TITLE
Geospatial data in the UK

AUTHOR
Jozefowicz, Suzanne; Merlin, Stone; Aravopoulou, Eleni

JOURNAL
The Bottom Line

DATE DEPOSITED
30 September 2019

Geospatial data in the UK

Suzanne Jozefowicz (Incorvus Ltd), Merlin Stone and Eleni Aravopoulou (St Mary's University, Twickenham, London)

Purpose

The purpose of this article is to explain the rise of geospatial data, its importance for business, and some of the problems associated with its development and use.

Design/methodology/approach

The article reviews a certain amount of previously published literature, but is based mainly on analysis of the very large number of responses to a consultation paper on geospatial data published by the United Kingdom government.

Findings

The findings are that while there is strong appreciation of the potential benefits of using geospatial data, there are many barriers to the development, sharing and use of geospatial data, ranging from problems of incompatibility in data definitions and systems to regulatory issues. The implication for governments and for providers and users of geospatial data relate to the need to take a long-term approach to planning in resolving the issues identified.

Research limitations/implications

The research findings are limited to the United Kingdom, but similar findings would be likely in any other large Western country.

Practical implications

The article confirms the need for a strong and coherent approach to the planning of geospatial data and systems, for the establishment of a clear basis for the different parties to work together, and the need to clearly separate the roles of the government in establishing frameworks and standards and the role of the private sector in developing applications and solutions.

Social implications

Society is increasingly dependent on the use of geospatial data, in improving living standards and dealing with social problems. The recommendations identified in this paper, if followed, will facilitate these improvements.

Originality/value

The value of this article is the tight synthesis that it provides of a wide ranging and complex range of responses to the United Kingdom government consultation and placing these responses in the wider context of the development of geospatial data.

Keywords

Geospatial data, locations, big data, visualisation, standards, open data

What geospatial data is

There are various definitions of geospatial data. Different companies and organisations are comfortable with different definitions. For the purposes of this article, our broadest definition is "the digital version of location in three-dimensional space (from below the earth to in space) of anything that can be assigned an identifier (e.g. people, vehicles, roads, geographical features, boundaries, pipes and wires, transmitters) and over time (the fourth dimension)". The data many be anything from a quantification using any number of variables, to digital images of the data subject and the location in which it is situated or through which it is moving. A significant source of this data is volunteered geographic information, which is user-generated content collected mainly via social media (Sester *et al*., 2014), highlighting the new role of the 'crowd'.

Geospatial data informs the location (and/or relative location) of a data subject upon, below or above the earth. It is used for many applications: transport and mobility; measurement of pipeline throughput; powerline mapping; signal tower location; crime and border management; disaster and event management; security and military activities; power and water utility monitoring; tracking (anything from parcels to wildlife); marketing (including location-based); culture; care; health; natural resource usage and the environment.

The Geobuiz Geospatial Industry Outlook & Readiness Index 2019 explains that provision of geospatial data was classically associated with surveys and maps, but has since evolved into an industry composed of several technology segments, including geographic information systems, spatial analytics, satellite positioning and navigation systems, earth observation and scanning (Geospatial Media and Communications, 2019). These have been summarised well by Gray and Lawrence (2019).

Analysis of comparative or historical locational change is important to many users, whether it be over seconds or decades. The locational data for which many of us are individual customers is most commonly presented in map form. The difference between locational information and geospatial data is that the latter is the raw data, usually stored as co-ordinates of some kind. Locational information typically results indirectly from analysis or manipulation of raw data.

Geospatial data can be seen as just the latest increment of big data, data which is of such a volume that its analysis cannot feasibly or effectively be achieved using traditional techniques. The Internet of Things brings fresh data sources with every new smart device and concept e.g. delivery drones, smart buildings, and 'intelligent white goods' all of which contribute to the growing flows and archives of big data. As with big data, volume and variety are an issue, but geospatial data adds new elements such as geotagged data, changing velocity and locational images. These exacerbate existing problems of big data management (e.g. storage and analysis, indexing, transmission) and create further challenges, for example, those associated with recording velocity and periodicity, with tracking and with forecasting. The geospatial dimension adds significantly to data volumes and increases the percentage of data held by organisations that is not well understood, making its value hard to realise.

Common examples of generators of high volumes of geospatial data include moving sources, such as smart phones, drones and sensor devices attached to moving objects (transport or delivery), and static devices that report on the state of static machinery, the environment, people, objects or landmarks in the vicinity of the sensor or on throughput or flow past a particular point. These devices can create, transmit and, for example in the case of autonomous vehicles, receive an enormous variety of data, such as the location of nearby relevant objects, temperatures, wind, rain, sound, vibrations, images etc., with greatly varying degrees of accuracy, depending on user needs. Some data capture is "purposeful", i.e. captured for a specific predetermined purpose, but other data capture is "opportunistic", sometimes combining data from many different sources. Examples of the latter include use of information from smartphone use to estimate passenger volumes or road congestion, or the use of ticketing system data to estimate station congestion.

Combining the data

Geospatial data, like many kinds of data, becomes more powerful and valuable as different sources are combined. For example, mapping data shows the two-dimensional (2D) location of buildings; computer-aided design (CAD) data for engineering and construction, producing three-dimensional (3D) models showing, for example, the height and extent of buildings. Combined, the data can be used to plot flight and landing paths for delivery drones. Mobile phones show the location of drivers in their cars; weather data shows whether rain is falling; combined, they show the likely locations for accidents and the need to vary or reduce speed limits, based on weather factors that increase that probability. However, combining geospatial data is not as straightforward as with other structured data. It combines many different specialists' views of the definition of the data objects and, because it is resident on different systems, using different software and standards, it is difficult to process, aggregate or analyse. The issue is an important one for the public sector, which is the source of much of the raw data and the beneficiary of its use, but data stewardship has not generally been the public sector's forte. Different standards and regulations also apply to different datasets, so a combined dataset may be subject to overlapping standards and regulations, and possibly different regulatory authorities (UKGI Digital Land Team, 2018).

The problem

Many organisations may not be aware of the positional data they may already be collecting nor how they might derive useful information from it. The challenge is to provide organisations with a clear place to start, by evaluating what geospatial data they already have, or have access to, and what data they should get access to in order to meet their business objectives e.g. which datasets are critical to their business processes and when combined can add value.

Behind key challenges facing industry in its use of geospatial data lies the fear that government's desire for value from geospatial data will not be supported by the political will needed to make the required legal and other changes that remove legislative constraints. For example, the legislation that constrains agencies with major UK geospatial roles, such as Ordnance Survey (OS), is well over 100 years old. The Ordnance Survey Act dates from 1841 and was written with military intelligence in mind - the very antithesis of information-sharing. The OS's strong reputation means that it is often invoked as a source of topological authentication by individuals clarifying property boundaries. The OS works closely with the UK's Land Registry, which holds records of most building ownership in the UK. The Land Registry uses OS maps to draw up plans of ownership title to properties, and these title plans show legal boundaries (Ordnance Survey, 2019). However, both the Land Registry and the OS make it clear that the exact positions of legal boundaries are rarely shown on registered title plans or on OS maps, so the Land Registry does not have nor use precise geospatial coordinates to define property boundaries, sufficient to meet legal tests, Even if it did, these would not correlate with the OS's topological data. Those who advocate Government as a Platform or Platforms for Government may find that concepts based on the idea that the government knows exactly where things are may be disappointed until these legislative anachronisms and discontinuities are addressed. Even if some progress is made in that direction, technology may be used to defend the government estate rather than as an enabling force for openness (Thompson, 2015).

Recognising issues and opportunities

The value potential of geospatial data has triggered initiatives internationally e.g. the US Federal Geographic Data Committee (Federal Geographic Data Committee, 2019), the Singapore Geospatial Master Plan (Geospatial.SG, 2019), the EU Infrastructure for Spatial Information in Europe (European Commission, 2019) and the UK Geospatial Commission (Geospatial Commission, 2019), the subject of this article. In the UK, specific interest was generated by severe flooding in 2007 and 2013/4 (Centre for Ecology and Hydrology, 2016), with the damage exacerbated partly by failed flood probability models (mainly due to inadequate data sharing between government departments). Recognition of these problems led to the formation of the Natural Hazards Partnership (NHP, 2019).

Governments are excited by possible improved productivity from geospatial information and emerging geospatial technologies. However, governments are also bounded by rules which predate geospatial data and its use. In the UK, the scope of the Geospatial Commission set it above the partner organisations which had traditionally been the owners, guardians or creators of such data. Locational data, for example, is particularly appealing to financial services for customer analysis and risk profiling e.g. for insurance purposes. Car insurance already uses new data sets e.g. from car navigation systems. Driverless vehicles will greatly change this data landscape due to the vast amount of data generated and to the demands this will place on the supporting data infrastructure.

Making data available and visualisable

A particular problem faces architects and engineers in establishing relationships between 2D drawings and 3D models. How do they establish which 2D footprint relates to which 3D-model? Over 30 years old and still in use today, the Initial Graphics Exchange Specification (IGES) proprietary file format published in 1980 by the United Sates National Bureau of Standards was proposed as a way to exchange data across engineering disciplines. However, IGES only provides models for surfaces, with no information such as weight, volume or surface area, or any metadata or parametric information (Sattel, 2016). Builders, engineers, architects and planners tend to use a mix of CAD or geographical information systems (GIS). CAD data are usually stored in individual proprietary file types, while GIS data tend to be stored as structured data in files or relational databases. Many approaches to exchanging files across formats have been tried and failed, and those that are used can be three decades old (Sattel, 2016). Storing data from both CAD and GIS type systems in the same database is possible, but can lead to 'lumpiness' due to the contrasting densities of information. 'Lumpiness' in turn, creates performance challenges for infrastructure as processing speed is erratic depending upon the 'lump' of data being processed. This has consequences for contract performance targets and can erode customer confidence in geospatial throughput. (Richta, 2006).

Geospatial data from different sources needs to be assembled in one place for it to be analysed and visualised. Where the data comes from one non-human source and is used by another, standards are needed to ensure that the data can be used inter-operably. Access is increasingly via portals, but portals do not always manage the complexity of data sets well. Visualisation and making sense of data remain problematic (Cook *et al*., 2012; Hoffer, 2014; Frankel and Reid, 2008; Keim *et al*., 2013; Shneiderman, 2014). Visual analytics help humans interpret complex images (Choo and Park, 2013) but combining different data sets is difficult and displays can be over-complex. Human cognitive abilities for processing complex images are limited (e.g. Hegarty, 2011; Hegarty *et al*., 2012), so new approaches to display are needed, especially if the images are used to support real-time or near real-time decisions.

Ownership of data

The variety of sources of geospatial data is enormous and growing fast, as new ways of implanting sensors and smartening activities and assets evolve. This raises real questions concerning the ownership of the data, not just for privacy reasons, but in terms of who benefits, as work on smart city data has emphasised (Stone *et al*., 2018).

Those who own the data though may not be able to make the business case for digitisation to provide datasets that are to a standard suitable for licensed use by others. To this end, in April 2019, the Geospatial Commission and its partner bodies announced a new single Data Exploration Licence to harmonise and simplify access and use of geospatial data. According to the UKGI Digital Land Team (2018), the Data Exploration Licence means that anyone can now freely access data held by the British Geological Survey, Coal Authority, HM Land Registry, the OS and the UK Hydrographic Office, for research, development and innovation purposes but critically, under one licence with a single set of terms, replacing the previous plethora of licenses issued individually by each agency (the OS, HM Land Registry, UK Hydrographic Office, the British Geological Society, and the Valuation Office Agency).

This is a big step forward, providing it applies to the full extent of MasterMap (the OS's definitive source of very-detailed geographic data, which is offered in layers – topographic, imagery, networks and other geospatial data) and does not, for instance, omit valuable elements such as polygons, which describe area (as opposed to coordinates). As an anonymous contributor wrote in replying to the Geospatial Commission's Call for Evidence: "… opportunities must be driven by the private sector and all that is required is freely available access to the widest set of raw information possessed by all organs of government." (Geospatial Commission, 2018).

The evolving UK geospatial data ecosystem

There are many "central" stakeholders in the evolution of the UK ecosystem for geospatial data – indeed, it might be simpler to identify who is not a geospatial data stakeholder! Possible public, private and NGO providers and users of geospatial data are identified as below. The categorisation has been developed by the authors.

Mapping, data and systems organisations

- The OS (MasterMap)
- United Kingdom Hydrographic Office
- Admiralty Maritime Data Solutions
- Meteorological Office
- The British Geological Society
- Open Data Institute
- Open Geospatial Consortium

Property, land management and taxation authorities

- Environment Agency
- Land Registry
- Treasury
- The Valuation Office Agency
- The Coal Authority
- Ministry for Housing, Communities and Local Government
- Revenue and Customs
- Digital Framework Task Group (part of Centre for Digital Built Britain)

Public internationally-focused bodies

- The Department for International Development
- The Department for International Trade
- The Foreign and Commonwealth Office

Security and Law Enforcement

- Ministry of Defence
- Armed forces
- Ministry of Justice
- Police, fire and ambulance services

Transport, environment and space

- The Department for Transport
- UK Space Agency (Earth Observation and role of LandSat and Copernicus satellites)
- National Infrastructure Commission
- Royal Geographic Society
- The Marine Management Organisation
- Local government and town planning authorities

Other government ministries

- The Department for Business, Energy & Industrial Strategy
- The Department for Digital, Culture, Media & Sport;
- The Department for the Environment, Food & Rural Affairs;
- Government Digital Service
- UK Government Investments
- The Cabinet Office (Government Property Agency and the Government Estate)
- The National Health Service and various health-focused agencies such as Public Health England
- Office of National Statistics and census
- Records Office

Information technology industry and associations

- Hosters of data and value-added services providers
- Software developers and maintainers
- Mapping companies
- Land owners, developers and vendors
- Property developers and estate agents
- British Association of Remote Sensing Companies
- Association for Geographic Information

Land owners, developers and users

- Construction and property companies
- Individual property owners
- Land, sea and air transport companies (e.g. stations and airport owners, carriers), transport equipment providers, constructors, maintainers and regulators
- Power, water and sewage utilities and telecommunications companies
- Retailers
- Agricultural businesses and organisations
- Oil industry
- Environmental, health care etc. charities
- Heritage organisations – Historic England, National Trust etc.

The professions and universities

- Engineering
- Information technology
- Marketing
- Legal profession, including property conveyancing for sale or rental
- Property surveying
- University researchers and teachers

Financial services

- Insurance and reinsurance
- Banking
- Asset management

The UK call for evidence

The UK Geospatial Commission

The UK Government established the Geospatial Commission in April 2018 to ensure that the UK was equipped to capitalise on the economic opportunity presented by using geospatial data and technologies, mainly through support, investment and bringing together and helping develop the location data of public sector organisations. Its main public sector partners are:

- The British Geological Survey, the UK's main centre for geoscience information and expertise.
- The Coal Authority, which manages many social, economic and environmental aspects resulting from historical mining in Great Britain.
- HM Land Registry, which holds the state register of ownership, interests, and mortgages and other secured loans against land and property in England and Wales. It contains over 25 million titles giving ownership evidence for over 85% of the land area of England and Wales.
- The OS, Great Britain's national mapping agency.
- The UK Hydrographic Office, which provides marine geospatial data and services.
- The Valuation Office Agency, which provides property valuations for taxation and benefits purposes.

The questions

The consultation questions covered areas such as:

- The definition of geospatial data;
- Geospatial skills required and skills gaps;
- Prioritisation of datasets (from infrastructure to applied datasets), whether/where public sector organisations should focus investments;
- Technology and ecosystem requirements and technology developments based on geospatial data;
- The relative roles of public and private sectors, how local government can help and benefit, and the role of the Commission itself;
- Current challenges in working with public geospatial data, and technology/standards required to facilitate this;
- Additional datasets available, use cases and access requirements;
- Innovations that will rely on geospatial data and associated regulatory issues;
- How the UK can position itself globally in this area, which other countries are considered exemplars, and international sources of best practice.

The responding organisations

The call attracted over 200 responses, including:

- Aerospace companies;
- Consultancies, including IT consultants, data specialists, niche geospatial technology companies and start-ups specialising in the application of geospatial or emerging technologies;
- Emergency services;
- Civil engineering, construction, housing and property organisations and companies;
- Data agencies and organisations;
- Financial services companies;
- Biological, forestry, geographical, geological, marine and weather organisations;
- Historical and environmental organisations and agencies;
- Local authorities;
- Management consultancies;
- Mapping companies and organisations;
- Oil companies and organisations;
- Private individuals;
- Property organisations;
- Retailers;
- Standards organisations;

- Telecommunications companies;
- Transport organisations;
- Universities.

The responses

Volume of responses

The responses amounted to 2300 pages. In this article we summarise the main issues raised by the respondents. The process of gathering responses did not follow market research rules, but the breadth of respondents and the experiential depth of responses demonstrates a broad consensus, as well as highlighting important points that the Commission should address. Our summary excludes only the positioning of the UK relative to international developments, which may be covered in a later article, as it requires substantial additional analysis.

What data should be included and how should it be provided?

- The data to be produced and hosted should be determined by public and private sector stakeholders working together, and should include a much wider set than currently available, including geo-locational information from: body-worn and asset-based sensors; mobile telephony devices; social media; news feeds; climate and weather modelling and forecasts; tides; magnetic fields; ground state; charging-point locations; access places; social care (e.g. vulnerable occupants); health; dangerous buildings or areas of construction;
- Provenance must record the different steps in the data value chain e.g. accurate translations between map reference coordinates and postal address codes (which may need to be in different languages and include local dialects);
- The data must include any precise actual or implied restrictions or boundaries and planned installations: access; survey needs; ecological, safety, flood and erosion risk; presence of old mines, wires, ducts, pipes and water courses; flight corridors; and geo-fencing for marketing and other applications;
- Information accuracy is critical, especially at scale, where combined tiny inaccuracies can produce significant problems, for example, heights and topologies of buildings in relation to autonomous vehicle routes and drone flight paths. Consumer acceptance of approximate locations is no respecter of commercial requirements or utilities installations standards and tolerances;
- Combination of datasets and including the right datasets are both critical;
- The dimensional nature of the data is important for many stakeholders, regarding application underground, in the air and over time, with time being a critical requirement for moving assets but also for monitoring fixed assets e.g. previous owners and locations (geo-history). In addition, different sources are likely to have very different periodicity frequencies – some may be in micro-seconds, others quarterly or annual or less frequent, which presents challenges during pre-analysis aggregation;
- Indoor contextual data should be included e.g. the positions of individuals and assets in mines, transport locations, shopping centres, big public buildings or their own homes - for uses ranging from emergency planning to customer services. Integrating indoor and outdoor data will be essential as indoor data moves beyond Wi-Fi routers and cellular base stations to include other beacons, sensors, broadband and even magnetic fields as sources of positioning data.

What should the Commission do support the provision of information?

- The need to balance efforts between stewarding and connecting existing data (including: the encouraged or enforced use of agreed standards; creating single or tightly integrated points of access with simplified terms of access; building partnerships and stimulating ecosystem development, ensuring quality, accuracy and usability – especially via mobile devices; ensuring that public sector bodies make data updates available promptly (e.g. by construction work) while encouraging, facilitating and optimising its innovative use by portals, cloud hosting etc.; encouraging the production and use of new data sets and (where necessary because the entities responsible are publicly owned) developing new public sector data sets;
- The need to co-ordinate "government as a customer", ensuring that different public sector bodies act as responsible and aligned stakeholders in the development of geospatial information, by identifying geospatial data needs in relevant government departments and agencies; consolidating them; identifying duplication or overlap; ensuring requirements are visible to industry (goes to investment and technology planning); coordinating

government procurement; guiding tendering for 'geospatial information as a service' (goes to relevant contract lengths, data longevity, standard, operational service level and quality criteria);

- The need to ensure infrastructures are designed and operated to meet private sector operational service standards for big-data infrastructures;
- The focus should not just be on geospatial data products but also on consequent services (e.g. monitoring and alert services);
- Private sector respondents nearly all stated that the government should not be involved in developing applications and services but should encourage their private sector development through open data, standards, and commissioning;
- Because UK public sector organisations invest in their own infrastructure to maintain their geospatial data sets this has given rise to inconsistent formats, standards, accessibility, licensing etc. The UK Open Data policy requires the public sector to make all non-personal data openly available, but public sector organisations are all at different stages of implementing this. This makes it hard for others (industry, academia or different government bodies) to access or even discover what data is available and where. Similarly, for UK stakeholders to exploit the dataset synergies, commonality of approach is needed to access and interrogate geospatial data: common standards, formats, interfaces, licences and data policies;
- The most advanced public sectors usage includes military application where advances could be made by brokering contacts and project experience;
- A common theme was that the government on removing or transcending legislative barriers, and free up, rather than try to nurse the geospatial market directly.

How should the data be provided and managed?

- Data should be made available freely, in a consistent and accessible format (to agreed geographical information system standards) via channels (mobile, web services, open data stores) under simple licensing arrangements which encourage, rather than discourage, use. The respondents were mostly well aware of the risks and rewards of the open data approach (see Johnson *et al*., 2017) - risks relate to privacy and security, rewards to big improvements in services and access to them (as demonstrated in the UK by Uber, Transport for London and City Mapper (Stone and Aravopoulou, 2018). The cost of the absence of this approach is visible in poor services e.g. health, government;
- Open source software should be used wherever possible rather than proprietary/commercial software;
- The move to the use of digital twins to manage assets (to understand how assets interact with each other and the environment) would demand high accuracy and real-time updates;
- Machine-readability is vital (as most data will be transferred between machines) so standards are key;
- Visualisation is essential for decision-making and modelling, so augmented reality and virtual/immersive approaches are needed, taking into account, for example, a device's direction of movement, height and sensing-direction;
- Security, performance and audit requirements may determine the appropriateness of approaches such as blockchain (already in use in some applications);
- A cloud-based approach facilitates data discovery and access for commercial uses, especially for near-real-time or frequently changing data but also, at least in the public sector, may be viewed with some security reservations;
- The privacy and trust aspects of data, including the importance of anonymity, must be understood, as often data protection regulation is used as an excuse not to release data when no personal data is included. The Information Commissioner's sandbox should be the place to test new services;
- All data should have appropriate and full metadata and licensing information, so users understand what data is available, of what quality and scope, and the terms under which it is available;
- Services are needed to alert users when they are using information of different precision/quality especially where these may have security or safety implications;
- Algorithms used for interpretation, inference and decision-making should be transparent. This may be a matter of some discussion though as the private sector will be reluctant to release such intellectual property;
- Strong data governance (including audit trails of how existing and newly acquired data, particularly personal data, is used) is needed: to ensure transparency and security; to maintain focus on data quality and management; and to create a strong sense of ownership and accountability for the acquisition and maintenance of data at all levels.

What skills are needed?

With larger datasets and more complex analysis required to get the best out of geospatial data, people entering the field need to have a stronger programming background than traditional geospatial training currently gives them, as well as geospatial understanding and disciplines. A shortage of skills is developing in this area. This includes:

- High level programming capabilities, especially combined with geospatial-specific skills and knowledge;
- Geospatial data scientists (with geospatial data processing and applications development expertise and technical understanding of how and what should integrate existing geospatial data and capabilities across systems);
- Earth observation data analysts/data scientists and data processing engineers applying artificial intelligence to geospatial data;
- Developers of geospatial applications for mobile and web;
- Geographical information system (GIS) experts;
- Remote sensing specialists;
- Big data analytics and application of machine learning skills;
- Cloud computing skills.

Skills and resources cited as being in short supply include experience with commercial and open source software products; analytics packages for data analysis, discovery and presentation; experience of fundamental extract-transform-load tools and the analytics, modelling and other skills needed to use them (including more specific visualisation and cartographic skills); awareness of geospatial data sets; and experience of using Application Programming Interfaces to access map libraries or geographic data. As the use of geospatial data grows, it will create other shortages in data skills, information architectures and infrastructural capability.

What education is needed?

Universities should develop courses on geospatial data engineering, software development and management. The main users are developing approaches to applying geospatial data to their operations but need more generally educated candidates as above. Specific mention was made of geography as a subject and the need to include the geospatial data element in syllabuses and professional qualifications. Several respondents argued for creating geospatial data awareness in schools so that students become interested and choose careers involving geospatial data.

As per Kolding *et al*. (2018), the mix of technical and more general skills is critical to the productive use of information technology, and this area is no exception. In many cases, using geospatial data will lead to new ways of doing business, new customer relationships and supply chains, and changing approaches to management. This will require more general consulting and communication skills, as well as geographical, locational or spatially specific skills. Relationships between the Open Source and developer community, the Open Data Institute and peer networking (via conferences and other network events) will become increasingly important.

Other skills and data knowledge required include those that allow geospatial data to be used: statistics, data science, earth observation data, artificial intelligence, deep learning and image recognition. There is some concern that spatial data management attracts lower salaries than other areas of the data profession.

Conclusions

It is clear from the responses that geospatial information provision is at a very early stage relative to what is possible, so it is not easy to predict how this will evolve. In the public sector much depends on government budgets, regulation and commitment. In the private sector it is likely that when a dataset (alone or in combination) allows any of the giant platform providers to make profit (directly or indirectly), they will mount the data in their cloud and encourage the development of an app ecosystem around it.

The keys to progress is to put data first: building insight from information and its governance. For geospatial benefits to take off, government (and business) can no longer divorce location from other data dimensions and will need to invest in its geospatial data assets. Failure to curate, maintain, standardise, describe, integrate and generally manage geospatial (as well as other) data will dilute its commercial benefits as it will fail the tests of interoperability, dimensionality, accuracy, aggregation and usability. Here, government holds three keys:

- Making available, without limit, the entirety of public geospatial data;

- Removing legislative barriers;
- Ensuring that related datasets, such as the Postal Address File, are correlated accurately with publicly held datasets to a level of precision requisite to a digital economy.

Agenda for future research

A technical research agenda has already been published (Li *et al.*, 2017), including the need to focus on spatial indexing and algorithms for real-time and streaming data and to move from descriptive to causal and explanatory relationships, display and visualization. In terms of management issues, many issues are those that confronted previous new sets of data, such as customer data, where identifying and propagating good practice proved to be the central requirement (Stone *et al*., 2019). The difference is the possible breadth and depth of the user base, within and across organisations, so in this respect it is part of the general big data problem. More research is also needed into the interaction between government and the private sector in this and similar new data areas, and into the link between these developments and the idea of government as a platform (Fishenden and Thompson, 2012).

References

Centre for Ecology and Hydrology. (2016), “Man-made climate change helped cause 2013/14 UK floods”, available at: https://www.ceh.ac.uk/news-and-media/news/man-made-climate-change-helped-cause-201314-uk-floods (accessed 3 September 2019).

Cook, K., Grinstein, G., Whiting, M., Cooper, M., Havig, P. and Liggett, K. (2012), “VAST challenge 2012: visual analytics for big data”, in *Proceedings of the 2012 IEEE Conference on Visual Analytics Science and Technology (VAST) in Seattle, USA*, pp. 251–255.

Choo, J. and Park, H. (2013), “Customizing computational methods for visual analytics with big data”, *IEEE Computer Graphics and Applications*, Vol. 33 No. 4, pp. 22-28.

European Commission. (2019), available at: https://inspire.ec.europa.eu/ (accessed 3 September 2019).

Evans, M.R., Oliver, D., Zhou, X. and Shekhar, S. (2014), “Spatial big data: case studies on volume, velocity, and variety”, in Karimi, H.A. (Ed.), *Big Data: Techniques and Technologies in Geoinformatics*, CRC Press, pp. 149-176.

Federal Geographic Data Committee. (2019), available at: https://www.fgdc.gov (accessed 3 September 2019).

Fishenden, J. and Thompson, M. (2012), “Digital government, open architecture, and innovation: why public sector IT will never be the same again”, *Journal of Public Administration Research and Theory*, Vol. 23 No. 4, pp. 977-1004.

Fitzner, D., Sester, M., Haberlandt, U. and Rabiei, E. (2013), “Rainfall estimation with a geosensor network of cars – theoretical considerations and first results”, *Photogr.-Fernerkundung-Geoinformation*, Vol. 2013 No. 2, pp. 93-103.

Frankel, F., Reid, R. (2008), “Big data: distilling meaning from data*”, Nature, Vol.* 455 No. 7209, p. 30.

Geospatial Commission. (2018), “Call for Evidence - Submitted Responses”, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/804285/CfeEresponses1.pdf (accessed 1 September 2019).

Geospatial Commission. (2019), available at: https://www.gov.uk/government/organisations/geospatial-commission (accessed 1 September 2019).

Geospatial.SG. (2019), available at: https://geospatial.sg/ (accessed 3 September 2019).

Geospatial Media and Communications. (2019), “GeoBuiz 2019 Report”, available at: https://geobuiz.com/geobuiz-report-2019/ (accessed 1 September 2019).

Gray, P. and Lawrence, H. (2019), “Future technologies review: How new technologies will shape the future of the UK’s geospatial sector”, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/827507/Final_Version_-_Future_Technologies_Review.pdf (accessed 1 September 2019).

Hegarty, M. (2011), “The cognitive science of visual-spatial displays: implications for design”, *Topics in cognitive science*, Vol. 3 No. 3, pp. 446-474.

Hegarty, M., Smallman, H.S., Stull, A.T. (2012), "Choosing and using geospatial displays: effects of design on performance and metacognition", *Journal of Experimental Psychology: Applied*, Vol. 18 No. 1, pp. 1-17.

Hoffer, D. (2014), "What Does Big Data Look Like? Visualisation is Key for Humans", available at: https://www.wired.com/insights/2014/01/big-data-look-like-visualization-key-humans/ (accessed 1 September 2019).

Johnson, P.A., Sieber, R., Scassa, T., Stephens, M. and Robinson, P. (2017), "The cost (s) of geospatial open data", *Transactions in GIS*, Vol. 21 No. 3, pp. 434-445.

Keim, D., Qu, H. and Ma, K.-L. (2013), "Big-data visualization", *IEEE* Computer Graphics *and* Applications, Vol. 33 No. 4, pp. 20-21.

Kolding, M., Sundblad, M., Alexa, J., Stone, M., Aravopoulou, E. and Evans, G. (2018), "Information management – a skills gap?", *The Bottom Line,* Vol. 31 No. 3-4, pp. 170-190.

Li, S., Dragicevic, S., Castro, F.A., Sester, M., Winter, S., Coltekin, A., Pettit, C., Jiang, B., Haworth, J., Stein, A. and Cheng, T. (2016), "Geospatial big data handling theory and methods: A review and research challenges", *ISPRS journal of Photogrammetry and Remote Sensing*, available at: doi:10.1016/j.isprsjprs.2015.10.012 (accessed 1 September 2019)..

Morais, C.D. (2012), "Where is the Phrase ''80% of Data is Geographic" From?", available at: http://www.gislounge.com/80-percent-data-is-geographic/ (accessed 1 September 2019).

NHP. (2019), available at: http://www.naturalhazardspartnership.org.uk/about-us/working-together/ (accessed 1 September 2019).

Ordnance Survey (2019). "Property boundary maps*",* available at: https://www.ordnancesurvey.co.uk/resources/property-boundaries-owners.html (accessed 1 September 2019).

Richta, T. (2006), "Issues of GIS data management", *Geinformatics FCE CTU,* Vol 1, pp. 56-63.

Riebeek, H. (2015), "Big Data Helps Scientists Dig Deeper", available at: http://earthobservatory.nasa.gov/Features/LandsatBigData/ (accessed 1 September 2019).

Sattel, S. (2016), "The Complete History of Failed ECAD-MCAD Exchange File Formats", available at: https://www.autodesk.com/products/eagle/blog/complete-history-failed-ecad-mcad-exchange-file-formats/ (accessed 1 September 2019).

Sester, M., Arsanjani, J.J., Klammer, R., Burghardt, D. and Haunert, J.-H. (2014), "Integrating and Generalising Volunteered Geographic Information", in A*bstracting Geographic Information in a Data Rich World – Methodologies and Applications of Map Generalisation,* Springer, Heidelberg, pp. 119–155.

Stone, M., Laughlin, P., Aravopoulou, E., Gerardi, G., Todeva, E. and Weinzierl, L. (2017), "How platforms are transforming customer information management", *The Bottom Line*, Vol. 30 No. 3, pp. 216-235.

Stone, M., Woodcock., N, Ekinci, Y., Aravopoulou, E. and Parnell, B. (2019), "SCHEMA: Information on marketing and customer management performance – reality versus dreams", *The Bottom Line, Vol.* 32 No. 1, pp. 98-116.

Stone, M**.** and Aravopoulou, E. (2018), "Improving journeys by opening data: the case of Transport for London", *The Bottom Line*, Vol. 31 No. 1, pp. 2-15.

Stone, M., Knapper, J., Evans, G. and Aravopoulou, E. (2018), "Information management in the smart city", *The Bottom Line*, Vol. 31 No. 3/4), pp.234-249.

Thompson, M. (2015), "Government as a platform, or a platform for government? Which are we getting?" available at: https://www.computerweekly.com/opinion/Government-as-a-platform-or-a-platform-for-government-Which-are-we-getting (accessed 1 September 2019).

UKGI Digital Land Team. (2018), “Location, location, location – tapping the economic potential of geospatial data”, available at: https://quarterly.blog.gov.uk/2018/03/28/location-location-location-tapping-the-economic-potential-of-geospatial-data/ (accessed 1 September 2019).

Wright, L. T., Robin, R., Stone, M. and Aravopoulou, E. (2019), “Adoption of Big Data Technology for Innovation in B2B Marketing”, *Journal of Business to Business Marketing,* available at: doi: 10.1080/1051712X.2019.1611082 (accessed 1 September 2019).