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

SECOND EDITION

FINAL DRAFT

For review by

United Nations Committee of Experts on

Global Geospatial Information Management

Contents

Acknowledgements and disclaimers

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A list of those who have contributed can be found at the end of the report. We are grateful to every person and organisation for giving their time, either to provide written contributions, attending the discussion forum, or taking part in individual evidence gathering sessions and allowing us to use their collective inputs in this report.

Executive Summary

This 2015 version of the Future Trends report recognises that the most significant changes in the geospatial industry will come not through a single technology, but rather from the linking of multiple technologies and policies. The first part of the report, which has been produced through a global consensus process, focuses on the new and emerging trends; these are explored through a series of themes covering one or more topics. The second half of the report updates, where relevant, changes that have occurred in the trends identified in the first edition.

Due to increased global urbanization, it is expected that more focus will be placed on urban environments. The integration of smart technologies and efficient governance models will increase and the mantra of 'doing more for less' will be more relevant than ever before. The emerging trends of Smart Cities and the Internet of Things, coupled with smart resource management and interoperable services, will lead to a focus on increased citizen services, better land management, and the sustainability of resources and the environment.

The development of intelligent information-processing technologies, will provide easier access to a wide range of different services which were previously used for separate applications. These include home and industrial automation, medical aids, mobile healthcare, intelligent energy management, automotive and traffic management, to name only a few.

The next five to ten years will see significant developments in the architecture of the internet. Currently the internet is human-orientated; the shift towards machine learning and the adoption of the Internet of Things will bring into play devices which are, to all intents and purposes, autonomous and act independently whether or not anyone, or any system, is actively using them.

There is an increasing tendency to bring together data from multiple sources: official statistics, geospatial information, satellite data, big data and crowd-sourced data among them. For the full potential of these data sources to be realised, it is agreed that data needs to be accessible, interoperable and standardised. This theme is recognised throughout the chapters of this report, and stems from this need for users to be able to integrate different sources and types of information.

The role of National Spatial Data Infrastructures will become increasingly important. They can provide the means to organise and deliver core geographies for many national and global challenges including sustainable development. The paradigm of data availability is changing; there is a huge increase in the tracking and availability of real-time data. It is now recognised that this data is no longer just for mapping and delivery, but for integration, analytics, modelling and aggregation – capable of providing more informed decision making.

Work continues at a global level with international standards. The widespread and effective application of standards in many digital information fields is crucial not only for the continual effective use of internet-based products and services, but also for collaborations between different data organisations.

Although views on policies for the use of authoritative data are fairly consistent around the world, culture has a big influence. Governments are moving towards being commissioners of information rather than creating it themselves. They are working increasingly closely with private sector organisations and are able to add a stamp of authority to data and services provided through public private partnerships.

New data sources and new data collection technologies must be carefully applied to avoid a bias that favours countries that are wealthier and with established data infrastructures. The use of innovative tools might also favour those who have greater means to access technology, thus widening the gap between the “data poor” and the “data rich”.

Governments 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 challenges faced, and the changes made will vary from country to country. Governments retain a key role in ensuring that comprehensive and robust frameworks are put in place with related policies, resources and structures to ensure that geospatial information is easily accessible to decision makers in a coordinated way.

Introduction

The first edition of the report "Future trends in geospatial information management: the five to ten year vision" has proved to be an important reference document. It has been appreciated by many different users and has provided a consensus view for the professional geospatial community to keep abreast of new trends in geospatial information; particularly with the impact of these geospatial technologies.

The Committee of Experts, acknowledging the benefit and impacts that the first edition has had in the global geospatial community, decided that an update to the Future Trends report should be completed in 2015. This second edition updated report, prepared through a global consensus process, will form an important contribution to the review of all aspects of the Committee's work and operations, to be submitted to the Economic and Social Council in 2016. As well as exploring new areas, this version highlights changes to the trends identified in the original report; showing how the role of governments is changing and documenting the increasing role that geospatial information will play as part of the post-2015 development agenda.

The role of geospatial information in measuring and monitoring the post-2015 sustainable development goals

2015 is a watershed year, providing a crucial opportunity for the value of geospatial information to be recognised by governments throughout the world. The United Nations Millennium Development Goals (MDG) conclude in 2015 after 15 years of effort. A global framework of eight goals and 21 targets, designed to reduce extreme poverty and improve the lives of all the world's citizens at local, national, regional and global levels, the MDG monitoring experience clearly demonstrated that the effective use of data can help to galvanize development efforts, implement successful targeted interventions, track performance and improve accountability.

A bold new post-2015 development agenda is being established by the United Nations, inclusive of 17 Sustainable Development Goals (SDGs) and 169 associated targets. The SDGs will be adopted and launched by the United Nations General Assembly in September 2015, and will frame the global development agenda through to 2030. In order for the goals and targets to be implemented and achievable, strengthening data production and the use of better data in policymaking and monitoring have been recognised as being critical.

Many of the targets are thematically based and geographic in nature. This provides an ideal opportunity for the global geospatial community to ensure that the role geospatial information plays – improving the availability, quality, timeliness, integration and disaggregation of data – in the development of the targets and indicators is realized. They all occur in a location-based environment and geospatial information provides a fundamental baseline for the global indicator framework, as well as for measuring and monitoring the SDGs.

In tackling these major global challenges, many governments will initially face problems associated with poor data quality, lack of timely data and a lack of interoperability between different sources of data. This may result in governments using, and then relying on, inaccurate or low quality data on which to base their decisions. It will be imperative that these early data issues are quickly resolved and overcome by the global geospatial information community.

In developing countries, the post-2015 development agenda is likely to be a trigger to accelerate the development and adoption of legal, technical, geospatial and statistical standards as the expectations and requirements for governments to report on sustainable development progress with consistent and reliable data evolve. These include, but are not limited to: openness and exchange of data and metadata, including interoperability of data and information systems, and demographic and geospatial information, including management and change.

Many of the sustainable development challenges are cross-cutting in nature and are characterised by complex inter-linkages which will benefit from using location as a common reference framework and are likely to take cost out of the process. In order to effectively measure, monitor and mitigate challenges we need to link demographic, statistical and environmental data together with the one thing they have in common – geospatial often known as location data.

Geospatial technologies represent an invaluable tool, due to the ability to integrate, fuse and visualise many different data from many sources, for enhancing the capacity to benchmark and measure performance of sustainable development at different scales. As an example, enabling the monitoring of progress at the sub-national level can help alleviate inequalities within countries, inform better decision-making and thus allow resources to be allocated to the areas that most need them.

Maximising the value of geospatial information

One of the issues that this report seeks to remedy is that many government officials and other stakeholders do not fully understand what geospatial information is, and more importantly the benefits it provides for sustainable development initiatives.

The paradigm of geospatial information is changing; no longer is it used just for mapping and visualisation, but also for integrating with other data sources, data analytics, modelling and policy-making. Once the geospatial data is created, it can be used over and over again to support a wide range of different applications and services.

How geospatial information is integrated into the architecture, standards and best practices of the 'location enabled society' continues to evolve at a considerable pace. The importance of location becomes apparent as every sensor/item connected to the internet has a location, and in many instances, this location is a vital piece of information that sets the context for the information transmitted. Geospatial information becomes particularly important when the sensor – or the object to which it is attached – is moving.

Knowing where people and things are, and their relationship to each other, is essential for informed decision-making. Not only is real-time information needed to prepare for, and respond to, natural disasters and political crises, but location-based services are helping governments to develop strategic priorities, make decisions and measure and monitor outcomes.

Governments need to see this foundation geospatial information for its "value", not for where it has come from or who owns it. Geospatial information needs to be treated as an essential component in decision-making processes, not just as a commodity that can be sold.

The reality of different professional communities having the same intent in contributing to the United Nations post-2015 sustainable development agenda provides the Committee of Experts the mandate to continue its awareness raising and educational efforts at local, national, regional and global levels.

From inputs received, geospatial information is increasingly being used in Africa, but more capacity building is needed to scale up existing initiatives and to bring innovative applications from other parts of the world. As an example, the lack of consistent up-to-date base mapping – fundamental geographic datasets such as geodetic control, elevation, drainage, transport, land cover, geographic names, land tenure, etc. – across Africa remains a challenge.

1 Smart Cities and Internet of Things

1.1 Increased urbanisation leading to global challenges

1.1.1 Today roughly 51 per cent of the world's population live in urban environments[1], there has been a substantial shift of population moving towards cities, cities themselves have grown, and informal settlements have got increasingly bigger. However cities disproportionally consume physical and social resources (circa 80 per cent) leading the United Nations to brand them the greatest challenge to mankind since we became social. However they are also economic engines of commercial growth with positive impacts on society.

1.1.2 This trend is projected to grow substantially not only in the next five to ten years, but also further into the future – it is estimated that by 2050 the global population will be over 9 billion, 80 per cent of whom will live in cities. Such growth will continue to put strain both on resources and on existing infrastructure such as the availability of safe drinking water, electricity networks, transport networks, waste management and property ownership. An approach has started to develop to identify and try to provide solutions to these problems through a number of initiatives variously badged as smart cities, eco cities, safe cities, resilient cities or future cities to indicate a particular focus on the system. For the purpose of this report we shall use the generic term Smart Cities to refer to the "effective integration of physical, digital and human systems in the built environment to deliver sustainable, prosperous and inclusive future for its citizens[2]".

1.2 The growth of Smart Cities

1.2.1 Even though the concept of Smart Cities and its various guises is widely used it remains abstract and difficult to grasp. It is often sub-divided into different dimensions, including smart mobility, smart environment, smart living, smart governance, smart people, and smart economy. Managing more complex surroundings offers several opportunities for the application of the Internet of Things (IoT) which stretches across all these dimensions.

1.2.2 The integration of smart technologies and efficient governance models will increase, not least due to the constant expansion of cities, and their demands on resources from a decreasing reserve. The mantra of 'doing more for less' is more relevant than ever before. Ensuring the supply of commodities, the resilience to disasters, or the provision of health care and security services asks for smarter and more sustainable solutions. Merging a high quality of life with resource sustainability drives much of the research to date. It is this combination of smart resource management and interoperable services that will become the focus of the Smart Cities infrastructure.

1.3 Connectivity through the Internet of Things

1.3.1 Information and Communication Technologies (ICT) have a vital role in various applications, ranging across the environment, economy, society, governance and health. Deploying smart devices and appliances will increase the need for technological standards and information exchange protocols in order to achieve full interoperability of all systems. The most prominent examples can be found in the energy sector where the Smart Meter is already being widely adopted in some developed countries as a tool to enhance user experience – remote access to household appliances,

[1] Decoupling Natural Resource Use and Environmental Impacts From Economic Growth, A Report of the Working; Group on Decoupling to the International Resource Panel", UNEP, 2011

[2] PAS 181:2014 Smart city Framework: Guide to establishing strategies for smart cities and communities

reduced utility bills – and drive a reduction on total energy consumption, supporting the goal of sustainability. We are likely to see an increase in the interconnectivity of new energy-related systems such as electric vehicles, storage devices or small scale renewable energy systems at household level.

1.3.2 Beyond urban IoT systems, which are designed to support the Smart City concept, the development of intelligent information processing technologies will make intelligent sensing, and machine learning widely available through information sharing, collaboration and the intelligent use of large data sets. The easy access and interaction with a wide range of devices finds application in different domains, such as home and industrial automation, medical aids, mobile healthcare, intelligent energy management, automotive, traffic management, to name only a few.

1.3.3 The Internet of Things is not limited to the urban environment – even though this may be the area that sees the fastest rates of growth. The network of sensors linked to the internet can be used, for example, to measure and monitor environmental changes in inaccessible areas or to locate cattle in large remote farms.

1.3.4 Monitoring and assessing the new technologies and services will open new frontiers for geographical information tools and systems. The 'omnipresence' of geospatial Information 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 IoT and the Uniform Resource Identifier (URI) assigned to a thing or object within that connected world. In order to maximise usability this will drive the demand for informative standardised metadata as part of geospatial data.

1.3.5 During the next five to ten years we may see significant developments in the architecture of the internet. Currently the internet is human-orientated, the change towards machine learning or the Internet of Things will need to take into account devices which are to all intents and purposes autonomous and act independently whether or not any person, or any system is actively using them.

1.3.6 A key factor of how the Smart Cities concept develops will be how geospatial information is integrated into the architecture, standards and best practices which are evolving. The importance of location becomes apparent as every sensor/item connected to the internet has a location, and in many instances, this location is a vital piece of information that sets the context for the information transmitted. Geospatial information becomes particularly important when the sensor – or the object to which it is attached – is moving.

1.3.7 We are seeing geospatial information being needed to assist the evolution of this connected ecosystem and this will increase even further in the near future. 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.

2 Artificial Intelligence and Big Data

2.1 Artificial Intelligence and machine learning

2.1.1 Our ability to create data is still, on the whole, ahead of our ability to solve complex problems by using the data. There remains no doubt that there is a huge amount of value still to be gained from the information contained within the data generated. The growth in the amount of data collected brings with it not only a growing requirement to be able to find the right information at the right time, but also challenges of how to store, maintain and use the data that is created.

2.1.2 The creation of such huge amounts of data will bring with it a requirement for the ability to make sense of these data, which will, given the importance of location to decision-making, drive demand for geospatial identifiers in the data. The need to address this problem will rely on the development of both Big Data technologies and techniques (that is technologies that enable the analysis of vast quantities of information within usable and practical timeframes) and artificial intelligence or machine learning technologies that will enable the data to be processed more efficiently.

2.1.3 The first edition of this report naturally assumed that the users and creators of geospatial information and its services would be people, rather than machines or robots. In future we may expect society to make increasing use of autonomous machines and robots, thanks to a combination of ageing population, rapid technological advancement in unmanned autonomous systems and artificial intelligence (AI), and the pure volume of data being beyond a human's ability to process it.

2.1.4 Developments in AI are beginning to transform the way machines interact with the world. Up to now machines have mainly carried out well-defined tasks such as robotic assembly, or data analysis using pre-defined criteria, but we are moving into an age where machine learning will allow machines to interact with their environment in more flexible and adaptive ways. This is a trend we expect to see major growth in the next five to ten years as the technologies – and understanding of the technologies – become more recognised.

2.1.5 Machine learning is moving beyond 'hard-coded' algorithms to towards algorithms that continually learn and update themselves, adapting to their environment. This is facilitated by the development of powerful methods of 'unsupervised learning' or 'representation learning' by which a machine may be instructed to seek structure within large quantities of apparently unstructured data.

2.1.6 Processes based on these principles, and the learning of geospatial concepts (locational accuracy, precision, proximity etc.), can be expected to improve the interpretation of aerial and satellite imagery, by improving the accuracy with which geospatial features can be identified. They will also be applied to complex geospatial analysis questions which may lead to new insights about the ways in which objects or their properties are related, with applications in health, crime, agriculture, environment and so on. An example could be automatic identification of building use from combinations of land cover, population and transport networks. Tools like these may run persistently on continuous streams of data, alerting interested parties to new discoveries and events.

2.1.7 Geospatial information is also an important input for intelligent devices that need to be aware of their surroundings. Many of the problems machines are expected to solve will require extensive knowledge about the world around them. Thus AI needs to represent objects, properties, categories and relations between objects; all of which can be represented in geospatial databases. Machines/robots will take advantage of AI to understand geospatial information themselves, and even "survey" their surroundings to get the geospatial information they need and process it in real time to do their job. The geospatial information thus "surveyed" and analysed may in turn be used to develop and update existing geospatial databases.

2.1.8 Another branch of AI that has long been of interest has been the expert system, in which the knowledge and experience of human experts is taught to a machine. Good results are already obtained in cartographic generalisation, but the increasing sophistication of expert systems will make this more of a routine procedure. The principle of collecting data once only at the highest resolution needed, and generalising 'on the fly' as required, can thus become reality.

2.1.9 Cartographic visualisation skills will remain an important tool through which data can be spatially interpreted. New methods for interpreting and representing data in a meaningful manner to inform human decision-makers will need to be developed alongside the processing of information. Intelligent systems may also be employed to develop new ways of conveying complex spatial relationships to human observers. Developments of augmented and virtual reality will allow humans to interact with data in new ways.

2.2 Value realised through Big Data

2.2.1 The value of AI to the geospatial industry in this sense is closely related to the Big Data issue. The sheer processing power available to researchers will mean that machines can be used to analyse and interpret, often in real time, quantities of data that would be beyond the capacity of human resources.

2.2.2 Big Data solutions have moved a long way in the last five years, and are now a real part of everyday life; for example, search engines such as Yandex and Google collect vast quantities of data, can combine this data with other sources of information, such as mobile phone information and provide services such as directing car drivers away from areas of high congestion.

2.2.3 The future of data will not be the conflation of multiple data sources into a single new dataset, rather there will be a growth in the number of datasets that are connected and provide models to be used across the world. As mentioned above, the need for more flexible information, stored in usable databases will see the continued rise of NoSQL technologies and linked data techniques.

2.2.4 There is a growing trend for the majority of Big Data applications to use de-facto standards, technologies and platforms. It has been suggested that there will need to be a universal means to discover, publish and maintain data; this can be supported by the adoption of open standards. As the use of Big Data becomes more common, there will be a growing need to move from technology supporting Big Data analytics and visualisations, to data about the data – that is provenance, quality, and so forth.

2.2.5 One of the central challenges when using Big Data is to derive information and knowledge from the massive amounts of raw data which is being produced, this challenge is exacerbated by very high data volumes and high rates of data change. The ongoing increase in the number of mobile phones has given rise to a generation of users who expect real-time information at their fingertips. Real time information is not a new context, however in recent times the number and variety of domains in which real-time information is a basic requirement, transport, logistics, disaster management to name a few, has significantly increased.

2.2.6 Efforts should be being made devoted to the integration of involuntary sensors – mobile phones, RFID sensors etc. – which aside from their primary purpose may produce information regarding previously difficult to collect information, this leads to more real-time information being generated.

2.2.7 Whilst the proliferation of devices generating 'raw location data' may reach most corners of the globe, the funds necessary to collate and manage the data in an effective way may not be so well distributed. Many developing nations have leapfrogged in areas such as mobile communications, but the lack of core processing power may inhibit some from taking advantage of the opportunities afforded by these technologies.

2.2.8 Big Data technologies will be used to overcome the challenge of data volume, velocity and variety. The continuing use of cloud computing capabilities will allow anyone to access scalable and on-demand processing power from anywhere in the world. In countries where securing funding to develop a base geospatial infrastructure is still the primary focus, prioritising the collection of basic geospatial data is likely to remain the primary focus.

3 Indoor Positioning and mapping

3.1 Trends in technology for indoor positioning

3.1.1 Indoor positioning is an increasingly important research area and new technologies to exploit the ability to find location within buildings or other structures are becoming increasingly available. With satellite positioning largely ruled out by the attenuation effects of the building's walls, a number of different technologies have arisen. These have included the use of wireless networks, inertial, magnetic, infrared, ultra wideband, air pressure sensors, ambient light, ultrasound, Bluetooth and RFID tags. All have advantages and disadvantages in terms of coverage, infrastructure required, accuracy, precision and reliability, but as a group these technologies are gaining a higher user base.

3.1.2 The trend towards development of indoor applications using geospatial data has been driven by commercial opportunities identified by the private sector. Applications have been developed to offer consumers price reductions and personalised marketing. However it is not only the commercial sector who are benefitting, as an example, wireless tracking of mobile phones has often played a critical role in the crime, security and traffic management/routing fields.

3.1.3 The miniaturisation of RFID devices/tags such that they can be attached to or incorporated into virtually any object including, for example, people, animals, clothing or individual sheets of paper (e.g. bank notes), along with their low cost, creates the opportunity to locate or find objects indoors and outdoors with a very high level of accuracy. Active RFIDs (as opposed to passive ones) require power in order to broadcast location, as well as other information, and there are new ways of generating that, such as through motion. This could have important implications for the kind and pervasiveness of RFID tags and the amount of location information which becomes available.

3.1.4 Meanwhile, outdoors the various global (GPS, GLONASS, Galileo, BeiDou) and regional satellite constellations (BNSS, IRNSS) are in orbit and respective receivers have been built into many kinds of devices, mobile phones being a prime example. The result of this is that the number and diversity of types of location based services using satellite based positioning systems are likely to expand in the future.

3.2 Integration between outdoor and indoor positioning

3.2.1 The proliferation of location information from both indoors and outdoors presents issues of integration. This is particularly the case for indoor positioning as there are so many different technologies involved, few standards and the localized nature of an indoor positioning system has resulted in design fragmentation.

3.2.2 However, there is considerable effort being expended on integrating the many sources of information such that there is seamless access to appropriate location information regardless of protocols, networks, frequency bands, and physical environments, as the user moves between outdoor to indoor.

3.2.3 As the theme of indoor/outdoor positioning develops further, issues will arise as to where do traditional mapping providers 'stop' mapping. Does it stop at the footprint of the building, or continue inside. This will have an impact on a number of different industries such as utility providers.

3.3 Standards

3.3.1 The integration will require some advancement in the creation of standards both for the technology itself and the data generated from it. There are advances being made in this area but the key issue is that much of this data is "proprietary" and not available for use in publicly available applications. As such the development of open standards is slow. There are some existing standards coming from the Building Information Management (BIM) sector such as IFC and InDoorGML for modelling and sharing indoor space data. InDoorGML is the latest Open Geospatial Consortium (OGC) standard focused on mobile indoor location applications - specifically navigation. The more challenging issue is the development of standards for indoor location detection/computation technologies. This may continue to be a brake on the development of seamless indoor/outdoor location applications.

3.4 Requirements for mapping

3.4.1 A prerequisite for indoor navigation is digital maps of all larger buildings which are in public use (hospitals, exhibition halls, stations, airports, town halls etc.). Thus there will be a shift towards indoor mapping initially driven by the consumer market. The third dimension will take on a new significance and hence coverage in 3D will have to be included in procurement budgets over the coming years.

3.4.2 There is a counter argument which is referred to in the chapter on AI which suggests that the growth in Internet of Things may lead to not having to 'map' a building as all the connected devices will indicate where the building is, especially when the devices start interacting with each other and therefore surveying their environment. However, these are really just two aspects of the requirement for a richer set of base information inside buildings on which to base navigation applications.

4 Integrating statistical and geospatial information

4.1 Integrating different data sources

4.1.1 As well as geospatial information, Governments and government bodies are increasingly reliant on statistical data to inform policy and decision making. As resources become constrained, it is increasingly important to make sure that they are used in the most effective way possible. Geography is often the medium through which statistics are interpreted whether at global, regional, national or sub-national level. As the need for better statistics increases so does the need for greater integration of statistics and geospatial information, resulting in so called spatial statistics.

4.1.2 One of the major drivers, and opportunities, over the near- to mid-term for the better production and dissemination of statistics, and integration with geospatial data, is the need to monitor and report against the Sustainable Development Goals (SDGs) at a national, regional and global level. Pledging that 'no one will be left behind', the SDGs will require National Statistical Offices (NSOs) to consider how to work collectively together to develop a global indicator framework and to address the challenges of producing and disseminating information at the right scale.

4.1.3 Delivering the statistics to monitor the progress of the SDGs will require NSOs to work together with the geospatial community to identify and develop requirements for spatial statistics within and across Member States. This includes covering a wide and diverse range of statistical and geospatial variables, and the needs to include a temporal element.

4.1.4 One option identified for this is to disaggregate data at high levels down to small area geographies. This will increase the need to evaluate and adopt alternative statistical modelling techniques to ensure that statistics can be produced at the right geographic level to enable consistent reporting, whilst still maintaining the confidentiality of personal data. A new model has emerged recently of linking authoritative data sources, for this to be successful it will require increased cooperation between the statistical and geospatial communities to allow data sources to be linked at the lowest geographic level.

4.1.5 To deliver spatial statistics at local levels through to regional and global levels, will require a global geo-referencing system to be in place. The statistical community needs therefore to contribute to the development of the UN Global Geodetic Reference Frame, and help to shape the requirements for spatial statistics.

4.2 The role of standards

4.2.1 One of the biggest challenges that have faced both the statistical and geospatial communities is the diversity of the semantic terminology used to describe statistical geography. Where different terms are used to describe the same or similar processes in the production of spatial statistics (such as geo-enable, geo-statistics, geospatial statistics, geo-referencing), this makes it difficult to compare outputs and metadata from different sources. The same can be said for the terminology used between the different communities of users, not just limited to statistics and geography.

4.2.2 There is currently a gap between the standards used for the publication of statistics, and those used for the publication of geospatial information that makes the integration of statistical and geospatial information more difficult at the working level. Existing statistical standards such as SDMX contain little geographic referencing within their structure which makes it difficult to link SDMX outputs to the geographic framework they operate within. Likewise, the existing metadata standards such as ISO-19115 do not contain the elements that show integration with statistical datasets. Both the statistical and geospatial communities will need to cooperate more extensively to support a greater integration of geographic and statistical standards.

4.2.3 One approach that may develop further during the next five years is the development of a Table Joining Service (TJS) standard. This standard offers a web service interface that enables the automatic, service oriented joining of tabular and geographic data across the web, while keeping the data distributed at the data providers source location. The TJS specification - a standard of the Open Geospatial Consortium (OGC) - is relatively new and so far only very few ready-to-use implementations of server-side and client-side software exist.

4.3 Integrated approach to the 2020 Round of Censuses

4.3.1 Any statistical spatial framework that is produced to support the production of spatial statistics should include the use of geospatial workflows and technology at least at the collection stage, as a key to advance on the integration of geospatial and statistical information. The work required for the greater integration of statistics and geospatial information needs to be done within the timescales of the 2020 Round of Censuses. As the lead-in time to deliver any census is significant, these challenges need to be considered now if standardised approaches are to be put in place in time.

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

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

5.1.1 It will continue to be the case that the most significant changes in society will not come from singular technologies – but from the combination of multiple technologies. The geospatial community is itself one of the best examples of this principle; the now ubiquitous nature of mapping is only possible from the universal availability of global positioning, the increased reduction in the size of computers and the ability to store and distribute large volumes of data over different technologies.

5.1.2 Data creation remains both active and passive. Users of social media in some countries are creating ever increasing amounts of spatially located information without it being a conscious decision. Sharing a picture or updating a profile of where you are is not a conscious effort to create and provide geospatial information, but the geo-referencing of the user is occurring within the profile data.

5.1.3 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, but as the use of social media for providing real-time information and expanded functionality increases, it offers new opportunities for location-based services.

5.1.4 The sensor systems and collection platforms are not just collecting the location and the properties of that location, but also the time that the information was collected, providing an important and foundation variable for so many applications and services. This is an important and growing trend which is expanded in more detail later in the report.

5.1.5 There is a growing body of evidence which suggests that location enabled technologies are drawing strong dialogue and debate among different sectors of the community. The different ways policy and legal frameworks are developing are also discussed later in the report.

5.2 Cloud computing

5.2.1 It is widely recognised and accepted that today and in the future more and more information will be generated and stored. In the IT professional world 'cloud computing' is strongly believed to be the only way to keep up to date with user demands for data storage and retrieval, management and analysis. Commercial organisations offer software, platforms and infrastructures directly connected to a cloud based environment.

5.2.2 Growing concerns around the issues of data storage have led to the creation of unstructured databases such as those using NoSQL, which allows the database the freedom to be freeform and queried. Scalability and performance are important, as are classifications of data. This does present a problem when users are trying to store structured data for a specific purpose.

5.2.3 The use of cloud computing has risen substantially in the last decade, and has become the current standard. Cloud computing offers many benefits, including a reduction in operating costs, reliability and a scalability of the service provision – there are however also challenges. For instance quality and security issues are still to be solved or clarified before some types of data are transferred to the cloud.

5.2.4 Use of the cloud, either Private – hosted entirely by an organisation for its own use, or Public – hosted elsewhere in a shared manner, provides a means to host and serve significant volumes of data without the accompanying investment cost required to own the necessary technologies independently. Due to the costs associated with creating a public cloud service, it is possible that not all countries will have access to them; therefore there is a risk that the technological gap between counties will grow.

5.2.5 Users will want to receive the right information at the right time. In order to achieve this, and in light of the volumes of data available, the geospatial computation required to do this will increasingly be non-human in nature. Accurate results will be generated automatically and provided directly to the end user. The earlier chapter on artificial intelligence explored this trend in more detail.

5.2.6 However, experience is uncompromising in showing that the geospatial community must understand its customers. In business, as in national security, faster and more informed decisions will give the edge over rivals and threats. This is not just achieved by technology but by intelligent skilled analysis by people who understand the decision-makers' problems, responsibilities, intent and time-pressures. It is not just about data and tools, these have limitations in gaining the edge over competition and threats, as they can use the same data and tools. Geospatial analysis is first and foremost about solving problems, not producing products.

5.3 Open-source

5.3.1 For the purposes of this section, open-source software can be defined as the provision of source code that is available at no cost and for use by anyone for any purpose[3]. The opposite of open-source software is proprietary software, where a user normally has to pay to access the software and abide by a number of restrictions in its use and distribution.

5.3.2 Community driven open-source software developments have matured over the last five years, and are being used by a growing number of government organisations. Private companies are increasingly focused on the technical support of open-source software.

5.3.3 Increased information and awareness of how open-source software can benefit organisations enables both organisations and governments to better understand their needs. This coupled with an understanding of requirements, for example different levels of security, means there is real choice between open-source and proprietary software.

5.3.4 The drive by some governments towards greater acceptance of open-source solutions has helped to remove many barriers to wider adoption of open-source software. Ready-to-play solutions, capable of operating in a micro-project environment will make it easier for different concepts to be showcased to senior decision-makers. Use of the Agile project methodology, which is an iterative and incremental method of managing the design and build activities for engineering, information technology, and new product or service development projects in a highly flexible and

[3] http://opensource.org/osd

interactive manner, is helping to drive down development times whilst increasing flexibility in delivering fit for purpose solutions.

5.3.5 Several National Mapping and Cadastral Authorities (NMCAs) have already adopted open-source solutions into some of their services, and these should be seen as examples of how open-source and proprietary software can work together for the benefit of the organisation and citizens.

5.3.6 As with any technology, significant education is required on the total cost of ownership of open-source technology. Whilst there is an upfront economic benefit from using open-source software – it may be free of charge – it can be expensive to customise and maintain and thus will depend on the community using the software, and the in-house knowledge of the user.

5.4 Open standards

5.4.1 The widespread and effective application of standards in many digital information fields is crucial not only for the continual effective use of internet based products and services but also the collaborations between different data organisations.

5.4.2 There are a number of organisations, both at national and international level, who are responsible for the development of standards for use in acquiring, implementing, maintaining and using geospatial information. At an international global level, these are led by the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO) in partnership with broader technology standards organisations to ensure interoperability.

5.4.3 Standards should be developed and adopted at a national or regional level of a country; failure to do so can lead to the inability to use data from multiple sources for particular decisions and prevent the data being used inter-operably regionally or globally.

5.4.4 Since the last Future Trends report was published, both OGC and ISO, in conjunction with the International Hydrographic Organisation (IHO), have worked closely with UN-GGIM to produce a standards guide, and a companion document[4][5]. These documents give an overview of the importance and availability of technical standards for the geospatial community. Although these documents have enabled governments to implement geospatial standards, work still needs to be undertaken to raise the awareness of geospatial standards, and their application to relevant policies.

5.4.5 Work continues at a global level with international geospatial standards, and a report on the initiatives by the international standards organisations on their continued collaborations, building on the previous standards guide and companion document, will be endorsed at the Fifth Session of the UN-GGIM Committee of Experts meeting in August 2015. The report includes case studies, the business value proposition, data capture, quality issues and related policies.

5.5 Trends in 'professional' data creation and maintenance

5.5.1 As well as the new themes identified at the beginning of the report, there are a number of trends that have been making steady progress over the last five years; this section explores some of the changes.

[4] http://ggim.un.org/docs/meetings/GGIM4/E-C20-2014-8_Essential%20Standards%20Guide%20for%20UNGGIM.pdf
[5] http://ggim.un.org/docs/meetings/GGIM4/E-C20-2014-8_Companion%20Document%20UNGGIM%20Essential%20Standards%20Guide.pdf

5.5.2 Since the last report there has been a breakthrough from 2D to 3D geospatial information, and this is becoming more prevalent. Developments in remote sensing have created opportunities to collect increasingly accurate 3D information about our environment. Software already exists to process this information, and to incorporate 'time information' to create 4D products and services. It is recognised that a growth area over the next five to ten years will be the use of 4D information in a wide variety of industries including: transport – including driverless car technologies, building construction – integration into Building Information Management (BIM), and environmental monitoring. The temporal element is crucial to a number of applications such as emergency service response, for simulations and analytics, and the tracking of moving objects.

5.5.3 The need to collaborate between different areas of specialism leads to an opportunity for public private partnerships to develop focused on delivering new and enterprising solutions. One example has been the development and effective adoption of BIM, the drawing together of different information sources, and using location to attach and link them together.

5.5.4 Developments in technologies and data models for 3D information and mapping needs to have the ability to link to the locations of citizens. This is important for a number of reasons including public safety or predictive modelling for national security or crisis management response. As well as moving towards the integrating of 4D information, another area of growth is likely to be in the area of predictive analysis – for example, possible future consequences mapped using predictive algorithms. This may focus on real time social-behavioural information.

5.5.5 Positioning and navigation in real-time to centimetre-level has been a real growth area, both in the indoor and outdoor areas. The mass market for systems based on accurate GPS and GNSS, integrated with other sensors, such as in driverless vehicles, continues to develop.

5.5.6 4D is particularly relevant in the context of real-time information; this has been linked to virtual reality technologies. Developments relating to virtual reality have been moving forward over the last five years, to a point where near-real-time virtual worlds can be created. The need to incorporate locational information within these virtual worlds is dependent on the use and function of the environments. It could be used for instance to monitor retail centres and to make discount offerings to potential customers as they pass particular shops, or to assist the spraying of crops in agriculture.

5.5.7 The trends highlighted above could be promoted and enhanced further through the publication of user case studies on the UN-GGIM Knowledge Base, this will allow others to discuss and explore different options available.

5.5.8 Imagery continues to develop at a steady pace. Greater coverage, quality and resolution has been achieved by the availability of both low-cost and affordable satellite systems, and unmanned aerial vehicles (UAVs). This has increased both the speed of collection and acquisition in remote areas, but also reduced the cost barriers of entry.

5.5.9 There has been a rapid uptake and use of UAVs and their related technologies in recent years. This increase has led to discussions around the tightening of security controls around the use of UAVs in several countries.

5.5.10 The use of UAVs for providing real-time information to decision-makers on the ground, providing for example information on disaster management, will increase as an invaluable tool when additional information is needed to improve vital decision making capabilities.

5.5.11 It is very likely that there will be a big trend towards the development of regulations for the use of UAVs for capturing remote sensed content, including greater privacy and security laws over the next five to ten years. How governments decide to regulate the use of UAVs will have significant implications for their use and their value. The role of UAVs and satellites is increasing but some fundamental information cannot be collected from an aerial image – addresses, for instance.

5.6 Positioning ourselves in the next five to ten years

5.6.1 One trend that was highlighted as an area for growth in the first edition of the report was geodesy and global positioning. This is an area that has seen significant progress over the last five years. One of the key drivers to this has been the creation of a UN Resolution on a Global Geodetic Reference Frame for Sustainable Development. This Resolution has been drafted by UN-GGIM and was adopted by the United Nations General Assembly in February 2015.

5.6.2 The Global Geodetic Reference Frame (GGRF) is a necessary tool to help address the growing demand for more precise positioning frameworks. It is also essential for effective decision making and a vital underpinning infrastructure which is applied in areas of natural hazard and disaster management, climate change and sea level monitoring, geospatial information, mapping and navigation by society at large every day.

5.6.3 The adoption of the Resolution is the first step in creating a common infrastructure to maintain and improve national geodetic frameworks. However key areas that still need addressing include the commitment to funding by governments, and the adherence to common standards and international obligations and coordinated policies.

5.6.4 In order to ensure long-term sustainability and optimal benefit from shared geodetic infrastructure, each participating government is strongly encouraged to maintain their portion of the network at the highest possible quality. At present, current participation in the development of geodetic infrastructure is on an all-volunteer best-efforts basis. Countries involved in, or benefiting from, the GGRF should make a formal commitment of support/participation at a mutually agreeable level.

5.6.5 Long term commitment of governmental support for developing and maintaining domestic infrastructure is critical to strengthening the value of any participating countries contribution to the GGRF, and crucial for the long-term sustainability of such a global asset.

5.6.6 Coupled with GGRF, positioning technology is evolving to a level that now enables the combination of geometric and gravimetric techniques for high-precision gravity measurements. Gravimeters utilising atomic interferometry can be used to bridge the gap between both space-based and terrestrial gravimetric instruments in order to obtain high-precision gravity measurements. Precise measurement of the gravity field enables numerous other geodetic observations, such as the determination of the earths' rotation.

5.6.7 An evenly distributed global network of standardised geodetic observatories equipped with the highest-precision clocks and gravimeters, alongside satellite based positioning and geometry will ensure continued progress in both technological development and support of secondary infrastructure worldwide.

5.6.8 Through a global effort, in the next five to ten years we are likely to have a seamless, durable, unified geodetic infrastructure on land, in the air and at sea, with uniform, global, referencing.

6 Legal and policy developments

6.1 Growing awareness within the GI community

6.1.1 Since the publication of the first version of the report, there have been several positive developments regarding legal and policy issues. This section highlights some of these new developments, and provides an update on some of the issues previously discussed.

6.1.2 One of the biggest developments in the area of legal and policy has been the growing awareness by the international community of the impact that laws and policies can have on the collection, use, storage and distribution of geospatial information. Both law-makers and policy-makers are beginning to understand the governmental, economic and societal benefits of geospatial information, this has led to the two communities starting to work together to make sure geospatial information can be developed while taking into account differences in legal and policy approaches.

6.1.3 As expanded on later in the report, the growing trend of governments, organisations and private citizens using unmanned aerial vehicles has led to problems with integrating the technology into their national airspaces. Those who have successfully integrated the technology are now faced with concerns over privacy and even national security.

6.1.4 A number of law makers and regulators have expressed privacy concerns regarding the collection and use of geospatial information in technologies such as mobile devices and intelligent transport systems. In many cases law makers are defining privacy differently for each emerging technology and applying different terms and conditions on the use of geospatial information. Because geospatial products and services cut across many different technology platforms and industry domains, organisations that wish to use geospatial information from different providers will need to understand and comply with each different set of regulations or laws, where they apply.

6.1.5 Awareness is growing within the geospatial community of the impact that laws and policies have on geospatial information and its management. However, the development of technologies continues to outpace the changes in the legal and policy frameworks. As a result, new products and services that collect and use geospatial information will face increasing resistance due to outdated, and in some cases inconsistent, legal and policy frameworks.

6.2 Funding in a changing world

6.2.1 The previous report noted that government and governmental bodies involved in the collection and management of geospatial information have traditionally been reliant on public money to fund their activities. On the whole this is a trend that has continued over the last 20 years or longer; the majority of countries still rely on funding from public appropriations.

6.2.2 Although other funding models exists, e.g. central government grants to organisations, and the growth of public private partnerships, convincing governments of the value of geospatial information, the benefits it brings and the need for sustainable funding, remains a challenge.

6.2.3 In response to funding pressures, there is a trend emerging towards data being produced "out of house", and many new business models are emerging that will include new processes and validation tools to integrate external data into the official databases. This recognises that authoritative data does not necessarily have to be produced by an official source; there are examples where some governments have moved from data collection and provision towards data facilitation and certification.

6.2.3 It is often left up to individual government departments, rather that the government as a whole, to demonstrate the value of geographic information as an indispensable part of the national infrastructure. This should not only underline the authority and accuracy of the data but also the defined quality, the long-term availability and the consistent maintenance, irrespective of commercial interests. In a marketplace that is increasingly dominated by regional platforms and international data providers, the challenge will be to receive sufficient funding to achieve these tasks.

6.2.4 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. In general, content is 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 cost of data collection, management and maintenance and securing the necessary funding to ensure this happens. This issue is accentuated by other sectors increasingly using and incorporating apparently "free" geospatial information into the solutions they provide.

6.2.5 Due to the high costs associated with the production of geospatial information it is important, when constructing business cases, to clarify the benefits from investment in geospatial information and state how geospatial information contributes to the development of society in all aspects.

6.2.6 In countries with less-developed mapping resources and National Spatial Data Infrastructures (NSDIs), relatively high 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 supporting other policy priorities increases.

6.2.7 Due to their many benefits, National Location Strategies and National Spatial Data Infrastructures have become more widespread and prevalent, and will continue to grow over the next five to ten years. Some of the benefits include the ability to make location data and processing services available to a wider customer base, in addition to creating proven return on investment cases.

6.2.8 Over the last five years, more case studies have emerged demonstrating the value of geospatial information to national development. As this awareness grows, it is likely that more governments will view accurate geospatial information as an essential building block of their country, and will see it as a necessary allocation of resources.

6.3 Open Data

6.3.1 The drive towards access to government-generated geospatial information free at the point of use has, and will, continue to develop. Economic models are likely to develop around open data, as was the case around the drive towards the use of open-source data. Such economic models may rely on governments pursuing an open data policy to make open data more accessible, more homogenous and more structured.

6.3.2 Governments may choose to provide information to their citizens free of charge either out of principle, because they believe in doing so will improve public life, or because they believe in doing so will stimulate economic growth. New technologies may continue to reduce costs; but there will continue to be costs associated with the creation, management and maintenance of the content.

6.3.3 More and more countries will adopt open data policies, in which the access to geospatial information will be realised as a national benefit. This trend towards growth can be seen in the increase of countries participating in the Open Government Partnership (OGP). Initially launched in 2011, the OGP has grown from 8 participating countries to 65 in 2015. In all of the OGP countries, governments and the civil societies are working together to develop and implement open data reforms.

6.3.4 It has become clearer over the past few years that the quality of open data, both governmental and crowdsourced, varies considerably in quality, completeness and consistency, particularly when it is assembled from many different sources. Even with organisations that are experienced in data supply, there can be variations in formats from one release to the next, often without prior warning, which causes difficulties to users.

6.3.5 Users increasingly rely on the accuracy and detail of geospatial information and use it as a base for decision making. Any degradation in quality will be noticed and will impact the decisions made, so the need to continually and reliably fund investments is a challenge for any government.

6.3.6 This has led to an emerging sector for businesses that merge, enhance, reformat, augment and provide other quality control processes on the raw open data – particularly when the source data is very raw – this allows the refined data to be sold, thereby funding the enhancement process. The costs to the data consumer are however generally far below that which would be charged to collect and manage the data from scratch.

6.3.7 Even though there has been a trend towards governments making data open, there is no universal definition of open data. This has led to the creation of many differing open data licenses around the world. Each of these different licences have different terms and conditions, making it very difficult to combine different datasets globally. If organisations are unable to easily combine open data from a variety of organisations, the potential benefits of open data may not be realised.

6.4 Licensing, pricing and data 'ownership'

6.4.1 The topic of licensing, pricing and data ownership continues to be of importance to both creators and users of data. As was reported in the first edition, the licensing of data in an increasingly online world is proving to be very challenging. There is a growth in organisations adopting simple machine-readable licences, but these have not resolved the issues to date. Emerging technologies like web services and the growth of Big Data solutions drawn from multiple sources will continue to create challenges for the licensing of data.

6.4.2 Data ownership issues will continue to evolve in the next five years. Historically intellectual property issues around geospatial information were relatively simple - the role of the data creator, processor and publisher were generally well defined. However the growth in the amount of data, the number of different actors in the data creation process, and the interconnectivity of these parties are likely to raise issues around data ownership. Some of these issues can be addressed through the effective use of metadata and adherence to international standards.

6.4.3 The on-going drive for cheaper access to information and the increasing richness of the information available means that the pressure to monitor and licence information at feature level, rather than at local, national or regional level will increase.

6.4.4 The lack of a multi-national legal or policy framework in place to deal with these issues will need to be considered. Data acquired in one country is likely to be processed in a secondary country by a corporate organisation domiciled in a third country. While the data itself is held 'in the cloud' – determining the legal framework, liabilities and warranties and so on will remain unclear without an attempt at a global accord. These issues are not unique to geospatial information.

6.5 Privacy

6.5.1 Concerns around location-based privacy have not been answered since the publication of the first edition of the report. In normal daily life, a person's location can be determined in many ways, for example through CCTV systems monitoring traffic flow, sharing information on social media, or using RFID enabled cards to enter buildings. With the increased ability to integrate data from different sources there is an increasing possibility of determining a person's location by the information they provide to different systems.

6.5.2 Concepts of what information should be kept private vary between cultures, age groups, interest groups and other demographics. They also evolve over time, sometimes quite quickly, as has been shown by the growth of social media sites where sharing personal information, including location, has become a feature, and in some cases an accepted norm.

6.5.3 In contrast to other aspects of geospatial information, cadastral data as part of the national land register is currently considered as personal data, although there are examples of open registries. Privacy and the well-defined procedures of the land register must be protected against duplication and corruption. The big differences between existing land registries and cadastral systems will ultimately prevent cross-border harmonisation.

6.5.4 Cybersecurity is a continual threat to privacy, where malevolent 'hackers' do not respect privacy policies. These policies are not just related to personal information, but also government and business information as well. Powerful encryption technologies and other security protection, both software and hardware, will increase in importance.

6.5.5 The issues described above are exacerbated when citizens move around the globe. In most cases the information they publish, and the means by which they do it remain the same, but the rights over the use of the data and the associated legal protections may radically change.

6.6 Liability and the issue of data assurance

6.6.1 Although National Mapping and Cadastral Authorities, like most other geospatial information providers, try to exclude formal warranties and liabilities, the data and services of NMCAs are considered reliable and trusted. Some of the reasons for this authoritative responsibility include professional competencies, tested quality assurance procedures and the absence of profit motives.

6.6.2 The issue of liability for the quality and accuracy of data has not developed in the way the previous report discussed, however the issues over quality and accuracy may drive a dividing line between crowd-sourced and government/commercial data.

6.7 Disparities between legal and policy frameworks

6.7.1 As mentioned above, legal and policy regimes differ significantly from country to country and between different regions, and will continue to do so in the coming years. The availability of global datasets may help to simplify the complexity of legal and policy issues.

6.7.2 There is still a major possibility that significant disparities will emerge over the next five years between countries where legal and policy frameworks have developed in line with technological changes and whose governments have developed frameworks to enable the growth of location or spatially-enabled societies, and those countries where such frameworks have not developed. Ensuring that this divide does not occur, or at least limiting its affects, represents one of the major challenges within the legal and policy environment in the future.

7 Skills requirements and training mechanisms

7.1 Skills for effective organisations

7.1.1 The understanding of skill requirements and training needs is a core component in ensuring the value of geospatial information is maximised. Early identification and action on these issues is vital, as there can be a long lead time in the development of appropriate capability and technical training. Demand is very likely to exceed the pace of development. Skills are not only needed in traditional geospatial roles, but also in geodesy, data collection and analysis. Capacity building of both producers and users of geospatial information will increase the culture of the discipline of geography as an established science. The closer and more involved governmental organisations are with academic institutions the greater the number of professionals with an understanding of the geospatial discipline will be trained adequately.

7.1.2 In many regions there is a lack of qualified personnel necessary to effectively manage and utilise geospatial information. In the next five to ten years the geographical location of software developers and data managers will become less important with many programming needs occurring remotely. This is reliant on understanding local needs and requirements to develop solutions that are fit for purpose.

7.1.3 Many of the critical issues where geospatial information can assist are found in developing nations. There is still a role for non-governmental organisations and development agencies to ensure that there is an effective skills base developed to promote a spatially-enabled society.

7.2 Extractive value from a world of data

7.2.1 Skills are required at three different levels, if we take a simplistic view they could be: the user, the policy- decision-maker and the geospatial specialist. The former requires general education to ensure all users have some understanding of how data and applications can benefit them in wide ranging circumstances, and also of the limitations; this also requires an understanding of the provenance of data and the value of an analysis or visualisation. The second usually depends on information provided by others, but needs an understanding of how data is processed and linked. The latter must also understand the environment in which they work, going beyond traditional geospatial information skills.

7.2.2 The geospatial specialist will have to bring assurances and certainty to solutions, driving a need for 'probability analyses' within the geospatial world where predictive analysis is taking place. As mentioned in the previous report, the number of experts who truly understand the inter-relationships between data models and data flows is still quite low in most database companies and government departments.

7.2.3 Data models continue to evolve to answer the range of questions and manage the increased volumes of data. The techniques and processes developed through Big Data analysis and AI will still need data experts who understand the complexities of linking geospatial and non-geospatial data with the ability to realise the potential benefits. This expertise will be spread across different sectors, computer science and mathematics, for example. Therefore appropriate education needs to be developed in conjunction with the academic sector.

7.2.4 In the future, it is likely that the traditional role of the geospatial analyst will be different from now; however the importance of geospatial information experts will not diminish, as data outputs will still need to be interpreted for policy- and decision-makers. These experts are becoming more comfortable with interpreting unstructured data, and will continue to find effective channels for communicating their results.

7.2.5 The development of robust open-source technologies has gained momentum over the last five years and increasingly sits alongside proprietary solutions. Software developers need to be comfortable in both environments, and specialisms in only one programming language will no longer be sufficient.

7.2.6 The skills requirements noted above will have a major impact on governmental organisations. 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, there is a need to empower and give the workforce the skills needed to deal with the technologies of the future. 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.

7.3 Education and Advocacy

7.3.1 Whilst there is a trend for more professionals without a geospatial background using geospatial data for decision making, these professionals have little or no understanding of the underlying principles of geospatial information. This leads to an increasing need for governments to incorporate experts in geospatial science in their high-level advisory groups.

7.3.2 Significant progress has been made towards educating policy- and decision-makers, planners and analysts at the highest levels in both governments and NGOs; this has enabled the value (economic, business and social) of geospatial data to be recognised. This continues to lead to better decision-making. The use of geospatial information in consumer applications has moved beyond simply displaying ‘points and colours’ on a map, to providing tools which allow users to create, manipulate and share data themselves. This is evidenced by the growing trend of health ‘apps’ where the user can upload cycling or walking routes.

7.3.4 A wider issue is the training and education of a broader community of developers and users of location-enabled content. At the same time there is a need for more automated approaches to ensuring the non-geospatial professional community get the right data at the right time.

7.3.5 Investment in formal training in the use of geospatial data and its implementation is still indispensable. Technical training schemes in specific areas of design, acquisition, production, processing and integration, will complement traditional academic offerings, although may not be at the undergraduate or graduate level.

7.3.6 Education is not only linked to formal training and development; several national mapping agencies including Great Britain, Denmark and Sweden have been developing and using their data to create models for the games industry. Based on topographic and geological data for use online outside of the traditional geospatial data field this information has a wider reach than traditional advocacy methods. Gamification is an area where geospatial data can be an important input when creating digital learning tools.

7.3.7 There is an opportunity to develop easily accessible educational tools and software materials for both research and education; this could be delivered through online training tools such as webinars and online courses, these can provide both general education as well as purposed instruction.

7.4 Investing in research and development

7.4.1 Investment in research and development in all sectors is vital to both the development of the skills required in the future, but also in order to ensure the potential benefits of emerging trends are realised.

7.4.2 Current research areas reflect many of the current and future trends that have been identified for the industry, including more effective and automatic processing of sensor data, the development of location-based applications and the integration of high volumes of unstructured data. As suggested in the earlier theme of AI, complex geospatial analysis questions are being asked, and answered, in a wide range of areas including relationships between objects, their properties and real-world locations. The benefits of these developments are being realised at an earlier stage, and are being put to use in a wide range of organisations.

7.4.3 A challenge that has been identified will be the adoption in developing countries of new technologies in such a way to decrease the technological gap. Many developing countries have an advantage due to the lack of legacy systems and technologies which restrict change; this will enable them to leapfrog some developed countries. This can be achieved through support from international agencies to develop programmes to promote research and development within these countries. Continuing to develop strong partnerships with standards organisations will also be crucial to ensuring research results can be used and deployed in different user environments.

8 The role of the private and non-governmental sectors

8.1 Making mapping accessible to the masses

8.1.1 The web, smart devices and the increase in spatially related services has ushered in an era where public users are not only consumers of geospatial information, but also act as producers of enriched geospatial data. Over the last five years, the ever increasing availability of smart devices and the ever expanding extent of communications networks, coupled with sensor-web enabled infrastructures (as discussed in the earlier chapter) means there has been a substantial increase in the use, and production, of geospatial data.

8.1.2 Beyond the previously limited public consumption of geospatial information, ubiquitous computing techniques provide the infrastructure for the public to produce, distribute and consume geospatial information. These concepts are viewed as seamless access from anywhere at any time, to easy-to-use geospatial information and services.

8.1.3 Available and accessible geospatial information provides an opportunity to improve the quality of life of citizens. The challenge is to ensure that geospatial information is available anywhere, at any time, whist respecting the principles of privacy, intellectual property and national security.

8.1.4 The reduction in the barriers to entry, the growth of the web and mobile mapping has massively increased the role of the private sector and the volunteer community over the last decade. Global brands and organisations have made digital mapping accessible to the masses.

8.2 The future role of the Private Sector

8.2.1 Historically the majority of location data was collected, maintained, and distributed by public sector bodies such as national mapping authorities. More recently private companies have played an increasing role as both data providers and service providers. High profile examples such as Google, with its Google Maps and Google Earth facilities, Microsoft, Apple, SAP, Nokia HERE, Facebook and Twitter all exist as global companies in the location space.

8.2.2 These big companies have a global perspective and can supply both data and services virtually anywhere in the world. Increasingly smaller SME companies are operating in the specialist, niche fields.

8.2.3 Despite the increased availability of spatial data, certain users will always require the use of authoritative data. A key challenge will be for users to be able to distinguish between, access and use, and ensure that they utilise the relevant data for specific uses.

8.2.4 As previously identified, if this trend towards location data being provided by private sector companies continues, there is a risk that the only unique attribute provided by public sector organisations could be the certification of data as authoritative. Given different working methods and resourcing strategies, even this role could come under threat from the private sector.

8.2.5 Increasingly important is the non-governmental organisation (NGO) sector. NGOs can, and do, offer systems and solutions to help governments and citizens when governments face shortfalls in funding – or where there is no defined business case for services. NGOs need to work collaboratively with other third sector foundations as they are increasingly working in the same area of geospatial information.

8.2.6 Cost and efficiency requirements may see many government departments outsourcing many processes to the private sector in the coming years. Much of the income generated by satellite and aerial imagery providers will continue to be sourced from governments and NGOs.

8.2.7 The geospatial industry has, and continues to, move rapidly up the value chain from data collection and provision to providing more comprehensive geospatial services, and extending their business models to provide customised analytical services. The ability to provide both government and commercial firms with deep analytic capabilities rather than just data provision has emerged as one of the potential key differentiators in the market today.

8.2.8 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, the private sector should place their focus.

8.2.9 The increasing amount of data created offers huge potential for the private sector to add value to existing geospatial information databases. The increasing role of private sector organisations in interpreting and analysing this information leads to enhanced services to consumers, businesses and governments. This is very likely to lead to more public-private partnerships (PPP). It may also lead to more direct commercial contracts, or licenced services, to governments and commercial users.

8.2.10 As recognised by the World Bank Group, PPPs combine the skills and resources of both the public and private sectors through sharing of risks and responsibilities. This enables governments to benefit from the expertise of the private sector, and allows them to focus on policy, planning and regulation by delegating day-to-day operations. To achieve this, the private sector will need to exploit its understanding of, and capability in, geospatial information to provide value back to governments. This will also open up markets and industries that have to date adopted geospatial information on a very limited basis.

8.3 The future role of VGI and crowdsourced geospatial data

8.3.1 Due to the massive increase in the use of geospatial information, volunteered geographic information (VGI) groups such as OpenStreetMap and WikiMaps have assisted towards popularising the collection of geospatial data. VGI can act as a valuable mechanism to encourage public participation and citizen engagement in geospatial information.

8.3.2 VGI can take various forms, one of which is commonly referred to as citizen science. In the environmental field, citizen science represents an important, relatively new way of monitoring environmental changes with the potential of implications for policy implementations. Tools to enable citizen science to take place in an orderly way have been developed, and new ways of obtaining VGI, verifying its validity, and managing content are constantly evolving.

8.3.3 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 data is currently available.

8.3.4 As well as generating data, VGI remains 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.

8.3.5 The concept of citizens' observatories, although not new, are now becoming more important. They provide a means for diverse communities of users to share technological solutions, information about products and services through appropriate communication networks including social media. A further benefit of VGI and of active crowdsourcing is as an educational tool; teaching citizens the value of geospatial information in daily life.

8.3.6 A benefit of citizen observatories is the engagement from the public in mapping processes. 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.

8.3.7 There is a common assumption that all VGI, and crowdsourced data, is open. In many cases this is not the case and there is a distinction between community-based-initiatives and private- or public-efforts supporting a professional organisation in cost-efficient data gathering. The latter, where many companies encourage their users to add and/or collect their own private data, requires a more open and collaborative attitude from both professional organisations and volunteers providing the data. Both 'open' and 'closed' VGI data play an important and necessary part of the wider data ecosystem. 'Closed' VGI data will not necessarily support published policy objectives.

8.3.8 The previous report suggested that whilst VGI brings with it many benefits, certain aspects mean that we are unlikely to see it erode the need for quality-assured and trusted geospatial information. Whilst in some areas VGI may provide an essential information source, its reliance on the voluntary contributions of a group of dedicated individuals, the lack of a quality assurance regime, and the absence of a regular maintenance regime, will not remove the need for a wide range of core, quality-assured, geospatial information.

8.3.9 Government organisations can, and do, work in partnership with active members of the VGI community. There are many examples of National Mapping and Cadastral Agency data being incorporated into volunteer mapping databases; changes to government licensing can enable further collaboration between governments and VGI communities. Currently it is perceived that there is a significant gap between authoritative and crowd-sourced data. This gap will reduce in the next five to ten years as collaborations between all organisations increase – this includes VGI incorporating government-sourced data and governments exploring ways to incorporate both passively- and actively-created user-generated data.

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

9.1 The impact of change

9.1.1 The World is moving towards more networked societies, where relationships are more fluid, less predictable and implicitly defined. These networks are characterised with both centralised and decentralised elements. In these networks, authority is based on organisations contributing to the network, it is “earned” credibility and trust, and it is “added value dialogues” with stakeholders. With an ecosystem like this, legitimacy becomes as important as legality.

9.1.2 Governments around the world are finding that funding for geospatial data collection is under pressure, and alternative non-government data sources are becoming more prevalent, reliable and sustainable. In effect, in some parts of the World some believe that governments are no longer the monopoly provider for many data sets. This, combined with the trend towards open data provision reduces the revenue generation provision for governments and leads to further financial pressures.

9.1.3 As mentioned earlier in the report, the public-private partnership will continue to develop, but essential roles for both the public and private organisations will continue to exist – this also applies to scientific organisations and NGOs. The focus of governments should be on providing citizen based services that are regularly provided by governments, whilst the private sector approach should continue to be commercially driven, user-centric.

9.1.4 These pressures are forcing governments to consider their roles as providers of reliable geospatial data. Governments, through the UN-GGIM Regional Committees, are considering what data themes should be considered “core data”; that is data the governments need to provide reliable content for, because of the critical importance for governments or the digital economy. This is leading to a shift in the role of governments from collection and provision to facilitation and certification of these core datasets.

9.1.5 Governments 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 challenges faced, and the changes made will vary from country to country.

9.2 Bridging the gap: coordination and collaboration

9.2.1 The next five to ten years is likely to see more collaboration between different sources, as a result the value of governmental information may be defined by the success of integration between multiple datasets, often perhaps socio-economically related, and geospatial information. The design of public policy will rely on evidence gathered from multiple sources of data.

9.2.2 As mentioned in the chapter on the role of VGI, additional data sources offer significant opportunities to enrich existing and future geospatial databases. As such, and combined with pressures to reduce costs, it will remain increasingly important for governments to facilitate coordination between all sources of information.

9.2.3 Finding new ways to join information into nationally recognised datasets is not only an issue for geospatial data. Key to the successful delivery of integrated data will be the development of standards and methods to assure the quality and fit of different information sources.

9.2.4 As well as the focus on linking geospatial and statistical information, there has been a growth in the interoperability and integration between marine geospatial information and broader hydrographic and topographic information. This development is of upmost importance to coastal and island states.

9.3 Marine geospatial information

9.3.1 The demand for marine geospatial information, for uses other than safety of navigation, is growing at high speed with regards to the blue economy, security of marine areas and emergency requirements for a wide range of users. Easy access, interoperability and integration between marine geospatial information, broader hydrographic information and topographic information in an e-government environment will develop to meet these growing needs.

9.3.2 Many countries already have an established National Spatial Data Infrastructure, or have initiatives in place to do so. The marine element is often less well developed, and there is a tendency to start building spatial data infrastructures on spatial products and not spatial data. The need for better integration of marine data is becoming increasingly apparent; this has led to some countries implementing the marine-oriented elements of the NSDI's at an accelerated rate.

9.3.3 Marine Spatial Data Infrastructures are expected to support activities such as coastal zone management, planning of energy production at sea, fishing, environmental protection of the marine environment and maritime spatial planning to name a few.

9.3.4 The development of hydrographic data models – such as the International Hydrographic Organization's Universal Hydrographic Data Model – will be a strong enabler of enhanced data sharing across a diverse range of purposes. Many hydrographic datasets have the potential to be used across a wide range of uses, the establishment of robust governance models and changes in organisational culture remain some of the biggest barriers to exploiting hydrographic data.

9.4 Developing a national geospatial information infrastructure

9.4.1 Increasingly, geospatial-related government decisions will require a robust geospatial information policy to be in place so as to plan, conduct and evaluate achievements of each project. Geospatial information (GI) projects could, under a single GI policy, be effectively managed by separate government agencies all working towards a common goal. The measurement and monitoring of a GI policy will enable governments to show the contribution of geospatial data and enables the identification of the value of geospatial information to decision-makers.

9.4.2 As well as being constructed using technical architecture, spatial data infrastructures need to be underpinned by a "social infrastructure", that is the conscious design of an environment that encourages a desired range of social behaviours leading towards a desired aim or set of aims. There is recognition that analysis of networks both within and across organisational boundaries provides a new way of understanding and developing collaborations beyond typical formal, hierarchical, organisational structures in which work is usually organised. Social architecture provides a means of understanding and implementation of information infrastructures.

9.4.3 There is a role for governments to consider and promote the existence of a spatial data infrastructure within each country. This should also include other relevant areas of knowledge, including national systems of geographical and statistical information, and should be supported by technical committees.

9.4.4 Effective governance alone is insufficient to steer information infrastructure initiatives. Efforts also need to focus on facilitating, encouraging and stimulating the community participation needed to move towards a common infrastructure framework. A broad range of activities must be coordinated in such a way that they become mutually reinforcing.

9.4.5 The exact role a government chooses to take will vary from country to country. However governments will have a key role in ensuring that comprehensive and robust frameworks are put in place with related policies, resources and structures which ensure that geospatial information is easily accessible to decision-makers in a coordinated way.

9.5 Maintaining an accurate, detailed and trusted geospatial information base

9.5.1 Over the time period since the last report, technologies have continued to develop, and the barriers to entry into the large-scale mapping environment reduced. There has been an increase in the number of private sector organisations competing in areas that have the potential for a high economic return. As a consequence, data may become cheaper in certain high-value areas, but in others it will therefore increase in price. This may lead to licensing by each feature on the landscape, rather than by geographical area, becoming more common.

9.5.2 Private sector providers will continue to need to justify all collection and maintenance based on a return on investment. The private sector will not recognise the Public Task that many public sector mapping organisations operate under; this could have the consequence of restricting sales for government in certain areas. If the government sector, operating under an open data mandate, switches away from certain geographies or attributes, there is a risk that the move towards open data could falter or even reverse.

9.5.3 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 equitable. With the continued growth in social media as a communication tool, governments will also have to communicate and demonstrate to an increasingly diverse audience the value and quality of government data.

9.5.4 A number of uses of geospatial information rely on the provision of information that is detailed, provided to a high level of specified information across an entire country, is trusted, and regularly maintained. Recognising the increase in value in data sources, a continuing role for National Mapping and Cadastral Authorities will be to define and maintain quality standards and data currency programmes for the data that is required by governments for their operation. Governments are still in a unique position to carry out this role, and to assess the levels of detail required to deliver such information.

9.5.5 In some nations governments, and their agencies whose main role is data collection, are likely to move towards incorporating consultancy services and the management of complete geospatial frameworks, into their mandates. Governments, in the role as authoritative suppliers of quality geospatial information, will become increasingly aware of the increased value of geospatial information for sustainable economic and social development.

9.5.6 The opening chapters of the report refer to the linking of geospatial information with statistical data. Governments will play a vital role in ensuring that frameworks are in place so that there are closer alignments between official bodies who supply data relating to statistics, the economy, and land. These frameworks will increasingly be involved in the cooperation and collaboration between different data providers and the management of geospatial information, to ensuring that the benefits of a spatially-enabled society are realised.

9.5.7 As mentioned above, the role of governments as an authoritative supplier of quality, detailed and accurate geospatial information, drawing together a wide range of valuable sources of information, will become increasingly crucial as the awareness of the value, and therefore the use, of geospatial information increases amongst decision-makers. End-users should be able to consume government-assured spatial data with a level of trust in its quality and provenance.

9.5.8 Geospatial information can provide an interesting opportunity to improve the quality of life of citizens; the challenge is to have the tools available to demonstrate its performance in economic, social and political spheres.

9.5.9 As highlighted by the video "Everything that happens, happens somewhere", produced by the UN-GGIM Secretariat, and available on the UN Department of Economic and Social Affairs (UNDESA) YouTube channel, geospatial information has a key role in delivering sustainable social and economic development across the globe. As economic and social issues, coupled with the adoption of the UN Sustainable Development Goals, continue to be increasingly cross-border in nature, we will see a growth in regional and global cooperation between governments, regional bodies and supranational agencies such as the UN.

List of contributors

We are grateful to all of the below who have contributed to this report either through providing a written submission or by taking part in the discussion forum during May 2015. 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 wishes to be recognised in the list in future publication versions to email James Norris at ftrends@os.uk.

Recognising the changing approach to consolidating the report, all UN Member States and observer States contributions are listed by UN naming conventions, rather than by individuals who submitted the report. The designation of any individuals relates to their position when they made the submission.

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