of liability for the quality and accuracy of data is likely to grow in prominence over this period. Historically, NMCAs and other providers of geospatial information have largely been able to avoid this issue, publishing disclaimers that strive to absolve them from any litigation risk. The wording of one government's open licence offers a typical example. 'The Information is licensed 'as is' and the Information Provider excludes all representations, warranties, obligations and liabilities in relation to the Information to the maximum extent permitted by law. The Information Provider is not liable for any errors or omissions in the Information and shall not be liable for any loss, injury or damage of any kind caused by its use.'[6]

2.6.2 However, there have been situations in the wider government data environment where attempts have been made to seek legal redress, where the data can be proven to have been inaccurate and hence the user has suffered a loss. It is hard to predict the impact if such a trend were to grow, but it is an issue that all data providers will have to consider carefully and may also impact on wider law-making within government.

2.6.3 The response to this increasing risk over the next few years seems likely to take one of two forms: a continued acceptance of the risk, with government legislation to minimise the litigation risk; or the development of a 'warranted' data model, where at least some attributes of data will contain a form of guarantee. This will inevitably command a higher price to cover the risk, but may genuinely be seen as a value-add by professional users using the data to make high-impact decisions.

2.6.4 The adoption of *big data* solutions may be dependent in part on the provision of warranties and liabilities, as it will not be feasible for users to check each piece of data.

2.7 Disparities between legal and policy frameworks

2.7.1 Legal and policy regimes differ significantly from country to country and will continue to do so in the coming years; indeed, this fact may in itself create one of the most significant trends over the coming five to ten years.

2.7.2 There is a major possibility that significant disparities will emerge in the next ten years between countries where legal and policy frameworks have developed in line with technological changes and whose governments have developed frameworks that enable the growth of location or spatially-enabled societies, and those countries where such frameworks have not developed.

2.7.3 Technological developments, as opposed to legal and policy frameworks, are, relatively speaking, without boundary. Technological developments may be leading us towards a spatially-enabled society and a society that feels confident in using and creating, both actively and passively, geospatial information and location-enabled services. However, the legal and policy frameworks required to facilitate the development of such a society are not developing in a consistent way and are tending to lag behind technological developments.

2.7.4 It is likely that, in the next five years, governments will have a greater understanding and recognition of the value of geospatial information as a reference framework for policy development and analysis, as an essential information base and as a growth area for the private sector. However, in many areas of the world, a consistent and transparent legal and policy framework in areas such as privacy, national security, liability and intellectual property, may not have developed.

2.7.5 There is a counter-argument to suggest that in areas where no such frameworks are in place, it may provide the space for appropriate framework development free of possible constraints from any over-zealous legislation

6 This is an extract of the UK Government's Open Government Licence, which can be viewed at **http://www.nationalarchives.gov.uk/doc/open-government-licence/**

in this area. However, the greater risk is that technological and business applications that would be of great value to society will not be available in certain countries due to a lack of clarity or a lack altogether of the necessary legal and policy frameworks.

2.7.6 Ensuring that this divide does not occur, or at least ensuring that the divide is not too pronounced, may represent one of the major challenges within the legal and policy environment in the coming years.

3 Skills requirements and training mechanisms

3.1 Maximising the value of geospatial information

3.1.1 In the next five to ten years an understanding of what skills are required and what training is needed will be an important component of ensuring the value of geospatial information is maximised. Early determination of, and action on these issues is vital, as the time needed to develop an appropriate training capability and then train the individuals is at least five years. The demand is highly likely to exceed the pace of development. This is being taken seriously and, in some quarters, is evidenced by recent pronouncements from the governments of some of the largest and fastest-growing economies of the world that have made substantial investment commitments in geospatial information in the last 18 months.

3.1.2 In certain regions, there is a lack of qualified personnel necessary to effectively manage and utilise geospatial information. Ensuring that programmes are put in place as quickly as possible to develop a suitable body of such professionals and to support retention of those skills within the country or region is most important.

3.1.3 Many of the most critical issues where geospatial data can assist are found in less-developed nations. There will be a potential major role for non-governmental organisations (NGOs) and development agencies in ensuring that the skill base necessary to ensure all countries reap the benefits of a spatially-enabled society is developed globally. Without this there is a risk of a 'brain-drain' as the limited pool of talented individuals could be drawn to other government positions or private-sector opportunities in higher-wealth economies.

3.2 Extracting value from a world of data

3.2.1 Although the use and availability of geospatial information will be increasingly democratic, for reasons identified elsewhere in the paper, the proliferation of data, especially unstructured data, will place a premium on highly-skilled data modellers. Even among the leading database companies and most advanced NMCAs, the number of experts who truly understand the interrelationships between data models and data flow is generally quite low for each organisation.

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3.2.2 Data models will need to continuously evolve to answer the range of questions and manage the rising volume of data. Hence the training of a cadre of data experts, who understand the additional complexities of geospatial, non-geospatial data and time-based data, must be a priority if the potential benefits are to be realised. In the future this expertise is likely to reside in all sectors and hence it will be in the interest of all to sponsor appropriate education. As today, much of this will be in collaboration with the academic sector, but increasingly focused in the areas of mathematics and computer science, rather than in the more traditional geographical information systems (GIS) field.

3.2.3 There will of course continue to be a role for traditional GIS skills, as data outputs will still need interpretation to create information for decision-makers. However, these experts will need to become more comfortable with interpreting fuzzy and unstructured data and will also need to find more effective channels for communicating their results.

3.2.4 There is still a tendency in many organisations to see GIS as a backroom function with little connection to policy or action; hence, as well as continuous development of technical skills, there is a need to focus on equipping geospatial experts with softer skills in areas such as communication, presentation and influencing.

3.2.5 As mentioned previously, the development of robust open-source technologies will also gain further momentum over this period, and will increasingly sit alongside proprietary solutions, as has happened elsewhere in the software industry. Developers will need to be comfortable in both environments – the option to specialise in one 'language' will no longer be sufficient. This type of learning would be particularly enabled through building global networked communities to share experience and ideas, reducing the reliance on formal structures.

3.3 The importance of visualisation skills

3.3.1 The role of cartography and data presentation has been understated over the past decade, as the industry has focused on data. However, cartography will remain the language through which the data explosion will be spatially interpreted and hence new methodologies need researching and developing. The fact that increasing amounts of geospatial information will be consumed and interpreted through mobile devices also necessitates an improvement in the quality of cartography for mobile devices.

3.3.2 The growth in 3D and especially 4D data capture will set major new challenges for those required to express the resultant information in any meaningful manner. Today tools exist to visualise 3D and time-based data, but the tendency has been to focus on look and feel rather than informing decision-makers. There will be a need for data interpreters from a more design-orientated background, rather than solely from the traditional cartographic skills, and a need for those involved in visualising geospatial information that will be displayed on multiple devices to harness skills from other related disciplines.

3.4 Formal mechanisms for the development of skills

3.4.1 The development of these skill bases will be delivered through a wide range of professional, academic and in-business approaches, as recognition grows of the need for a managed process of skills development and capacity-building.

3.4.2 The skills requirements noted above will have a major impact on NMCAs. The adoption of data-driven rather than cartographically-driven geospatial content will see a fundamental shift in the skills base and costs. Leading NMCAs are already finding that their data management staff are more costly to employ than those of their cartographic and data collection units. Hence, much of the reskilling will need to happen with capable in-house staff. For those countries with less-developed NMCAs, there is an opportunity to educate and seek the skill sets needed to accomplish the goals and objectives of the geospatial organisation.

3.4.3 The content of academic studies of geographic information (GI) will also need to evolve to attract and develop students with the necessary skills. Courses will need to be increasingly interdisciplinary, drawing on methods and best practice from traditional GI, computer science, design and the related social sciences.

3.5 Education and advocacy

3.5.1 As well as the development of core skills, there will be a need to educate policy- and decision-makers, planners and delivery agents in geospatial data, potentially to the very highest levels of governments and NGOs, to enable them to fully understand the potential of geospatial data in solving key issues. This will assist them in formulating questions and also in interpreting the data. This familiarity has been enhanced by the use of simple geospatial information in consumer applications, but needs to move beyond 'points and colours on a map'. These users will need training in and access to simple and intuitive tools that allow them to manipulate the data, rather than working through back-office specialists to obtain their solutions.

3.6 Investing in research and development (R&D)

3.6.1 Investment in research and development (R&D), in all sectors, will continue to be vital to both developing the skills required in the coming years but also in order to ensure the potential benefits of emerging trends are realised.

3.6.2 Current research areas reflect many of the current and future trends that have been identified for the industry, including the more effective and automatic processing of sensor data, the development of location-based applications and the integration of high volumes of unstructured data. Investing in early-stage prototyping, testing and evaluating in emerging areas of interest will mean both that the benefits of such developments will be realised at the earliest opportunity and that such developments will be understood within a wide range of organisations.

3.6.3 Building a stronger partnership with the standards community will be crucial to ensuring that research results can be rapidly mobilised to users and organisations and deployed in enterprise environments.

4 The role of the private and non-governmental sectors

4.1 Making mapping accessible to the masses

4.1.1 The reduction in barriers to entry, the growth of Web and mobile mapping and the enthusiasm for crowdsourced geospatial data have massively increased the role of the private sector and the volunteer community over the last decade. The fact that Google and Bing Maps are global brands highlights that it is the private sector that has made digital mapping accessible to the masses.

4.1.2 Alongside the massive explosion in the use of geospatial information, VGI groups such as OpenStreetMap have gone some way towards popularising, albeit within a relatively niche community, the collection of geospatial data.

4.1.3 User-generated content has already gained widespread acceptance in many aspects of our lives as a source of data. Wikipedia® perhaps offers the most well-known example, although issues around trust, reliability and – more recently evident – sustainable funding, remain. This use of user-generated content is likely to continue, as mentioned elsewhere, with both active and passive data creators providing a wealth of location data that would not be economically viable or in some cases even possible for traditional data collectors to have recorded.

4.1.4 The increasing need for cross-border information has highlighted the limitations of an approach based on national borders. Initiatives bringing together the NMCAs of regions have sought to address these issues but in most cases private sector suppliers, whether of satellite imagery or mapping, have perhaps inevitably transcended borders far better than government sources of information and have therefore been called upon to provide data where issues cross national boundaries. Private-sector and VGI groups are likely to continue to lead the way in this area, whilst governments, naturally constrained by their national borders in a way that the private sector and VGI groups are not, attempt to catch up through supranational and intergovernmental mechanisms.

4.2 The future role of the private sector

4.2.1 The private sector is likely to continue to play a vital role in providing the technologies identified earlier in this paper that will enable governments, and indeed other private-sector bodies, to produce and collect the vast quantities of data we are likely to see in the coming years, to provide the technologies to manage and make sense of this data and to find value in providing access to the skills necessary to maximise this data.

4.2.2 In the consumer sphere, and for uses where ease of access and use and a generalised location reference are the dominant requirements, the private sector, alongside the VGI community, may well continue to dominate people's everyday interactions with geospatial information. In general, however, this information is unlikely to come with the quality assurances, level of detail and maintenance regimes that are required to inform major business or public-service questions – for example, the management of energy supplies to a population, the recording of land extents, or the deployment and provision of a detailed common operating picture for emergency services. As such, demand is likely to continue for authoritative geospatial data collected, or at least provided by, a government entity.

4.2.3 Nevertheless, alongside the spread of VGI, the private sector is increasingly likely to wish to compete with government sources of information, analogous to the competition found in the telecoms and postal industries, in all areas of high economic activity. This will potentially move beyond areas where there is existing competition, such as aerial imagery and generalised data, towards large-scale detailed data.

4.2.4 However, in many cases, particularly outside the consumer sphere, distinguishing between private and public sector geospatial provision

can be artificial. While much of the provision of the data may be by private sector contractors, governments and supranational bodies often remain the largest customers and commissioning agents.

4.2.5 Cost and efficiency requirements will see NMCAs outsourcing many processes to the private sector in the coming years. Thus, much of the income generated by, for example, satellite and aerial imagery providers, will continue to come from governments and NGOs – indeed the proportion from these sources is likely to increase over this period.

Source: Mechanik/Shutterstock.com

4.2.6 Sector-wise, highly technical defence-related geospatial solutions will grow as a market for the private sector specialists, as defence structures refocus on new challenges and reconfigure into ever-more technology-driven solutions. Recent conflicts have shown how detailed geospatial data can greatly increase the effectiveness of forces – the trend over the next five to ten years will be applying these techniques across more governments and further into counter-terrorism and asymmetric conflicts.

4.2.7 Whilst the maturity of markets for location-based services is likely to vary from country to country, the proliferation of mobile devices in all regions of the world is likely to offer an increasing number of opportunities for entrepreneurs to develop valuable location-based services and companies. The private sector may be fastest to recognise some of the valuable uses to which geospatial information can be applied, or at least fastest at bringing these uses to the mass public, and in doing so can help to create many jobs as well as provide valuable services.

4.2.8 In other regions; however, a major challenge for private sector data collectors in the coming years will be finding ready markets outside those already established. Consumers and small and medium enterprises (SMEs) have an increasing expectation that data will be free at the point of use and also are often satisfied with 'good enough' data. Where profitable consumer niches are identified, there is a possibility that they will be rapidly occupied by mass global players who will be constantly seeking competitive advantage, using geospatial data or services to attract consumers to their wider offerings. Hence funding models for such organisations will increasingly need to be driven by either valued add-ons, which has proven difficult to make effective to date; or by releasing their data through, or selling the data to, a third-party, advertising-funded provider.

4.2.9 An added risk for the private-sector data creator will be the move towards open data, since high-quality maintained data created by NMCAs could, at the mandate of a government, be released free of charge for use by citizens. This could threaten previous streams of income or at least necessitate a shift in where in the value chain they should place their focus.

4.2.10 The predicted increase in passive crowdsourcing, whereby devices carried by individuals relay information, has been noted elsewhere in the paper and is likely to offer new opportunities to the private sector in the coming years. Already data aggregators are using mobile device movements to identify new road openings and the location of traffic incidents. With more accurate triangulation and faster processing of higher volumes of data, similar techniques are being applied to the movements of individuals and this data is being collated by mobile phone operators, packaged and sold on to users, such as retailers.

4.2.11 The wealth of data that will be created in this way offers huge potential for the private sector to add value to existing geospatial information bases. The private sector is likely to have a key role in interpreting and analysing the vast amounts of information that will be created and in using this information to offer enhanced services to consumer, business and government users of geospatial information. This new role, combined with squeezes on funding for many

government entities involved in the collection and provision of geospatial information, will probably lead to a greater number of public-private partnerships.

4.2.12 Increasingly, therefore, the private sector will need to exploit its understanding of, and capability in, geospatial information in order to focus further up the value chain. As well as continuing to play a key role in developing the technologies that will facilitate the development of spatially enabled societies, it will play a key role as data aggregator and intelligence provider, interpreting the data it collects, integrating it with other data sources to provide more complete information and thus eliminating the need for users to acquire skills and technology themselves. This will open up markets to industries that have hitherto adopted geospatial information on only a very limited basis.

4.3 The future role of VGI and crowdsourced geospatial information

4.3.1 The advent of global mass communication through mobile technology is already unlocking the potential for both the passive and the active crowd to enrich geospatial data. Examples, such as the Haiti earthquake, where volunteers helped to enrich other sources of information and fill the urgent need for data, are well known. However, the potential is enormous and will increasingly be realised over the next decade.

4.3.2 Whilst in some countries the availability of crowdsourced data may be an addition to a wide range of other sources of geospatial information, in others it may be an essential ingredient for social and economic development, particularly in areas where no or only limited other data is currently available.

4.3.3 As well as generating data, VGI can act as a valuable mechanism to encourage public participation and engage and empower citizens. Again, in countries where other sources of data are less readily available, this public participation may be a necessity as opposed to a choice.

4.3.4 In areas that currently lack any detailed geographic information, a user-led approach may enable a basic amount of geographic information to be gathered, thus enabling some of the benefits to the development of the economy and public services that such an information base can provide to be realised earlier. Such an approach should not be considered a replacement for sustained funding to enable a comprehensive national mapping programme; nevertheless, the generation of such information could at least create an initial source layer and, in time, be used to complement any further information that may be collected by an NMCA.

4.3.5 It is worth noting that countries that develop geospatial information bases in this way may be in a position to lead the way in exploring how VGI and crowd sourced information can best be integrated with government-maintained geospatial data.

4.3.6 A further benefit of VGI and of active crowdsourcing will be as an educational tool, teaching citizens the value of geospatial information in daily life. As community knowledge systems are built on this information, citizens will experience the value of geospatial information in a more direct and first-hand way, potentially reaping direct and significant benefit from geospatial information that they themselves have helped to generate.

Source: image courtesy of kiwanja.net

4.3.7 In those countries where well-established geospatial sources are already available, VGI and crowdsourced data is likely to include valuable additional information, which would fall outside the scope of most government data collection specifications. This data has the potential to provide a user's view of their geography, which if used by policy and decision-makers, could potentially allow for

more effectively targeted interventions and more tailored public services.

4.3.8 However, whilst VGI brings with it many benefits, certain aspects of it mean that we are unlikely to see it erode the need for quality-assured and trusted geospatial information. Its reliance on the voluntary contributions of a group of dedicated individuals, the lack of a quality assurance regime, which is widely recognised by the broader user base of geospatial information, and the absence of a regular maintenance regime means that, whilst in some areas it may provide an essential information source, it will not remove the need for a wide range of core, quality-assured, geospatial information. Furthermore, the very fact that this data is *volunteered* geographic information means that its supply is dependent on a group of unpaid volunteers and, as such, whilst potentially valuable, its provision is also inevitably somewhat inconsistent and unpredictable, making it unsuitable for a wide range of government and emergency management purposes.

4.3.9 Nevertheless, NMCAs could work in partnership with active members of the VGI community to help identify geographic areas and information types where there are data deficiencies. Recognising that part of the motivation for the creation of VGI was restrictive government licensing conditions for use of data, such an approach may require a genuine and marked shift to a greater collaboration between NMCAs and the VGI community.

5 The future role of governments in geospatial data provision and management

5.1 The impact of change

5.1.1 Many of the changes mentioned in this document will have a considerable impact on the role of governments in geospatial data provision and management. However, despite the increasing number of organisations and entities collecting geospatial information, NMCAs, and indeed government and business users of geospatial information, are unlikely to be able to or wish to wholly rely on data from the private sector or other sources.

5.1.2 Private sector providers will continue to need to justify all collection and maintenance based on a return on investment. For remote geographies, the main customer will be government agencies, so in this case the private sector will only collect data on behalf of the government – rendering the distinction between private sector and government somewhat irrelevant to collecting information of a certain kind or in certain places. VGI, as mentioned previously, tends to be limited in its coverage and, without a scheduled maintenance regime, not widely recognised by major users of geospatial information. Lack of reliability of supply updates and availability also mean that VGI is not likely to be suitable for those major users that rely on a steady supply of updated information and on the quality assurances that are often implicitly or explicitly provided by governments.

5.1.3 As such, governments will remain in a unique position to consider the requirements for geospatial information for society as a whole and will continue to play a key role in providing a reliable, trusted and maintained geospatial information base. The exact role a government chooses to take in geospatial information management, the predominant challenges faced and the changes made will inevitably vary from country to country.

5.1.4 In some countries, a major trend will be to replace obsolete data collected many decades ago as the economic benefits of up-to-date data can now be quantified; in other countries a major trend will be adapting business models and access regimes to meet the changing expectations of an ever-more demanding customer base accustomed to easy access to online mapping in a user-friendly environment. Some countries will look increasingly to limit their activities to what may be seen as their core task – whilst in others the focus may be on increased engagement and partnership with the private sector. Nevertheless, as in the previous ten years, government providers of geospatial data are likely to witness significant change in the coming years.

5.2 Bridging the gap: coordination and collaboration

5.2.1 Additional data sources, particularly crowdsourced information, offer a significant opportunity to enrich existing and future geospatial information bases. As such, and combined with pressures to reduce costs, it will be increasingly important in the years to come for governments to facilitate collaboration between all sources of information. This may include actively encouraging the collection of additional information by non-government sponsored bodies and providing frameworks to incorporate the data in a structured way.

5.2.2 Hence, it is possible that one of the key trends and key challenges over the coming five to ten years will be for NMCAs to increase their work with the private and VGI community, and to leverage the increasing amounts of crowdsourced information, in order to maximise the value available from these various datasets. At the moment there is a significant gap between authoritative and crowd sourced data. This gap is likely to decrease in the coming years as collaboration between all actors increases, with VGI incorporating government-sourced data and governments exploring ways to incorporate both passively- and actively-created user-generated data.

5.2.3 Finding ways to integrate the information available from other sources into national datasets and into the spatial data infrastructures of a country will be a key challenge for NMCAs

over the coming five to ten years. We may increasingly see NMCAs taking a role in developing quality assurance mechanisms and standards for VGI data so that a level of authority can be included with such data. In the area of VGI, as stated previously, countries where geospatial frameworks are currently less developed may actually be better placed to use VGI and crowdsourced data as a data source for their spatial data infrastructures from an early stage.

Source: Rafal Olechowski/Shutterstock.com

5.2.4 Key to the successful delivery of this will be for government entities such as NMCAs to develop standards, methods and, potentially, tools to assure quality and to provide authority to information. As awareness of the value of geospatial information in decision-making rises, and as more and more decisions are made using geospatial information, maintaining trust and confidence in the information being used will continue to be vital and will continue to form a vital part of the role of governments.

5.2.5 The provision of methods that include some quality assurance measures, such as consistency checking and the tracing of revisions, could increase the levels of trust in VGI and make it easier to incorporate it into government-assured geospatial information bases with confidence

5.2.6 Alongside the role, mentioned previously, in driving collaboration between different sectors of the geospatial information community, governments also are likely to play a key role in driving collaboration in the interoperability and integration of different types of geospatial information and indeed other information. The focus on interoperability and integration between marine geospatial information, broader hydrographic information and topographic information is likely to increase in the coming years, as will the focus on geological spatial information, as users seek a more comprehensive representation of the planet we inhabit.

5.2.7 Governments will also play a role in many countries in driving, or at least supporting, cross-sector collaboration in areas such as building, construction and public safety, through building information modelling (BIM), and farming, through agricultural risk management methods and systems. We also are likely to see stronger interoperability, and in some cases integration, between geospatial and statistical authorities, as well as with other information authorities, as governments look to connect and make sense of the significant volumes of data they will hold.

5.3 Developing a national geospatial information infrastructure

5.3.1 In those countries where the investment in infrastructure for geospatial information management is still in its early development stage, governments will have a key role in coordinating the various aspects necessary to facilitate the vision of a spatially-enabled society. Critical to this is demonstrating to those responsible for funding NMCAs that the investment is worthwhile and that a real return on investment will be seen. International case studies will assist in supporting investment, as it will increase the understanding of how geospatial information can be used and the economic and social benefits can be realised as demonstrated elsewhere in the world.

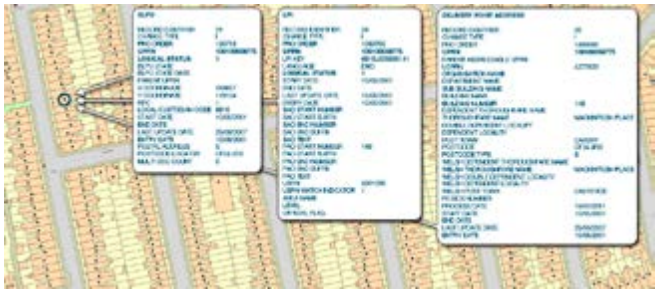
5.3.2 Whilst the exact role that a government chooses to take in the geospatial field will inevitably vary from country to country, governments will have a key role ensuring that comprehensive frameworks are put in place with related policies, resources and structures that ensure geospatial information is easily accessible to decision-makers and users in a coordinated way.

5.4 Maintaining an accurate, detailed and trusted geospatial information base

5.4.1 As technologies continue to develop and the barriers to entry into the large-scale mapping environment reduce, we are likely to see the private sector increasingly competing in areas of high potential economic value – primarily, high-density urban areas. This increase in the number of sources of geospatial information will challenge NMCAs, possibly leading to a reconsideration of the traditional role played by governments in geospatial data collection and provision.

5.4.2 As more organisations become involved in the collection and distribution of geospatial information, the geospatial marketplace will also witness change. As well as having a vital role in ensuring the availability of a trusted geospatial information base, government regulatory bodies may need to grow their awareness and understanding of the geospatial marketplace to ensure that competition and practices continue to remain fair.

5.4.3 However, despite the increase in producers and providers of geospatial information, government authorities will retain a key role in other areas of the geospatial environment where trust in the data produced is seen as vital and where natural government monopolies exist.



5.4.4 Whilst arguments over what constitutes what have been termed 'core reference datasets' are likely to continue, there is likely to remain a set of reference datasets for which it is both economically and socially sensible for the government to produce and maintain, in order to ensure they are collected only once, yet used many times.

5.4.5 A number of uses of geospatial information, essential for sustainable economic and social development and in some cases life-critical, rely on the provision of geospatial information that is detailed, is provided to a high level of specified accuracy across an entire country, is trusted and is regularly maintained. This information is used in many ways, but by example, it provides the registers of land to enable a managed system of property ownership and dispute resolution; assists in identifying health inequalities and effectively targets interventions to household level; and is used to route emergency response vehicles to a major incident, ensuring that all those responding have a common operating picture.

5.4.6 Recognising the increase in data sources, one of the key roles of the NMCA in the coming five to ten years, therefore, is likely to be to define and maintain quality standards and the data currency regimes for data that government requires for its operations. Governments are in a unique position to carry out this role and to assess the level of detail of information required to deliver such information.

5.4.7 Given the proliferation of additional sources of data and potential competition from other sectors, however, we may see government providers of geospatial information taking on a role that shifts more towards a policy, advisory and procurement role. In a trend that has already started to emerge, central governments may increasingly no longer see it necessary to collect all geospatial information required themselves, but may instead commission the data from the most appropriate and suitable source, be that local government, the private sector or, potentially, a VGI source.

5.4.8 Governments and those government agencies that have previously primarily played the role of data collector will instead move towards a role of commissioning and managing the delivery of a complete geospatial framework. In this role, governments are likely to continue to be relied on to ensure that data is captured and integrated from areas of lower economic activity, as well as those for which there is likely to exist a greater economic market, and to provide a trusted geospatial framework that can be relied on by users in their decision-making processes.

5.4.9 The procurement of data from a wider number of sources could release human and financial

resources that can then focus on overseeing the management and maintenance of the data collected. Effort can then be put on ensuring that rich sources of information are available, are maintained and are available as widely as possible, whilst ensuring the necessary funding is secured to ensure the sustainable provision of a maintained data supply.

5.4.10 The role of government as an authoritative supplier of quality, detailed and accurate geospatial information, drawing on the wide range of valuable sources of information, will become increasingly crucial as awareness of the value of geospatial information increases amongst decision-makers and reliance on this information in the decision-making process increases. End-users should be able to consume government-assured spatial data with the level of trust in its quality and provenance as they do when they consume water from a tap or electricity from the socket – knowing that as soon as they access data from that source they are going to get what they expect every time.

5.4.11 The increasing use of authoritative, trusted geospatial information will drive adoption of geospatial information and ensure that it reaches ubiquity in the government and business decision-making process, as well as in the consumer sphere. Increasing recognition of the value inherent in the data means that NMCAs are likely to become more closely aligned with other 'official' bodies in government who look after, for example, statistics, the economy or land. Governments will have a vital role in ensuring that frameworks are in place that will enable the effective cooperation and collaboration between the plurality of actors that will increasingly be involved in the provision and management of geospatial information, and in ensuring that the benefits that a spatially-enabled society has the potential to offer, are realised.

5.4.12 Geospatial information has a key role to play in delivering sustainable social and economic development across the globe. As economic and social issues continue to increasingly be cross-border in nature, we will see the growth of regional and global cooperation and solutions between NMCAs, and also with and between other regional and supranational agencies such as the UN. Awareness and understanding of this is likely to increase in the coming years as more people interact with geospatial information and an ever-greater number of people experience the value of using geospatial information to inform decision-making. Governments have a key role to play in bringing all actors together to ensure that our future society is a sustainable, location-enabled one, underpinned by the sustainable provision and effective management of reliable and trusted geospatial information.

Annexe A Full list of contributors

We are grateful to all of the below who have contributed to this work through either providing a written contribution or taking part in the discussion forum in April 2012. The designation of an individual relates to their position when they made their submission. We recognise that, despite our best efforts, some contributors may not be listed below. We apologise if this is the case and ask that anyone who contributed and who wishes to be recognised in this list in any future publications, please email either James Norris at **customerservices@ordnancesurvey.co.uk** or Greg Scott at **scott12@un.org**.

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