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CANADIAN GEOSPATIAL DATA INFRASTRUCTURE

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Canadian geomatics environmental scan findings report

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Canadian geomatics environmental scan findings report

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Executive Summary

Introduction

This report consolidates the findings of the Canadian geomatics environmental scan from all lines of enquiry for this part of the overall *Canadian geomatics environmental scan and value study*. The study was motivated by growing concerns about the lack of understanding of the geomatics sector's role and contribution to the Canadian economy and society, and the future of the sector in a period of rapid transformation of the market for geospatial information (GI) products and services. On the encouragement of the Canadian Geomatics Community Round Table[1], Natural Resources Canada undertook the study, in part to support the development of a Pan-Canadian Geomatics Strategy[2].

This part of the study developed a current profile of the geomatics sector in Canada, including the industry, government and academia components and the challenges and opportunities faced by each, examined the domestic and international markets for GI products and services and the trends and drivers of growth in the market, and explored the labour market supply and demand characteristics. The overall picture that emerged is of a market in a state of transformation and a sector that is rapidly evolving to capture the many opportunities that the significant market changes are presenting.

A number of factors have contributed to an explosion in the use of GI and the transformative changes in the nature of the GI market. Since the beginning of the modern digital GI period, which can be traced back to the development of the first GIS by Canadian Dr. Roger Tomlinson in 1963, the widespread adoption of global positioning systems (GPS) technologies, the increasing access to a wealth of high quality earth observation data, the emergence and rapid acceptance by both businesses and consumers of web mapping applications developed by the so-called Mass Market Geomatics providers (e.g., Google Maps, Mapquest and Microsoft Bing), and the proliferation of powerful, location-enabled mobile computing devices have combined to usher in a new era in geospatial information and technologies use.

Key implications for the sector include:

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[1] The Canadian Geomatics Community Round Table (CGCRT) is an open and collaborative group, made up of representatives from industry, academia, professional associations, NGOs and federal, provincial and territorial governments, spanning the geomatics (geographic, geospatial, location information) domain. This group is examining issues facing the Canadian geomatics community and developing a strategy to position the sector for future success.

[2] The Pan-Canadian Geomatics Strategy was developed by the CGCRT to better meet the needs of and enable the ever-growing Geospatial Community that depends on reliable, accurate and fit-for-purpose geospatial products, services and expertise.

- Growth potential is much more significant in GI use by 'generalists' (i.e., people with limited formal education or training in the use of geospatial information and technologies) than 'specialists' (i.e., people whose education and training background includes GI specialization).
- Demand is growing for hosted solutions and integrated data and software applications that are easy to use with minimal training.
- GI providers need to decide whether to develop the capacity to deliver their own integrated solutions or become a specialized part of a solutions value chain along with other partners.
- GI providers need to consider changing their business model, from a project-related income stream to a service-related model suited to medium- to long-term business relationships with clients.
- Geomatics educators need to adapt their curricula to the market changes and increased cross-disciplinary education is needed to better equip generalists with knowledge of basic geospatial concepts and principles.

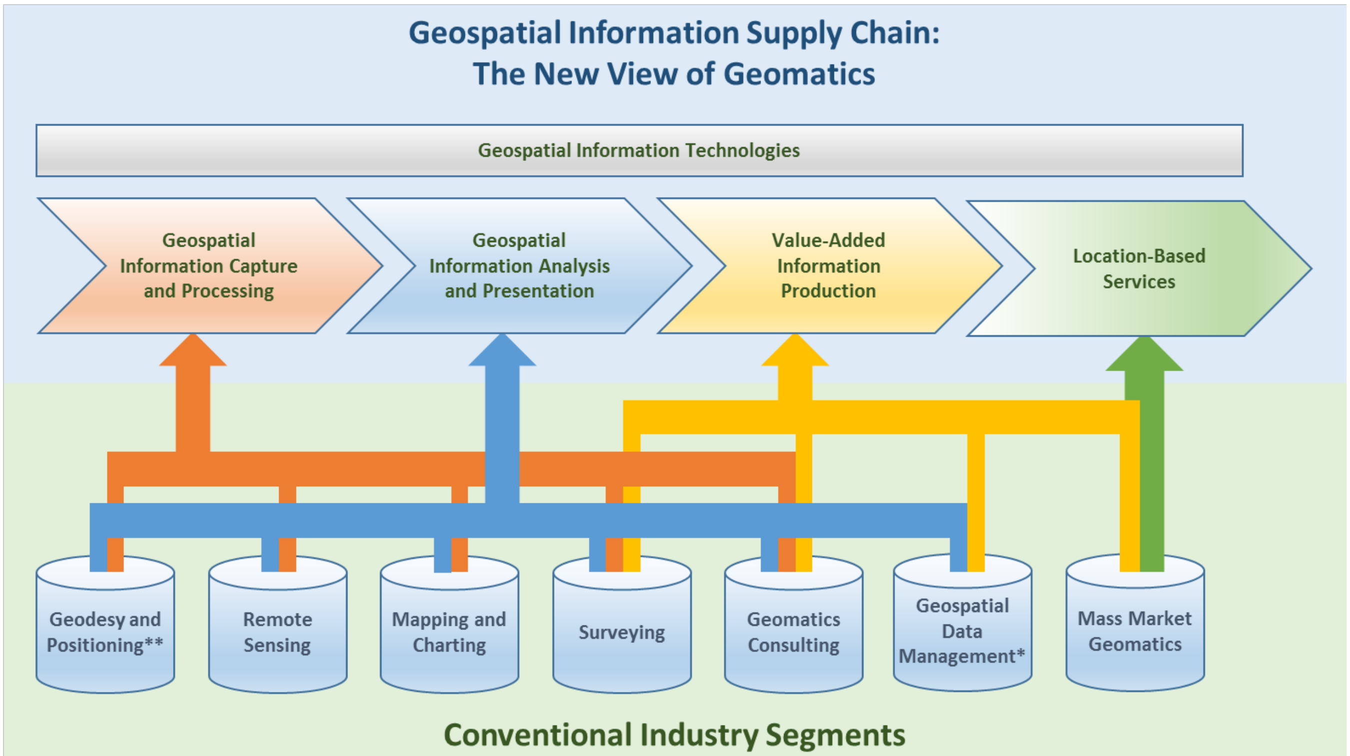
The Geomatics Sector

This section summarizes the current status of the industry, government and academic segments of the geomatics sector, research and development performance and key challenges and opportunities. It is important to recognize that the nature of this sector has resulted in close relationships being developed between the public and private sectors. The initial primary source of innovation was within government where the principal developers and users of geospatial information were located. As the private sector demand for GI expanded and governments began to involve private sector GI providers in their production work, the industry grew and developed and became a stronger engine of innovation, with the two-way exchange of new technologies and methodologies becoming more prevalent. The emergence of specialized post-secondary geomatics education and research programs in the early 1960s brought new sources of innovation and highly-qualified personnel into the mix. Since that time, geomatics leaders in government, industry and academia have worked together on several assessments of the sector and the markets that it serves to help position the community to best meet the needs of GI users in Canada and internationally. The CGCRT and development of the Pan-Canadian Geomatics Strategy is the most recent manifestation of this ongoing effort.

Private Sector Profile

A segmentation aligned with a modern geospatial information (GI) value chain, as illustrated in the following figure and defined below, has been used in this study to segment the geomatics industry. The figure also depicts a mapping of the conventional industry segments that have been used in previous geomatics industry studies into this value chain model.

Figure 1: Relation between Contemporary GI Value Chain and Conventional Geomatics Business Segments



** Includes use of all Global Navigation Satellite Systems
* Includes Geographic Information Systems

In each subsequent part of the first four components of the chain/segment of the sector, value is added; the fifth component straddles the other components, providing the essential tools for the production of products and services. The purpose of this diagram is not to suggest a relative importance of any stage in the chain, but to demonstrate that the higher value-added products and services are dependent upon those generated in the preceding stages. The segments are defined as:

- *Geospatial Information Capture and Processing* encompasses the activities of data collection using surveying, GNSS, hydrographic, and airborne and satellite imaging technologies, and the processing of such data for entry into data analysis and presentation technologies.

- *Geospatial Information Analysis and Presentation* encompasses the activities of data analysis using GIS, photogrammetric, cartographic and image analysis technologies to produce standardized or customized reports, plans, maps or charts, and the presentation of such outputs as electronic or hard copy geospatial products and services.

- *Value-added Information Production* – encompasses the integration of geospatial information with other types of information (e.g., resource, infrastructure, demographic, socio-economic, etc.) to develop value-added products and services to help inform decision-making and improve operational performance within organizations.

- *Location-based Services* encompasses a growing range of both Internet- and mobile device-based services that employ geospatial information to help users locate destinations and businesses, track shipments, navigate aircraft, ships and vehicles, receive consumer information, etc.

- *Geospatial Information Technologies* encompasses the production and distribution of software and equipment used for geospatial information capture, processing, analysis, presentation and value-added information production.

There are approximately 2,450 private sector GI providers doing business in Canada, which contributed $2.3 billion to Canada's Gross Domestic Product (GDP) in 2013. The geographical distribution of these firms was:

- Atlantic Region – 11 percent,
- Québec – 11 percent,
- Ontario – 20 percent,
- Prairies Region: 22 percent,
- British Columbia 17 percent, and
- the North –1 percent.

The annual revenue distribution in the industry was:

- 11 percent with <$200,00,
- 26 percent with between $200,000 and $1M,
- 33 percent with between $1M and $5M,
- 18 percent with between $5M and $25M, and
- 12 percent with >$25M.

Some 60 percent of firms operate in the GI capture and processing segment of the value chain, 70 percent in the GI analysis and presentation segment, 50 percent in the value-added information production segment, 2 percent in the location-based services segment and 20 percent in the geospatial technologies segment. Note that many firms operate in more than one segment of the value chain.

The primary focus of the 'other disciplinary' firms (i.e., ICT and engineering firms that are active in the provision of GI products and services) that are active in the geospatial information market is the third and fourth value chain segments, which are more closely aligned with their overall business interests.

Although the majority of Canada's GI technology providers are not market leaders, the tendency to focus on market niches (e.g., data conversion, image processing, hydrographic data management, assisted GPS, satellite radar, etc.) has helped companies to gain significant international market penetration (e.g., MDA, PCI Geomatics, CARIS).

Public Sector Profile

A significant proportion of GI supply capacity in Canada resides within government organizations at the federal, provincial / territorial, and municipal levels. The primary focus at the first two levels tends to be within natural resource departments, which have traditionally been the home of the surveying, mapping and remote sensing groups. At the municipal level, the primary focus tends to be within the public works / infrastructure departments.

Federal geomatics activities are concentrated in Natural Resources Canada (NRCan), the country's national mapping and cadastral agency, with another nine organizations also involved in GI supply. NRCan has primary responsibility for production of 'core' geospatial data (often referred to as 'base' or 'foundation' data layers) at the federal level, for standards development and for regulation of survey activities on Canada Lands. The vast majority of GI is freely and openly available through geoportals in individual organizations or the GeoConnections Discovery Portal (e.g., GeoBase core topographic mapping data, Statistics Canada geographic data, etc.). The Government of Canada's open data portal, data.gc.ca, is providing access to a growing number of geospatial datasets, which currently represent more than 95 percent of the content available through the portal.

A considerable amount of attention is given by NRCan to provision of 'core' data for general consumption by industry and government GI users, and the other GI organizations at the federal level focus primarily on providing GI products and services for internal clients, although making their data, the majority of which is thematic in nature (i.e., datasets that provide information on specific topics or themes, such as forest types, water contamination, historical flood areas, or disease patterns and trends), accessible to users outside their organizations is an increasingly important objective.

At the provincial / territorial and municipal government levels, the pattern at the federal level is generally repeated (i.e., a single agency with primary responsibility for most 'core' data and several additional organizations providing access to various other types of geospatial data). Open data policies are driving the increasing accessibility to free and open data within these jurisdictions as well; however, some municipalities still sell GI and are dealing with the requirement to transition to a more free and open access environment.

At all three levels of government, spatial data infrastructure (SDI) initiatives are underway or being planned in the majority of jurisdictions. This is a positive development for the industry, which has expectations of commercial applications potential as more and more data becomes accessible. The remaining challenges are to ensure that the data are of the quality required by the user community and to link the infrastructures so that there is seamless access to integratable and interoperable datasets.

Academia Profile

In addition to the traditional sources of university education in geography and geomatics science and engineering departments, GI-related courses are now routinely offered by most Canadian universities through departments in related disciplines (e.g., forestry, geology, agronomy, environmental sciences, civil engineering, and even health). Programs that are focused solely on GIS and geomatics tend to be at the certificate, minor or diploma level within the college environment and as a Bachelor degree at the university level.

Graduate programs include Masters of Science in Geomatics and Masters of Engineering in Geomatics (University of Calgary, University of New Brunswick, York University, Université Laval and Ryerson University), and more specialized programs such as Masters of Spatial Analysis (Ryerson University), Masters of Science in Environment and Geography with a research focus in Geomatics and Remote Sensing (University of Manitoba) and MBA program in Geomatics Management (Université Laval) and Masters in Geography programs at a number of universities across Canada.

Profiles of post-secondary geomatics programs at 94 Canadian universities and colleges have been compiled, including the faculty name, degree/diploma name, admission requirements, program description, and a list of courses offered. The inventory includes programs at 12 institutions in Atlantic Canada, 16 in Quebec, 36 in Ontario, 10 in Manitoba, Saskatchewan and the northern territories, 10 in Alberta, and 10 in British Columbia.

A number of programs include GI-related courses in their curriculum even though they are not the faculty to offer the course. For example, many of the Environmental Studies programs require GI courses delivered by the Geography faculty. A comparison of the geographical distribution of colleges and universities offering geomatics programs in 1999 and 2013 reveals that most of the growth has occurred in Western and Northern Canada, the number of programs at the university level has remained approximately the same and there has been a 35 percent increase in the number of colleges offering geomatics training.

Research and Development Performance

The average investment by GI suppliers in R&D is approximately 5 percent of annual revenues / budget, with a primary focus on improving operations or productivity by implementing new processes or technologies. Significant investment is also being made in improving existing or developing new products and services, and respondents suggested that more attention be given to new product commercialization and marketing.

Most R&D activity in industry is funded from earnings, but Canada's primary innovation support programs are also heavily used (e.g., Industrial Research Assistance Program, Scientific Research and Experimental Development tax credits, and specialized GI-related funding sources like TECTERRA and the Government Related Initiatives Program).

Budget restraint in the public sector has had a toll on R&D, with some respondents reporting difficulties in keeping up with new technologies and the demand from their users for new apps. The loss of R&D capacity within government has also been noted by industry respondents, who reported that access to valuable IP and technologies has been curtailed.

There is robust research and development activity in the academic institutions, which appears to be well aligned with market trends and growth drivers. Examples of current R&D foci include: geovisualization (e.g., augmented reality shared through social networking tools); volunteered geographic systems (e.g., examining the coincidence and variation in expert and public contributions); mobile mapping systems (e.g., calibration and data accuracy, tracking of features and automatic shape recognition); and complex systems (e.g., design of automated spatial decision support systems). Funding is an issue and there is concern that the reduced focus on 'curiosity-driven' research (i.e., scientific research in domains where specific applications are not immediately apparent but that have the potential to produce unanticipated scientific and technological breakthroughs) in favour of more funding support for 'industry driven' research and development (i.e., R&D to produce specific workable applications) will impede the development of real research breakthroughs that help ensure the future health and growth of the sector.

Data does not exist to conduct direct comparisons between the R&D performance of Canada and our main competitors in geomatics. While not necessarily attributable to the geomatics sector, Canada's business investment in R&D is declining. Overall performance as a country is slipping in comparison with 41 OECD and leading developing economies. According to the most recent data from the OECD, business enterprise expenditures on R&D as a percentage of GDP in Canada were 0.89 percent in 2011, compared to 1.04 percent in 2008. This placed Canada in 25th place in international rankings, down from 21st place in 2008, and considerably below the threshold of 2.4 percent set by the top five performing economies.

Key Challenges and Opportunities for the Sector

The transformation underway in the GI market, from specialized products and services for users with geomatics backgrounds to more general purpose GI applications for increasingly geo-literate generalist users, is presenting new opportunities to market innovative solutions where GI is embedded in other kinds of ICT systems. These changing market dynamics present considerable challenges for the GI supply industry, which is dealing with adopting new business models and creating strategic alliances to address higher GI value-added products and services opportunities.

In the consultations some respondents focused on the increased integration of geomatics and IT applications as a key factor affecting the identity of geomatics as a distinct sector. As noted previously in the Academia profile, students from many different disciplines are now part of the geomatics community by virtue of having taken GI-related courses and entering workplaces where they are using the acquired skills, which is contributing to the sector's growing heterogeneity and also the resulting identity challenge. The lack of a clearly articulated and marketed identity and profile or 'brand' for the sector is widely seen to be a significant challenge that is inhibiting its growth and development.

Closely linked with the identity challenge is the challenge of identifying and communicating the geomatics value proposition (i.e., justification for investment in geospatial information) through clear and relevant examples of its contribution to the Canadian economy and society.

Fragmentation in the sector (e.g., industry structure, disciplinary divisions, and representational bodies) and a weakness in leadership are also seen as significant barriers to improving its profile and making progress at a strategic level.

An opportunity has been identified to deal with concerns in the sector that increased use of GI products, services and technologies by generalists may result in misuse of data. Examples of such potential misuse include: data collected at a resolution applicable for overall crop yield forecasting being used for farm vehicle navigation, or high resolution property boundary data being integrated with low resolution land cover data to make land use planning decisions. There is recognition that the sector needs to take the lead in addressing this challenge and that a geospatial information certification model could provide the means of providing assurance to non-experts of quality and fitness for specific uses of geospatial datasets. This may be also an opportunity for the sector to increase its stature by improving standards of practice. The aging demographic profile is a challenge in the professional land surveying community (where there has been an insufficient influx of new members in several regions) and within government (where downsizing and hiring freezes have precluded the addition of significant new young recruits). Work on raising the profile of the sector is recognized as an opportunity to help increase recruitment into the profession.

Industry structure and representation are linked challenges that were identified by industry stakeholders concerned about the mismatch between the predominantly SME-based industry structure and changing market demands, and the difficulty of developing a consolidated view on business matters of concern.

A key challenge to be addressed within government is responding to demands for improvements in the quality (and particularly the currency) of core geospatial information. Constrained resources is viewed by respondents as one barrier to addressing this challenge (e.g., at the federal level 26,000 jobs have been cut since 2011 and by fiscal year 2017-18, the austerity measures currently being implemented will see government departments managing yearly ongoing savings of $13.7B, and these reductions have been felt in the GI provider organizations). The results of the Value Study and the work to implement the Pan-Canadian Geomatics Strategy are viewed as primary opportunities to develop the business case for reinvestment to help overcome this barrier.

A related challenge is the ongoing development and maintenance of co-produced core GI products like GeoBase, for which some provinces are not able to contribute data to all layers. A possible opportunity to help address this challenge is a distributed model with each province maintaining its own piece of the national dataset, rather than conversion of all data to a common data model, although the advantages over the current model would need to be carefully assessed.

A specific opportunity identified by industry respondents is changing the procurement practices for major GI systems development services, in which there has been an increased focus on contracting in expert resources. There is an opportunity to support the industry's domestic and international performance through more focus on contracting out complete solutions to be built by companies.

The biggest challenge identified for the academic sector is attracting the best and brightest students into geomatics education and training programs. This is closely related to the identity and profile challenge, and the focus in the Pan-Canadian Geomatics Strategy on education and capacity building represents a potential opportunity to address this issue.

Another growing academic sector challenge is securing research funding, in particular for curiosity-driven research.

A final challenge identified for the post-secondary education system is the inadequate innovation in cross-disciplinary GI education and training, to ensure that users have the necessary basic skills to make informed and effective use of geospatial information.

The Geospatial Information Market

This section highlights key trends and drivers of change in GI markets and provides high level profiles of current domestic and international markets for GI products, services and technologies.

Trends and Drivers of Change

The following table lists the key trends impacting the supply and use of geospatial information that were identified through the study research and consultations.

Type	Trend
Technological	▪ *Location-enabled mobile device use* ▪ *Mainstreaming of open source software* ▪ *Data volume growth* ▪ *Indoor positioning capabilities*

Type	Trend
	▪ *Data capture with unmanned aerial vehicles* ▪ *Big data analytics use* ▪ *Cloud computing adoption* ▪ *Location intelligence adoption* ▪ *Immersive video /augmented reality developments* ▪ *Broadband and cellular network capacity overloads* ▪ *Increasing difficulty in tracking data provenance and enforcing licences*
Economic	▪ *Globalization of GI products and services development* ▪ *Economic power shifts (particularly to Asia)* ▪ *Global economic uncertainty* ▪ *Business to Consumer (B2C) market growth*
Social and Demographic	▪ *The influence of the wired generation or 'Generation Y' in both demand for and supply of GI* ▪ *Increased location awareness or geo-literacy* ▪ *Crowd-sourcing / volunteered geographic information (VGI)* ▪ *Concern about privacy invasion* ▪ *Industry structure and demographics*
Political / Policy	▪ *Open government / open data* ▪ *Demand for horizontal solutions to key policy issues* ▪ *Overall budget restraint, government downsizing and changing priorities* ▪ *Authoritative geospatial information provision* ▪ *Development in Canada's north* ▪ *Business-supportive government policy* ▪ *E-911 standards*
Environmental	▪ *Growing environmental consciousness and activism* ▪ *Measures for global climate change rate reduction and adaptation* ▪ *Global food and water security concerns* ▪ *Emergency response, and disaster management and recovery*
Public Sector GI Use	▪ *Strong growth of and diversity in the use of GI products and services* ▪ *Increased innovation to manage with less (e.g., shared data procurement, managed services in the cloud, and collaborative projects between departments)* ▪ *Growing demand for web-enabled and mobile GI applications* ▪ *More easily discoverable GI through SDI initiatives* ▪ *More freely and openly available GI through open data portals* ▪ *New skills requirements*

The following table summarizes key drivers of growth and change in the geospatial information market.

Growth/Change Driver	Description
Mass Market Geomatics (MMG)	The disruptive impacts of the emergence in the GI market of global players like Google and Microsoft have included both the shrinkage of business with organizations that now handle GI internally and business growth through provision to new customers of lower cost, user-friendly applications using MMG data and platforms
Free and Open Data	Will help to drive new higher value-added GI products and services development, provided that the data meets the requirements of an increasingly sophisticated and informed buyer community
Increasing buyer geo-literacy	The majority of respondents are experiencing the benefits of increased knowledge and appreciation of the benefits of GI use in the form of growth in new applications with existing customers and in new market segments
Government Procurement	Consolidated data purchases by single government organizations on behalf of groups of other organizations has resulted in changes in how suppliers price and license these datasets Maturing IT and GI applications development methods has reduced government dependency on industry developers, reducing opportunities for them to build GI total solutions that can be leveraged in the private sector and international markets
Commercial	Near-term: non-renewable and renewable energy, residential and commercial property development, and infrastructure renewal Longer-term: health, insurance and transportation and logistics

The Domestic Market

Geospatial information supply in the private sector is now split between 'traditional' geomatics firms (i.e., those with their roots, and with strong disciplinary strengths, in surveying, mapping, remote sensing, hydrography, etc.) and a growing mix of 'other disciplinary' firms whose primary business is in other sectors (e.g., information technology, engineering and environmental consulting) but also have expertise in provision of GI products and services as one business line.

There is demonstrable movement up the GI supply value chain by both smaller and larger industry players, in response to decreased margins in the lower value chain segments, and growing demand for higher value-added products and services in traditional market verticals and turnkey managed services in emerging market verticals. Companies are being challenged to adopt new business models and consider the prospects of plugging into global value chains.

The primary public sector GI providers tend to be located within natural resource ministries at the federal and provincial levels and infrastructure departments in municipalities, but significant GI supply capacity also exists in a range of other government organizations with responsibilities, for example, for agriculture and food, safety and security, statistics, environment, and public utilities. Through spatial data infrastructure or overall GIS strategy initiatives, these organizations in most jurisdictions are working towards full interoperability of datasets and information sharing through adoption of common standards. The public sector service delivery focus has shifted dramatically to web portals and mobile devices for the provision of geospatial information and applications to primary clients and stakeholders, and to the general public.

An extensive inventory of the demand for geospatial information products and services has been developed (see Appendix B), which clearly demonstrates the pervasiveness of GI use that currently exists. While increased geo-literacy and geospatial technology ease-of-use have resulted in the internalization of GI product and service development within many market verticals, the demand for products and services provided by private sector GI providers remains strong and growth is expected in the demand for managed services in the cloud.

The International Market

A plethora of market research reports exist that characterize the size and growth prospects for the global GI market, and the numbers are very impressive[3]. Some of the projections must be treated with caution as their validity is increasingly challenging to assess since they are being made from so many diverse perspectives. However, what is certain is that much of this growth will be realized by applications that are now accepted as "business as usual" being implemented in the developing world. So the common theme is that this is a rapidly evolving market with a high potential for growth.

By far the largest segments are personal navigation, location tracking, entertainment and geo-targeted mobile advertising. Even if the figures quoted in industry reports are an order of magnitude too large, the potential of these largely B2C applications in financial terms could exceed all other parts of the market by a factor of at least ten. A clear message is that consumer-focused applications will drive growth in the GI market to a much larger extent than the traditional professional applications.

There are great variations in the drivers for GI data, products and services internationally. Details in some countries are not publicly available or only official sources exist which cannot be verified. In these cases, plans and aspirations cannot be easily separated from real progress on the ground. The approach adopted was to attempt to discern progress and trends from the best available evidence, while looking particularly for examples of best practice and tangible achievements. It is difficult to generalize for entire continents, so the following are highlights that distinguish progress in key geographies. Appendix C provides a more detailed analysis.

[3] Geoservices 2013 Oxera (http://www.oxera.com/Publications/Reports/2013/What-is-the-economic-impact-of-Geo-services-.aspx) - The economic value of the sector reported to be in the range of $150 billion to $270 billion.
Personal Location Data 2012 McKinsey (http://www.mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation) – Estimated that the domain offers the potential for revenue creation over the next ten years of more than $100 billion to service providers and as much as $700 billion in value to consumer and business end users.
GIS 2011 Daratech (http://www.directionsmag.com/pressreleases/gisgeospatial-sales-up-10.3-to-us4.4-billion-growth-forecast-to-top-8.3-in-/151989) – Reported that the GIS market grew worldwide 10.3 percent in 2010 to US$4.4 billion with a forecast of an additional 8.3 percent growth to almost US$5 billion in 2011.

The United States represents the best developed market in the world for geospatial information and services. The large market size and the availability of funding for new ventures results in more new ideas being nurtured to maturity there than anywhere else. Furthermore, all of the market sectors where GI is making significant impacts upon productivity and revenue growth are well developed.

The collection and use of geospatial data is very well established across Europe and the data are well integrated into many services both in the public and private sectors. With the rapid rise in mobile devices in the consumer market the consumption of geospatial data has risen exponentially. The emergent markets are the countries of the former Soviet block, where land reform is driving the need for digital land administration systems.

Australasia (including Australia, New Zealand and the Polynesian Islands) has long been a leader in geomatics and geospatial information markets, with some of the earliest computerization developments originating on the continent. Drivers of demand include mining, energy development, agriculture, and tourism but their economies have recently been hurt particularly by a slowdown in exports to China.

The market in the Middle East is in many countries disrupted by war or civil unrest. The Gulf States, particularly those with major oil revenues, are pressing ahead with capture, management and dissemination of geospatial data, and national SDI initiatives are well developed in several countries. Notable is Abu Dhabi Emirate, where active collaboration between supplier agencies is facilitated by the centralized nature of decision-making.

In Africa, there is evidence of significant investment in geospatial technology not only in the continent's larger economies such as South Africa, Nigeria, and Kenya but also in smaller countries such as Rwanda. Mineral and oil and gas development, agriculture, land management, environment, water supply and management, food security, poverty reduction and transportation are all areas that are attracting stronger political support to improve social and economic development.

In China, initially the geospatial expertise was developed in academic institutions, but was spun out into private enterprises (with investment from the state) that established themselves through state funded projects, such as the digital city drive, or the deployment of a large constellation of earth observation satellites. The Chinese government is acting as facilitator of the industry's export development ambitions, often by providing loans and aid to enable projects, particularly in the developing world.

The geomatics sector in India is dominated by private sector outsourcing firms, small and large, providing services to North American and European clients and increasingly targeting larger opportunities in other emerging countries. A prime reason for the domestic GI market remaining underdeveloped appears to be hindrances imposed by a multitude of large state bureaucracies where restrictive data policies have resulted in unexploited data silos proliferating. Where the private sector has been allowed freer rein, advanced efficient GI systems have been implemented, for example related to India's low cost mobile phone infrastructure.

The leaders in GI supply and use in the rest of Asia include Japan, South Korea, Taiwan, Singapore, Philippines, Indonesia, Malaysia and Thailand, all of which have established significant GI programs. The key internationally active firms are from Japan, South Korea and Taiwan and the region has a particular strength in remote sensing with most of these countries launching their own EO satellites. Utilities, safety and security, land and property and agriculture are key foci for market development.

In Latin America, recent growth has been spurred by the increasing emphasis on production of cadastral and risk assessment data. Peru, Chile and Brazil are building long term plans to improve their capacity in geomatics, with projects focusing on disaster management, cadastre, land use planning and geospatial data infrastructures. In other countries populist political concerns with health, environmental protection, agricultural reform and renewable energy are driving the investment agenda.

The Labour Market

This section summarizes study findings on the geomatics labour market – demand for and supply of geomatics practitioners and labour mobility within the sector and with related sectors.

Demand

As demand has shifted to higher value GI products and services, and integration of GI with other types of information has become a higher priority, there is a general trend to value domain specific skillsets over geomatics skillsets. The combination of the two (i.e., disciplinary undergraduate or graduate degree plus GIS diploma or certificate) remains in strong demand.

There is evidence that universities are increasingly making GI training accessible to students in other disciplines, either through opening courses offered by geography and geomatics engineering and science departments to those students, or offering GI courses within those disciplinary faculties. Feedback from employers suggests that there is still room for improvement, particularly because GI related courses are often electives.

The composition of staff in a significant number of organizations has changed substantially over the last 10 years, from being geomatics centric to more IT centric (i.e., applications development rather than data collection). There is a preference for those involved in applications development to have both GI context modelling and business modelling (application domain) skills. This combination results in the development of applications that are better understood by the users and more effective in meeting their needs.

A particularly popular practice is the use of GI cooperative education programs, through which employers have the low-risk opportunity to evaluate a student's suitability for future employment. There is an increasing prevalence of targeting top students as early in their educational program as possible to assess their capabilities through work terms and committing to hire the most promising candidates when they graduate.

Overall, the majority of respondents indicated that staff attraction and retention were not significant problems, although turnover is more prevalent in thriving labour markets like Saskatchewan, Alberta and British Columbia where the oil and gas and forestry sectors offer competitive wages, lucrative benefits and a wealth of job opportunities. Companies in very competitive labour markets are placing more emphasis on human resource programs (e.g., flexible work hours, offsite working provision, increased training, and career planning) to help with retention of top talent.

The gender imbalance seems to be improving, with more female graduates, particularly from geography education and GIS training programs. The study research and consultations indicate that the aging demographic profiles in the land surveying profession and within government are a growing concern.

While geomatics sector employers appear to be generally satisfied with the skillsets of recent graduates, there are signs that demand is shifting, with more emphasis being placed in future hires on web and mobile applications programming and visual analytics skills, and business analysts that fully understand the business processes in defined markets (e.g., utilities, health, and public safety). Also, there is concern that the demand for specialized skills in geoanalytics and geostatistics will outstrip supply as the emphasis on the exploitation of Big Data increases.

There is also increased emphasis being placed on baseline skills and core capacity for key GI users, such as engineers, medical professional, utilities operators, etc. to use geospatial information and technologies.

Overall, future growth in the GI workforce is predicted, although most of this growth is expected on the user rather than the supplier side.

Supply

Respondents in the west reported an over-supply of graduates with GIS training and an under-supply of those with survey training, and that one way employers are filling this gap is through the increased hiring of foreign-trained geomatics specialists. This situation may be partly the result of circumstances in the colleges, where there has been growth in GIS training overall, while a number of survey technology programs are reporting declining enrolment and others have been closed.

Educational institution representatives report that they regularly review their courses and that key trends impact program / curriculum evolution. In particular, in the future there will be less emphasis on courses related to data acquisition (as this is being replaced by cheap technology such as high resolution sensors, drones, etc.) and more focus on courses related to integrating and representing data in an accurate and safe way (i.e., privacy, copyright, semantics of data (use and standardization of terminology), and data misuse).

In the majority of cases, students graduating from a geomatics program, at both the university and college level, are reported to be receiving job offers (often multiple offers) upon graduation, with some students seeking employment internationally. An exception is graduates of GIS training programs, who are experiencing difficulties in finding employment.

Employers typically offer new grads entry level ‘technician’ positions, often with a fairly narrow focus and university students sometimes feel that such positions are ‘beneath’ them and do not take advantage of their qualifications. Overcoming this challenge will require employers to do a better job of describing career progression opportunities in their organizations, so that graduates understand that entry level work is only a stepping stone to more variety and increased responsibilities.

There are a number of responses by the post-secondary education system to market changes: more partnering between GI and non-GI faculties and departments (although there are still concerns that other professions do not have enough GI skills); more emphasis being placed on programming and applications development skills (universities are offering combined computer science and geomatics programs); and redefining the scope of geomatics and GIS technology programs to be offered as condensed term certificates (offered on-line or in the evening) for those already in the workforce and / or already holding an existing degree.

The relatively recent increase in the number of land surveying associations that have implemented mandatory continuing professional development (CPD) is resulting in growing demand for university and college extension courses and distance learning alternatives, and partnering to fill this need is already happening (e.g., AOLS partnerships with Ryerson and York Universities).

Given the prevalence in Canadian universities of foreign students in GI post-graduate programs, the majority of which return to their home countries, there is a shortage of Canadian Masters and PhD graduates to fill specialized roles in government and industry, or to fill vacancies in university and college faculties.

There appear to be limited options for training of new GI users within organizations in the fundamentals of geomatics so that they can become effective users of GI apps, other than by the in-house GI provider groups, which are hard pressed to address this requirement.

The majority of stakeholders consulted do not support the need for competency, licensing and certification models to address labour force requirements.

Labour Mobility

The most significant worker mobility challenges are occurring in Western Canada, but the robust labour market in that region is impacting employee retention to a lesser extent in the rest of the country as well.

Survey firms in Central and Eastern Canada have experienced loss of skilled workers to firms in Alberta, Saskatchewan and BC (salaries are reported to be on average 20 percent higher than in Ontario, for example). To mitigate the problems of attracting and keeping skilled people from the Maritimes, several Alberta firms have established production operations in Halifax and hired local people (often pulling them from local survey firms).

Most movement is between survey firms, but some technologists also leave survey firms for higher paying jobs in the oil and gas sector. There is little evidence of significant mobility between firms in other supply segments (e.g., GIS, remote sensing) or between supply segments (understandable because technology training is most often segment-specific).

Those consulted have reported limited problems with movement of workers from GI applications development into broader IT applications. For most geomatics companies, the workers involved in GI applications have GI education or training, as opposed to computer science backgrounds, so there is limited mobility potential of this type for these workers.

For those companies that have chosen to hire IT generalists and provide the training to enable them to undertake GI applications development, mobility is a more serious concern since compensation levels and advancement opportunities in the typically much larger IT companies are greater.

Implications for the Sector's Future

This section highlights some of the key implications of the study findings for the future of the Canadian geomatics sector and how the sector can adapt to create the most value for the Canadian economy and society.

Market Change Drivers

The maturation of indoor positioning systems is opening up new business opportunities for applications that require seamless determination of the mobile device's position regardless of location. As interest in location-based services (LBS) continues to increase in the business to business (B2B) market, demand for simple mobile apps targeted at field personnel in organizations hungry for productivity improvements is driving growth.

New developments in 3D mobile motion sensing devices (e.g., Google's Project Tango initiative) signal the potential for a new era of data capture and augmented reality applications in the workplace (e.g., utility workers, fire fighters and police officers being able to navigate through unfamiliar buildings, capture new location-tagged data to share in real-time with office workers, etc.).

As the quality and quantity of government open data improves and the growing plethora of free or low-cost EO data comes on stream, public and private sector geomatics providers need to be prepared to assess its applicability to clients' business requirements and quickly integrate appropriate datasets into their GI products and services.

Geomatics organizations that want to take advantage of the opportunities presented by the growing demand for analytics on Big Data need to position themselves to compete by developing/recruiting data scientists, developing or working with research institutions to develop new algorithms and optimization methods and acquiring or renting the scalable computing capacity to handle the data processing involved.

As global value chains are divided into smaller and smaller tasks in the emerging 'project economy'[4], opportunities for partnering and mergers are emerging. Canadian GI providers that want to take advantage of opportunities to plug into these chains, but have not already done so, need to adapt to new business models and increase the flexibility with which they provide services.

Volunteered geographic information (VGI) is a proven source of information for updating online mapping datasets, used routinely by a number of commercial and government GI providers. To take advantage of this opportunity, Canadian government geomatics organizations need to develop processes to address and find solutions to a range of technical and policy issues (e.g., quality control, security, and licensing).

Government policies can provide a stimulus to GI markets. Examples are open government/open data policies that improve access to GI with potential commercial value, and infrastructure renewal and 'green economy' policies that result in investment in GI. Governments can also help improve domestic and international business prospects and stimulate business investment by adopting procurement policies that challenge industry to develop innovative GI solutions and by adopting plans that help provide long-term stability in supply of GI products and services to government.

Government policy on the provision and ongoing maintenance of authoritative geospatial information can also be an important driver of growth. Shortcomings in existing 'core' GI need to be addressed to better respond to two important national policy objectives – more effective emergency management and northern economic development. For example, investment is

[4] An economy increasingly dominated by contract workers making specialized contributions to global value chains (see http://www.horizons.gc.ca/eng/search/site/project%20economy, https://www.youtube.com/watch?v=7EFgQb593VA).

required in geo-enabled common operational picture capabilities and flood risk mapping in flood plains across Canada and in selective upgrading of digital mapping and electronic charting in the North.

Growing public concern about environmental degradation and the impacts of climate change are expected to be an important stimulant of future GI market growth. The increasing complexity and diversity of available environmental data and demands of the regulators present opportunities for innovative GI providers to help both environmental groups to analyze the data and develop evidence-based positions and businesses to meet regulatory requirements.

Energy reduction targets are creating demands for precise three-dimensional energy performance modelling based on building information models (BIM) and geolocation of the building in relation to historical weather patterns, nearby structures, etc. These reduction and adaptation measures signal important opportunities for GI providers to better integrate BIM and GI environments and provide cost-effective solutions to support the required infrastructure programs, both at home and abroad.

Challenges and Opportunities

Based on the study consultations, the most significant challenge that the geomatics sector is confronting is the lack of a clear identity for the sector. If the sector's identity and the value that it provides to the Canadian economy are poorly understood, it will be less successful in attracting resources to keep GI current, develop and maintain the spatial data infrastructure, and conduct research and development that will help to keep the sector globally competitive. The Pan-Canadian Geomatics Strategy represents the best opportunity to address this challenge.

Identifying and articulating the sector's 'value proposition' (i.e., its distinct character and the value of its contributions to the Canadian economy and society) is another challenge that is linked to identity. One of the main purposes of this study was to help address this challenge and there is broad interest in the community in its outcome.

There appears to be a deficit of visible leaders and fragmentation and diffusion of effort within the sector (e.g., there are over 40 associations representing different geomatics interests) is clearly a factor. A key focus of the Pan-Canadian Geomatics Strategy is to create a new government/industry/ academia/not-for-profit leadership framework that will help to remove fragmentation and catalyze the sector.

There is a general consensus in the industry that Canada faces the significant challenge of regaining its international competitiveness. As the industry's competitiveness slips our reputation is damaged, reducing future chances of regaining market share. Since many of the growth opportunities appear to be in the international market, there is a strong correlation to the sector's future success. The loss of revenues from export sales reduces the industry's ability to provide innovative new GI products, services and technologies in the domestic market, which has a negative impact on the sector's image at home as well.

Considerable complexity is involved in addressing this challenge. The public and private sectors need to work more cooperatively and strategically to capture export business. Government GI providers can help to initiate projects and provide professional advice with teams of industry and government experts on the condition that downstream project work is available preferentially to Canadian businesses – a strategy that our European competitors have successfully used (e.g., DLR in Germany, Swedesurvey). Government can also act as a demanding and informed purchaser of innovative total GI solutions that have export potential and provide a valuable reference for foreign buyers. Coordinated government/industry/academia partnerships for innovation in geomatics, such as the TECTERRA initiative in Alberta, need to be created in other regions of the country.

Companies that want to export can position themselves as niche players with clearly differentiated products and services that address weaknesses in major international competitors' offerings. Alternatively, in order to meet the demand for higher value-added products and services they need to become more vertically integrated via mergers or by developing business relationships or strategic partnerships to address gaps in global players' GI supply chains.

Opportunities to address business model adaptation challenges facing GI providers include: developing business relationships with others up or down the GI value chain; switching revenue streams from projects to long-term service contracts; and migrating from internal to Cloud infrastructure. Key requirements for success in using external suppliers or participating in integrated value chains are due diligence and experimentation. Careful planning and execution and sharing the risk through strategic partnerships have been proven to mitigate revenue and infrastructure change risks.

There is widespread support within the geomatics sector for a strong government role in the provision of authoritative, accurate and accessible (AAA) 'core' geospatial data (i.e., base or framework and thematic data layers that are of common interest to the majority of users), but the ability to deliver with diminished resources is considered to be a significant challenge. The need to re-evaluate the content of core data has also been raised and the Data Sources dimension of the Pan-Canadian Geomatics Strategy addresses this matter.

The business case for reinvestment in core geospatial data in Canada needs to be developed and presented to senior officials and political leaders. Opportunities to adopt new business models that take advantage of crowd-sourced content and capture changes in geospatial data resulting from business transaction processes (e.g., building permits, proposed subdivision plans, etc.) need to be considered. Finally, the requirement to continue to provide high quality data through open government initiatives in order to generate the expected economic activity must be reinforced.

Attracting the 'best and brightest' high school graduates into geomatics education and training programs is an ongoing challenge. In the short term, the lack of recruitment success has resulted in the closure of a few college geomatics programs at a time when there are demand-supply gaps particularly in survey technology. The sector's long-term health and growth prospects are dependent upon the quality and resourcefulness of new entrants into geomatics workplaces. The Pan-Canadian Geomatics Strategy represents a timely opportunity to address this important challenge and establish a strong brand for the Canadian geomatics sector.

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1. Introduction

The *Canadian geomatics environmental scan (CGES) findings report* consolidates the results from all lines of enquiry for this part of the overall *Canadian geomatics environmental scan and value study*. The objectives of the CGES were to complete:

- An examination of the current geospatial information market in Canada and definition and profiling of the Canadian geomatics sector;
- An examination of the current state of participation by the Canadian geomatics sector in international markets along with an evaluation of the importance of this participation to the domestic market;
- An identification of the technology, economic, social and demographic trends that will have an impact on the geomatics sector in Canada;
- An examination of the contributions of industry, government and academia and the challenges and opportunities for each; and
- An analysis of the labour market, including an examination of education and training currently available.

The content of this report is based upon a comprehensive literature review and the input received during two rounds of consultations with geospatial information (GI) suppliers in industry and government, users of GI products and services, and providers of GI education and training programs. The proposed study methodology included online surveys of stakeholders. During the information collection phase of the study, it was learned that such surveys would not be permitted.

The report is structured to address the study questions posed for the CGES component of the overall study (see Appendix A for a list of study questions) as follows:

- Chapter two describes the GI market, including: key trends impacting market development and change, and drivers of future market growth; supply and demand in the domestic market, barriers to market access, and future GI production and use priorities; and supply and demand in international markets, barriers to accessing those markets, and roles and opportunities for Canadian companies.
- Chapter three describes the Canadian Geomatics Sector in terms of: the GI value chain; the profiles of the public and private sector segments of the Sector; the contributions made, and

the opportunities and challenges faced, by each; and the Sector's research and development capacity.

- Chapter four discusses the Canadian GI labour market, including: labour market supply and demand; gaps between demand and supply; labour mobility; and labour market challenges.
- Chapter five provides an analysis of the implications of the study findings for the sector's future.

2. The Geomatics Sector

This chapter defines and profiles the government, industry and academic segments of the geomatics sector, and the contributions made by, and challenges and opportunities, for each.

2.1 Setting the Context

There have been a number of previous attempts to define and profile the geomatics sector and describe the domestic market for geospatial (GI) products and services. For example, between 1985 and 1995, with funding support from Industry Canada, three studies of the sector were conducted (one by Canadian Institute of Surveying and Mapping, now Canadian Institute of Geomatics (CIG), and two by Geomatics Industry Association of Canada (GIAC)). In 2000, perhaps the most comprehensive previous attempt, the *Geomatics Sector Human Resources Study*,[1] was commissioned by a consortium of GIAC, CIG and Canadian Council of Land Surveyors (CCLS) with funding support from Human Resources Development Canada and several other federal government organizations. In 2004, Natural Resources Canada (NRCan) commissioned a Statistics Canada special survey, the *Geomatics Industry Census Survey*,[2,3] which encompassed not only geomatics companies, but also companies in several other sectors (e.g., IT, engineering, software, etc.) that are significant players in the GI market. Finally, in 2007 NRCan commissioned the *Geomatics Industry Human Resources and Market Competitiveness Issues* study[4].

Each of these studies suggested that geomatics was a sector in transition. As will be discussed in Chapter 3, the changes are being driven by changing market conditions and technologies, and trends that are impacting the GI market. While the geomatics sector definition was once restricted to 'core' geomatics organizations and individuals (i.e., those with their roots in and with strong disciplinary strengths in surveying, mapping, remote sensing and hydrography), there is growing recognition and acceptance that the sector now includes a growing mix of 'other disciplinary' organizations and individuals whose primary focus is in other sectors (e.g., information technology, engineering and environmental consulting) but which have expertise in provision of GI products and services as a significant business line or activity.

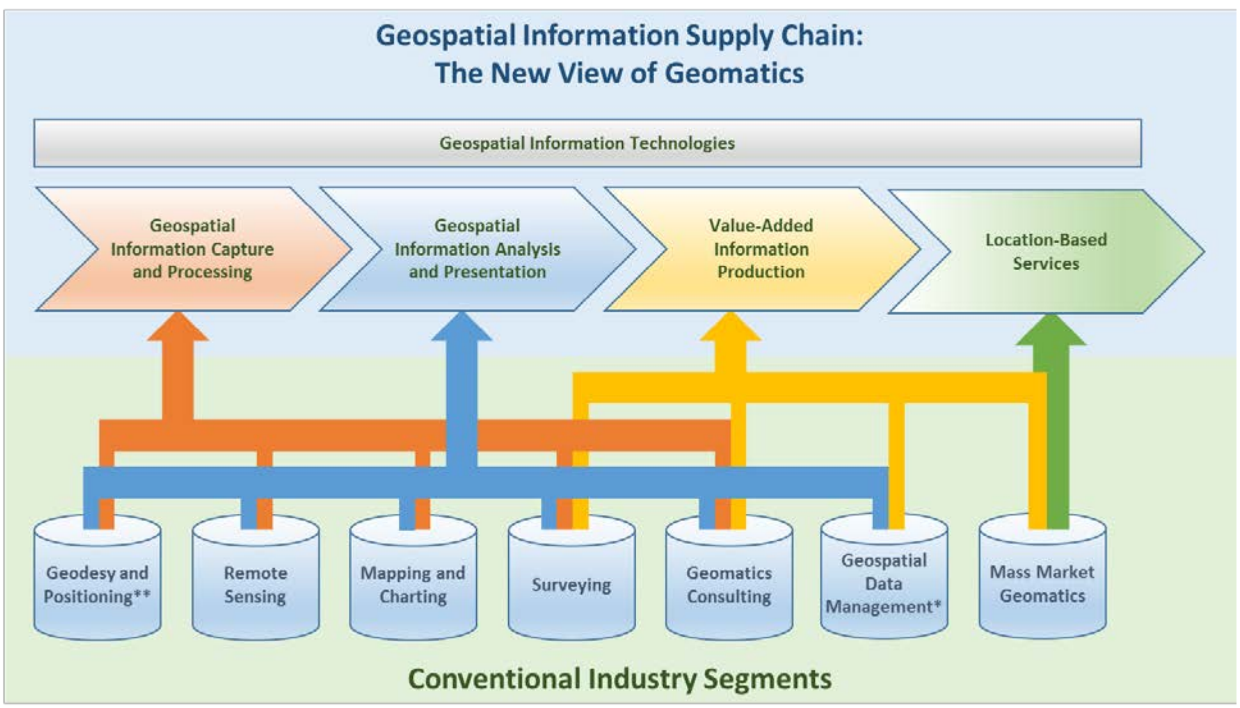
However, as was demonstrated at the 'Team Canada' Geomatics Strategy, Action and Implementation Planning Workshop held in June 2014 and in the social media discussion on the Pan-Canadian Geomatics Strategy[5] leading up to that event, consensus on what is included in the 'geomatics' sector (or even on the best name for the sector) is difficult to reach. As a result of the proliferation of GI use and the consequent migration of the sector's 'boundaries' outward, profiling the sector is becoming more challenging. In the description that follows we have attempted through the literature review and consultations to take the broadest possible view of the sector and its constituent parts. However, it must be recognized that many of the 'other disciplinary' organizations and individuals may not consider themselves to be part of the sector.

2.2 The Geospatial Information Value Chain

It is no longer practical to segment the contemporary geospatial information (GI) sector according to the traditional divisions of domain or discipline (i.e., surveying, mapping, remote sensing, etc.). There are two challenges with the traditional segmentation: many GI businesses do not categorize themselves in one of those disciplines; and the lines between the divisions (e.g., between surveying and positioning, and between remote sensing and mapping) have blurred.

Accordingly, we propose a segmentation aligned with a modern geospatial information value chain, as defined below and illustrated in Figure 1, which also depicts a mapping into this value chain model of the conventional industry segments that were used in the geomatics industry studies referenced in Section 2.1.

Figure 1: Relation between Contemporary GI Value Chain and Conventional Geomatics Business Segments



** Includes use of all Global Navigation Satellite Systems
* Includes Geographic Information Systems

In each subsequent part of the first four components of the chain/segment of the sector, value is added; the fifth component straddles the other components, providing the essential tools for the production of products and services.

Geospatial Information Capture and Processing – encompasses the activities of data collection using surveying, GNSS, hydrographic, and airborne and satellite imaging technologies, and the processing of such data for entry into data analysis and presentation technologies.

Geospatial Information Analysis and Presentation – encompasses the activities of data analysis using GIS, photogrammetric, cartographic and image analysis technologies to produce standardized or customized reports, plans, maps or charts, and the presentation of such outputs as electronic or hard copy geospatial products and services.

Value-added Information Production – encompasses the integration of geospatial information with other types of information (e.g., resource, infrastructure, demographic, socio-economic, etc.) to develop value-added products and services to help inform decision-making and improve operational performance within organizations.

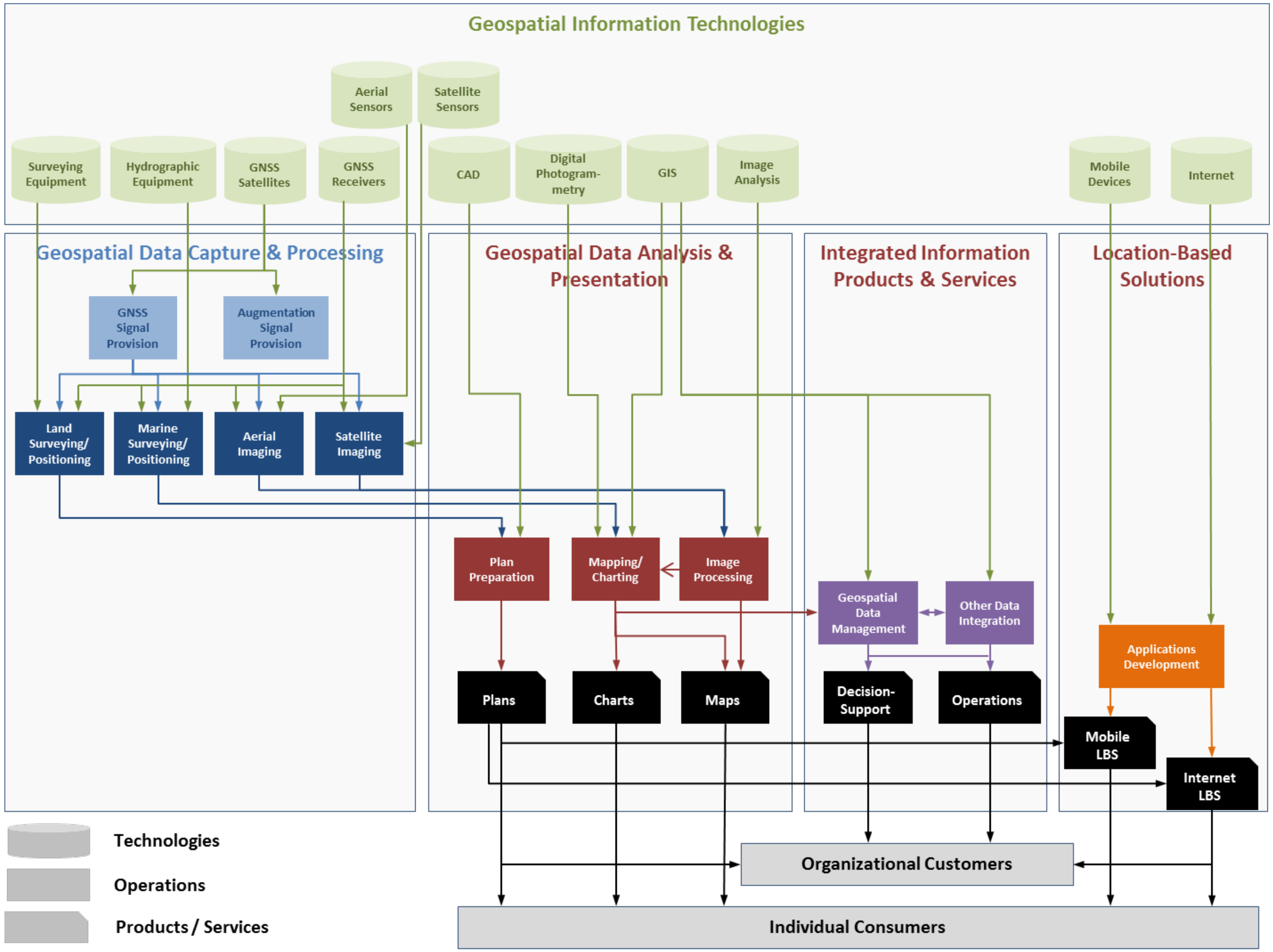
Location-based Services – encompasses a growing range of both Internet- and mobile device-based services that employ geospatial information to help users locate destinations and businesses, track shipments, navigate aircraft, ships and vehicles, receive consumer information, etc.

Geospatial Information Technologies – encompasses the production and distribution of software and equipment used for geospatial information capture, processing, analysis, presentation and value-added information production.

An expanded GI value chain diagram is provided in Figure 2, which illustrates the linkages between the technologies employed, typical operations undertaken, and the resulting products in the different parts of the value chain.

The profile of the GI supply industry that follows was created in accordance with this value chain segmentation construct.

Figure 2: Expanded GI Value Chain



2.3 Geomatics Sector Capacity

2.3.1 Profile of the Private Sector

As documented in the *Value Study Findings Report*, there are approximately 2,450 private sector GI providers doing business in Canada, which contributed $2.3 billion to Canada's Gross Domestic Product (GDP) in 2013. Figure 3 illustrates how the geographical distribution of geomatics businesses in Canada has changed between 1999, when there were 2,143 firms, and 2013.

Figure 3: Regional Distribution of Geomatics Business Establishments in 1999 and 2013

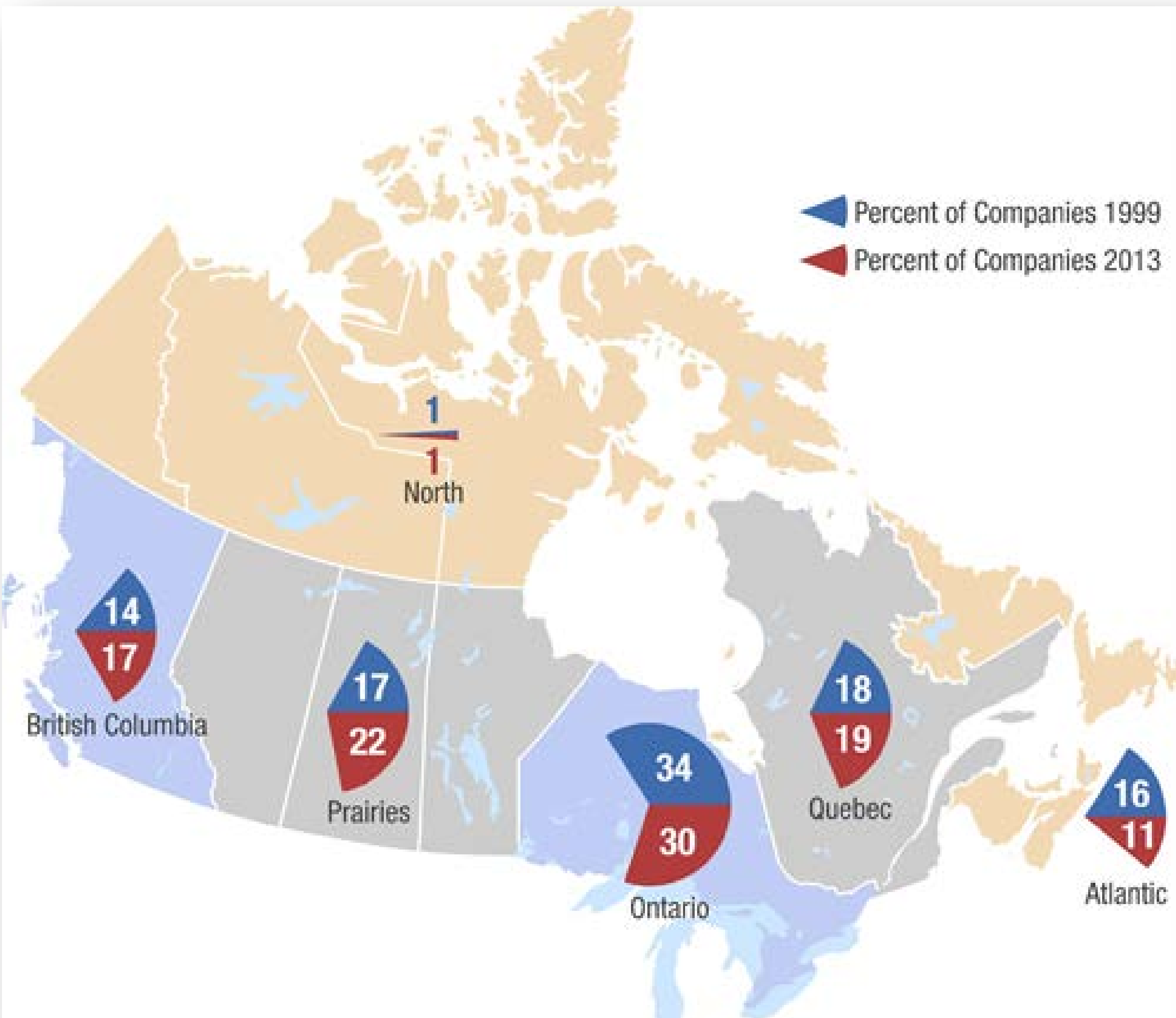


Figure 4 shows the current distribution of revenue by establishment. It is important to note that revenue figures cover all business activities of multidisciplinary firms that provide GI products and services as one of their business lines.

Figure 4: Distribution of Revenue by Geomatics Business Establishment

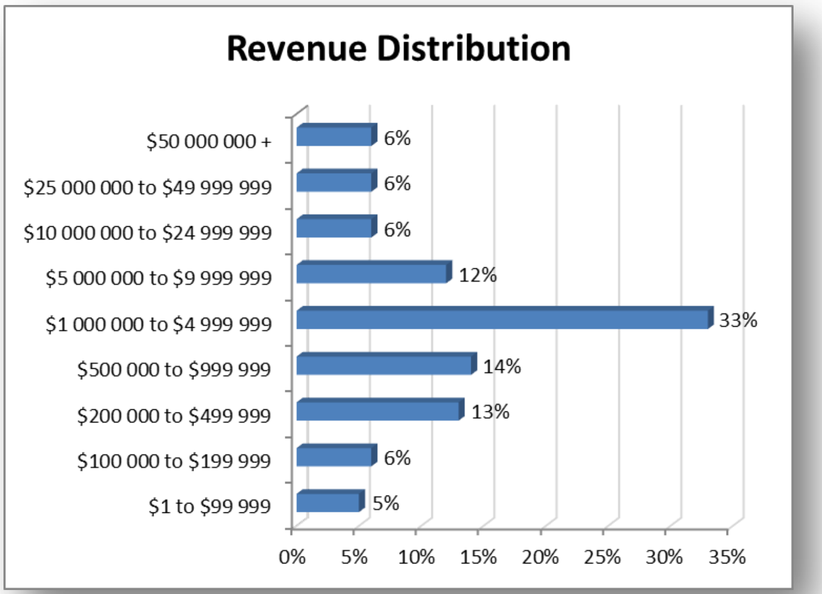
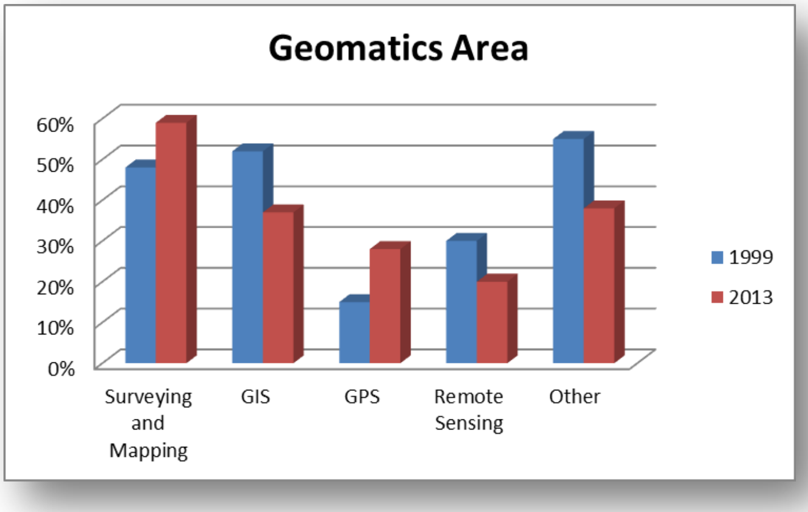


Figure 5 illustrates the percentage of companies operating in the traditional geomatics areas in 1999 and 2013. The company information available to the study did not provide a solid enough basis for detailed analysis of the shifts in the geomatics areas between these two years. For example, it was not possible to determine if a specific firm moved from one geomatics area to another, if substantial mergers impacted such migration, or the extent to which the firms in 1999 that were still in business in 2013 had expanded their business into other geomatics areas.

Figure 5: Distribution of Business Establishments by Geomatics Area in 1999 and 2013



While it is not possible to accurately estimate the number of firms that fall into each segment of the contemporary GI supply value chain, approximate percentages of firms in each segment are provided in the following sections. It is important to note that firms often participate in more than one segment.

Geospatial information capture and processing

Some 60 percent of geomatics firms operate in this value chain segment. The companies whose primary business focus is in this part of the value chain, tend to be small (i.e., fewer than 50 employees) and their overall numbers are declining as a result of business closures and mergers and acquisitions. The majority of them are also engaged in geospatial information analysis and presentation since the products they provide to clients are typically maps, plans or charts, rather than the collected and processed data.

This part of the value chain is dominated by surveying companies located in most communities across the country, which provide property and engineering surveying, and building and construction layout services. While a significant number of such companies have adopted GIS technology to move up the value chain in response to client demand for more sophisticated geospatial products and services, there appears to be limited participation by these firms in higher value-added information production. For example, although the GI products they develop are integrated with other property information to provide the essential foundation for property ownership and real estate transactions, such integration happens within government organizations and surveying companies are rarely involved in this process. The exception is the integrated engineering and land surveying consulting practices, of which there are an increasing number. Consolidation within land surveying and with the engineering sector is a consequence of both aging demographics and the natural complementarity between these two disciplines. Several respondents within the land surveying profession have recently been acquired by engineering firms, or expect to be within the next five years.

Another historically important business segment in this part of the value chain is aerial mapping. Once a dominant force within the GI industry, the companies whose primary focus is mapping (e.g., digital graphics, orthophoto, digital elevation models, etc.) have shrunk in number. While there is still a small number of companies whose primary focus is aerial image capture and processing (i.e., optical, radar, LiDAR, multispectral and hyperspectral), a significant part of this work is now being conducted by vertically integrated firms that also produce mapping and other value-added geospatial products. A number of factors have contributed to the shrinkage of photogrammetric mapping capacity in Canada, including: significant reductions in government contracts due to completion of topographic mapping coverage in many jurisdictions, reductions in map revision budgets and federal-provincial map productions partnerships; growing popularity of image products that many users can produce themselves; and the movement of considerable production offshore to component mapping businesses in places like India and China.

The provision of satellite remote sensing or earth observation (EO) imagery also falls under this part of the GI value chain. While few in number, the few companies in this business tend to be large in size and have a global footprint (i.e., distributing data internationally, either directly or via distributors). The only operator of a Canadian EO satellite is MDA Corporation, with RADARSAT (although another firm, COM DEV International provides a GI related satellite service – monitoring Automatic Identification System or AIS-equipped vessels through its subsidiary, exactEarth[6]). MDA also distributes satellite imagery from a range of US and EU earth observation systems (e.g., WorldView, QuickBird, GeoEye, IKONOS, Pléiades, SPOT, TerraSAR and RapidEye)[7], as does Effigis Geo-Solutions[8]. BlackBridge Geomatics operates the RapidEye satellite constellation from its offices in Germany and also distributes earth observation imagery from SPOT, Pléiades, WorldView and QuickBird.[9]

Finally, a few very specialized data provision services fall under this category. Examples include the provision of: real time, high precision GPS corrections for e911 services (‘assisted GPS’); property ownership and assessment information; and imagery captured with unmanned aerial vehicles (UAVs) and terrestrial LiDAR systems (although a number of surveying and engineering companies also reported acquisition of such data with their own resources).

Geospatial information analysis and presentation

As indicated in the previous section, most businesses engaged in GI analysis and presentation also capture and process geospatial data. In addition to those kinds of traditional geomatics companies, this part of the value chain includes companies from other disciplines that provide geospatial maps and digital mapping data as part of their offerings. Typical examples include engineering and environmental consulting companies that use GIS to analyze processed mapping or imagery data to produce such outputs as: map products for environmental assessment reports;

ice charts for shipping companies and northern hunters; real time tracking of oil spills and forest fires; and inputs to common operating pictures for response to disasters. Approximately 70 percent of geomatics firms operate in this segment of the value chain.

Value-added information production

This segment of the GI value chain is increasingly being captured by other disciplinary firms, although traditional geomatics companies are also transitioning up the value chain to meet growing demand for value-added information products. Examples of GI products and services offered in this category are:

- Risk analysis for petroleum companies combining meteorological, wind and wave, ice and surface temperature;
- Epidemiology mapping to support disease propagation analysis;
- Property valuation and insurance estimating combining property boundary, street view imagery and land registry data;
- Planning, operation and maintenance of utilities such as power, water, sewer and natural gas; and
- Outlet location planning for retailers combining geospatial information with demographic, address, and public services information (the loss of data that was collected with the long form census has had a negative impact on this application).

Demand for fit-for-purpose GI solutions that are delivered and supported on a turnkey basis is growing as organizations that do not have or want to develop in-house GI expertise recognize the value of geo-enabling key business processes and look for external hosted solutions. This will be discussed further in Section 3.1.1. Approximately 50 percent of geomatics firms operate in this segment of the value chain.

Location-based solutions

The location-based solutions market is dominated by major corporations headquartered in the United States (US) (e.g., Google, Bing, MapQuest and more recently, Apple). There are a small but growing number of Canadian geomatics companies that are focusing on this segment of the GI value chain. Examples of important Canadian players include Descartes (providers of logistics, routing, mobile and tracking solutions), Blackline GPS (serving the employee safety monitoring and business tracking market segments) and Shaw Tracking (providers of GPS fleet management solutions). While there are some 100,000 geo-enabled apps in Apple's app store, it is difficult to ascertain which ones were developed in Canada. There is evidence of a shift to the development of more and more GI web and mobile apps for clients, and that the focus is shifting from value-added information products and services to location-based solutions, including hosted solutions on the web. This will be discussed further in Section 3.1.2. Approximately 2 percent of geomatics firms operate in this segment of the value chain.

Geospatial information technologies

While the geospatial information technologies value chain segment is also dominated by the US and, to a lesser extent the EU, there are notable Canadian participants which are international players in this market. On the software side, these include companies like PCI Geomatics, CARIS, Array Systems, Avenza, Cengea, CubeWerx and Enghouse. Hardware providers include companies such as Applanix, COM DEV, Itres Research, Knudsen Engineering, MDA, Offshore Systems, Optech, NovAtel, CMC Electronics and Rx Networks. In addition, major external suppliers of GI technologies have a strong footprint in Canada through distributors, partners or subsidiaries, including such industry software leaders as Esri, Hexagon / Intergraph and ERDAS, Pitney Bowes / MapInfo, Autodesk and Bentley, and global hardware suppliers such as Hexagon / Leica Geosystems, Trimble, Ashtech, Garmin, FARO, Spectra Precision, Nikon and Topcon. Approximately 20 percent of geomatics firms operate in this segment of the value chain.

2.3.2 Existing Public Sector Geomatics Capacities and Service Delivery Models

There are strong GI supply capabilities at all three levels of government. Historically, federal, provincial and territorial government geomatics agencies were the primary sources of GI and played a lead role in geomatics research and innovation. Over the past 10-15 years, the role of these agencies has changed due to a number of factors (e.g., loss of resources through multiple rounds of budget cuts, emergence of private sector data providers and crowd-sourced data, increasing user-friendliness of GI technologies, etc.). In many jurisdictions, the focus has shifted from primary production of geospatial data to data integration from multiple sources, and programs to create infrastructure that facilitates discovery and access to all kinds of GI, including support for development of applications to make use of the infrastructure and the more readily accessible data.

There is now more effort devoted to facilitating interoperability and sharing of datasets through adoption of open geospatial standards and operational policies in connection with spatial data infrastructure initiatives. In addition, as the number and type of users has grown, GI providers are placing more emphasis on building and supporting web and mobile applications to better serve the needs of users within their own ministries and sometimes beyond. This shift in focus is consistent with patterns in the private sector and reflects a maturing of the use of GI, a growing awareness of its value, and a reprioritization of the activities of public sector GI providers in times of fiscal restraint.

The study research and consultations provide evidence that the impact of the GI provider organizations within government is expanding. SDI and geoportal development initiatives, along with widespread adoption of open data policies, are raising the visibility of geospatial information assets. With more visibility and easily accessible GI applications has come broader use of these assets and increased appreciation of their value. Appendix B provides ample confirmation of the proliferation of GI use within government. Over the past ten years, use of geospatial information products, services and technologies has grown well beyond geomatics specialists to produce benefits in the domains of other scientific disciplines, and their impact in policy development is beginning to be felt.

The following sections provide profiles of GI supply capacities and service delivery at the federal, provincial / territorial and municipal levels, respectively.

Federal government

Geospatial information provision at the federal level is spread between a number of departments and agencies, the majority of which are represented on the federal geomatics coordination body, the Federal Committee on Geomatics and Earth Observation (FCGEO), and the federal-provincial-territorial coordination group, the Canadian Council on Geomatics (CCOG).[10] FCGEO members include:

- Natural Resources Canada
- Agriculture and Agri-Food Canada
- Canadian Space Agency
- Environment Canada
- Aboriginal Affairs and Northern Development Canada
- Canadian Food Inspection Agency
- Fisheries and Oceans Canada
- National Defence
- Elections Canada
- Health Canada
- Industry Canada
- Parks Canada
- Public Safety Canada
- Public Health Agency of Canada
- Royal Canadian Mounted Police
- Shared Services Canada
- Coast Guard of Canada
- Treasury Board of Canada
- Statistics Canada

The federal government members of CCOG are:

- Natural Resources Canada
- Agriculture and Agri-Food Canada
- Canada Post Corporation
- Elections Canada

- Fisheries and Oceans Canada
- National Defence
- Statistics Canada
- Public Works and Government Services Canada

Under the leadership of Natural Resources Canada, significant investment has been made in Canada's national SDI initiative, the Canadian Geospatial Data Infrastructure (CGDI), a key service delivery mechanism that has been developed through the GeoConnections Program with the support of three successive rounds of funding starting in 1999. The GeoConnections Program has been successful in leading coordination of GI accessibility work nationally, providing data discoverability, and developing or endorsing geospatial data standards and operational policies.[11] Free and open access to GI is provided through the GeoConnections Discovery Portal and individual organizational portals, with increasing content available through the government's open data portal, data.gc.ca. There are approximately 198,000 geospatial datasets accessible through this portal,[12] representing over 95 percent of the total content available on data.gc.ca. A major initiative of the FCGEO to consolidate federal GI, the Federal Geospatial Platform (FGP)[13], is underway to build a shared infrastructure that will facilitate the government's most relevant information being managed spatially, analyzed, and visually displayed to enhance decision-making support of government priorities.[14]

Natural Resources Canada

The lead geomatics group in the Government of Canada is the Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan), primarily represented by the Canada Centre for Mapping and Earth Observation (CCMEO) and the Surveyor General Branch (SGB). Another part of ESS, Geological Survey of Canada, also has significant geomatics related programs and activities, including Geo-Mapping for Energy and Minerals (GEM), a program to advance geological knowledge in the North that invested $100M between 2008 and 2013 and is investing an additional $100M in 2013-2020. Other sectors within NRCan that have geomatics capacity include the Canadian Forest Service and the Minerals and Metals and Energy Sectors.

CCMEO results from the merger in 2013 of the Mapping Information Branch and Canada Centre for Remote Sensing to achieve: convergence of technologies in mapping and remote sensing; more robust applications and analyses for government and business solutions; and streamlining of parallel imagery and GIS/GPS data value chains.[15] CCMEO's business lines at the time of report writing were:[16]

- Canada Centre for Remote Sensing Innovation – Earth observation and geomatics research and development, the development of Earth observations and geo-based optical, radar, satellite and other such methodologies and operations.

- Canada Centre for Geospatial Data Management – management of all ESS-NRCan data, databases and archives, including Earth observation components and the production of energy, topographical and other specific mapping requests.

- Canada Digital Map and Collections Access division – web development and access, publications, collections management, geo analytics and client services.

- GeoConnections Division – geo-strategy development, connections with partners and stakeholders and the secretariat of several external committees (e.g., FCGEO, CCOG and the Canadian Geomatics Community Round Table[17]).

The Surveyor General Branch (SGB) is responsible for maintaining the Canadian Spatial Reference System (CSRS) that provides fundamental reference values for latitude, longitude, height and gravity, including earth's orientation parameters and rotation rate in space, as the foundation for the nation's evolving positioning and navigation activities. SGB also ensures boundary certainty through:[18]

- the proper maintenance of the Canada-United States international boundary for law enforcement, land administration, customs and immigration, and transboundary resource management;

- effective boundary surveys of Aboriginal settlement lands to meet Canada's obligations under land claim settlement legislation and treaties; and

- statutory registration of legal surveys on Canada Lands (the North, Canada's offshore area, Aboriginal Lands and National Parks), essential to the creation of property parcels.

Under the direction of the Minister of Natural Resources, the Surveyor General has the legal responsibility to manage all surveys on Canada Lands and to maintain all the original plans, journals, field notes and other documents connected with those surveys. Additionally, some 20 federal and territorial acts set out property rights systems that rely upon the work of the Surveyor General.[19]

The majority of ESS's geospatial information is discoverable via the GeoConnections Discovery Portal[20], and accessible through that portal or two other geoportals – GeoGratis[21] and GeoBase[22]. NRCan is leading the Federal Geospatial Platform initiative of FCGEO to create a collaborative online environment consisting of authoritative geospatial data, services, and applications.

Agriculture and Agri-food Canada

The AgroClimate, Geomatics, and Earth Observations Division is the primary GI delivery group within Agriculture and Agri-food Canada (AAFC), focusing primarily on soil and land cover mapping. It provides a number of online services to the agriculture community based on geospatial information. Included are: AgriMap, Biomass Inventory Mapping and Analysis Tool, Canada Land Inventory (CLI), Land Cover for Agricultural Regions of Canada, Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) datasets, National Ecological Framework for Canada, Plant Hardiness Zones of Canada, Agriculture and Agri-Food Canada (AAFC) Watersheds Project – 2012, Soil Landscapes of Canada, Soils of Canada, and Watershed Delineation Tool.[23] These freely and openly available datasets are viewable on geoportals and accessible via web services and, or downloadable from AAFC websites.

Fisheries and Oceans Canada

The Canadian Hydrographic Service (CHS) is the geospatial information production organization within the Department of Fisheries and Oceans (DFO). The mandate of the CHS is to: conduct hydrographic surveys that capture water depths, geographical features, hazards to navigation, man-made and natural features that aid navigation, tides, currents and water levels, and sea bottom characteristics; and produce authoritative nautical charts and publications which support a broad range of marine activities.[24] Indexes for paper and electronic charts and other nautical publications are viewable via a web mapping application[25] but are not freely and openly available; they are sold through a network of over 800 dealers across Canada and around the world.

Environment Canada

Environment Canada employs web mapping to display many different kinds of environmental information (e.g., air and water quality, biodiversity, greenhouse gas emissions, etc. The GI products that the department provides include: weather maps, produced by the Meteorological Service of Canada, whose mandate is to provide Canadians with access to vital weather and environmental information and warnings;[26] and ice maps, produced by the Canadian Ice Service, whose mandate is to provide timely and accurate information about ice in Canada's navigable waters.[27]

Statistics Canada

Canada’s national statistics organization, Statistics Canada, is both a significant user and producer of geospatial information, through its Geography Division. Free and open online access is provided to a range of digital datasets, including: [28] 2011, 2006 and 2001 census road network files; intercensal road network files; cartographic boundary files portraying the geographic areas using only the major land mass of Canada and its coastal islands; and digital boundary files portraying the full extent of the geographic areas, including the coastal water area. Statistics Canada also provides an interactive web mapping service – GeoSearch[29] – and maps in PDF format, such as: standard geographical classification reference maps; census tract and dissemination area reference maps; federal electoral district reference maps; and thematic maps showing the spatial distribution of one or more specific data themes for standard geographic areas.[30]

Aboriginal Affairs and Northern Development Canada

Aboriginal Affairs and Northern Development Canada (AANDC) is another major GI user, and the Geomatics Services unit in the Chief Information Officer (CIO) Branch helps departmental programs to deliver services and information to Canadians, including Aboriginal communities, using geographic based products, services and tools. Examples of the kinds of GI products and services provided by AANDC include: northern oil and gas disposition and call maps,[31] and major mineral projects north of 60th parallel in Canada,[32] both downloadable as PDF files. There are also a number of interactive web maps providing AANDC information including: GeoViewer; Petroleum and Environmental Management tool; and First Nation Profiles, Inuit Community Profiles, Urban Aboriginal Strategy, and Aboriginal mining agreements interactive maps.[33]

National Defence

The Department of National Defence (DND) is a significant producer of GI products for operational planning, operational support in theatre, and emergency response activities to support the Canadian military at home and abroad. Reorganization in 2014 brought together the following organizations under a new Defence Intelligence Group: Mapping and Charting Establishment, Joint Imagery Centre, Joint Meteorological Centre, National Counter Intelligence Unit, and Human Intelligence. DND's production capability is focused on data that cannot be acquired from another Canadian organization (e.g., NRCan digital mapping, CHS hydrographic charting, NavCanada aeronautical charting, EnvCan ice charting, etc.) or a defence ally. DND's GI products and services are entirely inward facing; they do not provide geospatial information to external parties except to other military partners. They do share information with partners in emergency response situations.

Elections Canada

Elections Canada produces geospatial data in partnership with Statistics Canada and provides free and open access to electoral boundary data in both digital dataset and PDF formats. The Federal Electoral Districts of Canada – 2011 and Federal Electoral Districts of Canada – Polling Division Boundaries – 2011 files are downloadable as digital files through the GeoGratis portal.[34] In addition, maps of electoral districts, provinces and territories, and Canada showing electoral district boundaries can be downloaded from Elections Canada's website as PDF files.[35]

Canadian Space Agency

The Earth Observation Applications & Utilizations Division of the Canadian Space Agency manages programs and activities that support and promote the development and use of Earth Observation (EO) technologies and applications. Geospatial information related programs include:[36]

- *Earth Observation Application Development Program (EOADP)* – promotes the development of applications by the Canadian private sector that will maximize the utilization of EO data generated by CSA-supported missions.

- *Government Related Initiatives Program (GRIP)* – focuses on developing government use of space-based land, ocean, and atmospheric observation systems and services.
- *Science and Operational Applications Research (SOAR)* – an International Announcement of Opportunity providing RADARSAT-2 products for R&D purposes.
- *Access to RADARSAT-2 data* – offers Canadian provinces and territories three mechanisms enabling access to this data.

Provincial / territorial government

All of the provincial and territorial governments in Canada are represented on CCOG by the primary geomatics organization in each jurisdiction. Provincial and territorial government members of CCOG are:

- GeoBC, BC Ministry of Forestry Lands and Natural Resources
- Surveyor General Division, Land Title and Survey Authority of BC
- Information & Data Provisioning Services, AB Department of Environment and Sustainable Resource Development
- Office of Geomatics Coordination, Information Technology Office of Saskatchewan
- GeoManitoba, Manitoba Conservation and Water Stewardship
- Manitoba Property Registry
- Information Resources Management, ON Ministry of Natural Resources
- Geomatics & Property Office, ON Ministry of Transportation
- Direction de la cartographie générale et administrative, QC Ministère des Ressources naturelles et de la Faune
- Bureau de l'arpenteur général du Québec, QC Ministère des Ressources naturelles et de la Faune
- Land Information Infrastructure, Service New Brunswick
- Information Management Services, Service Nova Scotia and Municipal Relations
- Property Assessment Services, PE Finance and Municipal Affairs
- Surveys & Mapping Division, NL Department of Environment and Conservation
- Client Services, YT Department of Highways & Public Works
- NWT Centre for Geomatics, NT Environment and Natural Resources
- Parks Geospatial Information, Nunavut Parks & Special Places

In addition to programs for the production of GI, which are more prominent at the provincial/territorial than the federal level, increasing attention is being paid to improving dissemination through the launch of SDI initiatives to make digital geospatial data freely and openly accessible through geoportals. This is in part due to open data policies being implemented in most jurisdictions. The information provided has been compiled from publicly available documentation, which varies in breadth and depth between jurisdictions. In some cases, programs and activities that may be almost universally underway (e.g., overall geomatics strategy development and geographical names) are not included unless they are specifically referenced in the available information.

Newfoundland and Labrador

The principal GI provider in this province is the Surveys and Mapping Division of the Department of Environment and Conservation. The division has five core programs:[37]

- Topographic Mapping – Provides detailed mapping (1:2,500 1:5,000 scales) from aerial photography of nearly all Municipalities and surrounding areas with the exception of the Cities of St. John's and Mount Pearl, vector digital data of the National Topographic Series (NTS) of maps (1:50,000, 1:250,000 scales) from Federal-Provincial cost shared digital conversion of paper maps, and digital orthophoto mapping (1:10:000 scale).
- Geodetic Surveys – Maintains network of markers and GPS reference systems.
- Aerial Photography – Provides air photo scanning, printing and enlargement services.
- Geographical Names – Under the Geographical Names Board Act, the Department has the authority to officially name all geographical features and places in the province.
- Provincial Geomatics Strategy – The Division is the designated lead agency responsible for geomatics and collaborates with the Federal/Provincial/Territorial GeoConnections program towards building the Canadian Geospatial Data Infrastructure (CGDI).

Nova Scotia

The GeoNOVA Program of Service Nova Scotia & Municipal Relations is the primary GI provider in Nova Scotia. The program operates the GeoNOVA geoportal[38], which provides discovery and access functions to a range of GI products and services, including: Data Locator, Property Online, Address Lookup, Nova Scotia Wind Atlas, Atlas of Nova Scotia, Electoral District Finder, and Place Names. The GeoNOVA Data Download Service provides access to the following digital mapping products: Nova Scotia Topographic Database (1:10,000 Resource Mapping Series), Nova Scotia Geographic Names, and maps from the Department of Agriculture. The portal also provides links to several other applications including: Coordinate Transformation, Forestry Division downloadable GIS data, Mineral Resources Branch geoscience digital products, Geoscience Maps, Databases and Images (NSGEOMAP) Internet Map Service, Nova Scotia Community Counts, and ExploreHRM, Halifax Regional Municipality's online, interactive mapping tool.

The Surveys Division of the Department of Natural Resources is responsible for the department's survey program and is accountable for coordinating, monitoring and evaluating all Crown land survey projects. The Division is also the record keeper for activities and interests on Crown land. After decisions are made on how Crown land will be allocated and used, the Surveys Division, with the assistance of Regional Services, provides the tools to complete these tasks.[39]

Prince Edward Island

The primary geomatics organization in PEI is the Geomatics Information Centre, part of Taxation and Property Records Division of the Department of Finance and Municipal Affairs. The Centre operates GeoLinc Plus,[40] a geoportal that provides access to assessment, tax, registry, and property mapping information for any parcel of land in Prince Edward Island. Free and open access is provided to a range of digital GI datasets in several formats.[41]

New Brunswick

Primary responsibility for GI products and services in this province lies with the Land Information Infrastructure Branch of Service New Brunswick. GeoNB is the name adopted by the Province of New Brunswick to describe its corporate approach to the creation, maintenance, and distribution of geographic information. The primary goals of GeoNB are:[42]

- Providing all users with easy access to geographic data, value-added applications and maps;
- Reducing duplication and costs through collaboration and the sharing of geographic data and infrastructure; and
- Promoting and increasing the use of geographic data and maps.

The GeoNB portal provides: a data catalogue that facilitates access to a list of the geographic datasets that are available for download, custom designed applications combining data and value-added functionality intended for specifically targeted user groups; and pre-generated, static maps created to convey a specific piece of information and may be of interest to multiple user groups for general purpose map display.

Québec

The Ministère des resssources naturelles du Québec (MRN) is the main producer of geospatial data for the Government of Quebec. The MRN works closely with other ministries to produce reference geospatial data sets such as the hydrographic network, the address database and the transportation network. Production includes themes like:[43]

- Framework data (topography, geodetic network, DEM, imagery, administrative boundaries)
- Address database (network, points of addresses, start and end addresses per segment);
- Forestry (stands, ecology, soils, sampling, administrative boundaries, etc.);

- Geology (geophysics, geochemistry, petrology, structural geology, showings, mineral potential, claims, etc.)
- Energy (gas and oil, seismology, wells, electrical utilities, aeolian potential and assets)
- Public land rights and tenure
- Cadastre and land registry

Foncier Québec maintains and develops the land registration infrastructure, helping to protect the land rights of citizens and the State and support Québec's socioeconomic development. As the manager of the land registration system, Foncier Québec is responsible for keeping and updating the registers that record divisions of private and public land, and for granting public rights in land.[44]

The geoportal Géoboutique Quebec[45] sells geographic information products and provides distribution services on request.

Ontario

The Mapping and Information Resources Branch of Ontario Ministry of Natural Resources (MNR) is the primary geomatics group in this province. The branch provides geomatics, surveying, data, and information management services to MNR and ministries across the government and leads the development and application of geographic information for natural resource management and decision-making.[46] Within the branch, the Office of the Surveyor General oversees all Crown land surveys and legal descriptions to ensure Ontario's Crown land is effectively managed. The Office provides professional survey advice and services to the Ministry of Natural Resources and members of the public with property adjacent to Crown land.[47]

The branch contributes to the government's information and information technology initiative by making geographic information about Ontario accessible through the Land Information Ontario (LIO) program.[48] LIO manages key provincial datasets and collects high resolution satellite imagery, and allows more than 400 public sector organizations to easily discover, share, and use digital geographic information under the Ontario Geospatial Data Exchange (OGDE) agreement. The LIO geoportal provides a gateway to maps, satellite imagery, road and trail network info, etc. and a web map application that can be used to make a custom map of any part of Ontario.[49]

Manitoba

GeoManitoba, part of the Department of Conservation and Water Stewardship, is the Government of Manitoba's primary GI provider. GeoManitoba was formed in 2011 to assume formal responsibility for the stewardship and evolution of Manitoba's shared geospatial technology and information assets. In addition to providing surveying, remote sensing, topographic, and cadastral mapping services and sales, GeoManitoba is developing corporate-wide GIS capacity to provide a revitalized approach to support delivery, acquisition and management of geospatial information for all Manitoba government departments.[50]

Within GeoManitoba, the Geospatial Data Acquisition and Product Development section coordinates geospatial data acquisition for government and provides digital mapping, land surveying and geodesy services to government.[51] The Geospatial Information Distribution and Support section provides geospatial products and services to the public and other government agencies.[52] A new Geospatial Technology Management section coordinates and manages Manitoba's Spatial Data Infrastructure (SDI) and Geographic Information System (GIS) initiatives identified in Manitoba's strategic GIS enterprise strategy.[53]

Saskatchewan

Saskatchewan's principal geomatics organization, Information Services Corporation of Saskatchewan (ISC), is a provincial Crown corporation responsible for the administration of land titles, surveys, mapping, geographic information system (GIS) data, and interests in personal property. ISC Geomatics Services include:[54]

- Geographic Information Systems (GIS) – ISC is the custodian of the provincial GIS Cadastral Base Map for Saskatchewan, which provides the digital geospatial depiction of parcels of land as well as their shape and location.
- Maps, Photos and Imagery – ISC offers a wide array of digital and hard copy maps and photo imagery for professional and customer use.
- Customization and Distribution Services – ISC offers a compilation of geospatial information for hardcopy or digital output, digitizing and plotting of output, and standard and custom enlargements of aerial photographs

ISC's geoportal, GeoSask, is a collaborative effort to facilitate the discovery and publishing of Saskatchewan geographic information system (GIS) information and maps.[55] It includes map viewing, metadata search, and data downloading capabilities.

Alberta

The Information and Data Provisioning Section of the Ministry of Environment and Sustainable Resource Development (ESRD) is the principal GI provider in Alberta, with responsibilities for base mapping, public lands plans examination, and imagery services.[56] The Director of Surveys Office, also located in ESRD, is responsible for coordinating the establishment, maintenance and preservation of the provincial land survey system and providing the provincial spatial referencing system. The Director of Surveys is designated by the Minister of Alberta Environment and Sustainable Resource Development (ESRD) to administer Alberta's Surveys Act.[57]

Another ESRD organization, GeoDiscover Alberta (GDA),[58] is the main access point for easily integrated, authoritative and usable geospatial data and services. GeoDiscover Alberta manages the SDI framework and fosters the collaboration needed to make geographic data and information more widely available. While GDA is not responsible for data production, they are involved in data related activities in the SDI context. For example, they are currently working on a provincial road network concept, similar to the federal NRN, but based on capturing data at source. The GDA portal provides data discovery and viewing functionality and links to downloadable dataset, as well as tools to measure, manipulate, identify and analyze data in the web mapping application.

Service Alberta is responsible for registering land ownership rights in Alberta.[59] The Land Titles Office, comprised of the Document Examination and Surveys Sections, is part of the Registry Services Division of Service Alberta. The Surveys Sections in the Calgary and Edmonton Land Titles Offices are staffed with Survey Technologists who are responsible for performing the review and associated data entry of all legal plans as well as documents associated with them. Today, all plans must be submitted for registration in digital format. As a result of automation, most titles and all plans can now be searched and retrieved electronically through the SPIN2 internet site at www.spin.gov.ab.ca/. In 2013-2014, Land Titles & Surveys completed more than 1.2 million registrations and nearly 3.6 million searches.[60]

British Columbia

The primary GI provision organization in this province, GeoBC, part of the Ministry of Forests, Lands and Natural Resource Operations, creates and manages geospatial information and products as well as provides consultation services across all natural resource sector (NRS) agencies. The group has four areas of focus:[61]

- Creating and maintaining a standard set of base spatial data (e.g., roads, hydrology, terrain, etc.) with the goal of progressively making this information open and accessible for use by all;
- Providing assurance for two of the Provincial Crown land registries, the information repositories of Provincial rights and obligations – specifically Tantalis and the Integrated Land and Resource Registry (ILRR);
- Offering Crown land research expertise to other government agencies, both rights-granting and otherwise; and
- Providing a custom solutions service to NRS business issues (e.g., developing mapping products and visualization for avalanche awareness, providing assistance to treaty teams, spatial design and project management support for clean energy projects, etc.).

The GeoBC geoportal has been integrated with the province's open data portal, DataBC, where authoritative geographic data can be discovered and accessed through a number of different online services.[62]

The Land Title and Survey Authority of British Columbia (LTSA) is a publically accountable, statutory corporation which operates and administers British Columbia's Land Title and Survey

Systems. The LTSA maintains these systems through the timely, efficient (electronic) registration of land title interests and survey records. Annually, about 3 million transactions are processed, of which approximately 650,000 are for registration of land title interests and 2.4 million are for searches of registered records and issuance of certificates. Approximately 11,000 land title survey plans and 2,500 Crown land survey plans are registered annually. About 1,000 information requests annually come into the Surveyor General for survey records, some of which are in electronic form. The LTSA is currently developing ParcelMap BC, a single, complete, trusted and sustainable visual representation of lands within a given parcel and its relationship to adjacent parcels.[63]

Yukon

Geomatics Yukon is part of the Department of Government Services with responsibility for distributing Yukon Government spatial data and imagery to the public. Services provided to the Yukon Government include:[64]

- Corporate Spatial Warehouse – stores corporate data collections in an easy to use, standardized and client specific manner
- Operational SDE Database support and infrastructure
- Web Mapping Support and Infrastructure – hosts a range of web mapping applications for Yukon Government departments and other partners.
- Host FTP site for downloading Yukon spatial data
- Host CSW Metadata Server – provides a data discovery function
- ArcGIS License Manager Support/Administration
- Maintenance of Government Image Repository
- Imagery Coordination – coordinates imagery purchases, storage, and distribution within the Yukon Government and provides support for orthorectification of imagery and compiling ground control data.
- GIS Technical Support and GIS recommendations to departments

Northwest Territories

The Northwest Territories (NWT) Centre for Geomatics, situated within the Department of Industry, Tourism and Investment, provides geomatics and geographic information systems (GIS) services to the departments of the Government of the NWT.[65] The Centre conducts geomatics projects, provides access to geomatics and geographic information, and promotes the application of geomatics and GIS in all departments by providing training, resources and advice. The Centre is equipped with a variety of systems for project work in geomatics. It hosts a geoportal with web mapping services where GI can be viewed or downloaded.[66]

Nunavut

Nunavut Parks & Special Places is the lead Territorial agency responsible for the protection and promotion of natural and cultural heritage landscapes and recreation opportunities in Nunavut. The Division is also obligated under the Nunavut Land Claims Agreement (NLCA) and the Umbrella Inuit Impact and Benefits Agreement for Territorial Parks. The division's Land Claims and Geospatial Information program:[67] facilitates the implementation of the NLCA; manages and administers the implementation of the Umbrella Territorial Parks Inuit Impact and Benefit Agreement (IIBA); represents the Government of Nunavut on Federal and other IIBA obligations; and coordinates geospatial information and the division's land use planning responsibilities.

Municipal government

According to the latest census[68], there were some 5,250 municipalities in Canada in 2011. Forty-five municipalities had populations between 50,000 and 100,000, fifty had populations between 100,000 and 500,000, eleven had populations between 500,000 and 1,000,000, and 3 had populations over 1,000,000. Municipalities of a significant size (e.g., typically populations over 20,000) have internal capability to produce and use GI, while smaller municipalities obtain GI services under contract. Base or core mapping is typically obtained under contract by all municipalities, while other layers of data (e.g., utilities, transportation, etc.) may be generated and maintained internally by the larger municipalities.

There is considerable diversity in the way that GI supply capacity and service delivery is handled at the municipal government level in Canada. There is often a 'surveying and mapping' group within municipal administrations that plays a primary GI supply role, but such capacity may also exist within 'GIS', 'geomatics' or other groups. A favoured location for such groups is within Infrastructure departments, but they may also be found in Parks, Planning and other municipal government organizations. While not intended to be comprehensive, the following sections provide illustrative examples of the municipal government capacity, as represented by the organizations that participated in our consultations.

City of Montréal

The Geomatics Division, Infrastructure Branch is the main GI provider for the City of Montreal, with approximately 100 employees. The Division is responsible for seven types of geomatics activities relating to data acquisition and maintenance: Legal surveying; Geodesy, mapping and 3D data; Engineering surveying; Infrastructure inventory; Maintenance of GPS networks; and IT support (projects, systems). The Division has grown from 40 to 100 employees in the last 10 years, showing clearly that Montreal puts a priority on GI to support its operations.[69]

The City announced in early June 2014 that the open data portal at donnees.ville.montreal.qc.ca will provide free and open access to, among other things, the following datasets:[70]

- Scanned aerial photographs from 1930 to 2003;
- A digital map base comprising geometric 2D representation of elements of the territory made up of buildings, pavement, sidewalks, street furniture, trees, etc.;
- A digital elevation model (DEM) with a simplified representation of the topography of the ground; and
- Over 300,000 3D buildings covering the entire island of Montreal.

City of Ottawa

The primary GI provider in the City of Ottawa is the Surveys and Mapping Branch of the Infrastructure Services Department. With a complement of 35 staff, they handle all surveys and mapping work for other departments as well (e.g., Planning, Public Works, Transportation, or any other department that needs GI). They are tasked with doing all the legal and engineering surveys, and photogrammetric and orthophoto mapping for the City, plus all the GIS work for the Department. Every 3 years, they collect aerial imagery for the entire City and produce orthophoto mapping. For the urban area they also do 1:1,000 vector mapping, about 1/3 of the area per year (urban resolution of 6 cm and rural of 20 cm).[71]

They contribute mapping, orthophoto and LiDAR data to the Corporate GIS system along with property boundary and ownership data updates received from Teranet monthly. The corporate database also includes different layers of information from others, such as addresses, street centerlines, etc. They are moving into a shared data environment that will allow data to be served up to the City open data portal for access to the public. The current geoOttawa portal helps users find their way around the city. Users can search by address, intersection, street segment or by facility and interact with the web mapping application by zooming in and out, adding additional layers of information, or printing views of the map.[72]

City of Toronto

The Geospatial Competency Centre at the City of Toronto provides enterprise geospatial framework data, technology solutions, and consulting for geo-enabled business applications and related architectures using a federated operational model in a collaborative working environment. With approximately 40 staff the Centre is responsible for geospatial technology services, products and support, geospatial data management, geospatial systems, land base mapping, topographic/photogrammetric services, street and parcel mapping, municipal street naming and numbering. They contract for city coverage of aerial imagery (4 cm resolution) and stereo model development every year, and City staff conducts digital mapping feature collection.[73]

Through the City of Toronto open data portal, the Centre provides free and open access to close to 90 downloadable GI datasets, and web map services to access base and socio-demographic data and ortho imagery covering the City.[74]

City of Calgary

The City of Calgary's principal GI providers are within the Infrastructure & Information Services Department:

- The Geospatial Business Solutions Division, with a staff of 50 are responsible for: GIS services; higher level emergency response; imagery (digital aerial survey, oblique, orthophoto, airborne LiDAR); and capital projects that span more than one department (e.g., buildings portal with data on assessment, condition, and access). They acquire digital aerial imagery for core growth areas and new subdivisions every second year and the remainder of the City every third year, used to produce planimetric and 10 cm resolution orthophoto mapping under contract. They licence the use of some of their GI by others outside the City and earn revenues of $2M annually. There is pressure to make more data open and free, but this has a cost that must be recognized.[75] Through the Cityonline open data portal, they make some 40 GI datasets available.[76]
- The Field Surveying Services Division (40 staff), provides a wide variety of engineering and land surveys including: preliminary, topographic, roads, utilities, local improvements, building grades, earthwork, precise engineering, as-built, control, legal boundaries, cadastral ties and registered plans.[77]
- The Asset Information & Mapping division provides enterprise-based spatial data creation and maintenance services, including managing and providing customers' geospatial information, key corporate data sets, and enterprise-based spatial data creation and maintenance services.[78]

City of Surrey

The GIS Section is located in the Engineering Department at the City of Surrey, with staff of approximately 15 people.[79] The group: creates and maintains 85 percent of the City's spatial data (property, infrastructure, etc.); develops and maintains the City of Surrey Mapping Online System (COSMOS), which provides visualization of information on zoning, land use, underground utilities, schools, parks, recreation centres, etc.; and creates custom web mapping applications for users within the City and the public (e.g., Low Cost & Free Resource Map, Property report, Engineering drawings, Community service maps, Historical imagery viewer, and Traffic volume maps and data.[80]

Through the City's Open Data portal,[81] free and open access is provided to a range of imagery (LiDAR, ortho, DEM, etc.) and digital GI data (e.g., paths and trails, ecosystem corridors, flood plains, sewer and water, land use, etc.) in several different formats (e.g., SHP, KML, TIFF, etc.). The Section is helping other departments like Finance to make their information more accessible through the portal.

Aboriginal government

An evolving form of government is under development in Canada as self-government responsibilities are devolved from the federal government to more and more Aboriginal communities. Under self-government agreements Aboriginal governments are established that are primarily responsible to their citizens, and a framework is established for intergovernmental relationships between the Aboriginal, federal and, where applicable, provincial governments. These agreements address: the structure and accountability of Aboriginal governments, their law-making powers, financial arrangements and their responsibilities for providing programs and services to their members.[82] As of June 2014, the Government of Canada had signed 21 self-government agreements involving 35 Aboriginal communities across Canada.[83]

The use of geospatial information is of great importance to these communities as they develop the resources and capabilities to manage their lands and natural resources. There are a number of ways that communities are accessing and using GI resources. Some communities have developed in-house geomatics groups (e.g., Simpcw First Nation[84], Lil'wat Nation[85], Matawa First Nations[86]) while others have contracted geomatics companies to build and maintain datasets and applications (e.g., Eeyou Istchee[87], Nunavik Landholding Corporations Association[88]). A not-for-profit corporation, the Aboriginal Mapping Network, was established in 1998 to support Aboriginal and indigenous peoples facing common issues, such as land claims, treaty negotiations and resource development, by providing access to common tools, such as traditional use studies, spatial data resources, GIS and other information systems. [89]

2.3.3 Profile of Academia

Canada has a comprehensive geomatics education and training system that is well respected internationally. In addition to the traditional sources of university education in geography and geomatics science and engineering departments, GI-related courses are now routinely offered by most Canadian universities through departments in related disciplines (e.g., forestry, geology, agronomy, environmental sciences, civil engineering, and even health). Community colleges also offer GI training through specialized geomatics and GIS programs (both diplomas and certificates), as well as through more general technology programs such as engineering and environment. Profiles of post-secondary geomatics programs at 94 Canadian universities and colleges have been compiled, including the faculty name, degree/diploma name, admission requirements, program description, and a list of courses offered (see the following tables). The inventory includes programs at 12 institutions in Atlantic Canada, 16 in Quebec, 36 in Ontario, 10 in Manitoba, Saskatchewan and the Territories, 10 in Alberta, and 10 in British Columbia.

Table 1: Geomatics Education and Training Programs in Western and Northern Canada

Western/Northern Canada				
Name of University/College	**Geomatics Degree/Program Available**			
	Coursework/ Certificate/	**Bachelor**	**Masters**	**PhD**

Western/Northern Canada				
	Minor			
British Columbia				
1. Simon Fraser University	1	1	2	1
2. University of British Columbia	2	1	0	0
3. University of Northern British Columbia	3	11	0	0
4. University of Victoria	0	3	0	0
5. Thompson Rivers University	0	1	0	0
6. British Columbia Institute of Technology	4	2	0	0
7. Camosun College	4	0	0	0
8. Douglas College	2	0	0	0
9. Okanagan College	2	0	0	0
10. Selkirk College	1	1	0	0
Alberta				
11. University of Alberta	6	0	0	0
12. University of Calgary	0	5	2	1
13. University of Lethbridge	0	2	0	0
14. University of Regina	0	3	0	0
15. Mount Royal University	1	1	0	0
16. Athabasca University	1	0	0	0
17. North Alberta Institute of Technology	2	0	0	0
18. South Alberta Institute of Technology	4	1	0	0
19. Lethbridge College	4	0	0	0
20. Olds College	2	0	0	0
Saskatchewan				
21. University of Saskatchewan	2	2	0	0
22. Saskatchewan Institute of Applied Science and Technology	7	0	0	0
Manitoba				
23. University of Manitoba	1	1	1	0
24. University of Winnipeg	0	3	0	0
25. Brandon University	1	2	0	0
26. Red River College	2	1	0	0
27. Assiniboine Community College	1	0	0	0
Territories				
28. Nunavut Arctic College	2	0	0	0

Western/Northern Canada				
29. Aurora College	1	0	0	0
30. Yukon College	3	1	0	0
Total	**59**	**42**	**5**	**2**

Table 2: Geomatics Education and Training Programs in Ontario

Ontario				
Name of University/College	**Geomatics Degree/Program Available**			
	Coursework/ Certificate/ Minor	**Bachelor**	**Masters**	**PhD**
1. Brock University	0	2	0	0
2. Carleton University	1	2	2	0
3. Lakehead University	1	5	0	0
4. Laurentian University	2	4	0	0
5. McMaster University	1	5	0	0
6. Nipissing University	1	3	0	0
7. Queen's University	1	0	0	0
8. Ryerson Polytechnical University	2	2	1	0
9. Trent University	0	2	0	0
10. University of Guelph	1	1	0	0
11. University of Ottawa	1	1	0	0
12. University of Toronto	2	0	0	0
13. University of Waterloo	2	1	0	0
14. Western University	0	1	0	0
15. University of Windsor	0	2	0	0
16. Wilfred Laurier University	0	1	0	0
17. York University	1	3	0	0
18. Algonquin College	1	0	0	0
19. Centennial College	3	0	0	0
20. La Cite Collegiale	4	0	0	0
21. Durham College	6	0	0	0
22. Fanshawe College	1	0	0	0
23. Humber College	1	0	0	0
24. Loyalist College	4	0	0	0
25. Mohawk College	5	0	0	0

Ontario				
26. Niagara College	4	0	0	0
27. Royal Military College of Canada	0	1	0	0
28. Sault College	1	0	0	0
29. Seneca College	5	0	0	0
30. Fleming College	2	0	0	0
31. St. Clair College	2	0	0	0
32. Cambrian College	6	0	0	0
33. Conestoga College Institute of Technology and Advanced Learning	3	0	0	0
34. Confederation College of Applied Arts and Technology	3	0	0	0
35. Georgian College of Applied Arts and Technology	2	0	0	0
36. Algoma University	1	1	0	0
Total	**70**	**37**	**3**	**0**

Table 3: Geomatics Education and Training Programs in Quebec

Quebec				
Name of University/College	**Geomatics Degree/Program Available**			
	Coursework/ Certificate/ Minor	**Bachelor**	**Masters**	**PhD**
1. Concordia University	0	2	0	0
2. Université Laval	0	10	4	1
3. McGill University	5	8	0	0
4. University of Sherbrooke	2	6	0	0
5. University of Montreal	1	2	1	0
6. Université du Quebec à Chicoutimi	0	4	1	0
7. Université du Quebec à Montreal	1	2	2	0
8. Université à Québec à Trois-Rivières	2	1	0	0
9. Bishops University	0	1	0	0
10. Cégep de l'Abitibi-Témiscaminique	1	0	0	0
11. Cégep de Chicoutimi	2	0	0	0
12. Cégep de Outaouais	1	0	0	0
13. Cégep de Rimouski	2	0	0	0
14. Cégep de Sainte-Foy	1	0	0	0
15. College Ahuntsic	5	0	0	0

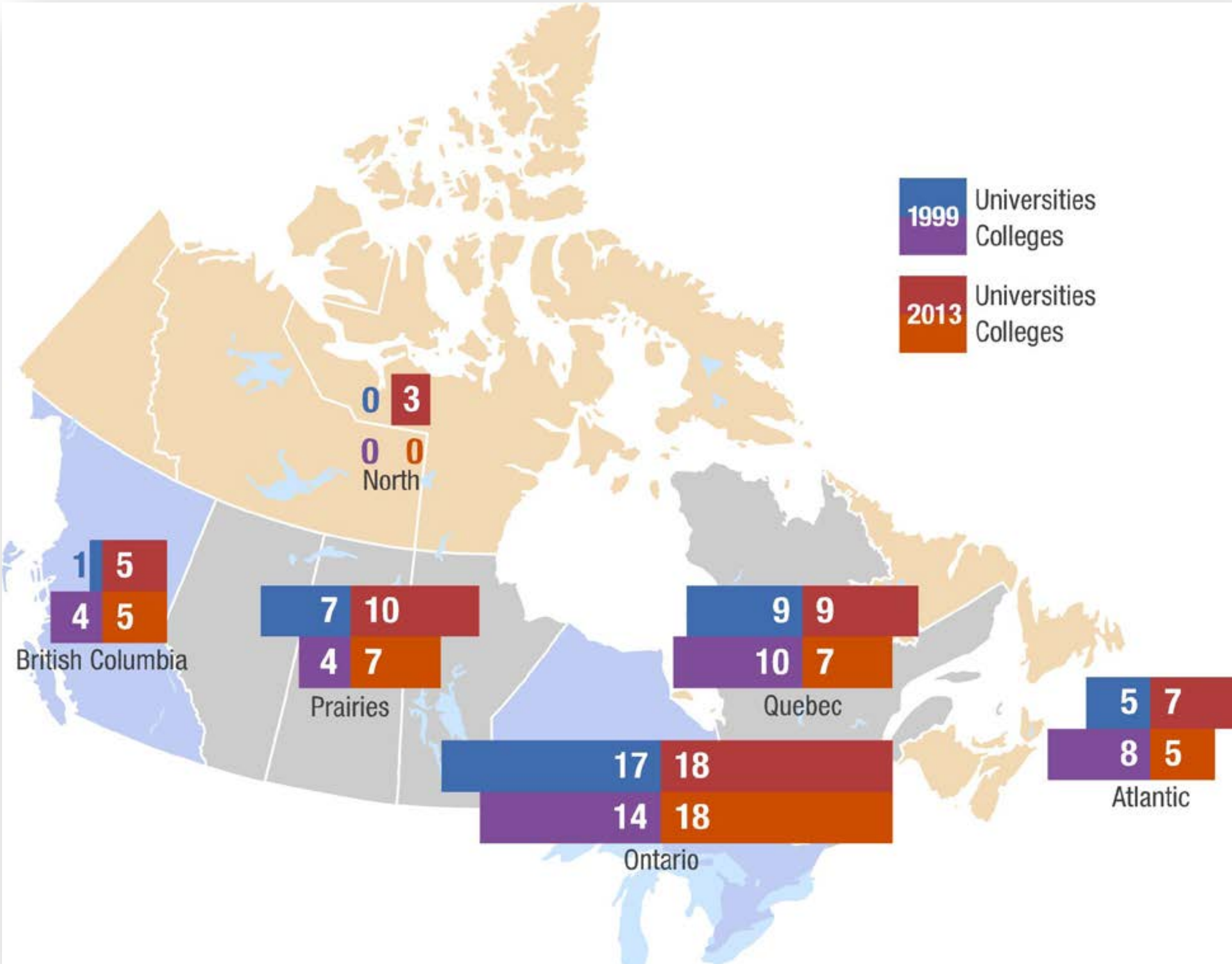
Quebec				
16. École Polytechnique de Montréal	0	1	0	0
Total	**23**	**37**	**8**	**1**

Table 4: Geomatics Education and Training Programs in Atlantic Canada

Atlantic Canada				
Name of University/College	**Geomatics Degree/Program Available**			
	Coursework/ Certificate/ Minor	**Bachelor**	**Masters**	**PhD**
Nova Scotia				
1. Acadia University	0	0	1	0
2. Dalhousie University	2	2	0	0
3. St. Mary's University	0	2	0	0
4. Centre for Geographic Sciences	12	0	0	0
New Brunswick				
5. Université de Moncton	0	3	1	0
6. University of New Brunswick	2	3	2	1
7. Mount Allison University	1	3	0	0
8. New Brunswick Community College	2	0	0	0
Newfoundland and Labrador				
9. Memorial University of Newfoundland	1	3	1	0
10. College of the North Atlantic	1	0	0	0
11. Marine Institute	1	0	0	0
Prince Edward Island				
12. Holland College	1	0	0	0
Total	**23**	**16**	**5**	**1**

Figure 6 shows the geographical distribution of colleges and universities offering geomatics programs in 2013 compared with 1999. Two conclusions can be drawn from this comparison: i) most of the growth has occurred in Western and Northern Canada, and ii) the number of programs at the university level has remained approximately the same, and there has been a 35 percent increase in the number of colleges offering geomatics training.

Figure 6: Regional Distribution of Geomatics Education and Training Institutions in 1999 and 2013



There are five Universities in Canada that offer Geomatics Engineering / Science degrees; four English language and one French language: (i) University of New Brunswick, (ii) University of Calgary, (ii) York University, (iv) Ryerson University (although this is positioned as a major within their Civil engineering designation) and (v) Université Laval. Laval and Calgary are the biggest in Canada, each with approximately 300 students enrolled in their graduate and undergraduate programs. These universities also offer Masters (geoinformatics, territorial and land management with both applied course work and thesis based programs) as well as PhD programs. Laval offers the largest geomatics program in the French speaking world and also offers (in conjunction with their business school) a complementary MBA degree with a concentration in Geomatics.

Most Canadian universities and colleges offer at least one or two courses in geomatics including GIS, remote sensing, spatial analysis and surveying, through a variety of departments including agriculture, forestry, geography, civil engineering and computer science. Other universities of note include Carleton University (Geomatics and Cartographic Research Institute), Memorial University (Marine Institute), Sherbrooke University (Centre for Research and Applications in Remote Sensing – CARTEL), and University of Victoria.

The following observations can be made from the analysis of the geomatics education database:

- Almost all civil engineering programs in Canada offer a surveying course (usually in the first year of the engineering curriculum).
- The majority of GI courses are offered within Geography faculties.
- The majority of mining, urban planning, and forestry programs offer at least one GI course, although these are often electives.
- Programs that are focused solely on GIS and geomatics tend to be at the certificate, minor or diploma level within the college environment and as a Bachelor degree at the university level.
- A number of programs include GI-related courses in their curriculum even though they are not the faculty to offer the course. For example, many of the Environmental Studies programs require GI courses delivered by the Geography faculty.
- A unique MBA program in Geomatics Management is offered at Laval University, which is one of only a few such programs offered in the world. It is delivered by the Business School and students (of which they are only two to three accepted each year) are required to have a minimum of three year’s work experience (in any domain area) before they can apply. The program is designed around a research/consultancy project and focuses on management science as well as developing competences linked with key strategic issues in the geomatics sector.
- Other graduate programs include Masters of Science in Geomatics and Masters of Engineering in Geomatics (Calgary, University of New Brunswick, York, Laval, Ryerson), and more specialized programs such as Masters of Spatial Analysis (Ryerson) and Masters of Science in Environment and Geography with a research focus in Geomatics and Remote Sensing (University of Manitoba).
- Some of the smaller programs do not offer a complete curriculum that would normally be found in a ‘geomatics’ diploma; for example, some programs offer only cartography, while others only offer GIS, or spatial analysis.

Most institutions in Canada’s extensive community college network offer GIS-type programs, usually in the form of a 1 or 2 year diploma for a GIS Technologist, Application or Cartographic Specialist, Resource Mapping Technician or a post-graduate certificate. The certificate programs are designed for university graduates that want to augment their GIS skills with courses in geographic information systems, remote sensing, marine geomatics, geographic information systems for business, cartography, community and environmental planning, surveying or geomatics engineering technology.

From its inception in 1948, The Centre of Geographic Sciences (COGS), Nova Scotia Community College, formerly the Nova Scotia Land Survey Institute, has been a leading college in the geomatics area graduating over 50 GIS and surveying professionals annually. Other key colleges offering GIS programs include Fleming College (which recently launched an innovative distance learning program linking northern students in remote communities to their GIS diploma programs), British Columbia Institute of Technology, Fanshaw College, Algonquin College, College Ahuntsic, and Southern Alberta Institute of Technology (SAIT).

Educational institutions regularly review their courses and key trends impact program / curriculum evolution. In particular, in the future there will be less emphasis on courses related to data acquisition (as this is being replaced by cheap technology such as high resolution sensors, drones, etc.) and more focus on courses related to integrating and representing data in an accurate and safe way (i.e., privacy, copyright, semantics of data (use and standardization of terminology), and data misuse). At present, most programs do not offer any courses in these areas. Many institutions are also incorporating co-op placements in their program requirements to ensure students are exposed to real-world scenarios and gain applicable industry / domain area knowledge.

2.3.4 Challenges and Opportunities for Industry, the Public Sector and Academia

Sector-wide challenges and opportunities

Geomatics sector identity and profile

Definition of the sector, its boundaries, and what should be included and excluded is becoming increasingly difficult because of the proliferation of GI use and their embedding in all kinds of information and communications technology (ICT) solutions. As noted previously in the Academia profile, students from many different disciplines are now part of the geomatics community by virtue of having taken GI-related courses and entering workplaces where they are using the acquired skills, which is contributing to the sector's growing heterogeneity and also the resulting identity challenge. There are two general schools of thought on this challenge.

One view is that it is possible and necessary to clearly articulate a sector identity and that there are benefits to being recognized as a distinct sector (e.g., common interests, distinctive contributions, better than being submerged within a much more diverse ICT sector). But considerable work is required, including: rebuilding leadership within the sector; articulating a strategy to define, articulate the value, and promote the sector's identity and value contribution; and engaging with and creating a 'home' for individuals and organizations that do not share the same educational background or disciplinary grounding as those in the traditional parts of the sector. The Pan-Canadian Geomatics Strategy is recognized as a positive step in working on the identity and profile challenge.

Another view is that being recognized as a specialization and a constituent part of the ICT sector makes more sense and provides more benefits (e.g., more business opportunities as ICT than as geomatics companies, better brand recognition) since GI has been submerged into ICT from this perspective. However, becoming recognized as a distinct specialty within ICT also requires effort. Recognition must be gained within the ICT community of the need for GI specialists in large geo-enabled ICT projects. However, there are signs that such recognition is growing, and the advocates of the integration of geomatics within ICT see that as an opportunity to further educate ICT professionals about the distinct challenges related to GI integration with other types of data, resulting in more successful implementations and better recognition.

Geomatics value proposition

Historically, the sector has not focused effectively on identifying and articulating to the public and decision makers its distinct character and the value of its contribution, and this is seen as an impediment to its future development. Quantifying the value of GI and the work that the sector does is considered to be very challenging and there is broad interest in the outcome of this study. Implementing SDI is a two-edged sword – if done properly, it becomes almost invisible to the user and taken for granted, but it also makes the job of value recognition for the sector more difficult. The proliferation of free data on the Internet and the prominence of the mass market geomatics players have created the impression for some decision makers that GI is already available and continuing investment is not necessary. The sector has a significant communications and marketing challenge in correcting this impression and improving understanding of its contribution to society and the economy.

Sector fragmentation

The sector is fragmented along disciplinary lines, with a number of associations representing the interests and serving the needs of the people and organizations in those disciplines (e.g., cartography, geography, remote sensing, land surveying, etc.), which makes it difficult to reach decisions and take action on a sector basis on matters such as strategy and profile improvement. On the other hand, such segmentation provides benefits that are acknowledged (e.g., ability to better service needs in specialized areas, feelings of belonging to a specific community of interest). The work of the Canadian Geomatics Community Round Table (CGCRT) is a very positive step in dealing with this challenge by creating a strategy and structure to bring the existing groups together around common goals and interests.

Sector leadership

Closely related to the previous three issues is a growing concern about the absence of effective leadership both within industry and government to take on the big challenges that the sector faces. Others believe that collaboration has been a sector strength, which one respondent phrased as,

> *"The kind of collaborative working environment that has been in place for a number of years in the sector provides a strong foundation to build on for the future, especially in the SDI environment."*[90]

The roots of the formation of the Canadian Geomatics Community Round Table (CGCRT)[91] in 2010 can be traced to this concern. An open and collaborative leadership group, the CGCRT is made up of representatives from industry, academia, professional associations, NGOs and federal, provincial and territorial governments, spanning the geomatics (geographic, geospatial, location information) domain. Initially focusing on high level issues facing the Canadian geomatics community, the group decided in 2012 to begin developing a comprehensive strategy to position the sector for future success. Subsequent work included the development of the *Canadian Geomatics Community 'White Paper' and Scenarios*[92], the *Pan-Canadian Geomatics Strategy*[93] and the *Pan-Canadian Geomatics Strategy Action and Implementation Plan*.[94]

The success of the 'Team Canada' Strategic Action and Implementation Planning Workshop in June 2014 is a positive indication that such leadership is emerging and that the work that CGCRT has been undertaking is being recognized as an opportunity for a revitalization of sector leadership.

Risk of data misuse

There is concern that the growing number of GI users with no background in the geomatics disciplines increases the risk of data misuse, with the consequent negative impacts on how the sector is viewed by decision makers. Examples of such potential misuse include: data collected at a resolution applicable for overall crop yield forecasting being used for farm vehicle navigation, or high resolution property boundary data being integrated with low resolution land cover data to make land use planning decisions.

There is an opportunity for the geomatics community to improve the communication of information quality and educate users about its limitations and fitness for a given purpose. One solution is to advance the need for the development of a geospatial information certification model that would provide the means of providing assurance to non-experts of quality and fitness for specific uses of geospatial datasets.[95] This may be an opportunity for the sector to increase its stature by improving standards of practice.

The potential for data misuse by non-geomatics practitioners also represents an opportunity for those companies building integrated GI solutions based on easy to learn, purpose-built tools with fit-for-purpose data behind them.

Challenges and opportunities for industry

Industry structure

The predominance of small specialized firms is generally viewed as detrimental to meeting the growth in demand for higher value-added products and services and total integrated GI solutions. According to one respondent,

> *"More concentration and diversity of expertise will be necessary to produce the types of services and information products to meet customer needs, especially for large projects. If the geomatics sector does not respond to this changing market environment, other sectors (e.g., engineering, IT) will."*[96]

However, there are contrary views; the structure of the industry is also viewed as a benefit in responding to rapidly changing market conditions (e.g., smaller firms are more agile, as demand widens there are more opportunities in many specialized niches for GI products and services). The industry structure is in part a reflection of the nature of many company founders (e.g., independent, more comfortable controlling a small business than merging and being part of a big one).

There is an opportunity for further consolidation in the industry to better address changing demand patterns. There is evidence that this is happening both within the traditional parts of the sector (e.g., mergers of survey companies and of GIS companies) and between geomatics and other disciplinary firms (e.g., ICT and engineering consulting companies). This trend is increasingly viewed as a natural response to market demand and is expected to grow.

Industry representation

The reduced stature of the Geomatics Industry Association of Canada (GIAC) and the difficulties that Professional Surveyors Canada has experienced in taking on an industry advocacy role provide evidence that a strong association to represent the interests of the industry may no longer be required. However, such an organization would be beneficial in dealing with fragmentation and provide a common voice for the private sector in strategic matters (e.g., working within the CGCRT governance structure on the Pan-Canadian Geomatics Strategy).

Repositioning on the GI value chain

The need to redefine business models and reposition on the GI value chain presents both challenges and opportunities for the industry. As former clients have started to undertake data collection activities themselves, some GI suppliers are shifting their focus to helping these clients to manage their data collection, processing and management efforts. Companies are embracing the challenge of delivering purpose-built applications / solutions for specific client groups (i.e., changing from a data-centric to a client-centric focus and business model).

There is growing recognition that the market has shifted from ‘push’ to ‘pull’ and that success in responding to this opportunity will depend upon how good companies are at really getting to know their customer’s business. As one of the respondents expressed this requirement,

> *“We need to be much better at understanding what their business challenges are and what questions they are trying to answer, and having fit-for-purpose products and services ready for them to use. In the past, we had the luxury of being the only place that people came to for GI and that is no longer the case – this is not a problem, it is an opportunity, but we need to get out of our chairs to really understand different client group’s specific needs.”*[97]

Changing business models

Companies are struggling with how to change their business model to deal with market changes; as one person put it,

> *“How should I bill for my services – a one-time fee or a ‘per click’ model?”*[98]

People also recognize that developing geo-enabled business applications that work easily for users is still very complex, and can involve a number of interrelated components in the supply chain. So a related concern is the challenge of forging the business relationships required to fill that increasingly complex supply chain. Adding to this complexity is the challenge of forging successful partnerships with companies in faraway places with much different business cultures, such as India and China. Those companies that have been able to develop such business relationships view this business model as an opportunity to be more competitive in a rapidly changing marketplace. The absence of an industry forum or organization that can facilitate business connections with potential partners in Canada has also been identified as a challenge, and filling this void as an opportunity in which the CGCRT perhaps has a role to play.

Government procurement practices

Canadian companies face the challenge of competing internationally with foreign companies that are perceived to be benefitting from their governments’ procurement practice of contracting-out total GI solutions. The practice in Canada of contracting-in experts (often referred to as ‘body-shopping’ in the industry) restricts the ability for innovative companies to build exportable solutions and use Canadian government buyers as references, which is often a competitive necessity in foreign markets. Given more opportunities to deliver total GI solutions (rather than rent staff), Canadian companies can become stronger and have better value-added products and services to offer in the domestic and international markets. This challenge has been voiced by industry in previous sector studies, most recently in 2007.[99] The increasing internalizing of competence development within government is viewed as a missed opportunity to help create a world competitive industry. A strong call for government to use procurement to stimulate private sector innovation was made by the Independent Panel on Federal Support to Research and

Development[100], which noted that Canada lags behind peer countries in leveraging government procurement for this purpose.

Challenges and opportunities for government

Funding and workforce demographics

Budget reductions and workforce adjustment measures, particularly evident at the federal level, are leading to new approaches to program delivery. While no specific numbers are available on the number of geomatics positions affected, The Globe and Mail reported in August 2014 that some 26,000 federal public service jobs have been cut over the past three years, and another 8,900 jobs are scheduled to be cut by 2017[101] and these reductions are being experienced in geomatics organizations. By fiscal year 2017-18, the austerity measures currently being implemented will see government departments managing yearly ongoing savings of $13.7B.

The Federal Geospatial Platform (FGP) initiative is viewed as a primary means of meeting this challenge because it is intended to be an enterprise solution that will help to eliminate duplication in the government and displace a variety of small GIS projects, producing both cost savings and opportunities to reduce the size of the workforce. Government is perceived to be facing a significant demographics issue, with impending retirements and succession planning a growing challenge. This can be viewed as an opportunity both to help meet workforce adjustment targets and to explore new ways of doing business and refocus efforts.

State of geospatial data in Canada

Concern about the state of geospatial data in Canada is growing. The widely held view is that key core data products like GeoBase and many of the provincial counterparts do not meet the currency requirements of many users and that funding for ongoing updating / revision of key data layers like road networks and digital elevation models is no longer available. There is also widespread recognition of the value of 'AAA' (i.e., authoritative, accurate and accessible) data provided by government as a fundamental requirement for the development of trusted GI applications. New opportunities for improving the quality and usability of core data were identified, including:

- New public-private partnerships incorporating transaction models that capture data at source when change occurs and delivering it in near-real time;
- Collaboration between authoritative data custodians and volunteered geographic information (VGI) groups to address existing challenges with integration of VGI in order to capitalize on the growing value of crowd-sourced data; and
- A renewed emphasis on confirming data needs and securing the necessary resources for ongoing data maintenance.

This issue has been highlighted in the Data Sources dimension of the Pan-Canadian Geomatics Strategy and there may be an opportunity to address it in the Action and Implementation Plan. .

Open data policies and programs

The prominence of open data policies and programs across the three levels of government is recognized as an opportunity for the geomatics sector. GI providers within government are leaders in provision of access to public sector information and in a number of jurisdictions, the designers of open data portals have taken direction from existing geoportals. GI datasets account for a large percentage of the total datasets available on the open data portals for many jurisdictions. Government geomatics organizations generally support open data initiatives, want to play a leadership role in making more information accessible to the public, and believe that there is additional potential for commercial exploitation of their datasets. The only concerns identified were that a few municipal organizations are still charging external users for access to their GI and rely on the recovered funds to help cover their operational costs.

Implementation of web services and standards and operational policies were highlighted as continuing challenges. Concerning access to GI via web mapping services, additional work is required to fully implement and operationalize this component of the CGDI and the spatial data infrastructures of many provinces, territories and municipalities. A recent study for GeoConnections also suggests that adoption and implementation of geospatial standards and operational policies by GI providers is still at an early stage in many jurisdictions.[102]

Meeting changing user requirements

A number of government respondents voiced concerns about being able to fully address changing user requirements. The demands of government GI users are shifting in concert with overall market trends (i.e., less interest in strictly data provision and more interest in integrated GI applications). GI providers in government face the challenge of delivering web and mobile applications to address this demand. There is an opportunity to use procurement to take advantage of the growing private sector competency in this area. Since funding availability is a challenge, respondents are attempting to retrain internal staff to meet the demand and resources to develop apps and support them are typically stretched.

Challenges and opportunities for academia

Attracting the top students

In the GI academic community, at the college level the challenge most often voiced was attracting the top students, often attributed to the identity and profile challenge discussed above. Since the sector does not have a high profile, students do not have much knowledge about its existence and the career opportunities unless there is a progressive geography or science teacher in the high school that introduces them to GIS and mapping technologies. There is the perception that the number of students that continue to take science and math courses throughout high school is in decline, so the candidates for a geomatics career are significantly reduced. A recent science and technology benchmark study confirmed the general lack of interest in high school populations in science and related careers.

> *"Interest in science falls by age. Seventy-eight per cent of 12 and 13 year olds are very or somewhat interested in science, compared to … 58 per cent of 17 to 18 year olds." "…52 per cent [of students] think studying science will be at least somewhat important to the careers they eventually pursue, but 39 per cent say studying science won't be important at all to their future careers."*[103]

This challenge is not unique to geomatics; the science, technology, engineering and mathematics (STEM) workforce challenges in Canada are a growing concern that is being faced by all technology sectors. For example, in 2012 the House of Commons Standing Committee on Human Resources, Skills and Social Development and the Status of Persons with Disabilities dealt with this matter[104]. In the same year Prime Minister Harper acknowledged this challenge,

> *"For whatever reason, we know that peoples' choices, in terms of the education system, tend to lead us to … a chronic shortage of certain skills. They are skilled trades, scientists and engineers,"*[105]

Enrollment in geomatics and surveying technology programs is slipping in a number of community colleges at a time when demand for survey staff is increasing and organizations in the west are not able to fill vacancies. A national strategy to deal with the profile challenge is being advocated. The CGCRT recognized this challenge and the Pan-Canadian Geomatics Strategy Action and Implementation Plan includes specific activities to address this need, building upon the work underway in organizations such as the Royal Canadian Geographic Society.

Funding support for research

At the university level, enrollment appears to be generally at acceptable levels based on student placement results, and the most significant concern identified is the shift in funding support for research. As research funding has tightened, competition has increased and the focus has shifted more to industry-funded research, which tends to be very application focused (i.e., closer to the 'D' end of the R&D spectrum). The challenge is to find adequate funding for more curiosity-driven research that has the potential to identify ground-breaking advancements in the production or use of geospatial information that can be commercialized in the future, to maintain longer term innovation capacity and competitiveness.

Lack of innovation

The need for more innovation in education and training is a key challenge. Opportunities for new, innovative approaches to education and training in the geomatics sector that have been identified include:

- Although formalized college-university linkages in geomatics already exist (e.g., Acadia University and NSCC Centre of Geographic Sciences[106], Brock University and Niagara College[107], Trent University and Fleming College[108], and University of Winnipeg and Red River College[109]), more innovation to meet changing market demands is being advocated. As expressed by one respondent,

  > *"We need to re-invent the wheel and articulate the pathways to leverage learning between the two".*[110]

- Adoption of a practice being used in the US – offering free GI courses as a 'teaser' to attract enrollments into full-time training programs.

- Remove the program 'silos' in favour of more interdisciplinary training (e.g., geography, with computer science and statistics) to better address market requirements.

2.4 Research and Development Performance

There is both a significant range of participation in R&D activities across the geomatics sector and diversity in the functions of geomatics research including development of new technology, applied geomatics research, improved use of existing platforms and staff development. The greatest inhibitor to making R&D investments reported by respondents is the need to focus resources on ongoing service activities. A primary use of research and development budgets is investment in keeping staff up to date through geomatics education and conference participation.

2.4.1 Relevant Geomatics Research and Development in Canadian Government and Academic Institutions and Industry

GI suppliers

Most research activity in GI supplier organizations is focused on improvements in data quality and access. Issues of outdated information and inadequate resolutions raised by some users have led industry and government suppliers to focus research efforts on using existing technology to improve resolution, scalability and metadata of available data sets. An example of such a project was a collaborative effort between the Coast Guard and NRCan to take precise point positioning measurements to enhance data, and using radar to monitor records of littoral and Distant Early Warning line sites.

For others, R&D efforts are concentrated on developing and improving portal tools and application usability. Even when new technology is accessible, incorporating it into existing business practices can present challenges. For example, one organization that acquired a terrestrial LiDAR system had difficulties convincing staff surveyors to enhance data acquisition practices with its use; it had only been deployed on one major project since its procurement. Small organizations with limited resources often think that ongoing business objectives require the majority of resources, leaving little time to interrupt production and services with experimental processes.

The majority of private sector GI suppliers make R&D investments in the range of 2-3 percent of annual revenues, while the highest contributors invest up to 20 percent, for an overall average estimated investment of approximately 4.5 percent. Companies investing in new product and service development continue to struggle with finding adequate budgets for commercializing and marketing developed technologies.

The importance of collaboration between industry, government and academia on research and development was expressed frequently. In particular, the reduced involvement of the former Canada Centre for Remote Sensing (now part of the CCMEO) in work with industry, and lack of evidence of the availability of new algorithms and software with commercial potential were noted. This was discussed at the June 2014 'Team Canada' Geomatics Strategy, Action and Implementation Planning Workshop. Cooperation with local academic institutions also plays an important role for industry. Examples of such collaboration include the engagement of universities for assessing which web standards to embrace, and testing predictive models using LiDAR data that were developed through academic research to determine usefulness to enhance regular business outputs.

Industry-government-academia collaboration is formalized in some sectors via so-called 'clusters'. A cluster typically develops when firms from interrelated sectors emerge or locate in a particular geographic region, where they draw a competitive advantage from the existence of specialized knowledge assets within the region.[111] Clustering firms normally exhibit interconnectedness with one another and with public organizations (e.g., key government organizations and research institutes, and universities and colleges), either formally through joint ventures or strategic alliances, or informally, through social ties that foster localized learning within the cluster. The key geomatics educational institutions have all produced commercial spin-offs and are located in centres where there are competitive groups of geomatics companies, but there is little evidence that those companies act as 'clusters' to improve their competitive advantage.

Academic institutions

While academia has led development of new geomatics technologies (e.g., visualization methods, 3D modelling, augmented reality), it has also concentrated research on the application of geomatics to issues in many other fields. For example, there have been successful results with projects that addressed a problem area relevant to biological, geological or environmental data. Many successful results of working closely with industry partners were reported, in many cases by pairing students with companies that had a specific project need. One university researcher indicated that many of their professors contributed to international teams, with Canadian expertise particularly respected in remote sensing.

Academic researchers are caught between the need to demonstrate a strong research component to be awarded funding from federal granting agencies and industry's desire for development of immediate, real-world applications. There is awareness at universities that companies are typically interested in supporting research only if it is in their own business interests – providing new solutions at lower costs.

Research collaboration networks (like the former GEOIDE Network of Centres of Excellence) are valued for allowing peers to share ideas and progress early research with wider support. The recently established CONVERGENCE network[112] (Convergence of Geospatial Intelligence for Innovation) is an example of this model. Funded mainly by the Quebec government, the CONVERGENCE mission is "to facilitate the collaboration and the partnership among academia, industry and government sectors in order to stimulate research and innovation activities in geospatial and to accelerate the knowledge transfer to potential users".

The challenge of funding academic geomatics work that has arisen in the past decade reflects the broader issue of classifying the geomatics sector. As it is a uniquely interdisciplinary field of research, it does not necessarily fit best with either the social sciences and humanities or the natural sciences and engineering granting programs with respect to funding. It is sometimes difficult to position proposals so that they meet the criteria in either of the funding programs. This suggests the need to reexamine funding criteria to enable more innovative cross-disciplinary research to be undertaken.

Research and development of technology and solutions related to geomatics has taken a number of forms in Canadian academic institutions. Examples of the themes that are the focus of Canadian university research in geomatics are:

- **Geovisualization**: Several programs aim to develop and explore new visualization techniques and interface methods for working with geospatial information. These researchers often work with real-world projects to integrate emerging trends like mobile platforms and volunteered geographic information to tie people to their environment. For example, Simon Fraser University's Spatial Interface Research Lab is working on augmented reality shared through social networking tools, using visualization technology in gaming applications and on mobile platforms. Other research focuses on the representation of GI, with programs at University of Calgary exploring map design for the visually impaired and work at Carleton attempting to record indigenous knowledge through cartography, for example.

- **Volunteered Geographic Information (VGI)**: Applications of VGI are being explored (parks, wildlife, geographic concepts of distance, base layer information (e.g., road networks)), as are the reliability and accuracy of the information they provide. At least one program (Geography at University of British Columbia) is examining the coincidence and variation in expert and public estimations reported through VGI. The program at UBC also uses this research in engaging the public to make contributions to informational atlases (i.e., E-Flora BC and E-Fauna BC).

- **LiDAR Systems**: Ongoing geomatics and geomatics engineering research at several institutions focuses on LiDAR. With this emerging technology, integration with photogrammetric processes is attempted to improve process from all remote sensing methods (e.g., LiDAR, aerial and satellite imagery). The ability to process laser point clouds and extract information efficiently is studied extensively even while the technology is refined. The Applied Geomatics Research Group at the Centre of Geographic Sciences in Nova Scotia has placed an emphasis on LiDAR data acquisition related to coastal erosion research, and has begun early development of a database to house an inventory of LiDAR metadata from across a number of organizations.

- **Remote Sensing and Photogrammetry**: Research programs that focus on the expanding remote sensing sector are interested in the processing and interpretation of information that imagery provides (e.g., DEM generation, stereo-viewing, feature extraction, etc.). Labs like SPECTRAL at the University of Victoria and the Definiens Centre of Excellence at the University of Calgary focus on methods for interpreting and making the most effective use of the plethora of data types recorded in remotely sensed information. Studies also include exploring traditional and new uses for photogrammetric products created with improving aerial and satellite image resolutions.

- **Positioning**: Engineering programs at some institutions have a strong focus on research and improvement of wireless positioning and navigation technologies, for both indoor and outdoor use. The focus of several such programs in Canada is signal acquisition and tracking, multi-frequency enhancements, and integration of multi-sensor platforms. New applications of the technology increasingly involve refining sensor sensitivity to allow for indoor and pedestrian navigation.

- **Geodesy**: Studied in the engineering segment of the geomatics sector, this field of research covers determination of the earth's shape and measurement of gravimetric forces, a primary focus at the University of New Brunswick. Studies in this field of geomatics engineering contribute to the refinement of GPS and satellite platforms, as well as the understanding of the earth's forces that affect the nature and measurement of geospatial information.

- **Mobile Mapping Systems**: Use of geomatics technology allows researchers (and industry) to track moving platforms upon which multiple sensors and measurement equipment have been placed, allowing for three-dimensional positioning in space and the simultaneously-collected geospatial data. Research has focused on calibration and data accuracy, tracking of features, automatic shape recognition, and integration of photogrammetric imagery.

- **Complex Systems**: Using collaborative GIS and computational intelligence approaches to evolve geospatial information modeling methods, this research area involves design of automated spatial decision support systems. These research groups concentrate on geocomputational approaches to improve the understanding of the interactions of human and natural systems to guide decision making – a strong research focus at the Centre de recherche en géomatique at Université Laval. Overall, the goal of these programs is to develop intelligent, computer-based spatial information systems that address applied geomatics problems.

- **Open Source Data and Specifications**: This research focuses on the interoperability between remotely warehoused data and information sources and GI users. This field particularly stresses the importance of standards and information sharing on preservation and data archival methods.

- **Applied Geomatics**: This research segment covers all aspects of applying geomatics technology and methodology to other fields. Examples include but are not limited to:
  - spatial analysis of interdisciplinary concepts, including spatio-temporal research (e.g., biodiversity and landscape change, population migration);
  - human processes and social geography;
  - environmental monitoring, digital elevation models, and feature mapping using remote sensing techniques;
  - forestry, soil, and vegetation modeling;
  - public health research, and emissions mapping to model toxicity and environmental impacts on health;
  - city planning, traffic and transportation;
  - historical research (e.g., archaeological site selection and planning);
  - atmospheric and weather modeling; and
  - extraterrestrial geography and geologic mapping.

2.4.2 Gaps in Canada's Geomatics R&D Capacity

Given the study limitations, only anecdotal evidence of R&D focus in industry and government is available, and as a consequence, it is difficult to isolate specific gaps in Canada's geomatics R&D capacity. There are no hard figures for the overall investment in Canadian geomatics R&D, other than approximate estimates of spending by industry as a percentage of annual revenues. Based on the estimate of total industry revenues, the total R&D investment by private sector GI suppliers probably averages $100M annually, which is generally consistent with R&D

spending identified in the 2004 Geomatics Industry Census Survey. However, as noted above, there is a strong focus on existing service improvement and on training, giving existing staff new skills to work with current GI infrastructure and maintain service levels.

As illustrated in the previous section on geomatics research in academic institutions, the range of research themes appears to address current demand and some themes are also well aligned with trends and drivers of future market changes. The perception exists in academia that there has been a shift in the allocation of funding, and that increasingly proposed research must be product-oriented and aimed at commercialization. This is a reflection of the changing focus of research funding from the main granting councils. Many of the more curiosity-driven academic research pursuits have value for the applied fields yet work independently of industry. Given this change of focus, concern has been raised about the ability of the academic research community to conduct research that will lead to commercial products and services five to ten years in the future. There is also room for improvement in the use of co-op programs and student projects to connect with community business interests and goals.

2.4.3 Alignment of Current R&D Efforts with Changing Demands for GI Products and Services

The general response from academic researchers is that university and college programs and research are directed to support efforts across all disciplines. They suggest that very little, if any, research is curiosity driven, instead focusing on applications of GI and how it can be linked to the private sector. One university official, whose institution has a strong focus on remote sensing, points to its focus on applying the technology to a broader field of study (e.g. image processing, health, natural eco-systems, water management, ice, northern environmental activities, meteorological assessments).

In industry, GI is often taken for granted as a readily accessible tool that needs no further research. For some, justification for GI research questions must directly address existing company policies and programs. As mentioned above, some programs seek to fill this gap by pairing students and research projects with industry partners who have data and a need to achieve GI solutions at efficient costs. However, while this benefits industrial-driven projects, some academics expressed the concern it is at the expense of basic research and “a longer-term vision”.

The shift in the market to demand for higher value-added products and services requires geomatics businesses that want to move up the GI supply value chain to increase their focus on innovation. This requirement is borne out by the consultations with GI suppliers, with respondents that indicated they were moving up the value chain reporting higher investments in R&D to support the development of integrated GI services and hosted solutions than those that did not report such refocusing (i.e., in the 10-20 percent range as opposed to 2-3 percent).

While there is evidence from the consultations with GI suppliers and users that current R&D efforts are generally keeping pace with market demands at present and that no major gaps exist in R&D capacity, the analysis of trends and drivers of future market growth (see Section 3.1) indicates that effort and capacity realignment will be necessary to meet future market demands. For example,

- The increasing demand for computing capacity to handle the processing of massive amounts of GI (Big Geo-data) will require advancements in database management systems and massively scalable, distributed systems for processing unstructured and semi-structured geo-data, as well as in analysis capabilities. There are signs that this gap is being recognized, with the recent establishment of new research initiatives at several universities (e.g., University of New Brunswick Cisco Geomatics Research Chair in Big Data Analytics, the recent NSERC Industrial Research Chair in Geospatial Business Intelligence at Laval University, and the private Research Chair in GeoBusiness at Sherbrooke University[113]).

- Rapid advances in immersive video technologies (e.g., Google's Project Tango) will provide dramatic new capabilities for the collection and use of GI. Research efforts will be required to explore how the power of these exciting new capabilities can be harnessed to develop productivity enhancing GI applications. Only one example of current research focused in this area has been found; geospatial tangible augmented reality (GeoSTAR) and mobile geospatial augmented reality (MAR) at Simon Fraser University's Department of Geography.

- The growing popularity of GI provision on the Web that is based on crowd-sourced or volunteered geographic information (VGI) contributions has encouraged a number of commercial GI providers (e.g., Google, TomTom) and government GI providers (e.g., State of Victoria, Australia, United States Geological Survey) to employ VGI for data updating.[114] However, capture of VGI potential by Canadian governments is being inhibited by remaining significant challenges (e.g., quality assessment, copyright and licensing issues) that require research attention. Only one example of research dealing with these issues has been identified (Department of Geodesy and Geomatics Engineering, University of New Brunswick[115]).

- There would be considerable value for life cycle management of facilities and infrastructure in integrating BIM and GIS technologies to enable the creation of seamless three dimensional models of above- and below-ground the built environment. Research projects to explore the impediments to such integration and develop data exchange protocols would be valuable.

2.4.4 Contribution of Canada's Innovation[116] Policies and Programs to Wealth Creation in the Geomatics Sector

Many private sector GI suppliers fund R&D efforts out of revenue, but the following Canadian programs to support industry innovation are also regularly used:

- **Industrial Research Assistance Program (IRAP)** is a funding program that is widely perceived to be substantial and accessible enough to be worthwhile. IRAP was praised by one supplier for the program's practice of learning about and understanding applicants rather than

  > *"forcing them through application processes based on preconceived notions of the business environment."*[117]

- Many of those companies consulted take advantage of **Scientific Research & Experimental Development (SR&ED)** tax credits to fund R&D.

- **Government Related Initiatives Program (GRIP)**, administered through the Canadian Space Agency, supplements internal R&D funding, specifically for the application of satellite (RADARSAT-2) imagery to Canadian government programs.

- **TECTERRA** funding has been used most often for commercialization support or hiring. The funding support was, however, critiqued by several people for being fragmented into a number of relatively small funding envelopes and available only to smaller companies.

- **Natural Sciences and Engineering Research Council (NSERC)** funding has been used under the Collaborative Research and Development (CRD) Grants funding envelope. This funding provides significant encouragement for academic researchers to work with industry and commercialization of research results.

- The **GeoConnections Program** has supported the development of products and services that help GI suppliers to make their data accessible via the CGDI and GI users to take advantage of the data that is available through the infrastructure.

A number of respondents reported that they had considered government R&D funding programs but had not pursued that option because of difficulties in finding the right programs or complexities in the funding application processes. The research conducted by the Independent Panel on Federal Support to Research and Development also noted the first difficulty, reporting that companies are having challenges navigating the many federal programs that promote business innovation.[118]

2.4.5 Comparison of Canada's Geomatics R&D and Innovation Capacity with Major Competitors

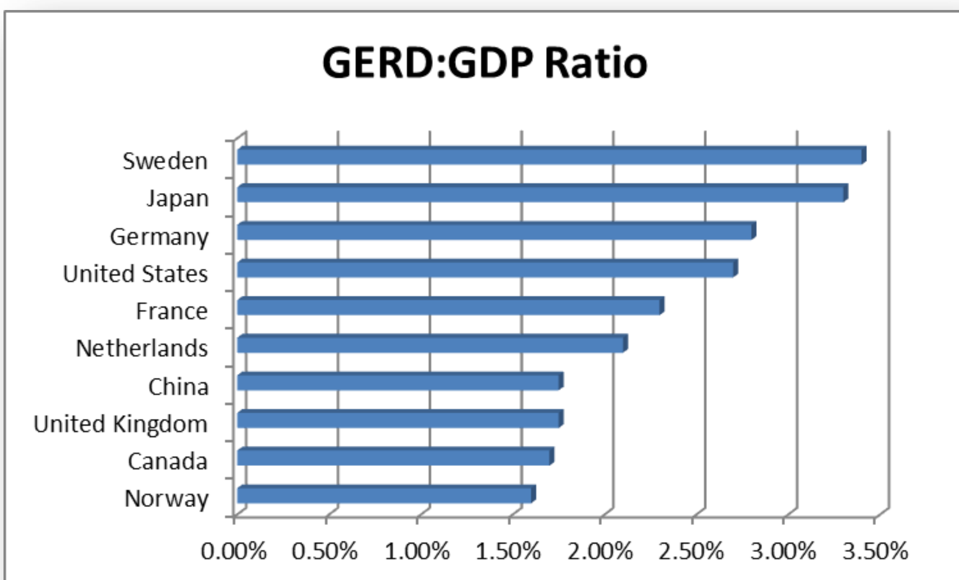
Geomatics R&D spending

There are relatively few indicators that exist in the public domain for R&D spending specifically in the geomatics sector. Furthermore, many organizations that make use of geomatics technology in their products do not consider themselves as conducting geomatics research. Where companies do not identify themselves in the GI value chain, their self-defined activities appear in other fields (e.g., information technology). It is difficult to isolate geomatics development funding from broader science, technology and innovation (STI). Thus, this section will look in brief at how Canada compares against other Organisation for Economic Co-operation and Development (OECD) members in R&D funding of STI activities.

According to the Science, Technology and Innovation Council's 2013 report *State of the Nation 2012: Canada's Science, Technology and Innovation System: Aspiring to Global Leadership*, Canada's gross domestic expenditures on R&D (GERD) had been stable at around $30 billion since 2010.[119] Canada's GERD as a percentage of gross domestic product (GDP) peaked in 2001, when it reached 2.1 percent. Despite wider growth in Canadian R&D spending, this ratio has been declining. Most recent calculations showed a low of 1.7 percent in 2011. By comparison, other advanced and emerging economies saw a rise of GERD-to-GDP ratio that corresponds with the total funding in that period.

Canada's declining intensity of R&D spending pushed its rank among 41 OECD and leading developing economies from 16th in 2006 to 23rd in 2011. In that year, Canada's GERD-to-GDP ratio of 1.7 percent placed it more than 1.5 percentage points below the world's top five investors in science, technology and innovation R&D. Figure 7 illustrates Canada's ranking against major competing countries on the basis of the GERD-to-GDP ratio.

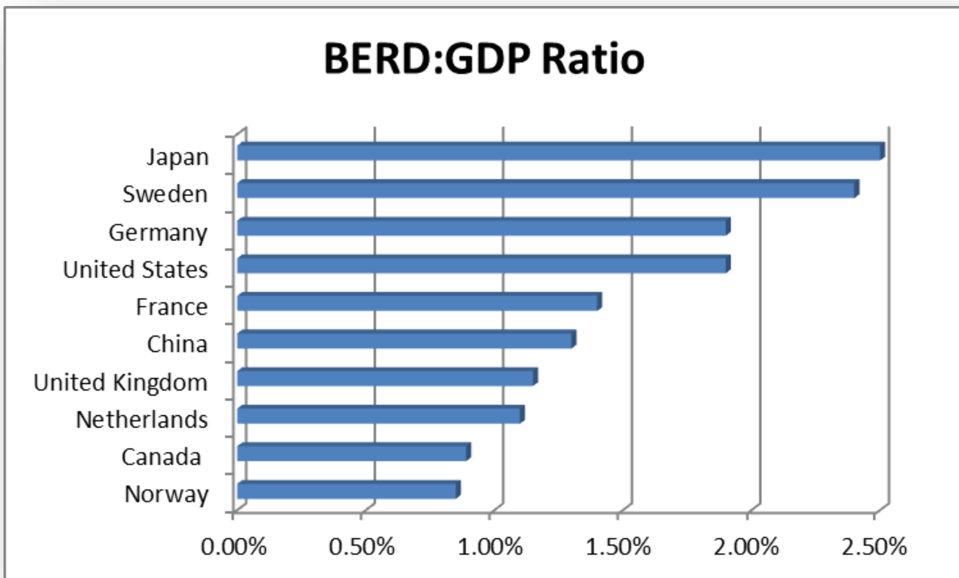
Figure 7: Ratio of Gross Expenditures on Research and Development to Gross Domestic Product



While this ranking does not necessarily reflect how overall Canadian geomatics R&D and innovation capacity compares with our major competitors, it is a proxy of our competitive ranking.

The other comparison of interest is how Canada ranks on business enterprise expenditures on R&D (BERD). According to data from the OECD, BERD as a percentage of GDP in Canada was 0.89 percent in 2011, compared to 1.04 percent in 2008. This placed Canada in 25th place in international rankings, down from 21st place in 2008, and considerably below the threshold of 2.4 percent set by the top five performing economies – Israel, Korea, Finland, Japan and Sweden, as illustrated in Figure 8. The geomatics sector's estimated average annual spending of five percent of revenues places it well above the Canadian average. However, because of the absence of publicly available information on R&D investment by key GI competitors, there is no basis for determining the Canadian GI industry's relative ranking.

Figure 8: Ratio of Business Enterprise Expenditures on Research and Development to Gross Domestic Product



GI innovation clusters

As discussed in Section 2.4.1, there are no actively functioning GI innovation clusters in Canada. However, several examples of such clusters in other jurisdictions have been identified:

- GIS-Cluster Salzburg (Austria) – a merger of geospatial SMEs and academic institutions representing this geo-competence area since 1999[120]
- GEOKomm Networks (Germany) – a network of expertise in Berlin with some 20 industry, government and academic partners, active since 2009[121]
- Future Position X (Sweden) – launched in 2006 as a non-governmental, non-profit cluster organization, which acts as an independent arena for research and innovation in the Geographic Information Industry field for the Smart City[122]

- Chinese GI Technology Parks – China has launched a series of industrial technology parks focused on GI (e.g., Beijing, Heilongjiang, Wuhan, Zhejiang, Shenzhen, etc.) to foster GI cluster development[123]
- Space Krenovation Park (Thailand) – set up by the Geo-Informatics and Space Technology Development Agency, the space agency of Thailand, for potential entrepreneurs to set up branches, subsidiary companies or regional offices to take advantage of clustering and market connectivity in Thailand & ASEAN[124]
- Enterprise for Innovative Geospatial Solutions (EIGS) (Mississippi, USA) – founded in 1998, EIGS works with private companies, university research programs, state agencies, and complementary partner programs to research, develop, and market new geospatial technology products[125]

Canadian experience with cluster success has been mixed and there is no guarantee that a functional GI cluster would provide competitive advantage. Although there is no readily available information on the success of the GI clusters in other countries, the longevity of several of them suggests that they are fulfilling their intended purpose and that the innovative capacity they have developed may be an important competitive differentiator.

3. The Geospatial Information Market

This chapter describes the evolving GI market and the trends and drivers of change that are affecting its characteristics. The market descriptions are divided into two sections – domestic and international. More detail on international markets is contained in Appendix C.

3.1 Trends and Drivers of Change

This section provides an analysis of the key political, economic, social, demographic, technological and environmental trends impacting GI production and consumption and the key drivers of growth and change in the GI market. It represents a synthesis of information identified in the literature review and the views provided by the organizations that were consulted.

3.1.1 Drivers of Growth and Change in Demand for GI Products and Services

A broad range of factors are driving change and growth in demand for GI products and services. The following sections describe key factors and the impacts they are having in the marketplace.

Mass market geomatics

The entry of major Internet-based private sector providers of GI like Google, Mapquest, Yahoo, Apple and Microsoft (the so-called 'mass market geomatics or MMG' players) has been a disruptive force in the market. Such companies dominate the provision of location-based services on the Web, using GI to help drive business to their advertizers. A minority in the industry has a negative view of the disruptive impact that these players are having on the market, but the majority recognize that their provision of free geospatial data has stimulated significant growth in GI use.

Perceived negative impacts include loss of potential business opportunities due to users developing their own applications employing MMG-provided data and platforms, and concern that decision makers have the impression that GI provision has been taken care of by the MMG players and that government investment may no longer be required. Positive impacts include the contribution that MMG has made to improving geo-literacy, increasing familiarity with the use of GI and broadening the user community, and the opportunities for the industry to build lower cost, user-friendly applications for users through deployment of the MMG data and platforms.

Free and open data

There are broad expectations in the industry that the growing availability of free and open authoritative data from government sources will also help to drive market growth. The early focus in most jurisdictions has been on the provision of framework or base data, driven primarily by SDI initiatives being implemented by the primary geomatics organizations. However, there are concerns that the declining currency of many such datasets will limit their full potential for value-added GI products and services development. The provision over time of the full range of thematic GI and geospatially linked data of all kinds generated by government is expected to enhance the commercial potential of open government data.

A particularly important factor is the increasing availability of free and open satellite imagery from government-backed earth observation missions in North America, the European Union and Asia. Examples of these sources include Landsat (US), Sentinel (EU), Resourcesat (India) and JERS (Japan)[126]. It has been publicly stated that the plan for the Radarsat Constellation Mission (RCM) is to provide free and open access to RCM archives[127], but the data policy has not yet been finalized. The industry views this as a positive development that will lead to increased growth in EO value-added products and services. A small number of companies that specialize in sale of satellite and airborne imagery have concerns about erosion of their markets, while others report that increased access to and use of such data have resulted in more demand for their high resolution airborne imagery services.

Government procurement practices

Changes in how governments (particularly at the federal and provincial levels) contract for provision of data and services are an important driver of change in the market. The practice of consolidated data purchases by a single government organization on behalf of a group of other organizations has had an impact on the competitive landscape for provision of airborne and satellite imagery. Examples of this practice include:

- Natural Resources Canada's purchase of SPOT imagery on behalf of the Federal Government;
- Ontario Ministry of Natural Resources' collection and regular replacement of high resolution aerial imagery for all of southern Ontario and selected parts of the near- and mid-north over a five-year cycle under the LIO Imagery Acquisition Strategy, in which both provincial and municipal governments participate[128];
- Alberta Environment and Sustainable Resource Development's three-year imagery refresh contract for satellite, airborne and LiDAR imagery on behalf of a number of provincial government departments;[129] and
- Saskatchewan Information Services Corporation's Saskatchewan Geospatial Imagery Collaborative (SGIC), a partnership of organizations within Saskatchewan sharing knowledge and costs relating to the acquisition and use of remotely sensed aerial imagery[130].

This practice has resulted in the purchased data being made available to users at no cost, increasing their dissemination and use. The practice has benefitted larger imagery providers, but has resulted in changes in how they price and license these data since dissemination of the data through open data portals limits their opportunities for data resale.

Another important impact of government procurement changes is the increasing use of a practice referred to in the private sector as 'body shopping'. The migration by governments more and more to this model (i.e., clients hiring companies' staff as contractors to build applications internally rather than contracting out the full project to them) is forcing prices down. This practice may be a reflection of the maturity of IT and GI applications development, which has decreased the complexity of systems development and the reliance on highly specialized firms. However, a significant (and probably unintended) consequence is that companies have more limited access to opportunities to build GI total solutions that can be leveraged in the private sector and international markets.

Increased geo-literacy

A number of factors have combined to drastically increase the levels of geo-literacy in the general public. The prevalence of geo-enabled Internet search engines, automobile navigation systems and mobile devices of all kinds has resulted in a growing awareness across all market segments of the value and usefulness of geospatial information. The increased ease-of-use of geo-technologies and availability of free and open data have placed the capability to consume and use geospatial information into the hands of growing numbers of practitioners in both existing and newer market segments. At the same time, the availability of GI-based mobile apps has mushroomed, driven by consumer adoption of this technology, as illustrated by the number of geo-apps listed in the Apple App store[131].

As with some other drivers of change, the impacts of increased geo-literacy on the geomatics sector exhibit primarily positive characteristics. In market segments that are historically strong users of GI (e.g., natural resources, utilities and transportation), the use is expanding into new application areas like inventory tracking, mobile workforces and 3D visualization of project plans, and the visibility of GI at senior management levels and its use to support decision making is increasing. For newer GI user communities (e.g., health, finance and insurance), the impacts of GI use are now beginning to be felt and there are expectations of strong market growth. In areas where GI use is still at the early adoption stage of the technology adoption life cycle, the industry is witnessing a shift in demand from data and technology to fit-for-purpose, hosted GI solutions that are delivered and supported on a turnkey basis. The only negative impacts that have been identified for this change driver are the loss by some firms of former clients that have established in-house GI capabilities, and the difficulties of changing business models to compete further up the value chain.

Commercial drivers

The commercial growth drivers that are most prevalent are energy development (conventional oil and gas and renewable, particularly wind) and property development, which in Western Canada go hand in hand. The oil and gas sector is the overall dominant engine of growth in the Canadian economy and is the leading consumer of GI products and services in the West. The demand for surveying and mapping services to support exploration and development of new finds and major pipeline projects, as well as for specialized value-added services in areas such as subsidence studies and risk analysis, is expected to be strong for the foreseeable future. While the residential, commercial and industrial survey market is generally flat in Eastern Canada, it remains strong in the West, in large part due to continued growth in energy development.

The infrastructure market is also a strong growth driver as governments continue to contract for infrastructure replacement consulting services that include considerable GI requirements for design and installation. The government's focus on northern economic development has not yet produced new business; industry's work there in the mining and oil and gas sectors has stagnated in recent years. The Geo-mapping for Energy and Minerals (GEM) program did provide significant contract work for those involved in 35 regional geophysical surveys completed between 2008 and 2013[132] and will continue to provide work until 2020 under the extended GEM program.

3.1.2 Emerging Technologies Influencing the Supply and Use of Geospatial Information

Technology provides the underpinning for GI products and services, and rapid technological change is having significant impacts on how geospatial information is produced and consumed. The following sections summarize key technology trends identified through stakeholder consultations and the literature review.

Location-enabled mobile devices

The widespread adoption of smart phones and tablets with built-in GPS is impacting how GI is supplied and used in a number of ways. On the consumer front, mobile devices with integrated voice and data communication, camera, GPS, compass, inclinometer, etc. are turning ordinary citizens into mobile sensors and geospatial information users, contributing to the demand for and supply of previously unimaginable amounts of location data. Social media sights provide the means to share geotagged images, geospatial apps provide users with a wide range of tools to use geography for trip planning, service locating, recreation and navigation, and cell phones become data collection devices for volunteer geographers who want to contribute to crowd-sourced online mapping sites.

On the business front, with GPS being installed in all new mobile devices, there is considerable business to consumer (B2C) business potential to be derived from location tracking. For example, with more accurate triangulation and faster processing of higher data volumes, mobile phone operators are already tracking the movements of individuals and this location data is being collated, packaged and sold on to users such as retailers. Concerns about privacy remain, as data is crowd-sourced passively (i.e., data collected from a device without the owner's knowledge or permission, such as travel patterns derived from data transmitted from their smartphone automatically and in real time), although Generation Y seems less concerned about this issue.

Business to business (B2B) GI applications have also migrated to mobile platforms. Organizations in the resource development, land management, logistics, infrastructure, engineering consulting and other sectors now routinely use mobile phones or tablets in the field to ramp up worker productivity. Either through downloaded or real time delivered (where cellular coverage is adequate to permit the use of web services) GI data and applications, field staff can navigate to points of interest, quickly access information on the structure, facility or resource inventory of interest, conduct site planning and data updating tasks, and create reports as the work is completed. GI suppliers are building these applications for deployment on their technology and also providing access to applications and, or data through software and data as a service (SaaS and DaaS) delivery models on the Cloud.

Data collection with mobile devices is reported to be on the rise across most of the business sectors covered by the study consultations. In many organizations, data is routinely being collected in the field with tablets and smart phones, often equipped with data accessed from corporate GIS that provides context and navigation, and providing uploading of collected data to the office in near-real time. This is resulting in significant productivity improvements (e.g., reducing the amount of time spent in the field and eliminating the need to return to the field after a problem has been discovered).

Mainstreaming of open source software

As the quality and sustainability of open source software improves, it is gaining popularity, particularly within government organizations facing budget constraints. The move to open source solutions is removing many of the perceived barriers to wider adoption and driving a virtuous circle where the value will grow as more users adopt and contribute improvements. Examples of GI open source software in common use can be found on the Open Source Geospatial Foundation (OSGeo) website and include: GeoServer, MapServer, MapGuide Open Source (web mapping applications); GRASS GIS, Marble, QGIS (desktop applications); and GeoTools, PostGIS (libraries). Increasing use of these tools within both the public and privates sectors is reducing the growth of commercial off the shelf software sales.

This is one reason that prices of software licences from the large vendors are dropping, as they move increasingly to enterprise licensing deals to encourage dependence and the spread of usage within customer organizations. It has been suggested that this trend will lead to commercial companies creating support facilities around open source GIS, following ICT sector patterns (e.g., IBM funding of Linux as competition to Windows).

Data volume growth

The embedding of GI into software applications and devices of all kinds is accelerating the growth in the volume of data to be stored, processed and managed. The literature is replete with examples of the generators of high volume data (sometimes referred to as 'Big Geo-data'), including:

- georeferenced webs of sensors to continuously monitor environmental conditions (e.g., temperature, pressure, sound, etc.);
- Smart Grid systems capturing georeferenced information about the behaviours of electricity suppliers and consumers;
- high resolution imaging sensors (e.g., optical, radar, LiDAR);
- crowd-sourced contributions of GI to online mapping websites (i.e., volunteered geographic information or VGI); and
- vehicle tracking (e.g., analyzing real time traffic volumes, congestion, etc. for calculating wait times, optimal routing and ultimately to support driverless cars).

The accelerating growth in geospatial data volumes will have a number of impacts. It will dramatically increase the complexity of managing the underlying databases in the petabyte size range and increase the importance of effective metadata and even faster, larger processing configurations. Database management systems will need to evolve to cope with the demands of huge volumes of data, including real time 3D location information feeds, and the challenges of finding the right information at the right time. With estimates of daily data production as high as 2.5 quintillion bytes[133], much of it georeferenced, reliance on technologies such as massively scalable, distributed systems for processing unstructured and semi-structured data, will continue to grow. As Smart Grid technology is being implemented across the electrical power infrastructure, electric utilities will have 10,000 times as much data as they had before, much of it georeferenced.

Big data analytics

There seems to be a common understanding that 'Big Data' includes simultaneously three characteristics that have reached a level never seen before, as stated in the definition proposed by Gartner: "Big Data are high-volume, high-velocity, and/or high-variety information assets that require new forms of processing to enable enhanced decision-making, insight discovery and process optimization."[134] Big Data benefits from geospatial solutions in various ways. For example, Big Data largely utilizes the position of objects, thanks to GPS-enabled devices such as smartphones, cameras and cars as well as to georeferenced sensor networks and digital maps.[135] Geospatial analytical tools are increasingly available for Big Data. For example, the GIS Tools for Hadoop[136] are a collection of geospatial information tools that leverage the Spatial Framework for Hadoop for spatial analysis of big data. MapLarge[137] is another product that provides an elastic, cloud-based geospatial platform for big data analytics and visualization.

Major business analytics players like SAP provide geospatial analysis capabilities (e.g., for example, their InfiniteInsight product[138]) and leading database technology vendor Oracle provides in-database spatial tools that provide the ability to add a spatial dimension to Big Data.[139] However, some experts believe that existing GIS and spatial database technologies are not efficient or robust enough to handle the volumes of data involved in Big Data analyses; new technologies are being developed to handle the variety, volume and velocity of Big Data creation.[140]

The scale and scope of changes that Big Data are bringing about are at an inflection point, set to expand greatly as a series of technology trends accelerate and converge. Incumbents tied to legacy business models and infrastructures will have to compete with agile new competitors that are able to quickly process and take advantage of Big Data. Growth in the integration of GI with Big Data and the use of spatial analytics is expected across a broad spectrum of sectors, including public health, security, disaster management, intelligent transportation systems, Smart cities, and environmental monitoring.

A critical shortage of the analytical and managerial talent necessary to make the most of Big Data is predicted to act as a restraint on the full exploitation of Big Data potential. Those nations that take swift action to fill this gap will enjoy business advantages. For example, McKinsey projects that demand for deep analytical positions in a Big Data world could exceed the supply being produced by 140,000 to 190,000 positions in the US by 2018.[141] So called 'data scientists' (i.e., data analysts with strong business acumen, coupled with the ability to communicate findings to both business and IT leaders in a way that can influence how an organization approaches a business challenge; someone who can sift through data with the goal of discovering a previously hidden insight, which in turn can provide a competitive advantage or address a pressing business problem) with the deep analytical skills to exploit the full potential of Big Data are in particularly short supply.

Location intelligence

Location intelligence (LI) has been defined as "the capacity to organize and understand complex data through the use of geographic relationships. LI organizes business and geographically referenced data to reveal the relationship of location to people, events, transactions, facilities, and assets."[142] Closely related to the Big Data community, the LI community focuses on combining analytics capabilities with the transactional approach of GIS to provide new insights in spatially-referenced business data such as from business intelligence (BI), enterprise resource planning (ERP), customer relationship management (CRM), and document management systems, etc. Examples of LI applications include[143], [144]:

- **Crime Analysis and Fraud Detection**: locating and tracking terrorists, drug dealers, money launderers, and others for the purposes of observation and monitoring; and combining location data with transaction data to identify unusual patterns indicative of fraudulent behavior such as identity theft, stolen credit cards, and even insurance or public assistance fraud.

- **Insurance**: informing operational activities such as balancing exposure to aggregate risk across different areas, catastrophe management, assessing theft and damage potentials, and regulatory reporting to governmental agencies and commissions.
- **Logistics**: increasing delivery speed by providing directions to high quality standardized addresses and calculating the optimized routing, and planning routes in which the delivery point is always positioned to the right of the vehicle, which reduces the risk of driver accidents.
- **Healthcare**: reducing or eradicating disease through better understanding of the environment by tying health records to user home and work location.

According to researchers at the Massachusetts Institute of Technology, companies that adopt 'data-driven decision making' achieve productivity that is 5 percent to 6 percent higher than could be explained by other factors.[145] Organizations are adding spatial analytics and interactive mapping to their business data systems to improve productivity even further.

Indoor positioning

There are a number of market forces driving the rapid development of indoor positioning systems (IPS). There is a growing demand for location information independent of situation (i.e., indoors or outdoors) and computing device (i.e., computer, tablet or mobile phone). So-called 'personal networks or PNs' interconnect users' personal devices at different places such as home, office, vehicle, etc. into a single network that is transparent to users.[146] To support location-based services when the PN is indoors, IPSs are required to complement GPS use when outdoors.

Indoor positioning systems use magnetic, other sensor data or a network of devices to wirelessly locate objects or people inside a building, where GPS loses significant power. The different types of indoor positioning techniques include: Wi-Fi triangulation, Wi-Fi fingerprinting, beacons, Bluetooth, sensors (accelerometer, gyro, compass, barometer, etc), indoor lights, magnetic field, cell tower signal, low orbit satellite, and cameras.[147] In order to make positioning signals ubiquitous, integration between GPS and indoor positioning is employed. The first reported use of IPS was around 2000, when Microsoft Research developed RADAR: an in-building RF-based user location and tracking system.[148]

The range of potential applications of indoor positioning is significant and growing, including[149]:

- Retail – driving consumers to specific products on individual shelves in shopping malls[150]
- Navigation – guided tours of museums, locating building and facilities on university campuses or commercial building complexes
- Health care – tracking doctors, nurses, patients and equipment within hospitals, and delivering medications and equipment robotically (i.e., with automated guided vehicles)[151]

- Asset tracking – tracking inventory and valuable assets in warehouses and large building complexes
- Emergency response – new E-911 requirements for indoor location of mobile phones (see Section 3.1.5)

A recent market report predicts that the ecosystem necessary to drive mass adoption of indoor location applications will be in place by 2016 with applications driving more than a billion downloads a year by then,[152] and that the global indoor location, positioning and navigation market will increase from US$448M in 2013 to US$2.6B in 2018.[153] Other market analysts predict that by 2017, the Indoor Location Market will reach revenues exceeding US$5 billion and will represent over 200,000 installations of infrastructure equipment, including Wi-Fi hotspots.[154] The potential business opportunities are generating a lot of development activity, with major existing location-based service players (e.g., Apple and Google) and start-ups jumping into the market.[155]

Unmanned aerial vehicles

The use of unmanned aerial vehicles (UAVs) for airborne imagery capture is steadily increasing. Under the *Canadian Aviation Regulations*, a UAV is any “power driven aircraft, other than a model aircraft, that is designed to fly without a human operator on board”.[156] Among the applications of UAVs for geospatial data collection are the following:[157]

- Remote sensing – using electromagnetic sensors, including standard cameras, infrared and near infrared cameras, as well as radar and LiDAR (light detection and ranging) systems.
- Surveillance – to more cost-effectively monitor livestock, wildfire, wildlife, pipelines, and roads.
- Natural resource exploitation – providing information on underlying rock structures and mineral deposits and surveying pipelines and other structures used in oil, gas, and mineral exploitation
- Search and rescue – to search for missing people, either through high resolution imagery or signal detection; synthetic aperture radar (SAR) allows imaging through most weather conditions.

Cloud computing

The first cloud computing infrastructure service was launched in 2002 by Amazon.[158] Software as a service (and bundling with data as a service) will become an increasingly attractive alternative to the purchase and maintenance of proprietary software, as the popularity of cloud computing and the market domination by non-professional GI users grows, significantly impacting current geomatics business models. Users will increasingly want their location information accessible, anywhere and anytime on the device of their choice. Use of the cloud will facilitate such access. Canadian GI suppliers are considering offering cloud services or moving significant data assets to the cloud, but concerns about privacy and security in public clouds, especially those using infrastructure based in the US, persist.

Analysis and reasoning may start to form part of Spatial Data Infrastructures, as the concepts of infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS), evolve further to model as a service (MaaS). The mass market geomatics players like Google, Bing and Apple are creating private infrastructure, although such infrastructure will not facilitate access to a broad wealth of open geospatial information. However, because such infrastructure may be perceived by decision-makers to be fulfilling the SDI role, there is some concern that this may inhibit government SDI development, Esri is positioning itself as a major provider of IaaS, by integrating GI content with demographics, landscape, community social values, etc. and their Esri MAPS for common business app products and ArcGIS Online.[159] Cloud solutions offer potential cost reductions for organizations struggling with the costs of spatial data infrastructure and data maintenance. In the near term, lack of cloud computing standards may pose problems for SDI operations wishing to adopt cloud solutions (i.e., vendor lock-in and interoperability issues), but the standards issue is being addressed by a number of organizations.[160] As this concern was expressed by one respondent,

> *"cloud computing and large datasets lead to issues related to the cost and complexities of data sharing".*[161]

Immersive video / augmented reality

Within ten years all smart phones (or whatever replaces them) will likely be able to film 360 degree 3D video and wirelessly stream it in real time. Google is leading the way on this technology, with their Project Tango devices that contain customized hardware and software designed to track the device's full 3D motion and simultaneously create a map of the environment.[162] Worn by workers (e.g., police officers, firefighters, utility workers, etc.), such devices may allow their colleagues in the office or in the field to see what they are seeing. Data from this network of devices, combined with sensors mounted in many vehicles, at street intersections, etc. will be merged in real time to provide an augmented reality view of the world.

The dynamic graphics and 3D visualization common in the video games industry, along with the increased availability of high resolution location data, may help to drive a new generation of more diverse geomatics software capable of 4D visualization (i.e., visualization in three dimensions with the addition of a fully integrated time reference). Demands will increase for adding the 4th dimension of time to data, in order to learn from the past and model the future, requiring the archiving of time-referenced location data.

Broadband and cellular network capacity

As GI becomes increasingly mobile, broadband and cellular network capacity is a factor of growing importance to market development. Canada's commitment to building high-speed broadband networks to 'underserved' regions lags far behind national digital programs in such countries as the United States, Britain and Australia, potentially contributing to the country's poor record of productivity growth and inhibiting the full potential of a distributed spatial data infrastructure (especially in regions like the Arctic). While the speed of networks continues to improve, there is concern that capacity is not keeping pace with demand and that this constraint to handling high volumes of location (and other high resolution imagery like video) data may cause user disillusionment with mobile devices and their location data handling capabilities.

Increasing difficulty in tracking data provenance and enforcing licences

The growth in the amount of data, the number of actors in the data creation processes, and the interconnectivity of these parties will make ownership tracking an increasingly difficult task. User intolerance for pricing and licensing models that are seen to be too complex, rigid and costly has been a factor in the rapid growth and popularity of VGI sites. GI users' expectations that data will be free and reusable with few conditions are growing. Consumer use of location data may become effectively free at the point of use in virtually all circumstances due to the combination of open data availability and the hacking and piracy of licensed data. Given the easy transportability of data and the sharing of data between countries, licence enforcement will become increasingly difficult in the absence of a multinational legal or policy framework.

3.1.3 Economic Trends Impacting the Geomatics Sector and the Supply of Geospatial Data / Information

The overall state of the economy, economic shifts and economic circumstances in the GI market influence the health of the Sector and its future prospects. The following sections summarize the key economic trends identified through stakeholder consultations and the literature review.

Industry structure and demographics

The structure of the Canadian geomatics industry (i.e., a few very few large firms and predominantly small and micro businesses) will continue to limit its ability to successfully compete in the international market, and will increasingly threaten its domestic competitiveness. The scope of the Sector is becoming more difficult to define as location information becomes increasingly embedded in other domains and the community's heterogeneity grows. This will impact the geomatics sector's ability to agree upon strategic directions and take collective action. A positive sign is the apparent widespread support of geomatics sector leaders for the Pan-Canadian Geomatics Strategy and Action and Implementation Plan, following a two-day workshop hosted by the CGCRT in June 2014.[163]

Globalization

Important policy and investment decisions in Canada will increasingly be influenced by global forces, with the potential for more open trade and less domestic industry protection, resulting in intensified competition in the GI market. Global industry consolidation is occurring with acquisitions focused on creation of vertical value chains encompassing data collection, management and applications technologies and services (e.g., Trimble, Rolta and Hexagon). According to Policy Horizons Canada, global value chains are being divided into smaller and smaller tasks in the emerging 'project economy', with more job instability and fewer benefits.[164] Outsourcing by global players of parts of their location information value chain is likely to grow.[165]

The consequences of this trend for the Canadian geomatics sector will be new opportunities for agile and innovative GI suppliers to be acquired by global players or to tap into their value chains. If information service providers cannot easily access Canadian data with limited restrictions on reuse, they may source alternatives globally, resulting in the replacement of Canadian government data with private sector data produced outside Canada.

Economic power shifts

The BRIC (Brazil, Russia, India and China)[166] and Next Eleven or N-11 (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea, and Vietnam)[167] countries are playing a much more significant role in shaping global policy and they bring new values, norms and priorities so that building consensus on responses to global issues may be more difficult. Canada can maintain its relative global influence by carving out a niche in providing new collaboration processes for idea-generation and consensus-building to help identify solutions that work for everyone. With its strengths in integration, analyze and visualization of multivariate data to support solutions identification and decision making, geomatics can play an important role in these processes.

China and India have money to invest and Canadian companies are on their radar, so attractive geomatics companies could face the decision of being acquired or competing. Intellectual capital is growing rapidly in China and India, producing an R&D advantage that Canadian geomatics players can access through partnerships and alliances. Competition from companies in lower wage countries will continue to increase in both domestic and international markets, although the rapid growth of the middle class in India and China is raising pay scales, which will reduce this competitive advantage over time.

Global economic uncertainty

Although the fallout from the 2008-09 economic downturn is still impacting global markets and economic uncertainty continues to have a dampening effect on private sector willingness to invest and create new jobs, there are positive signs for future economic growth. For example, in its April 2014 World Economic Outlook report, the International Monetary Fund (IMF) states,

> *"The strengthening of the recovery from the Great Recession in the advanced economies is a welcome development. But growth is not evenly robust across the globe, and more policy efforts are needed to fully restore confidence, ensure robust growth, and lower downside risks."*[168] *"Looking ahead, global growth is*

> *projected to strengthen from 3 percent in 2013 to 3.6 percent in 2014 and 3.9 percent in 2015…"*

In a similar vein, The World Bank's June 2014 Global Economic Prospects report states,

> *"Despite the early weakness [in 2014], growth is expected to pick up speed as the year progresses and world GDP is projected to expand by 3.4 percent in 2015 and 3.5 percent in 2016." "The bulk of the acceleration will come from high-income countries (notably the US and the Euro Area). A reduced drag on growth from fiscal consolidation, improving labour market conditions and a steady release of pent-up demand in these countries are projected to overcome first quarter softness [in 2014] and lift high-income GDP growth…".*[169]

The Conference Board of Canada's most recent economic outlook for Canada (2013) suggested that:[170]

- Canada's economy will remain soft until the United States picks up the slack, with real GDP growth averaging 2.4 per cent per year over the medium term.
- Beyond 2015, the growing number of retiring baby boomers will curb labour force growth, resulting in slowing growth in potential output.
- Government spending will be brought in line with historical levels over the medium term with provincial governments continuing to struggle to meet growing demand for health care.
- Our aging population and rising immigration will shape our demography and economy in the coming decades.
- The developing world's demand for raw materials will remain robust over the foreseeable future, keeping upward pressure on resource prices and the loonie near parity with the greenback[5].

The economic downturn impacted the geomatics sector in several ways. Reduction in demand for Canadian resources resulted in cutbacks in the resource industry on GI products and services. The focus within Canadian governments on investment to counteract the impacts of the global financial crisis has now largely shifted to deficit and debt reduction. Like many other government organizations, federal, provincial and territorial GI providers were impacted, and this resulted in reduced contracting out to the private sector. The GI provider organizations in the major cities appear to have been less impacted, with ongoing programs of contracted-out data collection and digital map production. Signs have emerged in the past year that economic recovery is resulting in improved business prospects for GI suppliers.

[5] Recent predictions are for the Canadian dollar to remain approximately 10% lower than the US dollar for the foreseeable future.

Business to Consumer (B2C) market growth

B2C is the highest growth segment for GI, with over 100 million people using web maps each month. However, the traditional geomatics industry players are providing very little of this data, and there are few prominent Canadian firms in this segment. Although geomatics firms may not see a role in the B2C market, they may soon be facing competition in the business to business (B2B) market from crossover B2C players that have developed new cost and business models.[171] Partnerships and alliances with B2C players may be the most suitable response to this trend.

Software developers in the B2C market use an entirely different business model – sales of apps at the cost of a cup of coffee through application stores linked to mobile phone operating systems, with limited investment in sales and marketing or distribution channels (e.g., over 15 percent of applications on Apple's AppStore utilize location in some way) – a major change for most GI companies.

Crowdfunding

According to the Financial Times, crowdfunding is "a new and emerging way of funding new ideas or projects by borrowing funding from large numbers of people often accessed through a website."[172] The crowdfunding model typically includes the people or organizations that propose the ideas and/or projects to be funded and the crowd of people who support the proposals, supported by an organization (the 'platform') which brings together the project initiator and the crowd.

As of June 12, 2014, the National Crowdfunding Association of Canada had a directory of some 100 active or beta Canadian crowdfunding platforms, funding portals and service providers.[173] Access to such pooled financial resources through the Internet will provide a new means for geomatics start-ups and small companies to grow their businesses. There is evidence that this is already happening in the geomatics community, with a number of GI providers having secured[174, 175] or currently seeking investment through crowdfunding.[176, 177, 178]. However, growing concern about the potential for scams is resulting in calls for accreditation schemes and potentially government regulation to prevent fraud.[179]

3.1.4 Social and Demographic Trends Impacting the Geomatics Sector and the Supply of Geospatial Data / Information

An array of social and demographic trends are having significant impacts in the geospatial information market, opening up previously unimaginable consumer applications of location data and technologies. The following sections summarize key social and demographic trends identified through stakeholder consultations and the literature review.

Influence of the wired generation or 'Generation Y'

The so called 'Generation Y' or 'Millennial Generation' is generally considered to be the demographic cohort born between the early 1980s and the mid1990s.[180] The latter part of this cohort that has entered the workforce in the past five years appears to have different expectations, which are helping to shape change within organizations and the market. For example, there is a more blurred distinction between work and social lives for this generation, which will be a driver of the crossover between the user interfaces and tools of the social web and those in the workplace.

There is a higher expectation than in previous generations that digital content (including GI) should be available free online, and a willingness to challenge the legal rights of content owners, which will encourage information providers to access new delivery channels and find viable new business models. There is also more market affinity with 'open' (data, standards, software), which will encourage suppliers of proprietary products and services dependent on licensing and maintenance fees to re-examine their business models. Generation Y expects that 'openness' will lead to greater civic participation and influence on public services.

This generation is influencing management practices in the geomatics workplace (e.g., decisions on staff retention programs and development of mobile applications for use by their workforce).

Location awareness

The growing familiarity with technology and ease of handling data streams by workers in other sectors and citizens will make them increasingly adept at recognizing trends (spatial, temporal and causal) within the vast quantities of data that will be available. This trend is expected to result in greater demands on the geomatics sector to ensure that geospatial information is of high quality and that different types of open data discoverable on public sector geoportals is integrated and interoperable.

Crowd-sourcing / volunteered geographic information (VGI)

The familiarity with the use of GPS and emergence of Internet mapping sites like OpenStreetMap and Wikimapia has raised the public's interest in being active contributors to the geospatial information in their communities (the so-called 'produsers' – individuals that are involved in both the production and use of the data, such as active VGI contributors), and acts as a valuable mechanism to encourage public participation and engage and empower citizens.

Government geomatics organizations are exploring the opportunity to capitalize on the potential of VGI to contribute to authoritative data maintenance. A range of technical and policy issues (e.g., quality control, security, licensing, etc.)[181] are significant considerations. As crowd-sourced content continues to improve, this may place more pressure on government authoritative data providers to justify expensive data maintenance programs, and encourage improved collaboration between these two groups. Precedents have been set for the use of crowd-sourced input to authoritative datasets (e.g., State of Victoria, Australia Notification for Editing Service,[182] and The National Map Corps in the US[183]).

Concern about privacy invasion

The pressure in some segments of society to ensure location privacy (i.e., preventing the invasion of a person's privacy through the use of location imaging such as satellite, airborne or street level images), and to prevent re-identification (i.e., loss of privacy through the possible combining of publicly available and privately held data layers or types with geographic coordinates) of individuals appears to be increasing, although generation Y seems to be less concerned with privacy invasion. The Office of the Privacy Commissioner of Canada (OPC) has conducted a number of studies on the topic[184] and the OPC has worked with Natural Resources Canada, which published in 2010 the *Geospatial Privacy Awareness and Risk Management Guide for Federal Agencies*.[185]

International organizations have taken up the location privacy cause. For example, the Internet Engineering Task Force has created a GEOPRIV Working Group to "develop and refine representations of location in Internet protocols, and to analyze the authorization, integrity, and privacy requirements that must be met when these representations of location are created, stored, and used".[186] The Electronic Frontier Foundation is "fighting to protect the privacy and prevent the misuse of location data that users of phones, GPS transmitters and location-based services leak to providers and to the government".[187] Demands may increase for regulatory protection of individuals' privacy, and if so, the geomatics sector will need to be informed participants in the policy debate and formulation.

The Canadian Radio-television and Telecommunications Commission (CRTC) has noted the importance of privacy protection as location-based services and tracking of mobile devices has expanded.[188] [189] Concerns have been raised about the failure of LBS providers to notify subscribers that their movements are being tracked and providing convenient means of opting out. Legislation has been passed in the US in response to these concerns (e.g., The Location Privacy Protection Act of 2012[190]) but no similar provisions have been adopted yet in Canada.

3.1.5 Political / Policy Trends Impacting the Geomatics Sector and the Supply of Geospatial Data / Information

Political institutions have a significant influence on the geomatics sector, not only because governments are primary suppliers and users of the Sector's products and services but also because public policy directions have important impacts on the market. The following sections summarize key political and policy trends identified through stakeholder consultations and the literature review.

Open government

As the general public becomes increasingly informed and engaged, pressure to make GI and other public sector information free to reuse and easily accessible and useable will continue to grow, making cost recovery from sale of geospatial data increasingly challenging. In addition, pressure to adopt common data licensing models is likely to mount as users experience licensing conflicts with multiple data sources. GI licensing is likely to become more challenging; as expressed by one stakeholder,

> *"Existing policies around licensing, privacy, etc. are out of step with trends in the marketplace, consumer expectations and technology capabilities. People are used to copying maps, music and video off the web at will without concern about copyright and licenses. It will become increasingly difficult for providers of authoritative data to control its use."*[191]

The Sector is well positioned to be the 'poster child' of the open data movement, with the investments that have been made in SDI initiatives, but proactive efforts to raise the geomatics sector profile and communicate the value of GI will be necessary to secure future resources to ensure infrastructure sustainability. In order to take advantage of the business opportunities that opening government data is intended to stimulate, geomatics innovators will need to learn to play in the broader information landscape and adopt new business models. For the sector to take full advantage of this opportunity to innovate and create new business, citizens and communities will require capacity building in GI adoption and use.

Finding horizontal solutions to key policy issues

The pressure to collaborate will increase as the shift towards more holistic and inter-disciplinary means of tackling public policy priorities continues, and the geomatics sector is a leader in making collaboration work. Location information will increasingly be brought to bear to help deal with priority horizontal issues such as integrated resource and environmental policy development, land use planning and land stewardship, devolution of land management responsibilities, responsible resource development, public safety and security, and disaster response and recovery. Pressure will increase to produce complex modeling of integrated data for 'what if' scenario development and strategic impact assessments in support of policy development and GI will be a critical element to enable visualization of different scenarios and impacts. Higher demands for interoperable information services will encourage the elimination of data and systems 'stovepipes' within government, and test the capabilities of SDI implementations.

Overall budget restraint, government downsizing and changing priorities

Governments struggling to meet the growing health care demands of an aging population with increasing incidence of multiple chronic health conditions will be further tempted to find resources by cutting less visible and politically sensitive government services, like geomatics, necessitating proactive measures to communicate the value of these services. However, as GI becomes more fully integrated within decision-support tools, the importance of authoritative, trusted data will become more widely recognized. There is the hope that the role of government to provide such data may be more clearly understood and accepted and that resources will be made available for its maintenance. At least two key requirements will ensure that authoritative location data will continue to be required: government's legal responsibilities and the requirements for international reporting (e.g., climate change, forest cover, CO_2 emissions, etc.), which will require integration of geospatial data with other types of data.

The increasing costs of data management and infrastructures are causing pressures on governments, particularly in a period of fiscal restraint. Streamlining expenditures through innovative collaborative solutions will offer new opportunities for cost containment and increased efficiencies (e.g., cloud computing, spatial data infrastructures, and shared procurement of satellite and airborne imagery). The Federal Geospatial Platform initiative being led by Natural Resources Canada on behalf of the Federal Committee on Geomatics and Earth Observation (FCGEO) is a good example of such a solution.

The kinds of cost reductions and efficiency measures governments are likely to adopt include: outsourcing processes to the private sector, partnering with VGI data providers and others, and focusing on the roles of commissioning and managing the delivery of a complete location information framework. An example of the changing roles of government and industry that was cited is the recent establishment of the independent Alberta Environmental Monitoring, Evaluation and Reporting Agency,[192] which is to be partially funded by industry, prompting speculation that geomatics agencies could perhaps be run as joint public-private sector ventures as well.

Business-supportive government policy

Certain types of government policy setting can serve as a stimulus to industry. Examples identified through our research and consultations include:

- Open data policies at the federal, provincial and local levels that provide access to more high quality geospatial data that applications can be built upon, stimulating innovation and economic development;
- Infrastructure renewal policies and 'green economy' policies (e.g., supporting wind and solar energy development) that result in new infrastructure development that requires location data and services for planning and construction;
- Regulations that require mapping and positioning (e.g., liability assignment policies that force utilities to conduct accurate as-built surveys or face liability for damages resulting from inaccurate location information);
- Procurement policies that favour contracting-out of total GI solutions over contracting-in of GI consultants to build solutions within government; and

- Long-term plans that help provide stability and encourage industry to invest and create new jobs (e.g., space plans, SDI sustainability plans).

Emergency management

Location-based initiatives are required to more effectively integrate a wide range of information to support the full disaster management cycle (i.e., mitigation, preparedness, response and recovery). There is growing recognition that the geospatial information and the geo-enabled decision-support systems to support rapid response to emergencies such as natural disasters in Canada are inadequate. Recent disasters such as the devastating Southern Alberta floods in 2013 demonstrated that access to available information and the quality of flood mapping information in Canada need improvement.[193] This problem has been highlighted by the insurance industry, which commissioned a study in 2013 that suggests that homeowners will never have access to comprehensive flood insurance in Canada unless there are new maps of flood-prone areas that take climate change into account.[194] It has also been acknowledged by Public Safety Canada, which commissioned the National Floodplain Mapping Assessment study in fall 2013 as part of a larger plan to help safeguard Canadian communities against the impacts of natural and manmade disasters.[195]

Another significant policy area is related to responses to 911 calls for assistance. Three-dimensional models of the built environment (buildings, facilities and above ground and underground infrastructure) and 3D cadastre (for multi-owner building units like condominiums) will be needed to support faster and more effective response to emergency situations in order to reduce loss of life and property damage (e.g., the Sydney Downunder project[196]).

E-911 standards exist in the US and Canada at present, and they are being considered in Europe. The Federal Communications Commission (FCC) and industry groups in the US are exploring capabilities of indoor positioning and are considering sharpening the requirements for position accuracy. This is a result of the recognition that over 50 percent of mobile 911 calls are made from indoors where GPS is not able to provide an accurate location to the 911 operator. A particular challenge indoors is height – locating people in distress within multistory buildings. The FCC announced in February 2014,

> *"We propose to revise our regulatory framework to require delivery of accurate location information to PSAPs [public-safety answering points] for wireless 911 calls placed from indoors. In the near term, we propose to establish interim indoor accuracy metrics that will provide approximate location information sufficient to identify the building for most indoor calls. We also propose to add a requirement for provision of vertical location (z-axis or elevation) information that would enable first responders to identify floor level for most calls from multi-story buildings."*[197]

Northern economic development

The Government of Canada has recognized that much needs to be done to secure the future of Canada's North and is taking concrete action to turn its vision for the North into reality. The government's plan for the north, *Canada's Northern Strategy*,[198] focuses on four priority areas: exercising Canadian Arctic sovereignty; promoting social and economic development; protecting the North's environmental heritage; and improving and devolving northern governance, so that Northerners have a greater say in their own destiny. This strategy is a key driver of economic development activities in Canada's north and action on all priorities requires access to and use of quality GI.

The consultations conducted for a recent project to develop a strategic framework and roadmap for Canada's Arctic spatial data infrastructure and marine cadastre [199] suggest the need for substantial additional work on geospatial data production. Many different types of data covering the region or parts thereof already exist, but efforts are fragmented, the level of detail is insufficient, standards are infrequently used and existing geoportals are often not of a design or standard that would make them useable nodes in a national SDI. Gaps were identified in the availability of the following GI content in strategically important geographical areas of interest: 1:50,000 core GI, hydrographic charting, medium and high resolution imagery and sea ice coverage and movement data.

3.1.6 Environmental Trends Impacting the Geomatics Sector and the Supply of Geospatial Data / Information

Environmental issues such as climate change, pollution, global food and water shortages, and severe weather events are becoming increasingly sensitive political challenges and the geomatics sector can play a central role in contributing to mitigation and workable solutions by providing an important means of integrating and assessing consequences, modeling different scenarios, etc. The following sections summarize key trends related to the environment that were identified through stakeholder consultations and the literature review.

Environmental consciousness and activism

Citizen concern about the deteriorating state of our environment will continue to rise, and expectations are high concerning the ability to access environmental information, most of which is connected to location. Crowd-sourcing of data (e.g., biodiversity observations, stewardship activities, etc.) by 'amateur environmentalists' (often referred to as 'citizen science') is growing, most of which will be georeferenced but may have little or no involvement of the geomatics community. Paradoxically, because the deluge of often conflicting information may breed citizen skepticism, how the information is presented becomes increasingly important, as does telling the story associated with the information in a compelling way. The geomatics profession has a potential role to play in the process of helping to communicate complex environmental decisions to citizens (e.g., augmented reality type solutions).

As citizens are increasingly engaging with the global environmental challenges of the 21st century, the geomatics profession has an opportunity to help connect citizens to these global issues through geography so that they can effectively participate in formulating and implementing solutions. Growing public concern about the environment is driving public sector investments in new geospatial data sources, particularly from ground-based sensor webs and satellite EO sensors (e.g., the EU's Copernicus initiative[200] – formerly Global Monitoring for Environment and Security (GMES)). This represents an important opportunity for the geomatics sector to play a leading role in the utilization of technology to help society adapt to global environmental challenges.

Citizens are not the only ones that have an interest in helping to solve environmental challenges – corporations want to, and want to be seen to, contribute as well. Businesses in a number of sectors (e.g., resource development, manufacturing, transportation, agriculture and food, health care, etc.) must meet environmental regulations and standards and are interested in promoting their 'green' processes and environmental track records. GI technologies have a role to play in helping companies comply with environmental regulatory requirements in such areas as sustainable forestry, efficient goods delivery, 'field to fork' agricultural practices, etc.

Global climate change rate reduction and adaptation

Geomatics professionals have a key role to play in responding to climate change through the effective management and use of information on the natural and built environments and the application of good land governance to help mitigate the damaging impacts on our world and society. The modelling of environmental phenomena such as climate change requires integrated environmental information in the land, marine and air domains that have traditionally been managed separately, and geospatial information has a key role to play in such integration efforts. In addition, since environmental issues don't stop at national boundaries, there will be a need to participate in regional and increasingly global SDIs (e.g., circumpolar Arctic SDI).

There will be an increasing demand for building infrastructure management applications (monitoring, recording and reporting on transformers, lights, air conditioners, etc.) driven by environmental regulation on building energy efficiency (e.g., in the EU, every new building will have to be designed to be 'near zero' energy after 2020,[201] and in the US, every new federal building will have to be 'net zero' energy after 2030[202]). This will require precise three-dimensional energy performance modeling based on building information models (BIM) and geolocation of the building in relation to historical weather patterns, nearby structures, etc.[203]

There is an opportunity for the geomatics community to work more closely with the architectural community to ensure the most effective integration of GI with BIM for improved long term management of building complexes. OGC released a Discussion Paper on *OGC Web Services Architecture for CAD GIS and BIM* in 2007[204], but a standard was never published. The buildingSMARTalliance, a council of the US National Institute of Building Sciences, initiated a GIS/BIM Information Exchange project[205] in 2010 to help ensure convergence of all spatial information so that it can be usable by any stakeholder in the facility environment. However, the committee does not appear to have met since July 2013 and no exchange standard has yet been developed. The inhibitors to progress on this front include overcoming the technical integration challenges and, perhaps more importantly, breaking down the cultural barriers between the two communities.

Global food and water security

Growth in world population and food and water shortages in certain regions resulting from more frequent environmental disasters (i.e., droughts, floods, severe storms, etc.) are combining to threaten global food and water security. Some countries may respond by protecting agriculture and natural resources to build national resilience and more robust value chains, and to facilitate the transition to sustainability. Water shortages in some regions will require new methods and infrastructure for transporting massive volumes of water from regions that have excess reserves; geospatial information will be required for planning and implementation of these initiatives.

As a result of a global search for land for large scale agricultural production, significant areas in Africa, India and South America are being bought or leased by foreign countries or corporations (so-called ‘land grabbing’,[206] in which countries like China, South Korea, Saudi Arabia, Qatar, and United Arab Emirates are reported to be leaders[207]). The geomatics sector has an important role to play in strengthening land governance across the globe to prevent abuses (e.g., removing local people from the land, loss of common grazing land, etc.). Good geospatial information management can assist land governance, to not only control and manage the effective use of physical space, but also ensure sound economic and social outcomes.

Since most of these concerns are focused outside of Canada (e.g., Africa and South America), the primary opportunities for Canadian GI providers will be through contracting opportunities with international aid organizations (e.g., The World Bank, Inter-American Development Bank, African Development Bank) that develop intervention projects to address food and water security.

3.1.7 Emerging Trends within the Public Sector Segments of Geomatics Use in Canada

Usage profile

There is strong agreement that the use of all information, including GI, will increase within government in the future, although government-produced GI may not be the most widely used because of declining quality. In addition to ongoing GI use by the traditional strong users in such mature program areas as agriculture, natural resources, transportation and public utilities, new users like public health and education are expected to offer growth potential.

At all three levels of government, geospatial information and technologies are contributing to operational programs, policy development, decision making, and services to the public. There has been a significant growth in the use of geoportals or online mapping applications for discovering, visualizing and accessing information in a geospatial context, particularly by the agriculture, resource, environment, statistics, safety and security, and infrastructure organizations. Lagging in this trend are organizations responsible for health, education and training, and social services programs, although the study has uncovered innovative uses in these areas as well.

A comprehensive summary of the uses of geospatial information within the public sector is provided in Appendix B.

Changing user requirements

Government GI suppliers report that their customers are now much better informed about what they want and need, and they have seen much more innovative uses of GI across government in the past five years (e.g., development and improvement of web mapping applications for public use, visualization tools to support decision making). GI suppliers within government are experiencing increased demand from users within their organizations for web and mobile applications. These demands are challenging them to be more innovative, and requiring the retraining of existing staff and changing the composition of staff complements. R&D budgets to help address these requirements and resources to maintain applications once built are often very limited.

Managing growth of GI use

Fiscal restraint has been identified as one of the most important growth inhibitors at present, and organizations are being more critical on where GI use is cost effective, the result being that the government market for private sector GI suppliers has been relatively flat or in decline. There is an increasing focus on adapting to budget reductions through collaboration, shared procurement, and managed services in the cloud. As noted in Section 2.3.2, the FGP initiative is a prime example of such collaboration at the federal level, and as discussed in Section 3.1.1, the federal, provincial and municipal levels of government are all involved in shared data procurement arrangements.

Cloud computing as a means of more cost effectively managing information, including GI, is being considered in many jurisdictions. For example, the Government of Canada is developing a cloud computing strategy and in April 2014 Tony Clement, President of the Treasury Board of Canada, invited Canadian cloud industry leaders and provincial governments to engage in developing clear and comprehensive cloud policies and guidelines.[208] Provincial governments in at least Ontario,[209] British Columbia,[210] and New Brunswick[211] are using cloud infrastructure and it is likely that a number of others have followed or are planning to follow suit.

3.2 The Domestic Market

3.2.1 Setting the Context

As discussed in Section 2.1, the geomatics sector has witnessed dramatic changes in the domestic market over the past 10 years, and those changes have generally been in alignment with predictions in previous geomatics sector studies. For example, the widespread embedding of GI into business applications, the Internet as a primary GI delivery mechanism, emergence of Mass Market Geomatics, shift in GI user predominance from specialists to generalists, increasing sector heterogeneity, etc. have repeatedly been identified as key trends and change drivers. Those drivers and trends, and significantly more that are described in Section 3.1, provide the context for the discussion of the Canadian geomatics market that follows.

3.2.2 Canada – Domestic Supply and Demand for Geospatial Information Products and Services, State of Domestic Markets, and the Role Played by Canadian Organizations

Supply side

The supply of geospatial information products and services in Canada is provided by both public and private sector organizations. Within the public sector, the primary GI providers have historically been the national and provincial/territorial surveying and mapping (often now called geomatics) organizations that are members of the federal/provincial/territorial coordination body, the Canadian Council on Geomatics (CCOG).[212] There are also a growing range of other significant GI provider organizations at those levels of government (e.g., defence, statistics, agriculture, environment), as exemplified by the membership of the FCGEO, which includes at least 10 departments and agencies that are producers of geospatial data.[213] At the municipal government level, although GI provision tends to be more fragmented, major cities have geomatics/surveys and mapping/GIS groups that play a central supply role, often located within utilities or infrastructure departments.

Geospatial information supply in the private sector is now split between 'traditional geomatics firms (i.e., those with their roots, and with strong disciplinary strengths, in surveying, mapping, remote sensing and hydrography) and a growing mix of 'other disciplinary' firms whose primary business is in other sectors (e.g., information technology, engineering and environmental consulting) but which have the provision of GI products and services as one business line.

The Canadian geomatics sector's GI supply capacity is profiled in Section 2.3, including the provision of GI products and services within both industry and government. GI provision by industry is characterized in accordance with the five components of the GI supply value chain (described in Section 2.2): geospatial information capture and processing; geospatial information analysis and presentation; integrated information products and services; location-based solutions; and geospatial information technologies.

Demand side

There is widespread and growing use of geospatial information and technologies across all market segments. Descriptions of the many ways that GI is being used in different sectors of the economy are provided in Appendix B. The *Value Study Findings Report* identifies the estimated percentage change in industry output as a result of geospatial information use for Canada's main economic sectors. Several sectors stand out as major beneficiaries of GI use.

Given the mining, quarrying, and oil and gas extraction sector's historical reliance on surveys and mapping and its early adoption of digital geospatial information and technologies, it is not surprising that it enjoys the largest percentage increase in output from GI use. Companies in this sector are at the leading edge of GI applications development and use for strategic planning, land and development rights acquisition, environmental protection, and resource extraction, processing and delivery to market. Routine use is being made throughout the sector of GI to target resource locations, estimate resource potential, guide extraction equipment, and reclaim mined land areas. Industry executives understand and rely on the power of GI data and technologies to support long range planning, community engagement, day-to-day operations and maintaining competitive position.

Another early adopter and beneficiary of modern GI and technologies is the utilities sector (i.e., water, sewer, electricity, natural gas). GI is embedded in all contemporary utility planning, construction and maintenance operations. From the time that utility infrastructure is being planned, GI is used to support the consideration of location options, selection of best locations, establishment of rights of way and design of facilities. During the construction phase, GI is required to layout the facilities and record as-built locations before they are buried. A number of studies have concluded that investment in accurately recording underground facility locations pays dividends, with cost savings of from $2 to $20 for every dollar spent[214]. Ground penetrating radar is now in widespread use[215] for determining the position of aging infrastructure for which as-built locations were not recorded. Utility managers are heavily reliant on sophisticated geo-enabled asset management systems to plan facilities replacement programs and organize day-to-day inspection and repair work, and deploy geo-enabled mobile devices with field staff to collect and electronically submit change data in real time.

The agriculture, forestry, fishing and hunting sector has enjoyed some of the most impressive increases in productivity through the use of GI. The automation of farm vehicles (e.g., vehicle guidance and variable rate application technologies) has had dramatic impacts on output increases. It is estimated that approximately 40 percent of farming operations in Canada are now deploying this technology. Important output improvements have also been realized through the growing use of crop yield mapping technologies. To remain competitive, Canadian forestry companies have also widely adopted GI and technologies to support planning and execution of logging and reforestation operations. Examples of the many areas in which digital GI is improving forestry sector output include planning and design of logging roads, stand demarcation, guidance of tree harvesting equipment, automated updating of forest inventory, optimal routing of logging trucks, and planning reforestation programs and generating tree planting work orders. Commercial fisheries are also heavily dependent on GI to help locate and track resource stocks, navigate fishing vessels and reduce the risk of collisions at sea.

A final beneficiary of GI use that is worthy of note is the transportation and logistics sector. The use of GI is deeply embedded in the commercial aviation, shipping and trucking industries. Air traffic control authorities are heavily reliant on the use of digital GI and GPS to track and guide aircraft, as are pilots for aircraft navigation. In a similar vein, port and harbor authorities use these technologies to guide vessels with vessel tracking service (VTS) technology and ship captains use geo-enabled electronic chart display and information systems (ECDIS) to navigate their vessels. In the truck transportation industry, geo-enabled dispatch systems are routinely used to monitor vehicles and provide optimal route information to drivers and navigation systems installed in trucks are becoming more commonly used. The use of GI for logistics (i.e., managing the flow of goods between the point of origin and the point of consumption) is also increasing as GPS chips are embedded in items of high value to help track them in transit in order to report on their location and estimated time of arrival at the destination, and improve the odds of recovery if they are stolen.

In addition to the traditional use of geomatics for operational purposes, many examples have been identified of how GI is being used at executive levels in organizations in connection with overall corporate strategy and planning processes. With very few exceptions, users indicated that the benefits of GI use outweighed the costs and that the technology is recognized as a strategically important asset. Comments like “companies cannot operate in this market without the use of geospatial information and technologies” and “it is a cost of doing business” were common.

Discussions about alternatives to the use of modern GI technologies revealed some interesting insights. While the only alternative to digital GI and modern GI technologies like GIS and GPS for those organizations with a long history of GI use is to revert to paper maps, this option seems almost inconceivable to consulted stakeholders. For those organizations that are newer GI users in areas such as precision farming, epidemiology analysis, insurance risk assessment, etc., no alternative seems feasible.

A number of organizations reported a particular challenge that would be difficult to overcome – the changes in regulatory reporting requirements. The advances in technology and increased adoption of GIS have made it practical for regulatory agencies to dramatically increase reporting (e.g., environmental information analysis) and data submission (e.g., ongoing forestry inventory updating) requirements. Meeting this requirement without rapid and cost effective digital data collection in the field and sophisticated data analysis and reporting in the office would be extremely difficult and cost prohibitive.

3.2.3 Barriers to Accessing Domestic Markets

Canadian GI suppliers are facing the following barriers in the domestic market:

- **Competitive environment –** This concern applies to companies that have a primary focus in the first two segments of the GI value chain. Aerial data capture firms are seeing more competition from hungry US operators whose domestic market has shrunk. Mapping companies are experiencing growing competition from low cost offshore suppliers (although several of those consulted are themselves using such suppliers to be more cost competitive. Companies in the EO value-added business are experiencing increased competition from the large EO data providers, which they assume are placing more emphasis on that business because of declining profit margins in data sales.

- **Labour shortages –** This is of particular concern in Western Canada, where the competition for talent is intense and difficulty filling key positions is a primary barrier to growing businesses. There is a shortage of experienced surveying technologists in Saskatchewan, Alberta and BC, and this has also had an impact in the rest of Canada, where companies are losing key staff to western firms. Another shortage is IT professionals with geospatial information applications programming skills.

- **GI value proposition –** Although there is general optimism about future GI market growth, there are still challenges in convincing prospective clients of the value of investing in geospatial information applications. There is a perception that executives in both industry and government are not convinced that such investments are priorities for their organizations, and making the business case remains a challenge.

- **Industry fragmentation** – The structure of the industry is a concern. For example, the relatively small size of most GI providers minimizes the resources that are available for new business development and often precludes employment of marketing specialists. Even relatively large companies are experiencing challenges in competing for very large projects (e.g., transportation and utilities infrastructure and major pipeline projects), which require integrated engineering, IT, GI and construction management expertise. Industry consolidation appears to be on the rise (e.g., merging of land surveying practices, acquisition of surveying firms by engineering firms), at least partly as a response to this business access barrier.

3.2.4 Priorities for the Production and Use of Geospatial Information Over the Next Five Years

Production priorities

The priorities with respect to production of geospatial information can be summarized as follows:

- There is strong support for the primary role of government as a provider of 'core' authoritative, accurate and accessible ('Triple A') data, and securing the necessary resources to bring this data up to the standard required by the user community and ensure its long term sustainability is seen as a top priority.

- Reassessment of the core data elements is also seen to be important, to ensure that the GI content that is given priority is well aligned with national policy priorities and critical user needs.

- The full implementation of spatial data infrastructure (SDI) initiatives at all levels of government, which are interconnected and interoperable, is a priority for providing easy access to free and open GI to all users. There is a general expectation that such facilitated access to both core and thematic data will help the geomatics industry to develop new commercial applications of geospatial information.

- There is a growing market demand for hosted or managed geospatial information solutions, which integrate fit-for-purpose data with applications software designed to solve specific business needs, in a cloud computing environment. This represents business opportunities for small and medium sized geomatics firms that want to reduce dependency on geospatial data and data products sales.

Use priorities

The priorities with respect to the use of geospatial information can be summarized as follows:

- Use priorities for geospatial information are driven by user requirements. Within government, GI applications are linked with public sector policy priorities, which vary by jurisdiction. In the current context, the general policy priorities across the three levels of government can be summarized as:

  - Infrastructure renewal
  - Resource development
  - Safety and security
  - Health
  - Education
  - Environmental protection

- There is a priority on improving the 'profile' or 'brand' of the geomatics sector as a trusted provider of quality geospatial information and geo-enabling solutions for broad application in government and industry. There is widespread consensus that an improved 'image' of the sector will help to expand the use of GI into new application areas.

- An improved effort to further improve 'geo-literacy' in user communities is a related priority, both to increase GI consumption and ensure that maximum benefits from the use of geospatial information and technologies are achieved. There is recognition both within and outside academia that secondary and post-secondary educational (PSE) institutions have a key role to play. GI use can be broadened and deepened through increased efforts to introduce geomatics concepts to students at an early age and within faculties across the PSE spectrum.

- There is general agreement that the sector must do a better job of educating GI users about the 'fitness' of GI for specific applications, to help ensure proper information use as well as build the professional image of the sector. A GI certification model is one possible solution.

3.3 The International Market

3.3.1 Setting the Context

The size of the global market that variously includes GI data, products and services has recently been estimated in a variety of studies:

- Geoservices 2013 Oxera[216] - The report quantified the economic value of the sector, based on reported commercial revenues, as being in the range of $150 billion to $270 billion.
- Personal Location Data 2012 McKinsey[217] - To quote directly from the report: "This domain offers the potential for huge new value creation over the next ten years that we estimate at more than $100 billion in revenue to service providers and as much as $700 billion in value to consumer and business end users."
- GIS 2011 Daratech[218] - According to Daratech, a long-time market observer, the GIS market grew worldwide 10.3 percent in 2010 to US$4.4 billion with a forecast of an additional 8.3 percent growth to almost US$5 billion in 2011.

The problem with each of these estimates is that they start from a different definition of the market. GIS is a well understood term and has the narrowest definition. Oxera take a very wide definition – all interactive digital mapping and location-based services. McKinsey includes all technology that locates people "within a couple of city blocks" from GPS chips in mobile devices such as phones and personal navigation systems; cell-tower triangulation data on mobile devices and in-person card payment data linked to a Point of Sales (POS) terminal.

The common theme from all is that this is a rapidly evolving market with a high potential for growth. The inclusion of personal location data as one of only five sectors highlighted by McKinsey is perhaps the most significant since it comes from outside the sector itself and covers only one part of our scope.

By far the largest segments are smart routing, location tracking, entertainment and geo-targeted mobile advertising, areas in which Canada is not particularly strong. Even if the figures are an order of magnitude too large, the potential of these applications in financial terms dwarfs all other parts of the market.

This sets the context for this assessment – consumer focused applications are a stronger driver of growth in the sector than the traditional business and professional applications.

3.3.2 Caveats

There are great variations in the drivers for GI data, products and services internationally. Details in many countries are not publicly available or only official sources exist which cannot be verified. Plans and aspirations cannot be easily separated from real progress on the ground. The approach taken has therefore been to attempt to discern progress and trends from experience, the results of the literature review and direct consultations, and more general soundings from experts around the globe. In doing so, examples of best practice and tangible achievements have been sought.

The following sections introduce the international markets in Europe, the United States, Australasia, the Middle East, Africa, Asia (subdivided into three sections – China, India and the rest of Asia), and Latin America. More detail can be found in Appendix C.

3.3.3 Europe

Introduction

The collection and use of geospatial data is very well established across Europe and has a very long history. Arguably, in terms of detailed large-scale topographic coverage, this is the most intensively mapped of all the continents. The transition from paper-based to electronic data is well advanced especially in Western Europe. The data are also well integrated into many services both in the public and private sectors. With the rapid rise in mobile devices in the consumer market the consumption of geospatial data has risen exponentially.

The European Union (EU), which brings together 28 countries in Europe, has had a major effect on the way that geospatial infrastructures have developed and evolved in Europe over the last decade. For example, the INSPIRE programme for a European SDI was driven by the need for improved environmental monitoring.

Western Europe has a large and well developed market for geospatial data and services and the Eastern Europe market is evolving rapidly. There are no surveys for the whole of Europe which deal specifically with the size of the geospatial market. However, drawing on such national surveys that do exist and using Gross Domestic Product (GDP)[219] and also figures for the size and growth of ICT industries within the Information Technology Outlook[220] published by the OECD, it is possible to come up with a very approximate estimate of the size of the market in Europe as a whole. This indicates the market could well be in excess of €15B (CAN $21.2B) per annum.

The national surveys that are available cover countries that represent about a third of the total GDP for all of Europe. Although small in number, the surveys do cover a large proportion of the market. Comparison of these surveys has to be made with some care because the scope, in terms of what is considered to be geospatial, varies from country to country. They include:

- **Netherlands –** The survey was undertaken in 2009 by a consortium of academic and business organizations. They estimated the economic value of the geo-information sector nationally at €1.4B (CAN $2.3B) in 2008[221]. This is based upon survey responses from about 100 geo-information companies and also takes into account estimates of the contribution of government employees working in the sector.

- **Germany –** This study was undertaken by the research organization MICUS for the Federal Government and covers what they describe as the 'geobusiness' sector[222]. It reports that all sectors of the geobusiness market have increased their sales. In the navigation sector especially, the volume of sales more than doubled between 2000 and 2007, from €350M (CAN $470M) to €728M (CAN $1.1B). They estimate that in 2000 the market volume amounted to €1B (CAN $1.3B), and by 2007 had increased by 51 percent to just over €1.5B (CAN $2.2B).

- **UK –** ConsultingWhere has undertaken a number of assessments of the size of the geospatial market. The latest full survey published in February 2012 puts the size at £1.23B (€ 1.37B or CAN $1.8B)) with an uncertainty of +/- 5 percent[223]. This work is based on a completely new analysis that extends the scope of the supply-side (turnover of companies operating in the sector) assessment to cover surveying and offshore companies. User organizations were assessed in terms of numbers of staff employed.

- **Switzerland –** This analysis is based on responses to a survey sent to companies dealing with geo-information and personal interviews with selected market leaders undertaken by Infras and published in 2008[224]. It focused on the private market for geo-information in Switzerland but includes an estimate of the production costs of public geo-information from a previous survey. It estimated the overall size at 720M SF (€529M or CAN $767M). Printed geo-information products were not included.

However, since some of these surveys were published, the knock-on effects from the global financial crisis have had a negative effect upon the geospatial industry across Europe. The Eurozone crisis, affecting particularly southern Europe, is beginning to abate but it has eroded business confidence and had a negative effect on spending.

All the larger economies in Europe, with the possible exception of Russia, have experienced cuts in public sector spending as a method of reducing their sovereign debt. In the UK for instance, local government has faced funding cuts of 20-30 percent and recruitment bans have stopped most projects requiring new resources. The structure of the French economy, with a reliance on Government spending, has recently suffered a downgrade by credit rating agency Standard and Poor's, as a result of doubts over their current strategy to produce improvements in medium-term growth[225]. The largest economy in Europe, Germany, has recovered more rapidly than the others. Overall there has been a significant effect on the geospatial industry because of the high proportion of customers, well over 50 percent in most countries, in the public sector.

For a more detailed consideration of Europe's geospatial direction, see Appendix C1.

Role played by Canadian companies and future opportunities

A number of Canadian companies (e.g., MDA, Canadian partners in PolarView) have benefitted from the opportunity to bid on earth observation related projects through the financial contributions of the Canadian Space Agency (CSA) to the European Space Agency (ESA). Such opportunities have diminished in recent years, as CSA's contributions to ESA have been significantly reduced. In addition, a few Canadian companies have been part of teams led by European partners that were successful in winning projects funded under the Framework Programme (FP), the EU's primary funding mechanism for supporting collaborative, transnational research and development. The most recent programme (FP7) ran from 2007 to 2013 with an EU budget of some €50.5B (CAN $68B).[226]

The markets of western and northern Europe are well served in respect to all supply side segments and also on the demand side. Southern and particularly eastern Europe may offer more opportunities for partnership arrangements with local organizations. The agricultural sector may be particularly attractive. To compete, Canadian companies will need to bring significant value-added into partnerships with EU firms, such as specialized expertise in particular market verticals or applications with a proven track record (i.e., significant market penetration in other jurisdictions).

3.3.4 United States

Introduction

The United States represents the best developed market in the world for geospatial information and services. Although innovation is found in many other parts of the world, the large size of the US market and the availability of funding for new ventures results in most new ideas being nurtured to maturity there. The largest worldwide conferences are held in the US; for example, the annual Esri User Conference[227] held in San Diego typically attracts around 15,000 delegates and is widely recognized as the biggest regular industry gathering. Furthermore, the largest GIS software suppliers (Esri, Pitney Bowes (MapInfo) and Intergraph) are all based in the United States and have their main development centres there too. The consumer mapping companies Google and Bing are both headquartered on the west coast, as are Bentley and Autodesk, who dominate the CAD world. This list could be extended with many other companies. In short, most of the geospatial and geomatics world still looks to the United States for leadership and this is expected to continue.

According to Boston Consulting Group (BCG), in a market report prepared for Google in 2012, the US geospatial industry generated approximately US $73B (CAN $75B) in revenues in 2011 and comprised approximately 500,000 jobs.[228] BCG defined the industry as "composed of geo-data providers, location-enabled device manufacturers, geo-app developers, and a growing network of geospatial experts and educators." The overall economic impact was also estimated; "geospatial services drive $1.6T (CAN $1.65T) in revenue and $1.4T (CAN $1.44T) of cost savings [for business], representing 15 to 20 times the size of the geospatial services industry itself." In addition, BCG found that US consumers are willing to pay up to $37B (CAN $38.1B) for access to geo-services.

Role played by Canadian companies and future opportunities

Canadian geomatics companies have a long history of competing in our closest export market. In particular, Canadian technology companies (e.g., PCI Geomatics, Novatel, Safe Software, Enghouse, Optech, Avenza Software, etc.) have depended significantly on the US market to build and expand their businesses, often including the establishment of US subsidiaries or sales offices. Major data and service providers such as MDA, Blackbridge, JD Barnes, Northwest Geomatics, Focus, C-CORE, etc. are also very active in the US market. In addition, some of the major international GI players with significant presence in Canada (e.g., Esri, Hexagon/Intergraph, AECOM, Fujitsu, Opus, etc.) use Canadian expertise in teams assembled for US projects. A number of companies have done business in the US as a result of work they have done in Canada for US companies that are active in this country (e.g., oil and gas and agriculture sectors).

The US geospatial information market is one of the largest and most competitive in the world, and represents significant ongoing business opportunities for Canadian GI suppliers. As the major GI business opportunities continue to move higher on the GI supply value chain, expertise in the embedding of GI into business systems in vertical market segments will be particularly important. Larger Canadian companies with this expertise and a track record of success can expect business growth potential. Smaller value-added GI services companies may need to plug into US value chains to gain a share of this market. The market for small niche companies will be more limited, but those with competitively priced specialized services will continue to secure contracts (e.g., turnkey GI-enabled property assessment solutions). Partnering with local suppliers is a critical means of gaining competitive advantage in all market segments.

3.3.5 Australasia

Introduction

In considering Australasia, this report includes the Polynesian islands of the Pacific Ocean in addition to New Zealand and Australia itself. The region has long been a leader in geomatics and geospatial information markets, with some of the earliest computerization developments originating in the region. It is not difficult to see why geography matters in Australasia – there are vast areas of outback in Australia with sparse population but huge mineral and other natural resource wealth. This is paralleled offshore by the expanse of the Pacific Ocean, considerable areas of which have not been charted since the days of Captain Cook. Today the region is one of the leaders in the development of applications and exploiting the explosion in data availability, particularly from earth observation satellites.

The economy of Australia is mixed with services representing 78 percent of GDP by origin. However, the health of the economy has become increasingly tied to mining, with coal and iron ore, principally exported to China from the Pilbara region of Western Australia, as an important ` contributor. The recent slowdown in exports to China linked to the slowdown in the Chinese economy has been a major cause of the decrease in the value of the AU dollar against other currencies. However, the mining industry remains at the forefront of innovation in the geospatial market, attracting many of the most able professionals with high salaries.

In the most recent study on the geospatial information sector in Australia, conducted by ACIL Tasman in 2007, the industry was estimated to generate revenues of approximately AUS $1.4B and produce a gross value-added of AUS $682M (CAN $617M). In 2006-07, the industry was estimated to contribute a GDP gain of between AUS $6.43B (CAN $5.8B) and AUS $12.6B (CAN $11.4B) on a cumulative basis.[229]

The economy of New Zealand also has a sizable sector complementing a highly efficient, export-oriented agricultural sector. Hydro-electricity and geothermal provide abundant sources of relatively cheap energy and this has allowed the development of energy-based industries such as aluminum refinement. This translates into a high demand for GIS in primary industries including agriculture, central government and business services sectors. In their 2009 study on the spatial information in the New Zealand economy, ACIL Tasman found that the use and re-use of spatial information added approximately NZ $1.2B (CAN $924M) in productivity-related benefits, equivalent to slightly more than 0.6 percent of GDP or GNP in 2008.[230]

Appendix C3 elaborates on the continent's market.

Role played by Canadian companies and future opportunities

Canadian companies have had a limited footprint in the Australasia region. While a few Canadian software companies have been successful in selling into the Australian market through affiliates or distributors (e.g., PCI Geomatics, CubeWerx, Safe Software, Latitude Geographics, CARIS), there is no evidence that GI products and services companies have been active in the region. Similar to Europe, the market is well served by indigenous suppliers and Canadian companies will need to bring significant value-added into partnerships with local firms, such as specialized expertise in particular market verticals or applications with a proven track record, to have any chance of success.

3.3.6 Middle East

Introduction

The market in the Middle East is in many countries disrupted by war or civil unrest. The economy in Egypt, formerly the engine of many major GIS projects in the region, is currently in turmoil. Many of the best Egyptian GI practitioners have moved to the Gulf States.

The Gulf States, particularly those with major oil revenues, are pressing ahead with the capture, management and dissemination of geospatial data. Most Gulf States are dominated by the public sector, with many of the largest commercial sector industries, such as energy and utilities, also being owned or effectively controlled by the ruling families. The public sector is very keen to promote Spatial Data Infrastructure (SDI) initiatives which are present, with varying degrees of enthusiasm and investment, in virtually all countries.

In the region, Turkey[231] is an exception in many respects. The national mapping organization is part of the military and this influences much of the priority and availability of base mapping. The geospatial market is quite well developed internally, but it is difficult for outside commercial entities to establish a foothold in the market – German companies being the exception.

There are a number of significant bilateral trade deals involving the overseas arms of Ordnance Survey (GB)[232] and the Dutch Kadastre[233] currently being negotiated in the region, providing support in areas such as SDI, land administration and geodata management. Long-term sustainability of these initiatives, which are largely being implemented by expatriate work forces, remains a major concern. For more information see Appendix C4.

Role played by Canadian companies and future opportunities

Canadian geomatics companies have demonstrated limited interest in the Middle East, but in the past several companies have secured data collection and processing contracts (e.g., Terra Surveys, MDA, Kenting), and at least one firm has secured SDI consulting work (Intelec Geomatics). The UAE has been one of the most robust markets and another Canadian company, Gartner Lee (subsequently acquired by AECOM), pursued GIS opportunities from a base in Abu Dhabi for several years starting in 2006. Companies interested in pursuing business in the region face stiff competition from well-established firms from the US and EU, and increasingly from India and China. Current political instabilities make the long-term investment that will be required to meet this competition less attractive than in other export markets.

3.3.7 Africa

Introduction

At the Global Spatial Data Infrastructure (GSDI) and Africa GIS 2013 combined conference in Addis Ababa[234], the quality and diversity of the papers from African projects was impressive. In this context the phrase 'Africa rising'[235] seems particularly apt. This is evidence of significant investment in geospatial technology not only in the continent's larger economies such as South Africa, Nigeria, and Kenya but also in smaller countries such as Rwanda. In Rwanda, the emphasis on Information Technology as a driver for the economy is illustrated by the recent announcement that the Government has purchased sufficient laptop computers to provide access to all school children[236].

There are also some other statistics that are pertinent; the size of the continent for instance. The land area relative to other parts of the world is often misunderstood – in part because of the map projections our industry uses. This is illustrated very graphically in Figure 9.

Figure 9: The True Size of Africa

Source: http://www.economist.com/blogs/dailychart/2010/11/cartography

Other headline figures to consider in relation to the "geo" potential of Africa include:

- "Over the next decade Africa's GDP is expected to rise by an average of 6% a year, not least thanks to foreign direct investment."[237]
- "By far, the largest regional percentage increase in population by 2050 will be in Africa, whose population can be expected to at least double from 1.1 billion to about 2.3 billion."[238]
- "Review of statistics in Ghana led to GDP being re-valued by 60% and it being re-classified as a middle income country."[239]

Mining, oil and gas exploration, agriculture, land management, environment, water supply and management, food security, poverty and transportation are all sectors that require strong support to improve social and economic development. Geospatial information is a key asset to support such initiatives.

It is clearly impossible to generalize for the entire continent, so Appendix C.5 highlights significant developments that identify future directions. In summary, although huge problems, often institutional or political continue to hamper growth, the signs of an increasing pace of development of geospatial information in Africa are encouraging.

Role played by Canadian companies and future opportunities

There has been considerable past experience with mapping activities by Canadian companies in Africa, primarily funded by the Canadian International Development Agency (CIDA) and The World Bank. In addition, Canadian firms have been active in more recent years with GIS activities in countries like Morocco, Algeria, Nigeria, South Africa, and Kenya (e.g., Intelec Geomatics, Worley Parsons Geomatics, Challenger Geomatics, Focus) and CIDA-funded spatial data infrastructure projects in Tunisia (DMR) and Senegal (Fujitsu Canada). Canadian GI software companies have also had success selling into Africa (e.g., PCI Geomatics, CubeWerx, Safe Software, Latitude Geographics, Avenza Systems, and CARIS).

The Canadian private sector must develop strong partnerships with non-governmental organizations (NGOs) to do business in Africa. Two major requirements include consulting services for SDI implementation and mapping and surveying services. Education in geomatics and GIS also stands out as most countries lack skilled professionals and technicians.

3.3.8 China

Introduction

There are 23,000 geospatial enterprises in China with over 400,000 employees; the industry had an output of 200B Yuan (US$32B or CAN$ 31.6B) in 2012 and the industry is growing at an annual rate of 25 percent[240]. This alone justifies its selection from the Asian continent for more detailed treatment in Appendix C6, which is summarized here.

The People's Republic of China is ruled by the Communist Party of China. Since the country's opening up in 1978, China has experienced a sustained period of rapid economic growth. This development has been branded state-led capitalism, or capitalism with Chinese characteristics, and typically involves significant input from central government in terms of strategy and investment.

The geospatial industry's development has been typical. Initially the geospatial expertise was developed in academic institutions, which spun out as private enterprises (with significant investment from the state). These enterprises established themselves through state-funded projects, such as the digital city drive, or the large constellation of Chinese satellites. Some of the Chinese companies that routinely apply GIS technologies have grown into significant multinational corporations and are exporting their products and services internationally. Once again the Chinese government is acting as facilitator, often by providing loans and aid to enable these projects, particularly in the developing world. The recently established UN GGIM China Trust fund is significant in this context.[241] Created to strengthen the geospatial information capacity in China and other developing countries, it covers institutional and policy frameworks; data acquisition, management and delivery; enabling technologies and information services; and the requirements for data standards, sharing, accessibility, and dissemination.

In addition to facilitating the Chinese private sector the Chinese state maintains strict control over all surveying activities within the country, where it is also illegal to carry out mapping activities without a licence.

Role played by Canadian companies and future opportunities

China represents an attractive market for Canadian geomatics companies because of its size and rapid modernization. Canadian companies have been actively pursuing business in the country for many years and have achieved success on a number of fronts (e.g., software sales – PCI Geomatics, Avenza Systems, Safe Software, Enghouse; data sales – MDA, BlackBridge Geomatics; GIS services – Esri Canada). The market has become extremely competitive as the domestic GI supply industry has developed and matured, with very competitive products and services.

Success in the market in the future will depend upon competitiveness in very specific niches where local firms have not yet developed expertise. Partnering with Chinese firms may be a means of entering the market, but the risk of intellectual property theft is not to be taken lightly.

3.3.9 India

Introduction

According to a 2011 study by Boston Consulting Group the Indian geospatial services industry is estimated at US$3B and provides jobs to 135,000 people[242]. Although this figure has not been independently validated and almost certainly includes overseas activities, it indicates the size that the industry has reached on the sub-continent.

The sector is dominated by private sector outsourcing firms, small and large, providing services to North American and European clients and increasingly targeting larger opportunities in other emerging countries. In the domestic Indian market GIS has been successfully pioneered by private sector utilities and telecoms firms. Public sector projects have to date been less successful. A number of large-scale projects for land registration and utilities including significant geo-spatial components have been launched, but have run into difficulties. The sheer scale of these projects, combined with India's significant cultural and geographic diversity, in a public sector environment known for bureaucracy and lack of transparency, resulted in understandable delays. However progress is being made in the Indian public sector with plans for an ambitious National GIS announced in the 12th five year plan in 2012. The national GIS concept is currently being pioneered in the state of Karnataka (home to 60 million people and Bangalore, the world IT outsourcing capital) where a nascent geo-portal is already in operation[243].

India has a large technologically literate middle class who are open to new innovations. It has significant geospatial data assets and a large GI industry operating mainly within the IT outsourcing sector. The potential GI market has been further expanded in recent years by almost blanket telecoms coverage. Despite the proven capacity of the domestic Indian GI industry many Indian GI needs remain unmet. India has numerous challenges, but it seems that the prime reason for the domestic GI market remaining underexploited is hindrances imposed by a multitude of large state bureaucracies where restrictive data policies have resulted in unexploited data silos proliferating. Where the private sector has been allowed freer rein advanced efficient GI systems have been implemented, for example related to India's low cost mobile phone infrastructure.

For more detailed discussion, see Appendix C7.

Role played by Canadian companies and future opportunities

Canadian software companies have been successful in selling into the Indian market through affiliates or distributors (e.g., PCI Geomatics, CubeWerx, Safe Software, Latitude Geographics, CARIS), but there is little evidence of GI products and services companies being active in the country. A number of companies were involved in several trade development and Canada-India partnering missions organized by Canadian GeoProject Centre in cooperation with Natural Resources Canada during the period 2003-2006, but few significant opportunities were developed, other than access by the Canadian firms to lower cost offshore production capabilities.

Recently there are signs that the Indian data market may be opening up. Currently these initiatives are mainly confined to central government, for example the National Data Sharing and Accessibility Policy and the Open Data Initiative[244]. Whether these initiatives will produce results (e.g., previous announcements by the Survey of India (SoI) of a new policy to open up access to their data have not been fully implemented) and trickle down to the states and parastatal organizations remains to be seen. If they do it could result in a blossoming of the GI market. However Canadian companies should exercise caution; as the case of Google Streetview and Wonobo demonstrates, Indian companies are often best placed to negotiate the often challenging Indian business environment.

3.3.10 Rest of Asia

Introduction

This section deals predominantly with the countries of eastern Asia not covered elsewhere in this review. Due to the huge range of levels of development across the region, examples have deliberately been chosen in Appendix C that illustrate best practice and advanced thinking.

A number of East Asian countries have active remote sensing/earth observation satellites, including Japan, Malaysia, Pakistan, Singapore, South Korea, Taiwan, Thailand and Vietnam. Japan also has an active satellite-based GPS augmentation system, the Quasi-Zenith Satellite System, which works in conjunction with a comprehensive GNSS ground-based Earth Observation Network. Significant progress has also been made in opening up Japan's geospatial data since the enactment of new legislation in 2007. South Korea is embarking on an ambitious cadastral reform project, which will run until 2030 and has a budget of US$1.7B (CAN $1.8B). In November 2013 the Singapore Land Authority launched the geo innovation fund to spur innovation in the use of GI in Singapore.

Good examples of advanced GI applications can be found in the region. Among them are: the Singapore Geospatial Collaborative Environment (SG-Space), a cross-government initiative with the aim of implementing Singapore's NSDI and geoportal projects in the Philippines, Indonesia and Malaysia; innovative integration of the GIS database with the customer relationship management database by Manila Water in the Philippines; the Sarawak Land and Survey Information System (LASIS), which manages digital land and cadastral data for the state of Sarawak; a series of GIS systems employed by the East Japan Railway Company to design, build, manage, analyze and inform the public on transport issues.

There are a number of major companies in the region that are active internationally. Pasco Corporation is Japan's largest provider of digital maps, has a fleet of 42 aerial survey aircraft, and also provides cloud hosting, consulting, implementation, and end-to-end solutions. The Hitachi Zosen Corporation manufactures and deploys a range of equipment based on high precision GPS technology. Samboo Engineering is a leading Korean geospatial solution company that has carried out projects both domestically and internationally. InSpace is a Korean certified Venture Company that develops hardware and software solutions for the collection and processing of satellite imagery and provides consultancy services in the application of satellite imagery.

Role played by Canadian companies and future opportunities

Southeast Asia has been a target market for the Canadian geomatics industry for several decades, with success being achieved in the sale of GI software and some services (e.g., aerial photography, GIS and remote sensing consulting services). Countries in the region that have received the most attention from Canadian industry include Thailand, Malaysia, Viet Nam, and Indonesia. Several trade missions to the region were organized by Natural Resources Canada and Canadian GeoProject Centre / Geomatics Industry Association of Canada between the mid 1990s and 2006, which resulted in some small consulting projects and software sales.

Future prospects in the region will depend upon specific niche expertise, as competition from local firms and firms from Japan, China and Australia has intensified.

3.3.11 Latin America

Introduction

Market research firm TechNavio's analysts forecast in 2012 that the Large Geographical Information System market in South America will grow at 9.2 percent over the period 2011-2015. One of the key factors contributing to this market growth is the increasing adoption of GIS by governments. South American countries put their priority on framework geospatial data production, including geodesy. However, production of cadastral and risk assessment data are receiving more and more attention. In the last 10 years though, many South American countries have improved their geomatics capabilities and increased human resource capacity.

In Brazil, the region's largest economy, according to a survey by Magalhaes & Granemman, there are more than 200 companies working with GIS. Market research from Intare Consulting in Information Management pegged the market potential for geotechnology in Brazil at US$350M in 2008, taking into account all the data components, software and services, with a growth of 9 percent between 2006 and 2007 and estimated 20 percent for 2008.[245]

The ITC sector presents great opportunities in Brazil, Venezuela, Columbia and Argentina. However, ITC opportunities likely concern large companies. Peru, Chile and Brazil are building long term plans to improve their capacity in geomatics, with projects focusing on disaster management, cadastre, land use planning and geospatial data infrastructures. In other countries in the region populist political concerns with health, environmental protection, agricultural reform and renewable energy are driving the investment agenda, as Appendix C9 elaborates.

Role played by Canadian companies and future opportunities

Similar to the Indian and Southeast Asian markets, there has been considerable interest in geomatics business opportunities in Latin America. A number of trade missions to this region have also been organized by Natural Resources Canada (NRCan) and Canadian GeoProject Centre / Geomatics Industry Association of Canada between the mid 1990s and 2003. In addition, NRCan funded the placement of a geomatics specialist at the Canadian Embassy in Chile to assist with business development, which produced some concrete results. Business opportunities have been limited for Canadian companies due to strong local buying practices, limited funding for GI projects and, in some cases, language barriers. Canadian software suppliers have achieved the most success in this region.

It is worth mentioning that local taxes might greatly affect profitability, with rates ranging as high as 30 percent. In addition, Canada is not a member of MERCOSUR, introducing another foreign rate between 0 and 20 percent. Canadian firms then should look for partnerships to ease market development, resolve legal barriers and adapt to financial constraints.

3.3.12 Barriers to Accessing International Markets

As demonstrated in the previous sections of this chapter, the use of geospatial information is expanding in every geographic region of the world. While a primary focus remains on basic data collection and provision in some geographies (particularly Africa and Latin America), the market demand has shifted in the US, Europe and the more advanced economies in Asia to higher value-added geospatial information products and services. The Canadian Geomatics Industry faces a number of challenges in responding to this demand shift. The barriers to accessing international markets that have been identified are discussed in two categories: (i) geospatial data and products, and (ii) value-added products, services and technologies.

Geospatial data and products markets

This category includes the first two segments of the geospatial information supply value chain – Geospatial Data Capture and Processing, and Geospatial Data Analysis and Presentation. Key barriers to accessing international business in this category include:

- **New competitors –** Over the past 50 years Canada developed a well-deserved reputation for excellence in producing high quality geospatial data using state-of-the-art equipment and processes with highly skilled people. This reputation was translated into success in capturing surveying, mapping and remote sensing business around the world. A combination of lower technology barriers to entry into this market, and improved education and training in emerging economies has resulted in the emergence of strong new competitors, significantly weakening Canada's differentiation in this market segment.

- **Lack of competitiveness for international financial institution (IFI) business –** The IFIs (e.g., The World Bank, Inter-American Development Bank, African Development Bank and Asian Development Bank) are the primary source of project financing in Southeast Asia, Africa and Latin America. Although outside the scope of this project, a detailed assessment of GI components in projects in the IFI pipelines in 2001 found some $73M in potential business from these sources at that time.[246] The Canadian geomatics industry has not been successful in developing a winning track record for these kinds of projects. One of the challenges is that the competitive playing field is not level; a good proportion of these projects are won by quasi-government organizations which can bid at lower prices (e.g., Swedesurvey[247], Dutch Kadaster[248], and Ordnance Survey International[249]).

- **Falling prices –** The provision of geospatial data (e.g., airborne and satellite imagery) and data products and services (e.g., maps and mapping data) has become a commodity business as competition has intensified, particularly from countries in Asia and Eastern Europe that have much lower labour rates. Canadian companies in the data business must increase their scale of operations by selling outside Canada and those in the geospatial data products business must reduce their costs through off-shoring of production activities in order to survive, increasing both business complexity and risk.

- **Weak business development strategies** – The primary markets in this category are in the developing countries of Asia, Africa and Latin America, where financing of data provision and data products and services comes predominantly from development aid. Canada's competitiveness has suffered in part because there is limited focus in Canada's foreign aid program on geomatics projects. In addition, key competing nations (particularly from the European Union) have developed more effective integrated public-private sector business development strategies. Government geospatial agencies often provide advice and expertise to developing country geomatics agencies to help initiate projects on the condition that their companies will be hired to complete the projects.

- **Supports of indigenous industry** – Local buying preferences are not new and exist in most countries, including Canada. This barrier has been reported particularly in accessing business in the US at the local level (e.g., aerial mapping restricted in some states to licensed land surveyors).

Value-added products and services and technologies markets

This category includes the other three segments of the geospatial information supply value chain – Integrated Information Products and Services, Location-based Solutions, and Geospatial Information Technologies. Key barriers to accessing international business in this category include:

- **Industry fragmentation** – The market for higher value-added geospatial information products and services is increasingly being captured by large vertically integrated firms. There is concern in the Canadian geomatics sector that the expertise is too fragmented among predominantly small firms with low profit margins to be competitive. There are a number of niche technology suppliers based in Canada, but this market is dominated by US and EU technology companies.

- **New competitors** – Canadian geomatics firms are also witnessing increased competition in these market segments from firms based in Asia (e.g., China, India, Japan, etc.) that have moved up the value chain beyond data products. In addition, competition is coming from outside the core geomatics sector, especially from the IT and engineering consulting sector where there is more strength in integrating GI with other types of business and technical information.

- **Loss of market differentiation** – Canada's historical competitive advantage based on differentiation through early adoption of advanced technologies and processes has slipped. Rapid development of similar capabilities by lower cost competitors has been a key factor. .

In addition, the innovation pull of government as a demanding and informed purchaser of GI solutions has diminished with changes in government procurement practices (e.g., more in-house development and less contracting out of solutions).

4. The Labour Market

This chapter discusses various characteristics of the geomatics labour market in Canada, including current demand and supply and gaps between the two, labour mobility, and labour market challenges and opportunities.

4.1 Labour Market Demand

4.1.1 Current Demand Characteristics

Consistent with the trends and drivers in the GI market identified in Section 3.1, shifts are occurring in the sector's labour market demands. As demand has shifted to higher value GI products and services, and integration of GI with other types of information has become a higher priority, there is a general trend to value domain specific skillsets over geomatics skillsets. While there is still a relatively healthy demand for GIS program graduates, employers prefer people with a solid foundation in their business area (i.e., engineering, forestry, environmental science, finance, etc.) over those with a geomatics specialization. The combination of the two (i.e., disciplinary undergraduate or graduate degree plus GIS diploma or certificate) remains in strong demand.

The increasing ease of use of GI technologies has made it easier for employers to train experts in their business domain to use GI technologies than geomatics specialists in the business area fundamentals. This is perhaps understandable as GI becomes increasingly integrated and embedded and becomes a mechanism to assess, visualize and disseminate all kinds of other business information. A typical goal is to ensure that operations people have enough GI skills to do basic analyses and produce map outputs, and reduce dependency on specialized GI resources. There is evidence that universities are increasingly making GI training accessible to students in other disciplines, either through opening courses offered by geography and geomatics engineering and science departments to those students, or offering GI courses within those disciplinary faculties. However, there is still room for improvement (e.g., educating disciplinary faculties on the need for GI skills, making GI courses mandatory rather than optional, etc.).

To effectively deliver higher value-added GI products and services, employers on the supplier side are staffing their organizations with the following types of resources: GIS manager, GIS Project Manager, GIS Analyst, Cartographer, GIS Programmer Analyst, Spatial Database Analyst, GIS software and Application Architects. Most organizations have a minimum required education level of a university degree (supported by a GIS certificate) or college diploma in GIS engineering/technologist area, depending on the nature of the job and the complexity of the tasks.

Some organizations prefer to hire staff with some work experience while others like to recruit staff directly from educational institutions and support them with internal staff training and development programs.

The composition of staff in the sector has changed significantly over the last ten years, from being geomatics centric to more IT centric (i.e., applications development rather than data collection). The general trend is to favour dual track education and experience – in both GI and IT. Many application development people have no training in geomatics and future requirements will be more for IT graduates than GI graduates. However, some issues with IT people developing GI-related apps without sufficient GI knowledge have been reported. Most organizations prefer that those involved in applications development have both GI context modelling and business modelling (application domain) skills.

Workforce distribution

The workforce distribution of geomatics establishments was analyzed using the Canadian Business Patterns database, the best publicly available source of this information. Since the database is broken down by NAICS code, the analysis was restricted to those firms that fall into one of two industries: i) Geophysical surveying and mapping services (NAICS 541360), and ii) Surveying and mapping (except geophysical) services (NAICS 541370). Other elements of the geomatics sector (e.g., software and hardware development, IT-centric business applications development) cannot be extracted from this database.

The database counts two types of locations: i) with employees, and ii) indeterminate employees[6]. Those locations with employees are further divided by size category: 1 to 4 employees, 5 to 9 employees, 10 to 19 employees, 20 to 49 employees, 50 to 99 employees, 100 to 199 employees, 200 to 499 employees, and 500 and plus employees.

If assumptions are made about average number of employees within each size category, a rough estimate can be made of the employment within survey and mapping establishments[7]. In 2013 this totaled 22,504 employees[8] in Canada.

Examining previous versions of the database can provide some indication of how the survey and mapping industry has changed over time.[9] In 2005, the establishments had about 24,420

[6] The locations in the "indeterminate" category do not maintain an employee payroll, but may have a workforce which consists of contracted workers, family members, or business owners. However, the Business Register does not have this information available, and has therefore assigned the locations to an "indeterminate" category. This category also includes employers who did not have employees in the last 12 months.

[7] Note, Statistics Canada recommends against doing this: “Please note that the employment size ranges are mostly based on data derived from payroll remittances. As such, it should be viewed solely as a business stratification variable. Its primary purpose is to improve the efficiency of samples selected to conduct statistical surveys. It should not be used in any manner to compile industry employment estimates.” (see: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=5510005&pattern=canadian+business+patterns&tabMode=dataTable&srchLan=-1&p1=1&p2=-1)

[8] Statistics Canada notes that: “Employment, grouped in employment size ranges, is more often than not an estimate of the annual maximum number of employees and does not represent a full time equivalent number of employees. For example, a measure of ‘10 employees’ could represent ‘10 full-time employees’, ‘10 part-time employees’ or any combination.” (ibid)

employees. The 2013 numbers represent a decrease of 8 percent from the 2005 numbers. Although the nature of the data does not allow for a rigorous analysis of the reasons for this decline, it is likely that increased automation (particularly in field data collection and in data processing) has been a significant factor.

Figure 10 shows the distribution of surveying and mapping employees by size of establishment. Most employment is in firms with 20 to 49 employees, followed by those with 1 to 4 employees. The greatest drop in employment between 2005 and 2013 was in firms of from 100 to 199 employees.

Figure 10: Workforce by Establishment Size

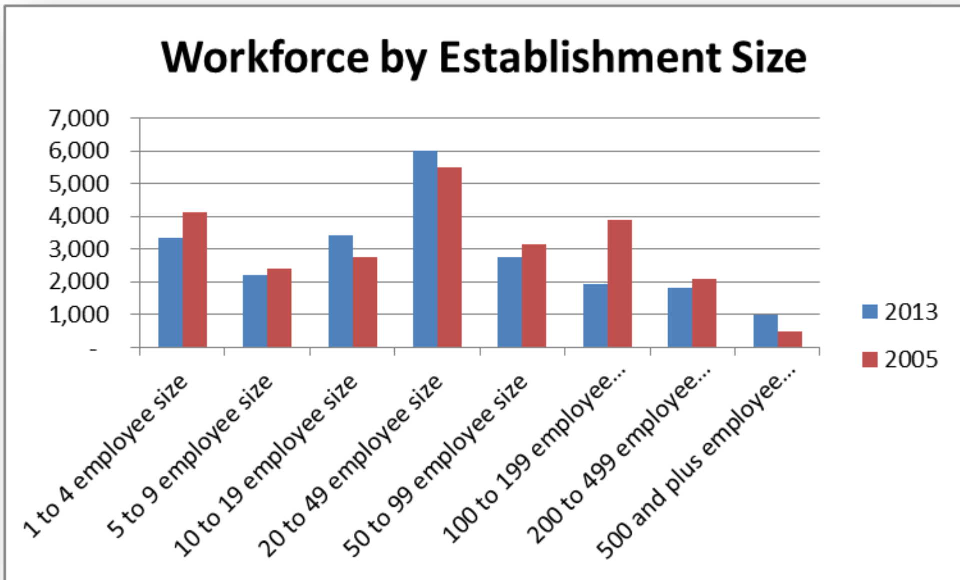
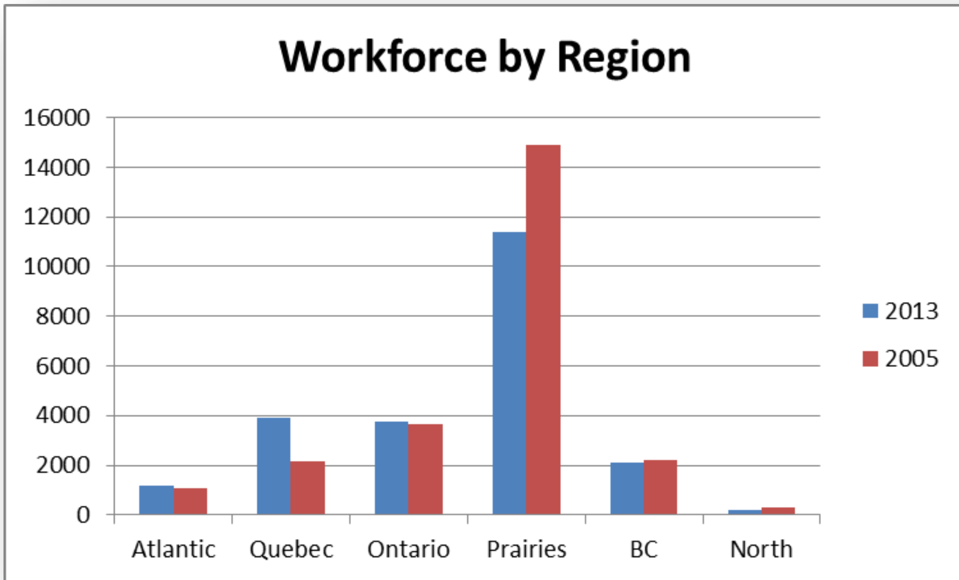


Figure 11 shows the workforce by region. As can be seen, surveying and mapping is focused in the Prairies, and in particular servicing the oil and gas industry in Alberta. It is essentially this region alone that accounts for the decrease in employment between 2005 and 2013.

[9] Note, Statistics Canada again cautions against doing this: “Changes in business industrial classification strategies used by Statistics Canada's Business Register over the past year have created increases in the number of active businesses shown by the Canadian Business Patterns. As a result, these data do not only represent changes in the business population over time. Statistics Canada advises users to not use these data as a time series.” (ibid)

Figure 11: Workforce by Region



Labour sources

Not surprisingly, most employers have a preference for work experience when filling vacant positions, and the more responsible the position the higher this factor in hiring decisions. Consequently the preferred labour source is typically another (often competing) organization in the geomatics sector. Junior positions are often filled with new graduates, and depending upon the nature of the job, employers may prefer either university or college graduates.

Labour sources also vary with the business focus of the hiring organization. For positions with a primary focus in information capture and processing, or analysis and presentation, the preferred sources are college programs in geomatics and surveying technology, and university geomatics science and engineering programs. For professional level positions (e.g., licensed surveyors), most recruits come from university programs, although it is still possible to obtain professional recognition with the combination of a technology diploma and rigorously supervised work experience plus examinations, as in the case of articling to become a member of a Land Surveying Association. Graduates with the combination of a university degree plus a post-graduate GIS diploma appear to be better positioned to compete for value-added GI products and services jobs than those with only one such educational background.

Particularly popular are GI cooperative education programs, through which employers have the low-risk opportunity to evaluate a student’s suitability for future employment. A growing recruitment trend is targeting top students as early in their educational program as possible, to assess their capabilities through work terms, and committing to hire the most promising candidates when they graduate. This trend was emerging in 2007, when the last geomatics human resources assessment was conducted.[250]

Attraction and retention

Overall, staff attraction and retention are not significant problems, although turnover is more prevalent in thriving labour markets like Saskatchewan, Alberta and British Columbia where the oil and gas and forestry sectors offer competitive wages, lucrative benefits and a wealth of job opportunities. Recent GIS technologist recruitment experience suggests that there is an abundance of qualified candidates, with healthy responses to job postings. This is most likely due to the readily available GIS training currently offered through faculties across Canada (colleges, universities and on-line certificates, many supported by co-op opportunities) with these programs attracting a significant number of new students. There is an under-supply of surveying technologists in Ontario and Western Canada where the hiring of foreign-trained geomatics specialists appears to be on the rise. The aging demographic profile in the sector, and particularly in land surveying, is a growing concern; succession planning efforts are mixed, particularly for smaller firms, and many expect that this will result in more consolidation within the industry.

Some employers have experienced minor retention challenges with younger employees, who have high expectations of the work environment (limited patience with outdated technology, demand for readily accessible tools and data) and are generally more mobile with less loyalty to employers. Government departments and agencies are sometimes having difficulty attracting new staff as their compensation may not be competitive with industry and they can often only offer term contracts that are less attractive than full time employment. Personnel are moving from industry to government organizations, which respondents attribute to the offering of more stability and better benefits including a secure pension.

Location of the organization (the more remote the organization, the more difficult it is to recruit) and ability of the human resources department to effectively profile and market the job opportunity also impact employers' ability to attract new talent. However, organizations that provide competitive compensation, a variety of interesting work, and opportunities for training and advancement believe that they will continue to be successful in attracting and retaining the best geomatics people.

Demographics

While the study methodology precluded the capture of comprehensive demographic information, the following is anecdotal evidence of demographic trends in the geomatics sector that was revealed by consulted stakeholders:

- There is a strong male-female imbalance in the sector and firms have particular difficulty hiring women for GI applications development positions because there are fewer female IT grads and most of them are quickly snapped up by large IT firms with hiring quotas.

GoGeomatics recently launched a 'Women in GIS/Geomatics' section on their website[251] to profile women that have chosen to make geomatics their profession and encourage others to investigate it as a career possibility. Another interesting project to highlight the role of women in the sector is the 'Making History...GIS and Women' map initiated by Dr. Linda Loubert of Morgan State University, to which dozens of Canadian women in the sector have contributed.[252]

- A number of educators reported change in the gender balance in their classes, with a greater number of females in GI programs. A theory for this change that was advanced by one respondent is that

> *"girls are more likely than boys to think about the impact of what they are learning, and how it helps people, and with geomatics it can be very tangible (e.g., help in locating oil spills, search and rescue, etc.)".*[253]

- The overall demographics of staff appear to be stable, but there are a couple of areas at risk due to impending retirements of large cohorts (e.g., private sector land surveying and public sector GI provider groups, where much of the workforce is over 50 years old).
- Due to growth in some industry sectors (e.g., oil & gas, resource planning, location-based services) over the past few years, there has been aggressive hiring and the overall composition of the workforce in these sectors is younger.

Skillsets

As noted above, an interesting aspect of the field today is that more geomatics professionals are working for companies and agencies whose primary business is not geomatics. They work for environmental consulting firms, forestry companies, engineering firms, retailers, banks, etc. This leads to more fragmentation among those in the field and no particular standardized skills set beyond basic understanding of spatial data, mapping and some programming skills.

Geomatics is increasingly interdisciplinary in nature – with the blending of a range of skillsets with the requirement to think critically and creatively about how to generalize and visualize data. A key challenge that has been identified is finding good software architects that have experience developing spatial information systems and business analysts that fully understand the business processes in the defined markets (e.g., utilities, health, public safety) thus allowing them to effectively exploit the spatial data/maps to support improved decision-making and planning.

The most prevalent IT skills deficiencies are lack of 'deep' GI programming skills (i.e., C-plus, Python scripting, etc.) and an understanding of open source coding, which is becoming more prevalent. There is also need for advanced skills in photogrammetry and geodesy.[254] To complement this, required core skills in business fundamentals (i.e., ability to work effectively in teams, strong written and oral communications, project management and negotiation skills) are often lacking.

The requirement is growing for anyone working in the science, technical or data analysis areas to have a fundamental knowledge of spatial thinking. Using GI needs to be a baseline skill and core capacity for engineers, medical professional, utilities operators, etc. and is seen by many as a key analytical tool that cuts across many professions and business sectors. This is comparable to the need for a fundamental understanding of statistical analysis or database management. However, full GIS analytical capabilities are not necessary for the vast majority of users, because the new web-based GI tools that are being launched to support mapping services and location management projects are very intuitive and will provide increased functionality without the need for in-depth GIS knowledge and experience. These tools also provide the option to access more sophisticated analytical capabilities if desired.

This premise was echoed at a recent conference promoting spatial thinking across the college curriculum[255], where more than 40 participants explored the rationale for expanding student exposure to concepts, tools, and applications of spatial reasoning across a range of science, engineering, and humanities disciplines. It was acknowledged that spatial thinking is not fostered in the educational system and that current practice depends more on selection of the most able students for spatially demanding disciplines than on fostering the spatial intelligence of all students. Similar themes were also present in a recent US Study that reviewed Geography Education for the 21st Century.[256] This study notes that there is substantial demand in both the public and private sectors for people who have the skills to interpret and analyze geographic information. By not preparing young people for careers that depend on geospatial reasoning, the US is expected to be vulnerable as other countries (in particular Australia and England) are moving forward in this area.

Finally, GI provider groups within user organizations in government and industry are having difficulty meeting the demand for training in the use of GI and of GIS and GPS technologies in the web and mobile environments. As the use of GI continues to expand and permeate more organizational units, the pressure on them to develop easy to use apps and provide training in their use is mounting. There appear to be limited options available from the postsecondary institutions to address this training demand.

4.1.2 Future Demand Trends

Size and nature of future demand

Overall, future growth in the GI workforce is predicted in user organizations, and much of it will be in positions whose primary focus is not GI (e.g., business analysts, engineers, health specialists, etc. who use GI as part of their job). As more operations and decision-making processes become geo-enabled, the demand for basic GI skills will continue to proliferate into all sectors of the economy. Most organizations appear to be grasping the value and adopting use quickly, while others, often those dominated by older employees, are resisting the change. Generally, younger staff are more receptive, most likely because they are more comfortable with technology use.

As workers in fields such as engineering, environment, utilities, and forestry are increasingly equipped with mobile devices that contain geospatial information and can capture locations of facilities, resources, etc., they need training, so the demand for GI specialists to both develop easy-to-use applications, and train specialists in other domains in their use, will grow. This applies to office-focused GI applications as well.

On the supplier side, the general expectation in industry is for continued growth in demand for skilled human resources; in government, limited growth is expected. In the surveying sector in particular, many of those consulted expect continuing strong demand for technical level people, and that the aging demographics at the professional level will result in shortages of licensed land surveyors and create career advancement opportunities. Given the apparent current over-supply of GIS graduates, there is some concern that this may lead to decreased enrollment in these educational and training programs, resulting in shortages in the near future. As the supply of GI products and services continues to diversify (i.e., increasing number of IT, engineering, Internet businesses with GI offerings), the demand for specialists in those domains to have GI skillsets is expected to grow more strongly than the demand for GI specialists.

New / improved skillsets

In the future, skills such as crowd sourcing, human geography, visual analytics, and hosting web applications to support both internal/external users as well as the mobile environment, will be requirements for the workforce. Also, there is concern that the demand for specialized skills in geoanalytics and geostatistics will outstrip supply with increasing emphasis on the exploitation of Big Data by:

- the Location Intelligence community (focusing on combining analytics capabilities with the transactional approach of GIS to provide new insights in spatially-referenced business data);
- the Geospatial Business Intelligence community (focusing on adapting BI analytical data structures and operators to provide decision-makers with interactive multi-scale, spatio-temporal data exploration); and
- the Geovisualization community (focusing on users' real-time interactions with visualization tools for large volumes of static and dynamic geospatial data).[257]

4.2 Labour Market Supply

4.2.1 Current Supply Characteristics

There appears to be general satisfaction with the current supply of people into the geomatics workforce, with the exception of survey technologists. While requirements for skills improvement in specific areas (e.g., project management, programming and applications development, proposal and business case writing, familiarity with open source software) were identified, there are no significant skills gaps and people are happy with the recent graduates they have hired.

There is an apparent under-supply of survey technicians / technologists and an over-supply of GIS specialists, particularly in Western Canada. Companies in that region have lots of applications for GIS positions and lots of vacancies for survey positions, and acknowledge that the strong local economy is a primary contributor to the difficulty in finding survey technologists. The strong demand in Western Canada has resulted to difficulties in filling survey technologist openings in Central and Eastern Canada. This situation may also be the result of circumstances in the colleges, where there has been growth in GIS training overall, while a number of survey technology programs are reporting declining enrolment and others have been closed.

Education and training program inventory

Profiles of post-secondary geomatics programs at 94 Canadian universities and colleges have been compiled, including the faculty name, degree/diploma name, admission requirements, program description, and a list of courses offered.

Graduates profile

In the majority of cases, students graduating from a geomatics program, at both the university and college level, receive job offers (often multiple offers) upon graduation, with some students seeking employment internationally. An exception is graduates of GIS training programs, who are experiencing difficulties in finding employment. Employers actively recruit on campus from a variety of sectors including municipal/provincial governments, tourism, forestry, agriculture and IT. The average starting salary for college graduates is roughly $30,000 per year. Graduates of specialized GIS programs, such as cartography, typically have higher starting salaries of roughly $40,000.[258]

A few educators reported that their graduates sometimes have unrealistic expectations of the workplace. Employers typically offer new grads entry level 'technician' positions, often with a fairly narrow focus and university students sometimes feel that such positions are 'beneath' them and do not take advantage of their qualifications. Overcoming this challenge will require employers to do a better job of describing career progression opportunities in their organizations, so that graduates understand that entry level work is only a stepping stone to more variety and increased responsibilities.

Fulfilment of demand

The extent to which demand is being satisfied by the GI education and training programs is discussed in Sections 4.1.1 and 4.2.1.

4.2.2 Future Supply Trends

In the GI academic community at the college level, the challenge most often voiced was attracting the top students. Since the sector does not have a high profile, often students do not have much knowledge about its existence and the career opportunities unless there is a progressive geography teacher in the high school that introduces them to GIS and mapping technologies. Enrollment in geomatics and surveying technology programs is stable for some colleges, others are experiencing a surge in enrollment with waiting lists in place (e.g., Algonquin, BCIT), while still others are seeing declining enrollment and programs have been cancelled or significantly modified in response to reduced market demands (e.g., Assiniboine, Fleming); there does not appear to be a uniform trend. Enrollment levels are primarily dependent on:

- The established reputation of the program (i.e., those colleges that are known for the geomatics programs are stable or growing);
- The institution's priorities (some colleges have put a strategic focus on increasing the depth and breadth of their geomatics offerings as they see future growth opportunities in the field, such as SAIT); and
- The job market they serve (those in the west and those focusing on the marine environment see high levels of employment success for their new graduates and thus enrollment is positive).

Of relevance on the subject of improving student attraction into geomatics careers is a recent report commissioned by the New Zealand Geospatial Office, *The Geospatial Skills Shortage in New Zealand*.[259] The report included the following recommendations to deal with this issue in that country: (i) develop clear graduate pathways for new graduates wishing to gain initial industry experience; (ii) support current staff in attainment of skills, especially recognized academic qualifications; (iii) raise awareness of geospatial careers with secondary school students; and (iv) raise awareness amongst managers and other key stakeholder of possible benefits of applying a geospatial approach. In a similar vein, a 2014 paper from Australia reviews the impacts of shortages in graduates entering the profession and approaches to improve the marketing of the surveying and geospatial professions.[260] Although Canada does not have a current skills shortage in the geospatial area, with the exception of surveying technologists, these recommendations are applicable to future supply as well as capacity building through training, education and increased awareness.

Response to demand changes

There are a number of market trends that are impacting labour force supply (e.g., shift in demand to more generalists with GI skills, increasing demand for web and mobile apps, over-supply of GIS specialists, technology turnover rates, etc.). These trends are impacting university and college GI education and training programs in a number of ways and the institutions are responding accordingly. There is more partnering between GI and non-GI faculties and departments (although there are still concerns that other professions do not have enough GI skills), more emphasis is being placed on programming and applications development skills (universities are offering combined computer science and geomatics programs), and a number of geomatics and GIS technology programs have been redefined as condensed term certificates (offered on-line or in the evening) for those already in the workforce and / or already holding an existing degree. ‘Change management’ is a common theme in the workplace as both GI supplier and user organizations struggle to cope with changing user requirements, rapidly evolving technologies, and in some cases significant staff turnover (e.g., in the Alberta surveying business), so there is growth in demand for these skills. Organizations are typically looking for graduates with employable skills who require minimal on the job training, so keeping up with the latest technology is a challenge that all GI programs face.

There are a number of unique challenges in the land surveying profession. The ‘retirement cliff’ that many feel the profession is facing will put more pressure on the geomatics degree programs to produce more graduates that want to enter the profession. A concern reported by several respondents is that the majority of geomatics engineering graduates choose to become professional engineers rather than professional surveyors. The relatively recent increase in the number of land surveying associations that have implemented mandatory continuing professional development (CPD) is resulting in growing demand for university and college extension courses and distance learning alternatives, and partnering to fill this need is already happening (e.g., AOLS partnering with Ryerson and York Universities).

Enrollment expectations

Despite the robust job market and predictions of growth in employment, it is often difficult to attract high school students into geomatics programs, as neither the field nor the terminology are well known to the younger generation. Interest levels are often dependent on the breadth and depth of the geography program offered at high school. In a report to identify and address workforce challenges in America’s Geospatial Technology sector[261], it was recommended that a geospatial curriculum be developed for schools (K-12) and there be an increased focus on highlighting interesting careers that utilize geospatial thinking with practical applications for students to understand. The report also noted that GIS courses should be added to business school curricula to broaden the reach of GIS enrollment. As demonstrated by the Education and Capacity Building strategic objectives in the Pan-Canadian Geomatics Strategy, these recommendations are of interest in the Canadian context.

In the engineering field, future students (often with encouragement from their parents) tend to gravitate to the traditional engineering disciplines such as mechanical, civil, chemical and electrical. Students often switch over to geomatics once they become more familiar with the curriculum and future employment opportunities. However, despite these concerns, most universities and colleges that were consulted anticipate either stable enrollment or minimal growth within their undergraduate GIS/Geomatics focused programs, and as noted previously, surveying technology programs are experiencing difficulties with enrollment.

Educators reported that Masters programs are primarily populated with international students, due to Canada's excellent reputation in geomatics education and research funding. Canadian students are reported to be less likely to pursue postgraduate education given the healthy job market.

Innovations required

While respondents expressed mixed views on the need for competency, licensing and certification models to address labour force requirements, the majority did not favour this option. Those opposed to such models expressed the following reasons for this view:

- Efforts to implement such models appear to have had only limited success (e.g., CIG, several provincial survey technology associations), suggesting that there is no significant demand.
- People that have been certified under such programs do not command a higher rate of pay or have more success in career advancement, so there is little incentive for individuals to become certified.
- They would not distinguish between certified people and those without certification in their hiring practices or in establishing the pay rate for new recruits; education, experience and demonstrated skills are the key factors in hiring.
- The existing certification processes (outside the professional land surveyor associations) do not carry any weight because there is no real testing to qualify, or oversight or disciplinary processes.
- It would be challenging to implement an effective certification program in geomatics because it covers such a diverse range of specialized skills.

Those who favour such models advanced the following arguments:

- There would be value in having survey technologists meet standards, like professional land surveyors do (e.g., discussions are underway to amalgamate professional and technologist/technician associations in some provinces).
- As GI use extends into the hands of individuals with no training in its use, mistakes will happen, liability actions will be pursued and regulation of geomatics product and service provision is likely to follow.
- Some of the certifications (e.g., CIG Geomatics Manager) apparently carry some weight in the international market.

A few innovative ways to address challenges discussed in the previous sections were suggested:

- Develop partnerships between educational institutions and equipment manufacturers to less expensively access the new data collection equipment required to train students.

- Place more emphasis on teaching Open Source software applications.
- Proactively outreach to GI users in other faculties / departments in the post-secondary educational system, making sure that courses on the use of GI are available in their curricula; the GI professional programs need to partner with other faculties to help embed GI into their programs.
- Work with university / college Continuing Education offices to offer summer or evening courses for geomatics practitioners who want to upgrade technical skills, and specialized instructors, on-line components, and evening classes for people that are working in other fields (health, retail, transportation) that may want to learn more about GI and how to apply it in their current position.
- Offer a GI option as a minor across all graduate programs offered at universities (e.g., specialized, interdisciplinary, spatial statistics and GIS without any need for a prerequisite).

4.3 Labour Supply-Demand Gaps

The following captures, at a glance, some of the trends that are influencing the supply-demand gap in the geomatics workforce:

- Impending retirements of large cohorts of the geomatics sector (e.g., private sector land surveying and public sector GI provider groups, where much of the workforce is over 50 years old)[262, 263, 264] will put pressure on the availability of experienced geomatics professionals. To address this, employment of experienced people who have been trained outside Canada is increasing, particularly in surveying occupations, to fulfill the supply gap.
- GI employment opportunities in Western Canada are growing (particularly within the oil and gas sector) while employment in Central and Eastern Canada is generally flat or shrinking. This has resulted in new graduates re-locating from their home province to secure geomatics job opportunities.
- Due to growth in some industry sectors (oil & gas, resource planning, location-based services) over the past few years, there has been increasing demand for geomatics professionals in these areas however, supply, in most cases, is keeping pace.
- GIS diploma graduates are being produced in large numbers from colleges across Canada each year. They are in abundant supply and often find it difficult to secure employment. However, a large number of survey professionals are retiring and several Provincial Land Surveying Associations are seeing declining membership, thus leading to a current and pending supply gap.
- Concern has been expressed over future supply of graduates into the field (e.g., because of the aging workforce, growing demand for GI skillsets in other occupations, and difficulty in attracting students as geomatics is not well known within the high school environment). The

K to grade 12 system does generally recognize geo-technology as a career option, and more needs to be done to show students how they can translate core science and math skills into careers in technology fields such as geomatics and related fields (e.g., engineering, environment, healthcare, etc.) where GI is becoming increasingly integrated.

- Given the prevalence in Canadian universities of foreign students in GI post-graduate programs, the majority of which return to their home countries, there is a shortage of Canadian Masters and PhD graduates to fill specialized roles in government and industry, or to fill vacancies in university and college faculties.
- There appear to be limited options for training of new GI users within organizations in the fundamentals of geomatics so that they can become effective users of GI apps, other than by the in-house GI provider groups, which are hard pressed to address this requirement.
- Given the growth in the size and complexity of accessible GI and the challenges of data modelling, there are predictions of shortages of skilled people with mathematics and computer science backgrounds who truly understand the inter-relationships between data models and data flow.[265]
- For the true potential of GI use in improved policy and decision making to be realized, geomatics practitioners need improved skills in areas such as communication, presentation and influencing, with the use of visualization technologies of particular importance. Those involved in policy and decision making roles in user organizations will also need basic skills development in use of and access to simple and intuitive tools that allow them to manipulate the data, rather than always working through back office Geomatics specialists. User skills development has been identified as a priority, and education and capacity building objectives of the Pan-Canadian Geomatics Strategy are seen as a positive step in the right direction.

4.4 Labour Mobility

4.4.1 Within the Sector

The most significant worker mobility challenges are occurring in Western Canada, but the robust labour market in that region is impacting employee retention to a lesser extent in the rest of the country as well. In the survey discipline, respondents reported that turnover of 10-20 percent annually is not uncommon. Mobility of professional surveyors is facilitated by the relative ease of gaining professional recognition in other provinces through the harmonization of entrance requirements to the profession. Most movement is between survey firms, but some technologists also leave survey firms for higher paying jobs in the oil and gas sector. Survey firms in Central and Eastern Canada have experienced loss of skilled workers to firms in Alberta, Saskatchewan and BC (salaries are reported to be on average 20 percent higher than in Ontario,[266] for example), although a few respondents in the East reported the recent return of some workers to their firms. To mitigate the problems of attracting and keeping skilled people from the Maritimes, several

Alberta firms have established production operations in Halifax and hired local people (often pulling them from local survey firms).

There is little evidence of significant mobility between firms in other supply segments (e.g., GIS, remote sensing) or between supply segments (understandable because technology training is most often segment-specific). The higher level of mobility in the survey segment is primarily attributable to the intense competition for qualified people to service the needs of the oil and gas industry.

4.4.2 With Other Sectors

Those consulted have reported limited problems with movement of workers from GI applications development into broader IT applications. For most geomatics companies, the workers involved in GI applications have GI education or training, as opposed to computer science backgrounds, so there is limited mobility potential of this type for these workers. For those companies that have chosen to hire IT generalists and provide the training to enable them to undertake GI applications development, this is a more serious concern since compensation levels and advancement opportunities in the typically much larger IT companies are greater. There is strong competition, for example, for good software architects that have experience developing spatial information systems, so companies try hard to ensure high retention rates. Several of those in this situation that were consulted advised they have developed more sophisticated employee retention methods (e.g., flexible work hours, offsite work arrangements, formal career pathing, etc.) to help ensure their investment in recruiting and training these workers pays off.

4.5 Labour Market Challenges and Trends

The following are general labour market challenges and trends that were identified:

- Employment opportunities with GI suppliers in Western Canada are growing (particularly within the oil and gas sector) while employment in Central and Eastern Canada is generally flat or shrinking. Government downsizing in the past few years has been an important factor. Employment in GI user organizations is increasing, both in terms of GI specialists and generalists who use GI as part of their work functions.
- Organizations that are experiencing downsizing or no growth are still seeing the demand for their GI services grow despite budgetary reductions. Better prioritization may be required to avoid negative consequences in terms of the quality of the GI products and services that are available (i.e., as management recognizes the value of GI and demands more and more applications, additional resources will be required). Within government organizations, more is being expected from junior level geomatics staff, with very little investment in their career planning and training.

- Employment of specialists with some GI skillsets in other domains is growing at a faster rate than of GI specialists, with the exception of surveying, which is experiencing rapid growth in the West.
- Aging demographics is of concern within government organizations, where there is less hiring flexibility generally due to a general downsizing trend. It is also of concern in the surveying profession, where entry into the profession is flat or in decline in several provinces. The most recent assessment of demographics in the surveying community in Canada found that some 46 percent of professional surveyors were more than 45 years of age.[267] There is also concern that proper succession planning is not taking place, and that this will have a significant negative impact when blocks of retirees leave organizations together.
- While work status is predominantly full-time employment, there is an increasing prevalence of different employment models such as: contracting-in of expertise within government (i.e., contract, term or project employees, and so called 'body shopping' from consulting companies); partnering by companies with other GI suppliers in the value chain to deliver total solutions; use of more 'associates' and fewer employees, to cope with and manage large fluctuations in workloads; and contracting with offshore suppliers to reduce product and service pricing and remain competitive.
- Industry restructuring is impacting the employment profile of geomatics occupations. Continuing mergers and acquisitions activity is expected, which may see more geomatics companies subsumed within engineering and IT consulting companies, changing the mix of people that are deploying GI solutions.
- Public-private sector competition for top talent is a challenge; in Western Canada industry typically can offer better salaries and benefits than the public sector and in the rest of Canada the opposite is often true.
- Movement to increased working condition flexibility (e.g., working from home, flexible working hours, etc.) is on the rise.
- Employment of experienced geomatics specialists who have been trained outside Canada is increasing, particularly in surveying occupations.
- Canadian geomatics professionals are often viewed favourably in international markets and are frequently rewarded with job offers when competing for international positions. One respondent noted,

  > *"Many other markets are behind Canada so their expectations are lower – Canadian candidates come across as more advanced and well educated".*[268]

- Graduates of Canada's five key Bachelor of Engineering/Science programs in Geomatics do not have difficulty finding employment; organizations (ranging from agriculture to public health to tourism) actively recruit on campus and as one professor noted,

  > *"every student has a choice of jobs; it has been like this for years".*[269]

5. Implications for the Sector's Future

The previous chapters have provided the key findings from the environmental scan concerning the current status of the geomatics sector and the domestic and international markets it serves, and the future trends and drivers of change in the production and use of geospatial information. The Value Study report indicates that the use of geospatial information and technologies contributed C$20.7 billion (or 1.1 percent) to Canadian real GDP in 2013 and this report clearly demonstrates that there is significant potential for additional growth in that use. This chapter addresses the question, "What are the implications of these findings for the future of the Canadian geomatics sector and how can the sector adapt to create the most value for the Canadian economy and society?"

5.1 A Market Undergoing Transformation

The market for geospatial information products, services and technologies is undergoing a significant transformation. The beginning of the modern digital GI period can be traced back to the development of the first GIS by Canadian Dr. Roger Tomlinson in 1961, the formation of Esri in 1969 to bring the first commercial GIS product to market, the launch of the first commercial earth observation satellite, Earth Resources Technology Satellite (later renamed Landsat) in 1972 and the availability of fully operational GPS in 1995. The emergence of the Mass Market Geomatics internet applications, and especially Google Maps in 2005 and Google Earth in 2007, had particularly transformative impacts. With continuing advances in technology, the market has been transitioning for some time from specialized to more general purpose applications.

A number of factors have contributed to the explosion in the use of GI and the changes in the nature of its use. The widespread adoption of GPS technology and dramatic increase in the size of the market for GPS positioning and navigation resulted in the miniaturization of GPS chips, and the dramatic improvement in capability, simplification of use and reduction in cost. This put GPS-enabled devices into the hands of millions of users who had no geomatics training. Similar advances in digital mapping and image handling combined with the emergence of Mass Market Geomatics companies, which provided easy and convenient GI access on the Internet, helped to significantly increase GI awareness and the capacity of individuals and businesses to use GI in many innovative new ways. Finally, market transformation has also been driven by rapid advances in mobile computing, the embedding of GPS chips in most mobile devices and dramatic increases in the availability of geo-enabled mobile applications.

Confronted with these transformative forces in the market that it serves, the Canadian geomatics sector needs to change and adapt if the full economic potential of the Sector is to be realized. While 'specialist' GI users (i.e., those from the traditional geomatics disciplines like surveying, mapping and remote sensing or from other disciplines that have received significant geomatics training) continue to be an important force within the GI market, GI providers are witnessing an erosion in this business as former clients can more easily serve their own needs. The 'generalist' users (i.e., people with little or no training in the geomatics disciplines) represent the primary growth opportunities. Meeting the needs of these users requires a different approach to the market. For these users, demand has shifted from the traditional focus on production of data products and software applications that they can deploy on their GIS systems, to the provision of integrated data and software applications that are easy to use with minimal training. In addition, this user group is increasingly interested in hosted solutions (Data as a Service, Software as a Service and Infrastructure as a Service in the Cloud) and geo-enablement of an array of business ICT applications (e.g., linking geography with customer demand information, business intelligence, inventory, etc.). Demand is also expected to grow for expertise in performing spatial analytics on Big Data.

Geomatics organizations that want to effectively serve these new market demands need to change in a number of ways. GI providers in both government and industry need to decide whether to develop the capacity to deliver their own solutions or become a specialized part of a solutions value chain along with other partners. More focus is required on the business environment and processes of target client groups, potentially involving hiring people with the appropriate business background. New software and data management skills may be required, such as developing apps for the mobile environment, provisioning and managing Cloud services, integrating GI with business ICT applications, and providing training and ongoing support for hosted solutions. Most importantly, serving the needs of generalist users may present the opportunity to adapt the GI provider's business model, from a project-related income stream to a service-related model suited to medium- to long-term business relationships with clients.

There are also important implications of the market transformation for the educational and training institutions that produce research and development outcomes and highly qualified personnel for the sector and GI users. Geomatics educators need to adapt their curricula to the market changes to ensure that graduates have the necessary skillsets to meet future demand for mobile app development, Big Data spatial analytics, etc. Increased cross-disciplinary education is needed to better equip generalists with knowledge of basic geospatial concepts and principles (i.e., improve the levels of 'geo-literacy') so that the full potential of geo-enabled business ICT applications can be realized. Research and development focus on such areas as Big Geodata analytics (e.g., spatially-partitioned, pre-aggregating, pre-integrating optimization methods to facilitate Big GeoData Analytics, spatial extensions for adding spatial-awareness to traditional Big Data technologies and new Big GeoData-specific metadata engines and services[270]) is required.

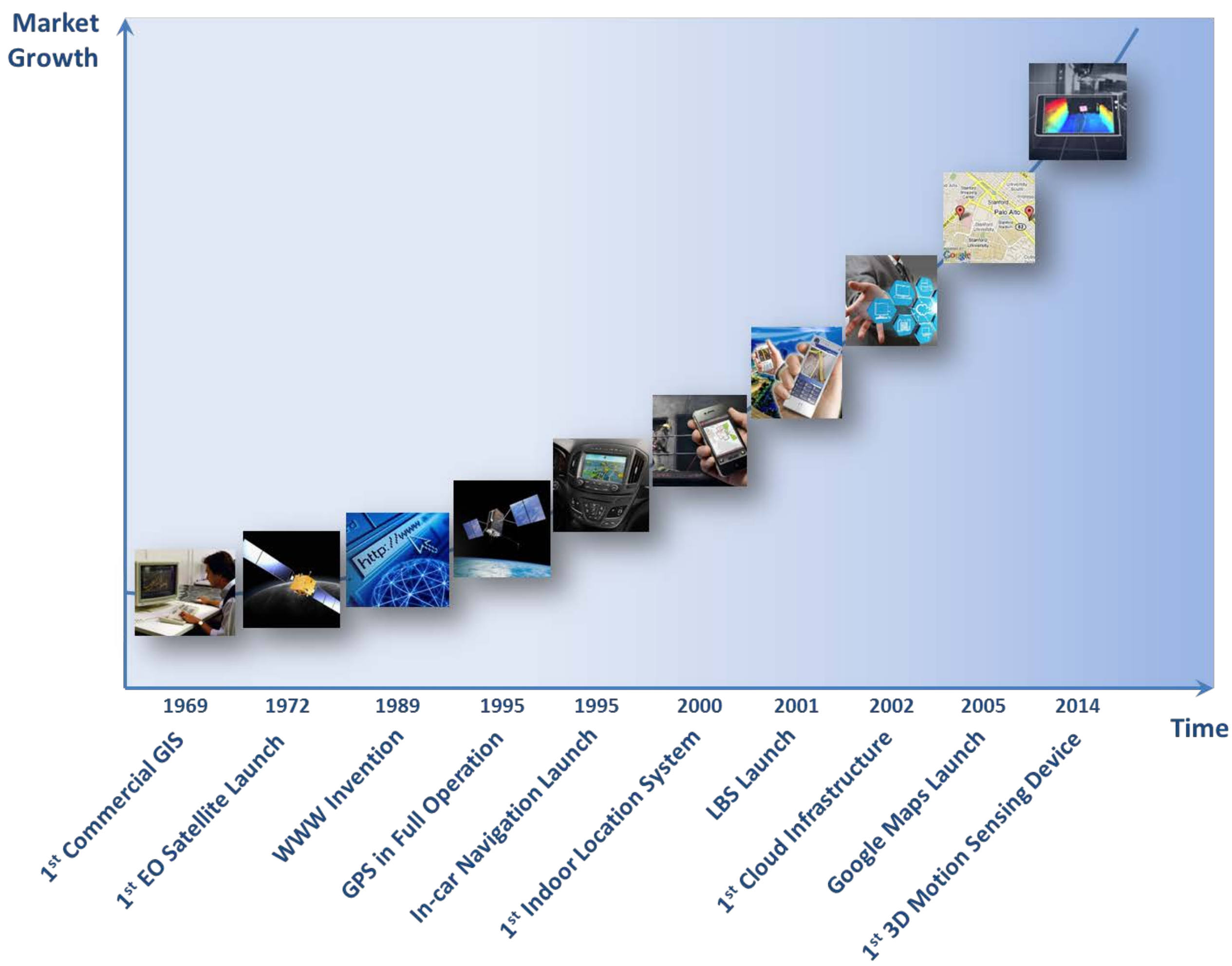
5.2 Market Change Drivers

A broad range of drivers of change in the GI market will impact how the sector delivers GI products, services and technologies in the future, as discussed in Section 3.1. The following sections highlight the most important drivers and their implications for the Canadian geomatics sector.

5.2.1 Technological

Figure 12 illustrates some of the technological developments that have driven market growth since the beginning of the modern digital geospatial information era in the late 1960s.

Figure 12: Transformation of the Geospatial Information Market



A number of these technologies have particularly important impacts on future growth in the use of GI for the geomatics sector in Canada. For example, while commercial location-based services in the mobile environment have been developing since 2001, the primary focus has been on the business to consumer (B2C) market, dominated by the major Mass Market Geomatics and mobile telephony players. The maturation of indoor positioning systems is opening up new business opportunities for applications that require seamless determination of the mobile device's position regardless of location. As interest in LBS continues to increase in the business to business (B2B) market, there are growth opportunities available to geomatics organizations that can develop simple mobile apps targeted at field personnel in organizations hungry for productivity improvements. The research and consultations for this study indicate a very low penetration of the LBS market by the Canadian geomatics sector.

New developments in 3D mobile motion sensing devices signal the potential for a new era of data capture and augmented reality applications in the workplace (e.g., utility workers, fire fighters and police officers being able to navigate through unfamiliar buildings, capture new location-tagged data to share in real-time with office workers, etc.). Geomatics organizations that want to capture future LBS business opportunities will need to be nimble to meet the intense competition that the potential of this market will generate.

Another critically important driver of market growth is the increasing availability of free and open data from government open data programs and government-backed earth observation (EO) missions. As the quality and quantity of government open data improves and the growing plethora of free or low-cost EO data comes on stream, public and private sector geomatics providers need to be prepared to assess its applicability to clients' business requirements and quickly integrate appropriate datasets into their GI products and services. A particularly important opportunity is the use of free and open data in the development of offerings to emerging growth segments (e.g., health, finance) as a means of introducing GI applications at a lower cost to help stimulate increased demand.

Related to this driver is the expanding interest in performing analytics on Big Data. A large number of Big Data sources include a spatial reference, which can serve as a means to integrate diverse datasets. Specialists in geomatics have the knowledge to make the necessary links and transformations from one reference system to another, to consider precision issues and to calculate the impacts of spatial and temporal distortions on analytical results. Geomatics organizations that want to take advantage of the opportunities presented by this growth driver need to position themselves to compete by developing/recruiting data scientists, developing or working with research institutions to develop new algorithms and optimization methods and acquiring or renting the scalable computing capacity to handle the data processing involved.

5.2.2 Economic

Globalization is driving significant change in the GI market, both in Canada and internationally. As global value chains are divided into smaller and smaller tasks in the emerging 'project economy', opportunities for partnering and mergers are emerging. Canadian GI providers that want to take advantage of opportunities to plug into these chains, but have not already done so, need to adapt to a new business model and increase the flexibility with which they provide services. Companies that want to improve their cost competitiveness by adding suppliers from lower cost countries like India and China need to conduct thorough due diligence and perform adequate testing before committing to contractual relationships. For companies that want to position to be acquired by global GI players, focusing on development and improvement of niche products and services that address a gap in the preferred acquirer's portfolio will be necessary. Governments that want to conserve resources by outsourcing functions like data management in the Cloud must also ensure that security and privacy requirements are met, especially if data is housed in infrastructure in foreign countries.

5.2.3 Social

One of the important drivers of increased awareness of geospatial information and technologies has been the emergence of web mapping applications that are developed and improved with crowd-sourced or volunteered geographic information (VGI) contributions. This social phenomenon has resulted in the creation of a growing cadre of 'producers'[10] and an alternative source of up-to-date mapping, particularly in urban areas. VGI is a proven source of information for updating online mapping datasets, used routinely by a number of commercial and government GI providers. In an era of government fiscal restraint, VGI represents a largely unexplored opportunity for public sector GI providers in Canada to improve the quality of their GI products and services. To take advantage of this opportunity, these organizations need to develop processes to address and find solutions to a range of technical and policy issues (e.g., quality control, security, privacy and licensing).

5.2.4 Policy

There are at least two areas of public sector policy development that can drive change in the GI market. The first is government policies that can provide a stimulus to GI markets. Examples are open government/open data policies that improve access to GI with potential commercial value, and infrastructure renewal and 'green economy' policies that result in investment in GI. Governments can also help improve domestic and international business prospects and stimulate business investment by adopting procurement policies that challenge industry to develop innovative GI solutions, as recommended by the Independent Panel on Federal Support to Research and Development, and by adopting plans that help provide long-term stability in supply of GI products and services to government.

The second policy area relates to the provision and ongoing maintenance of authoritative geospatial information. In particular, information to support emergency management requires improvement in Canada. Recent natural disasters such as the extreme floods in Southern Alberta and the Greater Toronto Area in 2013 clearly demonstrated the inadequacy of existing GI for disaster mitigation, response and recovery activities. Governments need to make coordinated investments in geo-enabled common operational picture capabilities and flood risk mapping in

[10] In the geospatial data context, individuals that are involved in both the production and use of the data, such as active VGI contributors

flood plains across Canada. Such investments will provide opportunities for GI applications development for communities and insurers across Canada.

The same holds true for Canada's northern and offshore frontiers, where the current level of geospatial information is inadequate to meet the demands of resource development projects. While core GI exists for the northern territories, it is of a lower standard than is typically available below 60° latitude and does not fully address the requirements for planning and development of natural resources and supportive infrastructure in the region. The federal and territorial governments need to make coordinated investments in selective upgrading of the GI as required to support resource and infrastructure developments in selected areas. New hydrographic mapping has been developed in Canada's Arctic in connection with the nation's submission under the United Nations Convention on the Law of the Sea, but there remain concerns that the existing electronic charting information will not support the needs of increasing shipping, fishing and tourism activities in the Arctic. Significant investment by the federal government in hydrographic surveying and electronic chart production is required if the objectives of Canada's Northern Strategy are to be fully realized.

To improve emergency response inside buildings, governments also need to follow the lead being taken by US regulators to require delivery of accurate location information for wireless 911 calls placed from indoors and provision of vertical location information that would enable first responders to identify floor level for calls. Such policies will stimulate the demand for creation of 3D models of the built environment (buildings, facilities and above ground and underground infrastructure) and 3D cadastre for multi-owner building units.

5.2.5 Environmental

Growing public concern about environmental degradation and the impacts of climate change are expected to be an important stimulant of future GI market growth. Citizens are becoming empowered through access to information on the Internet and 'amateur environmentalists' are contributing crowd-sourced biodiversity and environmental indicators data and taking on stewardship responsibilities. Businesses are being challenged by their customers to act environmentally responsibly and by environmental regulators to submit environmental information, the majority of which is georeferenced. The increasing complexity and diversity of available environmental data and demands of the regulators present opportunities for innovative GI providers to help both environmental groups to analyze the data and develop evidence-based positions and businesses to meet regulatory requirements.

Efforts to reduce the rate of climate change and adapt to its impacts will also be a GI market growth driver. Energy reduction targets are creating demands for precise three-dimensional energy performance modelling based on building information models (BIM) and geolocation of the building in relation to historical weather patterns, nearby structures, etc. Adapting to food and water shortages will require massive investments in identification of optimal areas for food production and new methods and infrastructure for transporting enormous volumes of water from regions that have excess reserves to those that are suffering from significant shortages.

These reduction and adaptation measures signal important opportunities for GI providers to better integrate BIM and GI environments and provide cost-effective solutions to support the required infrastructure programs, both at home and abroad. To capture the first set of opportunities, the industry will need to proactively engage with the architectural community to address the BIM-GI integration challenges and break down the cultural barriers. The industry will need to work with government to develop innovative solutions for Canada that will help position it to compete for international projects related to climate change adaptation.

5.3 Challenges and Opportunities

5.3.1 Promoting Sector Identity and Value

Based on the study consultations, the most significant challenge that the geomatics sector is confronting is the lack of a clear identity for the sector. However, there are divisions between those that advocate action to develop and promote a unique sector identity and those that believe that promotion of 'geomatics' as a constituent part of the ICT sector has more advantages.

The implications of this lack of consensus are significant. With individual geomatics practitioners and organizations pulling in different directions, the ability to formulate and take strategic actions to raise the sector's profile and use common messaging about the sector's work and value is diminished. If the sector's identity and the value that it provides to the Canadian economy are poorly understood, it will be less successful in attracting resources to keep GI current, develop and maintain the spatial data infrastructure, and conduct research and development that will help to keep the sector globally competitive.

The Pan-Canadian Geomatics Strategy represents an opportunity to address this challenge. The identity dilemma was the key issue that triggered the Canadian Geomatics Community Round Table to commit resources to the development of the Strategy. Identity is one of the most important Strategy dimensions and a Working Group is now actively engaged in the development of an action plan to deal with this challenge. An important part of this work will be creating agreement on how the sector should be profiled (i.e., developing a recognizable sector 'brand') and marketed to decision-makers in Canada and in export markets.

Identifying and articulating the sector's 'value proposition' (i.e., its distinct character and the value of its contributions to the Canadian economy and society) is another challenge that is linked to identity. Quantifying and qualifying the value of GI and the work that the sector does have historically been considered to be a weakness. One of the main purposes of this study was to help address this challenge and there is broad interest in the community in its outcome.

5.3.2 Strengthening Sector Leadership

A closely related challenge to developing and promoting the sector's identity is overcoming weaknesses in sector leadership. The general consensus is that one of the main reasons for the low profile of the sector and its inability to address strategic priorities is the lack of visible sector leaders. There appears to be a deficit of visible leaders and fragmentation and diffusion of effort within the sector (e.g., there are over 40 associations representing different geomatics interests) is clearly a factor.

The Canadian Geomatics Community Round Table, an informal group of geomatics sector leaders, was created in part in recognition of this challenge. The Pan-Canadian Geomatics Strategy, which identifies this as a strategic priority, is a unique opportunity to also overcome this challenge. There is the potential to use this initiative to create a new government/industry/academia/not-for-profit leadership framework that will help to remove fragmentation and catalyze the sector. The Working Group focusing on the Leadership and Governance dimension of the Strategy is considering options to create a new permanent leadership and governance structure to succeed the Round Table.

5.3.3 Regaining International Competitiveness

There is a general consensus in the industry that Canada faces the significant challenge of regaining its international competitiveness. Although there are no recent statistics to prove it, based on the evidence from the study consultations Canada's share of international business is in decline. There appear to be several key reasons for this decline:

- Canada does not use the kind of integrated business development strategies or commit the same level of resources to research and development that key competitors (e.g., European Union) employ.
- The recent global economic crisis has resulted in a number of key export markets favouring local suppliers more than in the past.
- As competitors who are lower-cost, quasi-government organizations (e.g., Dutch Kadaster and SwedeSurvey in the land reform/cadastre market niche and Ordnance Survey International in the SDI niche) gain more market traction, it becomes increasingly difficult to match their track records.
- Aggressive new competition has emerged from lower-cost countries (e.g., India and China).
- The relatively fragmented industry structure is not compatible with market trends (i.e., higher value-added geospatial information products and services dominated by large vertically integrated firms).

There are a number of important implications for the sector of failing to address this challenge. Many of the growth opportunities appear to be in the international market, so there is a strong correlation to the sector's future success. As the industry's competitiveness slips our reputation is damaged, reflecting badly on the sector's international image and reducing future chances of regaining market share. The loss of revenues and profits inhibits companies' ability to invest in the research and development required to remain competitive. This reduces the industry's ability to provide innovative new GI products, services and technologies in the domestic market and has a negative impact on the sector's image at home as well.

There are several opportunities to address this challenge, but considerable complexity is involved. The public and private sectors need to work more cooperatively and strategically to capture export business. For example, government GI providers can help to open doors by developing partnerships with foreign governments based on helping to initiate projects and providing professional advice with teams of industry and government experts on the condition that downstream project work is available preferentially to Canadian businesses – a strategy that our European competitors have successfully used. Government can also act as a demanding and informed purchaser of innovative total GI solutions that have export potential and provide a valuable reference for foreign buyers.

Funding for geomatics research and development in Canada is not keeping pace with major competitors. For example the European Commission's Framework Programmes for Research and Technological Development and the European Space Agency's funding programs for EO applications development provide EU competitors with access to billions of Euros to help them develop competitive GI products, services and technologies. Natural Resources Canada can better support industry competitiveness by improving technology transfer from their research labs to industry. Canadian government academic research funding programs need to be reexamined to ensure a proper balance between industry-focused research that strengthens short-term competitiveness and curiosity-driven research that leads to new inventions that will help to secure long-term competitive advantage. Coordinated government/industry/academia partnerships for innovation in geomatics, such as the TECTERRA initiative in Alberta, need to be created in other regions of the country.

The market change drivers discussed in Section 5.1 present opportunities for innovative Canadian companies to develop export business. Companies that want to compete internationally need to position themselves as niche players with clearly differentiated products and services that address weaknesses in international competitors' offerings. Alternatively, they need to become more vertically integrated in order to meet the demand for higher value-added products and services via mergers or by developing business relationships or strategic partnerships to address gaps in global players' GI supply chains. Given the strength in growth of consumer location-based applications in the international market, an increased focus by the industry in this area represents considerable potential for business development. The average industry investment in R&D will need to increase to capture higher value-added business opportunities and to remain competitive with US and EU rivals and aggressive new players from countries like India, China and Brazil, which are making substantial research and technology development investments.[271]

5.3.4 Improving Business Models

The transformation of the GI market from 'technology and data push' to 'solutions pull' and the shift in user predominance from geomatics specialists to generalists is creating significant business model adaptation challenges for GI providers. Mitigation measures can include:

- Developing business relationships with companies to add to their supply chain or companies that want to add them to their supply chain;
- Switching from a project revenue stream to revenues based on long-term service contracts;
- Migrating from internal technology infrastructure to a Cloud infrastructure; and
- Switching from pricing of one-off applications developed in projects to pricing apps sold multiple times online to a broader audience.

As with those previously discussed, these challenges represent opportunities for organizations willing to adapt to the changing market circumstances. The experience of many Canadian companies that have used external suppliers or participated in integrated value chains with other companies demonstrates that success is possible. Key requirements are due diligence and experimentation, with a particular focus on ensuring that intellectual property rights are protected[272]. While significant changes in sources of revenue and pricing strategies can be risky, market trends and evidence from the study consultations strongly suggest that the rewards will be realized by those organizations that take the plunge and mitigate the risks with careful planning and execution and sharing risk through strategic partnerships.

5.3.5 Reinvesting in Canadian 'Core' Geospatial Data

There is widespread support within the geomatics sector for a strong government role in the provision of authoritative, accurate and accessible (AAA) 'core' geospatial data (i.e., base or framework and thematic data layers that are of common interest to the majority of users), but the ability to deliver with diminished resources is considered to be a significant challenge. If this challenge is not addressed, there are a number of implications for the sector's future. Loss of confidence in government as the preferred provider of AAA data will reflect on the overall sector's credibility. If the government data content and currency does not meet user expectations, they will turn to alternatives (e.g., mass market geomatics or VGI sources), further eroding government's ability to continue to provide this service.

The government consortium that was formed to create the GeoBase product is viewed as a positive step to meet this challenge. However, there is the perception in the user community that the financial and human resources to maintain the data in a current state have been eroded. However, documentation of the scope and scale of government GI provider resources is not readily available, and a future project to access and compile this information is needed. The need to reevaluate the content of core data has also been raised and the Data Sources dimension of the Pan-Canadian Geomatics Strategy addresses this matter.

Action on a number of fronts is needed to address this challenge. The current requirements for core data layers need to be evaluated, and the Working Group focusing on the Data Sources dimension of the Strategy is assessing how best to handle this. The business case for reinvestment in core geospatial data in Canada needs to be developed and presented to senior officials and political leaders. The documentation of concern in this study is expected to help make the case for reinvestment. Innovation needs to be incorporated into the development of the business case. For example, opportunities to adopt new business models that take advantage of crowd-sourced content and capture changes in geospatial data resulting from business transaction processes (e.g., building permits, proposed subdivision plans, etc.) need to be considered. Finally, the requirement to continue to provide high quality data through open government initiatives in order to generate the expected economic activity must be reinforced.

5.3.6 Attracting the Best and Brightest

Attracting the 'best and brightest' high school graduates into geomatics education and training programs is an ongoing challenge. This is related to the identity challenge, since it is most often attributed to the public's general lack of knowledge about the sector and career opportunities, the sector's low profile and lack of a clear image of its role and value in the minds of the public. Students with the requisite math and science background to enter geomatics programs often opt for careers in other engineering or science fields that are more widely recognized and understood. As a consequence, geomatics educators are reporting a diminishing cadre of top quality students and programs are operating below peak capacity.

There are a number of implications for the future of the geomatics sector. In the short term, the lack of recruitment success has resulted in the closure of a few college geomatics programs at a time when there are demand-supply gaps particularly in survey technology. In addition, some of the most promising new business opportunities are for spatial analysts and data scientists, requiring graduates with very solid analytical and innovative thinking strengths. The sector's long-term health and growth prospects are dependent upon the quality and resourcefulness of new entrants into geomatics workplaces. To the extent that other sectors overlapping with geomatics in some market spaces have access to more of the highest quality university and college graduates, they will have a better chance than the geomatics sector. The work underway on the Education and Capacity Building dimension of the Pan-Canadian Geomatics Strategy represents a timely opportunity to address this important challenge and establish a strong brand for the Canadian geomatics sector.

A. CGES Study Questions

1. What is the current status and emerging trends in the geomatics sector?
2. What is the current supply and demand for geospatial products and services?
3. What are the key drivers for growth in the geomatics sector in terms of supply and demand?
4. What are the challenges and opportunities facing geomatics in Canada?
5. What is the state of domestic and international markets in geospatial information products and what role is played by Canadian organizations?
6. What barriers exist in accessing domestic and international markets?
7. What are the labour market requirements and projections for skills in working with geospatial data and information?
8. What are the key emerging technologies influencing the geomatics sector?
9. What are the key economic and social trends that will likely impact the geomatics sector and the supply and use of geospatial data / information in the coming years?
10. What priorities should Canada adopt in respect to the production and use of geospatial information over the next five years?
11. What is the profile of the private sector with respect to the number and size of firms; regional distribution and markets; growth; and, associated issues in the various segments that constitute geomatics?
12. What are the contributions of industry, the public sector and academia; and, what are the challenges and opportunities for each?
13. What are the existing capacities, service delivery models, and emerging trends within the public sector segments of geomatics in Canada?
14. What relevant research and development is on-going in Canadian government and academic institutions?
15. Are there any key gaps in Canada's R&D capacity with respect to geomatics?
16. What is the employment profile of geomatics occupations (e.g., where are people employed, in which geomatics domains, employment growth, labour force distribution, demographics, employment status (self, consultant, employee), education, skills gap, wages / salaries, size of establishment / company, etc.?
17. What training programs exist within Canadian universities and colleges to support geomatics?
18. What innovative programs, competency, licensing and certification models should be examined within the Canadian context?

B. Geospatial Information Use Examples

The following sections provide illustrative summaries of the GI demand in Canada – the key ways that geospatial information is being used within the three levels of government and across a broad range of business sectors.

B.1 Federal Government

B.1.1 Agriculture and Food[273]

Biomass Inventory Mapping and Analysis

This is an interactive mapping application that provides Internet-based GIS functionality to query and visualize biomass inventory data. Biomass supply and location information is made available through a collection of thematic maps and interactive queries of the herbaceous and woody databases.

Canada Land Inventory

The Land Capability for Agriculture dataset illustrates the varying potential of a specific area for agricultural production. Classes of land capability for agriculture are based on mineral soils grouped according to their potential and limitations for agricultural use.

Crop Inventorying (2009-2013)

The process of generating annual crop type digital maps used a Decision Tree based methodology applied with optical (Landsat-5, AWiFS, DMC) and radar (Radarsat-2) based satellite images. This approach consistently delivered a crop inventory that meets the overall target accuracy of at least 85 percent at a final spatial resolution of 30m (56m in 2009 and 2010).

Agroclimate Impact Reporting

This is an online spatial tool to view an ongoing dataset of weather impacts, which provides monthly snapshots of current and historic individual impacts, as reported by registered volunteer reporters.

B.1.2 Fisheries

Fisheries management[274]

Protection and conservation of fisheries resources are a key component of fisheries management. DFO is coordinating multi-year stock assessments and advice with multi-year fisheries management planning in more fisheries. Annual stock assessment advice and fisheries management planning will continue to take place where fish stock biology requires this approach, such as Pacific salmon fisheries.

B.1.3 Natural Resources

Geological mapping

A major activity at the federal level to support the mining sector is the production and publication of geological mapping information. Geospatial information is used in the capture of geological features in the field so that it can later be mapped, and the geological map is normally produced by superimposing the geological data over topographic data. The Geo-mapping for Energy and Minerals (GEM) program is developing modern geological maps and data sets that will completely cover Canada's North by 2020.[275]

Storing geophysical data

The Geoscience Data Repository for Geophysical Data provides facilities to discover, view and download the following information: airborne and marine geophysics, gravity data, borehole geophysics, and seismic and magnetotelluric data.[276]

Forestry inventorying

The National Forest Inventory, a collaborative effort between the federal, provincial and territorial governments, compiles detailed information for each of Canada's forested ecozones. The Canadian Forest Service maintains a national database and leads data analysis and reporting. The provinces and territories collect the data, including tree ages, volume of wood, dominant species and land use.[277]

Wildland fire monitoring

The Canadian Wildland Fire Information System (CWFIS) includes daily maps that display fire danger and fire occurrence nation-wide. Data used to create CWFIS map products includes: weather observations from federal and provincial/territorial networks' weather forecasts; satellite imagery; fire statistics and reports; geographical features; and vegetation classes. The Fire Monitoring, Accounting and Reporting System (FireMARS) provides burned area polygons mapped nationally on an annual basis through the integration of data from fine and coarse spatial resolution satellite data with provincial/territorial agencies.[278]

Biodiversity monitoring

BioSpace—Biodiversity monitoring with earth observation data—uses remote sensing technology to observe the landscape, gather data on biodiversity and monitor changes, all from space. BioSpace gathers data on four landscape characteristics: topography, productivity, land cover, and disturbance.[279]

Crown lands administration

The Canada Lands Survey System (CLSS) provides the framework and infrastructure for defining, demarcating and describing boundaries of Canada Lands and of private lands in the North. Crown lands administration involves: setting standards that ensure a level of quality for legal surveys and survey products; maintaining a ground-based parcel fabric that provides the basis upon which additional surveys can be built and from which cadastral mapping and land information systems can be derived; safekeeping of and access to legal survey documents for Canada Lands; and supporting some 20 land registry systems.[280]

B.1.4 Safety and Security

Search and rescue operations

Search and rescue (SAR) can be divided into three categories: marine, aviation and ground operations. In all cases, Emergency responders use maps and GPS to help locate and navigate to the persons in distress. The COSPAS-SARSAT provides accurate, timely, and reliable distress alert and location information. Canadian SAR Planning (CANSARP), a computerized search and rescue program developed to establish the drift of SAR targets, also uses GPS to determine the search and rescue patterns required to locate people/ships in distress. GPS and GIS are also used for asset tracking, monitoring and planning, reporting, and documentation purposes.

Policing operations

National, provincial and municipal police services in Canada use GPS for positioning assets, navigation purposes, border integrity and to assist in search and rescue operations. Some police force vehicles have been equipped with a GPS and computer with an electronic map to facilitate quicker response to calls. This allows the police dispatch system to know the precise location of each vehicle at all times and can then determine the most appropriate resource and closest vehicle to a particular incident. The police are using GIS for tactical mapping, situational awareness mapping, security exercises, crime analysis, incident reporting etc.

Managing emergencies

Geospatial information and tools are critical in all phases of the emergency management cycle. To prepare for and mitigate emergencies, GIS can map and model potential disasters to help visualize critical vulnerabilities and damage consequences. Preparedness involves developing plans of action for when disaster strikes and GIS is used for selecting sites for adequate evacuation shelters, selecting and modeling evacuation routes, and identifying and mapping key tactical and strategic facilities. During the response phase GIS is used in providing warnings to people, determining appropriate shelter activations based on the incident location and optimum routing for affected populations, and providing common operating pictures for all agencies involved. GIS is used during recovery for assessing damage, prioritizing recovery efforts, obtaining funding and monitoring progress. GPS is also heavily used during response and recovery efforts to collect data on rapidly changing situations in the field and navigating response vehicles.

B.1.5 Environment

Biodiversity and habitat conservation

Geospatial information and tools are used for inventorying habitats, studying endangered species, correlating species and geographic relationships, analyzing change over time, and evaluating the effectiveness of conservation practices and policies. Environment Canada (EC) is mandated to protect habitat by conserving and protecting migratory birds, species at risk, and other species of national interest, thereby preserving biodiversity at regional, national and even international scales. They use geospatial information to provide access to information on Canada's protected areas via the web map application 'Interactive Indicator Maps', which can be used to search geographically, and this information can also be displayed on Google Earth.

Air quality reporting

The Air Quality Health Index (AQHI) is a scale designed to help people understand what the air quality around them means to their health. EC uses geospatial information to provide access to air quality information at specific locations across Canada, updated daily, with the Web application 'Your Local Air Quality Health Index Conditions'.

Water quality reporting

While water quality is primarily the responsibility of provinces and territories in Canada, Environment Canada plays a leading role in scientific research, monitoring and leadership on the development of guidelines for water quality. EC uses geospatial information to provide access to information on Canada's fresh water quality (and quantity) via the web map application 'Interactive Indicator Maps'. The Canadian Aquatic Biomonitoring Network (CABIN) is an aquatic biological monitoring program for assessing the health of freshwater ecosystems in Canada. EC uses geospatial information to provide access to information on the sampling locations where data has been collected in support of the CABIN program with the web map application 'Current Activities of sampling locations Map'.

Environmental indicator reporting

Canadian Environmental Sustainability Indicators (CESI) measure the progress of the Federal Sustainable Development Strategy, report to Canadians on the state of the environment, and describe Canada's progress on key environmental sustainability issues. EC uses geospatial information to provide access to information on a range of indicators via the web map application 'Interactive Indicator Maps', which can be used to search geographically for this information, and the information can also be displayed on Google Earth.

Greenhouse gas emissions reporting

The Greenhouse Gas Emissions Reporting Program (GHGRP) is Canada's legislated, publicly accessible inventory of facility-reported greenhouse gas (GHG) data and information. EC uses geospatial information to provide access to information on greenhouse gas emissions from large facilities in kilotonnes of carbon dioxide equivalents with the web map application 'Interactive Indicator Maps', which can be used to search geographically, and this information can also be displayed on Google Earth.

Pollution reporting

Environment Canada's National Pollutant Release Inventory (NPRI) is Canada's legislated, publicly accessible inventory of pollutant releases (to air, water and land), disposals and transfers for recycling. EC uses geospatial information to provide access to NPRI data .KMZ format for use with Google Earth™ and other 'virtual globe' software. Information for facilities reporting to the NPRI is plotted on a series of eight static maps on the web according to facility latitude and longitude coordinates, while emissions from area, mobile and open sources (e.g. agriculture, construction, road dust, waste and prescribed burning) are distributed using spatially resolved surrogates from Statistics Canada, Natural Resources Canada and other sources.

Weather reporting

Environment Canada's Meteorological Service provides information about weather, air quality, climate, ice and other environmental issues. The weather.gc.ca website offers up-to-the-minute information on current weather conditions, forecasts and warnings for over 800 locations across the country and uses a map interface to allow users to navigate to the geographical location where they want to retrieve this information. Their GeoMet service provides access to the Environment Canada's Meteorological Service of Canada (MSC) raw numerical weather prediction (NWP) model data layers and the weather radar mosaic via Web Map Service (WMS) and Keyhole Markup Language (KML).

Sea Ice reporting

The Canadian Ice Service (CIS) provides accurate and timely information about ice in Canada's navigable waters. This information is derived from analysis of RADARSAT imagery. The CIS uses geospatial information to display the latest ice cover in Canadian waters on Online Maps, updated on a daily basis from the most recent regional and daily ice charts.

B.1.6 Statistics

Census planning and conduct

Geospatial information is critical for all phases of a census. GIS applications are used for pre-enumeration (data design, collection and preparation), enumeration (conducting the census), and post-enumeration (data analysis).

Census reporting

Statistics Canada provides census geography covering a wide range of geographic areas – from provinces and territories down to city blocks. These geographic areas have boundaries, names, and other information that make it possible to locate them on the ground and relate census data to them. Mapping data available includes: interactive maps (census and non-census boundaries, patterns, and distribution based on interaction with the user and the map); thematic maps by subject (population distribution, earnings of Canadians, etc.); and reference maps by geographic area (boundaries of geographic areas, such as provinces, cities, health regions, or watersheds).

B.1.7 Parks and Protected Areas

Resource conservation

Parks Canada's Resource Conservation (Res Con) program uses GIS for wildlife monitoring to provide location analysis of collared animals and species at risk; for monitoring glaciers in national parks via monitoring protocols; and for the collection and storage of available Landsat and Radarsat images used to assist in fire mapping.

Other parks services

There is an increasing demand for GIS services in other areas (e.g., realty, digital images and coordination of assets, maps and information for law enforcement officers, internet maps and on-line campground reservations for visitors). For example their Planning Your Visit website has a map interface for linking to information on visitor experiences by geographic region.

B.1.8 Aboriginal Affairs and Northern Development

Mining and minerals

In the northern territories the rights to sub-surface lands including hard-rock minerals, precious gems and coal are administered through the Nunavut Mining Regulations and the Northwest Territories Mining Regulations and the Territorial Coal Regulations. NORMIN, a database of mineral showings, and a database of references to geology and mineral exploration in the

Northwest Territories and Nunavut, stores geographical location and geological information about showings, as well as information on the content of references. AANDC publishes a map on Major Mineral Projects North of 60th Parallel in Canada.

ASNDC is modernizing the way that mineral claims are acquired in Nunavut, which will allow licence holders to acquire mineral rights using a web-based system which includes an interactive map.

Petroleum

AANDC works in partnership with Northern and Aboriginal governments and people to: govern the allocation of Crown lands to the private sector for oil and gas exploration; develop the regulatory environment; set and collect royalties; and approve benefit plans before development takes place in a given area. Northern Oil and Gas disposition and Call maps are available for various regions within the jurisdiction of the department. In addition, digital boundaries for existing exploration licences, significant discovery licences, production licences, former permits, former leases and the Norman Wells Proven Area are available for download.

Land claims and self-government

The Government of Canada negotiates Comprehensive Land Claim Agreements (modern treaties) and Self-Government Agreements with Aboriginal groups and provincial/territorial governments across Canada. AANDC produces an interactive map that shows the location of Aboriginal communities negotiating agreements, including specific information on all negotiations in progress. Surveys have been required to confirm/establish the boundaries of the settlement areas and boundary maps are produced for inclusion in the agreements.

Aboriginal peoples

AANDC is one of the federal government departments responsible for meeting the Government of Canada's obligations and commitments to First Nations, Inuit and Métis. A variety of geospatial information tools and products have been developed in relation to this mandate. The GeoViewer is a full-fledged ‘Web GIS’ application that provides searching, viewing, measuring, emailing and printing capabilities for some departmental geographic data on Aboriginal communities and lands. The First Nation Profiles interactive map is a collection of information that describes individual First Nation communities across Canada. The Inuit Community Profiles interactive map provides information about their location, traditional name, population and other statistics. The Urban Aboriginal Strategy interactive map provides information on the 2006 census demographic characteristics for Aboriginal people living in urban areas.

Economic development

The Government of Canada, through Canada's Economic Action Plan initiated in 2009, is continuing to deliver on its commitments to Aboriginal people through investments in economic development, skills development and community infrastructure. The Aboriginal and Northern Investment Announcements Map shows the locations of where these initiatives are taking place across the country. The Interactive Map of Aboriginal Mining Agreements shows where mine development agreements are taking place across the country and provides specific information on exploration projects and mines, Aboriginal communities, and the types of agreements signed between communities and mining companies. The Northern Oil and Gas Disposition static maps display all current dispositions of oil and gas rights. The Petroleum and Environmental Management Tool (PEMT) displays generalized environmental and socio-economic information for selected Arctic regions to inform decisions about oil and gas exploration and land management.

B.1.9 Health

Epidemiology

Epidemiology involves the study of patterns, causes, and effects of health and disease conditions in defined populations, which informs policy decisions and evidence-based practice by identifying risk factors for disease and targets for preventive healthcare. Geospatial information is used in epidemiology for the description and examination of disease and its geographic variations. Results of these efforts are used to guide resource allocation decisions, target outreach efforts, assess program outcomes, and guide public health policy and program enhancement decisions.

B.1.10 Defence Services

Operational planning

Defence organizations are heavily dependent on geospatial information for planning military operations. Mapping and charting products are primary tools for planning operations on land and sea and in the air. GIS is used to quickly identify patterns, trends and threats to help military personnel make better decisions, then share their knowledge. Typical operational planning applications are: creating maps for military operations, analyzing the impact of terrain and weather conditions on operations, defining an engagement area plan, sketching a plan for a beach landing operation, creating a lodgment plan, creating a vehicle checkpoint for stability operations, and creating range cards for known firing positions.

Operational support in theatre

During military operations in the field of conflict, access to high quality geospatial information and tools is equally important. Situational awareness requirements include such things as troop movements, locations of enemy personnel and assets, etc. and mobile units are often deployed to collect, analyze and present this information in mapping formats. GIS is used in such applications as: in-vehicle and mobile situational awareness analysis, creating patrol tracks on maps, and customizing common operational pictures to monitor significant activities and events, track friendly and enemy units, and assess the status and performance of daily operations.

Emergency response

Defence organizations are often called upon to assist local, provincial and national governments in responding to disasters and emergencies in Canada and abroad. In addition to current geospatial information on the local environment (e.g., transportation routes, major buildings like hospitals, schools and government offices, flood mapping, etc.), real time updates on the emergency situation are critical to response and recovery efforts. GIS emergency response applications include: creating Common Operational Pictures, incident analysis to discover spatial patterns and trends, viewing and analyzing real-time video streams or digital images, and efficiently and effectively releasing information to the public and sharing information with other response organizations.

B.2 Provincial / Territorial Government

B.2.1 Natural Resources

Renewable energy mapping

Geospatial information is used to map a jurisdiction's potential for renewable wind and water energy production. For example, Ontario's Renewable Energy Atlas is a web mapping application that illustrates Ontario's renewable energy potential and provides information to assist with identifying a potential renewable energy site. The Atlas is an interactive web tool that allows users to create and view maps of wind and water energy resources in the Province.

Invasive species tracking

Geospatial information is used to position and map locations where invasive species have been reported. The Ontario Invasives Tracking System is an interactive web mapping application that allows users to enter information on their sightings and also to identify where invasive species have been sighted in the past by geographical area.

Natural heritage areas mapping

Geospatial information is used to record and make available the locations and extents of natural heritage areas such as provincial parks, conservation reserves, wetlands and woodlands. For example, The Make a Map: Natural Heritage Areas application enables users to interactively view the available natural heritage information for the province, which is also available digitally for those with GIS capabilities.

Forest fire fighting

Geospatial information is important for both fire response planning and daily fire operations support. For example, GIS is used to forecast problems (moisture, weather, lightning strikes) to plan deployment of resources and monitor for fires, in advance of actually fighting fires. The Fire Management Information Systems and Daily Fire Operations Support System at OMNR make use of GIS and a wide variety of spatial data including Ontario Base Maps (OBM), Forest and Land Cover inventories, and the Natural Resources Values Information System (NRVIS). In addition, GPS receivers, used either on the ground or in the air, capture the location and size of ongoing wildfires, and document other features and facilities. The Ontario Fire program uses the collected information to carry out spatial analysis and to develop decision support tools that will enhance tactical and strategic planning and decision-making.

Forestry management

Provincial ministries responsible for forestry management typically develop and periodically revise comprehensive inventories of forestry assets, using a combination of aerial imagery and interpretation of that imagery to provide mapped attributes for forest and non-forest land and water features, and ground surveys to provide volume estimates of forest stand types, typically using GPS. Forest inventories are being called upon to answer increasingly complex forest management questions, and GIS is helping to address this need.

Water resource management

Management of Canada's water resources is typically a provincial responsibility and involves the use of geospatial information for: protecting human life, property and natural resources through forecasting and warning about flood / drought / erosion hazards; ensuring sustainable use of water resources; and ensuring integrated management of water resources through water budgeting, river management and watershed planning. For example, Ontario`s Water Resources Information Program (WRIP): uses airborne and satellite imagery to identify and measure the size of features on the ground, locate objects (like wells), etc.; produces a provincial digital elevation model to be used in flow analysis as well as producing standardized river and stream databases; and uses GIS to produce a variety of maps to support different projects in WRIP as well as other water-related programs.

Fish and wildlife management

Management of these resources involves such things as protecting and restoring aquatic ecosystems and wildlife habitat, ensuring resource sustainability through monitoring and enforcing regulations, setting catch and kill quotas, monitoring of harvest levels and population trends, protecting species at risk, etc. Web applications allow users to spatially explore fish and stocking related data. GIS technology is an effective tool for managing, analyzing, and mapping fish and wildlife data such as population size and distribution, habitat use and preference, changes in habitats, and regional biodiversity. GIS and GPS offer an indispensable means of tracking threatened animals to help prevent further harm or even extinction. GIS is also well suited to monitoring habitats. Once an area is found to be suffering from human disruption, weather, forest fires, or other interferences, it can be targeted as an area for conservation practices to be implemented.

Managing crown land

Geospatial information is indispensable for crown land acquisition, disposal, and land use planning. This land management role has two important components. First, ministries must maintain careful records about who has rights to use or occupy Crown land, typically using automated land index systems to track title and survey records. Second, when individuals illegally use Crown land, ministry staff may take enforcement action to resolve those situations before public ownership of the land is jeopardized, and GIS is used for risk assessment, operations planning, vehicle navigation, and recording offenses. GIS applications are used to allow users to view the boundaries of Crown land use areas as well as associated land use policies via Internet web mapping portals.

Mineral development

Ministries responsible for minerals use geospatial information in a variety of ways. For example, most provinces have mine claim management systems to handle mineral land tenure, and some have adopted electronic mine staking processes. Provincial Geological Surveys usually work closely with the Geological Survey of Canada on the preparation of geological mapping products that are accessible to the mining industry. GeologyOntario is an example of provincial online warehouses that contain all of the publically available digital data collected on geology, geochemistry and geophysics, which is available for download and can be discovered using spatial and attribute-based search. Some provinces (e.g., Ontario) develop annual recommendations for mineral exploration based on the wealth of available geological and exploration data and any new information or concepts derivative from the current year's activities.

B.2.2 Agriculture and Food

Soils Mapping

Geospatial information is used to map and display the distribution and areal extent of soil attributes such as drainage, kind of material and classification of soils. Existing soil maps, and their classifications of soil and land attributes, are digitized and electronically 'stitched' together to produce a single digital soils coverage. For example, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAF and MRA), in cooperation with the Ministry of Natural Resources and Agriculture and Agri-Food Canada, are compiling a high quality, detailed, geospatial soils database for Ontario.

Drainage mapping

'Constructed Drains' are watercourses in the form of ditches or natural watercourses that have been modified to improve drainage, or they are in the form of buried tile systems. Provincial agriculture agencies are creating mappable layers of constructed drains that can be easily updated and then integrated with watercourse data from other agencies. For example OMAF and MRA is making enhanced drainage data available to users so that they can make more knowledgeable observations and decisions about current drainage conditions, future drainage plans, and environmental conditions.

Land use mapping

Detailed land use information such as fields, farmsteads, fencerows and ditches is often provised by provincial agriculture ministries. For example, OMAF and MRA's Agriculture Operations Inventory contains detailed information such as crop type, row direction, ditch and farmstead locations, livestock raised, irrigation and tillage method use, which assists with environmental modeling and agricultural land use decisions.

Emergency planning and response

Geospatial information is used in planning for potential agriculture emergencies and their response and to support biosecurity initiatives. For example, when there is an outbreak of animal disease, GIS is used to identify the locations of the outbreak, and establish the boundaries of quarantine areas. Biosecurity at the farm level means preventing the movement of disease-causing agents onto and off of agricultural operations.

Food chain tracking

Agriculture ministries are being challenged increasingly by the public to track food production problems (e.g., disease, etc.) directly to farms. A traceability system captures, stores and shares information about products received, internal production and operational processes, all the way to finished goods that are shipped and sold to the customer.

B.2.3 Health

Healthcare service planning

Given the important relationship between location and health, geospatial information can be used in public health tasks such as planning to improve healthcare service delivery. By visualizing this information in a geographic format, planners are able to identify how well their current service locations are situated to accommodate target populations. Taking advantage of the network analysis capabilities in GIS, planners can determine the optimal path for delivery of medical supplies and execute what-if scenarios to measure the catchment areas of hospitals.

Health Emergency Planning

Spatial analysis can be used to forecast disease outbreaks and track them wherever they spread. As cases are recorded, statistical analysis can reveal trends that can then be used to identify at-risk groups in the population. Increased capacity for spatial epidemiological analysis enables generation of new information to inform decision making. Using demographic and socio-economic census data, maps can be created in a GIS that depict where the at-risk groups are concentrated, and by superimposing known cases onto at-risk groups, emergency health planners can mobilize their resources more effectively. For example, Vancouver Island Health Authority's Emergency Management GIS (VEMGIS) is an interactive, web based GIS tool that allows users to access detailed information related to planning for emergencies such as a tsunami, explosion, gas leak, etc.

Health analytics

Ministries of health use geospatial information and GIS to provide information, analyses, and methodological support to enhance evidence-based decision making in the health system. For example, under the Geographic Information System (GIS) Strategy adopted in 2010, the Health Analytics Branch of the ON Ministry of Health and Long-Term Care has significantly increased their breadth of geospatial data and GIS use. Data holdings include: administrative boundaries for Local Health Integration Networks (LHINs) and subLHIN planning areas; number of beds available, and physical locations of a number of health service providers (e.g., hospitals, long-term care homes, community health centres, family health teams), etc. BC Ministry of Health is using GIS for operational review of immunization program – using GIS to visualize coverage rates that were previously reported only in tables, drilling down into smaller and smaller coverage areas in the province.

Outbreak investigations

GI applications are being used for investigations such as E-coli and salmonella outbreak geocoding and mapping to determine if there are any patterns. With E-coli, environmental factors may come in, so data like agricultural lands, water bodies and topography are integrated with the outbreak locations.

Location allocation analyses

GIS allows health agencies to send out harm reduction supplies across the province to fill gaps in communities where there are no services, identify clinics that would be best able to serve as hubs for services, etc. By using demographics on susceptible populations, they can identify the best clinic if there is a large vaccination campaign required for disease outbreaks like measles or mumps.

B.2.4 Education and Training

Educational resources mapping

Education and training ministries are using GIS to provide information to the public about educational and child care resources available within their jurisdictions. For example the BC Ministry of Education has an online interactive mapping tool that provides locations and contact information for StrongStart BC programs, public schools and board of education offices in British Columbia. BC Ministry of Ministry of Children and Family Development provides the locations and contact information for a variety of early childhood development programs and services (Early Years Services Map) and child care services (Child Care Programs Map) in their province.

Service locations mapping

Similarly, Ministries are using GIS to provide information to the public about employment assistance service providers. For example, the ON Ministry of Training, Colleges and Universities provides a mapping tool to help users find information about service providers in their geographic region.

Student transportation

Ministries of Education typically provide funding to school boards for student transportation. Geospatial information is critical in student transportation management software that is used for such functions as: automated student data upload, creation of transportation eligibility boundaries; and performing school bus run and route optimizations.

B.2.5 Social Services

Service locations mapping

Social services ministries are using GIS to provide information to the public about social program resources available within their jurisdictions. For example, the BC Ministry of Social Development and Social Innovation has an online interactive mapping tool that provides locations and contact information for WorkBC Services Centres, which provide resources and support to assist people in their search for work.

B.2.6 Environment

Biodiversity and habitat conservation

Geospatial information and tools are used for inventorying habitats, studying endangered species, correlating species and geographic relationships, analyzing change over time, and evaluating the effectiveness of conservation practices and policies. GIS is being used for targeting and planning habitat protection and restoration projects by focusing on habitats that are at highest risk and where they can have the biggest impact, and remote sensing is being used for identification of wetlands.

Air quality

The Air Quality Index (AQI) is a scale designed to help people understand what the air quality around them means to their health. Provincial environment ministries use geospatial information to manage and provide access to air quality information at specific locations, updated regularly, with Web applications.

Water quality

Water quality is primarily the responsibility of provinces and territories in Canada, and environment ministries use geospatial information to provide access to information on Canada's fresh water quality (and quantity) and drinking water quality via web map applications.

Environmental information reporting

Provincial ministries provide web-based GIS applications to access authoritative environmental datasets. Users can choose between viewing the raw data, locating features on a map, querying datasets, performing GIS analysis and generating reports.

B.2.7 Transportation

Planning and design of transportation facilities

GIS provides a framework to inform models, such as those used to forecast travel demand and plan capital improvements, and to support strategic decision making. In addition, GIS applications for making environmental evaluations can shed light on the consequences of various transportation alternatives. GIS-based planning and analysis allows transportation ministries to assess and prioritize construction and maintenance activities, ensure regulatory compliance, complete risk and integrity analyses, and better understand customer needs. GIS tools that can integrate CAD files and support surface and hydraulic models and soil and geotechnical analyses provide capabilities for designing context-sensitive projects.

Facilities layout and as-built location

Geospatial tools like GPS and electronic total stations are used in laying out roads, bridges, overpasses, sidewalks, etc. and recording their final as-built locations following construction. For maintenance projects, precise geospatial information is essential, for example, in replacing overpasses on busy highways, where the new structures are built close by and the replacement takes place overnight to reduce driver inconvenience (e.g., Hwy overpass replacements at given avenue).

Snow Clearing

GIS and GPS are being used to plan snow clearing routes, monitor clearing operations and report post-clearing road conditions to the public in near real time.

Transportation planning and forecasting

Geospatial information is used for long term transportation systems planning and forecasting purposes, in helping to find the right balance between the need to accommodate demand on public infrastructure and the responsibility to preserve quality of life and environmental sustainability in communities. An appreciation of existing transports hubs and networks in relation to expected population growth trends can identify areas of future bottlenecks in the absence of any forward planning. Spatial information is integral to transport modelling and managing congestion and freight.

Road user safety

Engineers are using GIS to perform safety analyses and identify root causes of dangerous highway segments.

B.2.8 Municipal Affairs

Land use planning

Provincial land use planning systems typically give municipalities the major role in planning decisions. Provincial ministries have such roles as: identifying and protecting provincial interests, and promoting sound infrastructure planning, environmental protection, economic development and safe communities. GIS applications primarily designed for land use planners provide visualization of GIS layers from many sources. GIS-based planning support systems can measure and compare performances of different planning scenarios according to planner- or citizen-defined indicators for land use, transportation, natural resources, and employment, to name a few.

Archeological mapping

GIS-based, user-friendly planning tools are used to enable municipal planners from various departments (e.g., public works, engineering, parks and recreation, and planning) to screen development proposals and identify areas for which a detailed archaeological assessment by a licensed archaeologist would be required. The goal is to inventory, classify and map significant archaeological resources and provide direction for their appropriate assessment and protection, as required.

Tracking municipal changes

Provincial municipal affairs ministries need to keep track of land use changes in municipalities to ensure that they are in alignment with provincial planning guidelines for growth (e.g., sustainability of robust economies; complete and strong communities that use land, resources and existing infrastructure efficiently, with amenities and community infrastructure to support a good quality of life; healthy environments and cultures of conservation).

Registry operations

Land titles/registry organizations examine applications to register interests in land, including transfers of ownership and the registration of charges against title, register survey plans that define the boundaries of parcels of titled land, such as subdivision and strata plans, and provide access to those records to lawyers, notaries, land surveyors and other stakeholders.

B.2.9 Provincial Policing

Planning service delivery

Geospatial information is extremely important in developing strategies for deterring and preventing crime as well as developing tactical plans for dealing with today's issues. Data-driven policing through GIS enables police forces to leverage their analysis of crime and intelligence information to proactively focus scarce resources in solving community problems, preventing crime and apprehending criminals.

Situational awareness

GIS provides command staff with the most up to date information by integrating the police force's high-value static data (crime hazards, gang territories, critical infrastructure, imagery, etc.) with dynamic event data (crimes, traffic, incidents, cameras, and other sensors, etc.) and analysis through a map. This map provides the comprehensive situational awareness needed to make better decisions as well as the ability to share this information with other involved agencies.

Field operations

Law enforcement agencies want to put the best available information in the hands of their first responders to improve their effectiveness and ensure their safety. Equally important is the ability of these officers to provide a timely and accurate picture of what is actually occurring in the field. A mobile GIS provides the capability for this rapid data exchange in a manner that is easy to understand and that can be integrated, visualized and shared through a map-based common operating picture.

B.2.10 Aboriginal Government Services

Land management

As Aboriginal communities move to self-government, they are making increasing use of geospatial information for management of their lands. As discussed in Section 2.3.2, these communities are developing internal geomatics capabilities and accessing products and services under contract with private firms.

B.3 Municipal Government

Infrastructure design, construction and management

Geospatial information supports a broad range of infrastructure related activities, including: planning and design of new infrastructure facilities; assessment of right-of-way infrastructure condition and needs; annual infrastructure rehabilitation; environmental assessments of rehabilitation projects; and maintenance of infrastructure records (i.e., asset management application).

Urban planning

Urban planners deal with a wide range of spatial information: parcel, zoning and land use data, addresses, transportation networks, housing stock, etc. Planners also study and keep track of multiple urban and regional indicators, forecast future community needs, and plan accordingly to guarantee the quality of life for everyone in livable communities. Some jurisdictions have incorporated automation into their planning approvals process, allowing submission of proposed development plans electronically, producing efficiency gains for both the municipalities and developers.

Realty services

Cities acquire and manage real property rights as required, for municipal needs consistent with city-mandated programs. Geospatial information supports the responsibilities of realty services organizations for: departmental acquisition needs assessments; and legal surveys, appraisals, negotiations, expropriations, legal and other activities related to the real property acquisitions.

Street operations and maintenance

Geospatial information is invaluable for the ongoing management of city streets and roads and for planning and executing maintenance activities. Some major cities are using web mapping and mobile applications to facilitate the reporting and viewing of maintenance issues such as potholes, malfunctioning traffic signals, dead animals, etc..

Parks and recreation

City departments responsible for parks and recreation use geospatial information and tools for planning parks and recreation facilities, maintenance activities, and providing services to the public (e.g., identifying recreation facilities locations and information in web mapping applications).

Water and sewer

Similar to Water, sewage and other systems

Fire and police services

Similar to Ambulance services and Provincial policing.

Some fire departments are using GIS to plan performance improvements much better (i.e., having very accurate time data on when calls received and dispatched, when crews arrived on scene, how long they were there, activities undertaken, etc.).

Public health

Municipalities typically have public health organizations and Boards of Health, which are responsible for approving policies developed by a Medical Officer of Health and staff of the public health organizations, who together identify the health needs of the community. These needs are addressed by a range of programs and services in areas such as health protection, health promotion, disease and risk factor surveillance (population health assessment), and injury and disease prevention. Geospatial information is being used to help facilitate citizen access to health care information and facilities (e.g., hospital locations, restaurant inspection reports, etc.) with web mapping applications.

B.4 Emergency Services

Planning optimal routing of ambulances

Similar to Truck transportation

Ambulance navigation

Onboard GPS transmit vehicle location and status information to a centralized ambulance dispatch centre. Incident locations are determined by geo-enabling the 911 address of the caller by matching the address to the street network GIS layer. Shortest path calculations are automatically calculated to all emergency vehicles within a minimum specific radius of the incident and the appropriate vehicle is automatically identified as the most suitable to dispatch.

Monitoring locations of ambulances

Similar to Truck transportation

B.5 Utilities

B.5.1 Electric power generation, transmission and distribution

Planning optimal locations of new generators, dams, powerlines, service delivery lines, etc.

To support long term planning, a combination of asset data, performance data and GIS analysis is used to help utilities understand how their utility networks are performing. It can then be used to identify the best location for new generators, dams and powerlines and to estimate project costs to support project evaluation, management and budgeting. For example, electrical power utilities use repeatable geoprocessing models that take into account many weighted factors to rate their assets on condition, reliability, criticality, performance, etc. This information is then used to help guide where to best spend capital dollars to maximize the value of investments in a utility's assets. This is a good example of the use of location intelligence.

Facilities layout and as-built location

The spatial analysis capabilities of GIS are used to assist in the design and operation of utility's facilities from a single authoritative database and it can also be used to build or enhance overall facilities technology systems. The ability of GIS to do analysis and apply models based on different scenarios allows facility managers to create efficient building and other structure layouts that provide the best space usage and energy efficiency possible. Creating geographically aware facilities means managers are equipped to effectively manage everything from maintenance to emergency response. Viewing facilities in 2D, 3D, and even 4D means facilities are more functional and layout is optimized. Geospatial tools like GPS and electronic total stations are used in positioning structures, powerlines, etc. and recording their final as-built locations following construction.

Asset management

GIS supports the asset management process as an authoritative system to store, manage and maintain accurate asset records that can be shared utility wide. Ideally there is integration among all of the systems that store information about an asset and an ability for staff to access data stored across multiple systems enabling a comprehensive view of the location, connectivity, status, history and description of an asset. Additionally, data visualization tools available within the GIS are used to isolate power lines in emergencies thereby reducing the impact to customers. As such, GIS tools help reduce power outages over an annual cycle and provide high service standards.

Balancing supply and demand and ensuring optimal market performance

GIS can assist power companies intelligently monitor and manage their transmission networks. A geodatabase is a key component for maintaining and managing accurate transmission asset data such as sub-stations, lines, and associated structures. GIS can assess grid reliability levels and formulate plans for compliance requirements, as well as manage transmission corridors, schedule right of way maintenance and analyze load growth or changes in load shape or strain on substation capabilities to ensure optimal market performance.

Smart grid

A smart grid is a modernized electrical grid that uses analog or digital information and communications technology to gather and act on information. Smart grid is all about situation awareness and effective anticipation of and response to events that might disrupt the performance of the power grid. There are a number of areas where spatial analytics / location intelligence are beginning to be applied including reducing non-technical losses, targeting demand response, distribution operations planning, transformer load management, assessing data quality, voltage correlation (linking meters to transformers), energy modeling, voltage deviation monitoring, geographical outage frequency analysis, and predictive analytics for electric vehicle adoption to name just a few.

Alternative energy planning

Geospatial information plays an important role in planning and optimization of renewable energy systems for power production. Data on cloud cover, solar irradiance, and on wind/wave speed and direction (combined with other environmental parameters such as land elevation and land cover models) are vital elements in developing a strategy for the location and operation of solar, wind, and wave power facilities.

Meeting energy conservation targets

GIS tools can be used to develop different series of thematic grid maps showing the electric power distribution across a city/region. The maps can be color coded to denote areas of low; average and high power consumption levels. The commercial/industrial consumption analysis can be developed through a combination of GIS mapping and the addition of the North American Industry Classification System (NAIC) code assigned to each customer record. This analysis provides a detailed overview of the mix of businesses/residential customers within the area and their total consumption per year thus supporting targeted power conservation communications and social marketing campaigns.

B.5.2 Natural gas distribution

Planning optimal locations of pipelines

Gas utilities rely on GIS for planning, maintaining, and reporting on utility infrastructure and millions of miles of pipes. GIS-based planning and analysis allows gas utilities to assess and prioritize construction and maintenance activities, ensure regulatory compliance, complete risk and integrity analyses, and better understand customer needs. Through GIS, utility asset data links directly to other key information providing situational awareness to proactively monitor work orders and emergency shutdowns, and to ensure public safety.

Facilities layout and as-built location

Similar to Electric power generation, transmission and distribution

Asset management

Gas utilities must know the status of their assets at any time. With GIS, managers can make updates to keep your records current. Once a complete system inventory is in place, informed decisions about operations and maintenance can be made. As such, a GIS-based asset and facility management system optimizes workflows so operation of the distribution system can be done more efficiently. With GIS, analysts can monitor asset conditions to assist in infrastructure life cycle planning and replacement; field crews can capture inspection information and quickly update centrally stored as-built construction data and engineers can monitor cathodic protection systems to view information in relation to the distribution system, diagnose problems, and ensure corrosion protection.

Outage Management

With GIS, analysts can identify, isolate, and map areas of concern during a leak or outage. Managers can also trace the network to identify customers who are downstream of a main break, complete valve isolation traces, create leak reports, and reroute resources in an outage. For inspections or surveys, GIS can quickly produce professional maps or map books. Through GIS, managers can also communicate leak or outage information to customers and related agencies such as public works and water companies.

B.5.3 Water and sewage

Planning optimal locations of pipelines, water/sewage treatment facilities

To support long term planning, a combination of asset data, performance data and GIS analysis is used to help utilities understand how their utility networks are performing. It can then be used to identify the best location for new pipelines, and treatment facilities and to estimate project costs to support project evaluation, management and budgeting. For example, water utilities use repeatable geoprocessing models that take into account many weighted factors to rate their assets on condition, reliability, criticality, performance, etc. This information is then used to help guide where to best spend capital dollars to maximize the value of investments in a utility's assets. For main pipeline extensions; land records, demographic projections and proposed development plans are often used to help guide long-term system expansion plans.

Facilities layout and as-built location

Similar to Electric power generation, transmission and distribution

Balancing supply and demand and ensuring optimal market performance

GIS can assist water and sewer utilities intelligently plan, build, monitor and manage their watermains as well as treatment and distribution networks. A geodatabase is a key component for maintaining and managing accurate asset data on pumping stations, watermains, treatments facilities, sewage lines, and associated structures. GIS can assess pipeline reliability levels and formulate plans for compliance requirements, as well as mange capital infrastructure upgrades, schedule right of way maintenance and analyze water testing results to ensure reliable, plentiful, and safe supply of water for customers while at the same time exceeding market performance.

Hydraulic Network Modeling

GIS and Geospatial data forms the basis for the development of the Hydraulic Network Model. Water mains, valves, hydrants and their related attributes are loaded in the GIS model and once built this data can then be used for (i) water demand analysis and forecasting; (ii) network design and optimization (iii) fire flow and network resilience analysis (iv) optimization of operating scenarios and capital improvements (v) redesigning the network for pipe routing and pipe sizing for new development or land use rezoning; and (vi) operational efficiency studies such as the identification of areas for energy efficiency.

Meeting water conservation targets

GIS tools can be used to develop different series of thematic grid maps showing the distribution of water consumption across a city/region. The maps can be color coded to denote areas of low; average and high water consumption levels. The commercial/industrial consumption analysis can be developed through a combination of GIS mapping and the addition of the North American Industry Classification System (NAIC) code assigned to each customer record. This analysis provides a detailed overview of the mix of businesses/residential customers within the area and their total consumption in millions of liters per year thus supporting targeted water conservation communications and social marketing campaigns.

Supporting field staff mobility

Mobile field workers at water utilities need information that is current, delivered in any easy to use format and optimized for their needs to assist them to carry out their work in an effective manner. They also generate information that needs to be relayed to the office and managed in enterprise business systems. GIS tools support the field crews by providing interactive/real-time maps and map centric applications that can be rapidly updated and are easy to use. GIS also supports the field mobility business pattern by enabling field crews to capture GIS data in the field and efficiently pass it back into the office. Some utilities are deploying mobile GIS applications for field crews that act as an interactive version of the traditional utility map book and also provide decision support and data capture tools (GPS) while in the field.

Providing Real-time Operational Network Awareness

GIS supports utility operational awareness by enabling management to have a web map based view into the current state of network operations so they are aware of how their assets and personnel are performing and how they are affecting each other. An interactive map is also an effective way for utilities to take information from multiple business systems and present it through a common application. The interactive maps support decision-making by showing the utility networks overlaid with locations of recent callers, new service requests, open work orders, out of service customers, crew locations, recent sewer over flows, planned capital projects, etc. The maps can also show historic operational data on demand and be able to zoom far enough in to see all of their utility assets in detail as necessary.

B.6 Telecommunications

Planning optimal locations of facilities

Similar to Electric power generation, transmission and distribution

Facilities layout and as-built location

Similar to Electric power generation, transmission and distribution

Asset management

Similar to Electric power generation, transmission and distribution

B.7 Construction

B.7.1 Non-residential building construction

Building design/Building information modeling (BIM)

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. Building owners use BIM to manage data particular to individual buildings. Challenges such as querying information in multiple buildings, such as across a campus, or performing geographic analyses, like a best path analysis from one building to another, can be overcome by integrating BIM data with GIS.

Building layout

Typical building layout services include accurately defining the building location relative to property limits, confirming by-law conformance, providing horizontal and vertical references for construction purposes, and issuing various certificates required. The layout is often preceded by a property boundary survey, a topographic survey illustrating the location of natural and man-made features, and contours and spot heights required for designing the location of the proposed structure. The layout may involve: stakeout for excavation; placement of caissons, pilings, or footings; perimeter column grid layouts; precision alignment of pads for heavy machinery; and control of vertical datum for structure and grading.

B.7.2 Transportation engineering construction

Planning and design of transportation facilities

Transportation planning is the field involved with the siting of transportation facilities (generally streets, highways, sidewalks, bike lanes and public transport lines). Geospatial information has a critical role to play in planning for the development of new transportation facilities. Transportation planners use mapping data and GIS to identify and analyze alternative routes for new highways, locations of bridges, etc., to pick the best route to minimize life cycle costs and negative environmental impacts and maximize traveler convenience. High resolution geospatial data collected from aerial or ground surveys are incorporated into the design process using CAD or other design software.

Facilities layout and as-built location

Surveying services are required to layout the locations of all highways, streets, bridges, sidewalks, berms, etc. during the construction phase. Once these transportation facilities are built, surveys of their as-built locations are conducted, and the resulting data is captured and managed in transportation GIS applications.

Construction machine control

Machine control involves the integration of positioning tools into construction machinery. The term 'machine guidance' refers to systems that purely display the design difference to the operator. The term ‘machine automation’ refers to those systems that not only show the operator the design difference but are also able to directly control the machine hydraulics to maintain a desired position. This technology incorporates GPS, Motion Measuring Units and other devices to provide on-board systems on construction equipment with information about the movement of the machine in either 3, 5 or 7 axis of rotation. Feedback to the operator is provided through audio and visual displays, which allow improved control of the machine in relation to the intended or designed direction of travel.

B.8 Land and Property

Planning subdivision of land

Land subdivision means the division of a parcel of land into two or more lots for the purpose of sale or of building development. It is normal for local authorities to require submission of an application to subdivide, which includes a tentative or proposed plan of subdivision that is often prepared by a registered professional surveyor. Such plans normally include geospatial information such as: location, dimensions and boundaries of the land to be subdivided; location, dimensions, and boundaries of each new lot to be created; existing rights-of-way of each public utility, or other rights-of-way; location and boundaries of the bed and shore of any river, stream, watercourse, lake or other body of water that is contained within or bounds the proposed subdivision, elevation contours, etc.

Subdivision layout

Laying out a subdivision of land typically involves a legal field survey to establish the boundaries of the original parcel of land, and the placement of legal survey posts in the ground to establish the new parcel boundaries. Surveying the boundaries of utility easements or rights of way may also be required. Following completion of work in the field, a Plan of Survey is prepared showing the measurements and dimensions of existing and new parcel boundaries.

Optimizing commercial property selection

Commercial real estate companies are using GIS to help them service clients' needs for leasing commercial space. Applications combine information from a variety of sources (e.g., mapping data, customer demographics, tax information, zoning, tax incentives, floodplains, nearby businesses, and traffic counts) to allow brokers to help their clients make more informed and timely lease decisions. GIS use also enables agents to give clients virtual tours of potential sites, and to prospect on behalf of landlords for prospective tenants or buyers.

Property valuation

Property assessment organizations are using GIS to map valuation and appraisal information and integrate it with a variety of other data (e.g., parcel boundaries and ownership, structure type, improvement square footage, structure information, recent sales, tax history information, and year built). GI-enabled systems can be used to partially analyze real estate transactions data coupled with other data layers and statistics to not only provide more rigorous valuation but also to consider a wider range of data [larger geographic area] and comparisons with other similar communities.

B.9 Transportation

B.9.1 Air transportation

Aircraft navigation

Aircraft navigation is the process of piloting aircraft from one place to another that includes determining position, orientation, and velocity, establishing course and distance to the desired destination, and determining deviation from the desired track. GPS-equipped avionics that are certified for IFR flight meet en route, terminal area and non-precision approach requirements, but approaches with vertical guidance require augmentation of GPS with either a Satellite-Based or Ground-Based Augmentation System.

Route planning

Prior to departure on a flight, pilots must plan and submit to the local aviation authorities a flight plan. Official air navigation charts are the primary tool required to plot the intended route that is submitted as part of this plan.

B.9.2 Water transportation

Route planning

Similar to Air transportation

Vessel navigation

Most navigation on water involves the use of GPS either wholly or in part. The most common marine navigational technology is the Electronic Chart and Display Information System (ECDIS), which displays the information from electronic navigational charts (ENCs) and integrates position information from GPS and other navigational sensors, such as radar and automatic identification systems (AIS).

B.9.3 Truck transportation

Planning optimal routing of deliveries

Trucking company dispatch centres use geospatial information along with other information (e.g., traffic flow, road conditions, weather, etc.) to optimize delivery efficiencies. Either in advance of truck dispatch or en route in real time, dispatchers provide drivers with instructions on which route to take from warehouses to destinations.

In-vehicle navigation

Automotive navigation systems use a GPS navigation device to acquire position data to locate the user on a road in the unit's map database. Using the road database, the unit can give directions to other locations along roads also in its database. As a supplement to GPS, when the signal is lost or multipath occurs due to urban canyons or tunnels, dead reckoning can be employed using distance data from sensors attached to the drivetrain, a gyroscope and an accelerometer.

Monitoring locations of trucks

Automatic vehicle location (AVL) is a means for automatically identifying and transmitting the geographic location of a vehicle, which is normally determined using GPS. Location data is periodically polled from each vehicle in a fleet by a central controller or computer and, in simpler systems, displayed on a map allowing humans to determine the location of each vehicle. More complex AVL systems feed the data into a computer assisted dispatch system which automates the process.

B.9.4 Urban transit systems

Planning optimal routing of buses

GIS is being used as a framework to create predictive models, such as those used to forecast travel demand and plan capital improvements. Typical GIS applications include: helping to understand travel demand characteristics in community, residential, and employment locations; segmenting ridership populations to deliver the most appropriate and effective transit service; and studying current ridership patterns and monitoring the effectiveness of existing service levels.

Monitoring locations of buses

Many transit authorities use automatic vehicle location for automated dispatch, vehicle re-routing, schedule adherence, and traffic signal pre-emption. AVL systems are becoming integrated into multifunctional systems such as Urban Traffic Management and Control (UTMC) Systems. By integrating the technology, a wide range of traffic management options become possible, including: route prioritization; traffic density monitoring; real-time public transport messaging; parking information; and general road conditions monitoring.

B.9.5 Taxi and limousine service

In-vehicle navigation

Similar to Truck transportation

Monitoring locations of vehicles

Similar to Truck transportation

B.9.6 Pipeline transportation of crude oil and natural gas

Planning optimal locations of pipelines

Similar to Water, sewage and other systems

Facilities layout and as-built location

Similar to Water, sewage and other systems

Asset management

Similar to Water, sewage and other systems

Balancing supply and demand and ensuring optimal market performance

Similar to Water, sewage and other systems

B.9.7 Support activities for transportation

Air traffic control

Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of traffic, and provide information and other support for pilots. Air traffic controllers use Automatic Dependent Surveillance – Broadcast (ADS-B) technology for tracking aircraft. ADS-B uses GPS-supplied target information from aircraft as the basis for air traffic controllers to determine aircraft locations.

Monitoring locations of vessels (AIS)

An AIS is an automated tracking system used on ships and by Vessel Traffic Services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships and VTS stations. AIS uses a transponder system that transmits information relating to ship identification, embedded GPS-derived location, vessel type, and cargo.

Vessel traffic services

Most harbour and port authorities have established vessel traffic services (VTS), which use radar, closed-circuit television (CCTV), VHF radiotelephony and automatic identification systems (AIS) to keep track of vessel movements. Because the ship's GPS position is embedded in these transmissions, all essential information about vessel movements and contents can be uploaded automatically to electronic charts.

B.9.8 Postal service and couriers and messengers

Planning optimal locations of postal outlets

Similar to Retail

Planning optimal delivery of mail/parcels

Similar to Truck transportation

B.10 Agriculture

Farm vehicle navigation

This application (often called auto-steer) uses GPS receivers integrated with the farm vehicle's steering system to automatically navigate the vehicle over a field. Typically configured with a touch screen computer in the vehicle cab, the application allows the use of map displays to show the location of the vehicle in the field. The farmer maps the boundary of the field in situ or virtually, and after the first turn the computer figures out where on the field the machine is located and how to steer to complete the field. The operator only needs to monitor the display and check that turns happen in the proper direction.

Crop yield mapping

Yield mapping involves collecting georeferenced data on crop yield and characteristics, such as moisture content, while the crop is being harvested using a range of sensors (e.g., flow sensors to determines crop volume harvested, moisture sensor to measure crop moisture variability, etc.) Various methods, using a range of sensors, have been developed for mapping crop yields. Farmers use GPS to map crop yield at harvest time through the technology built into their machinery. Agronomists and soil scientists can then develop prescription maps for the next spring planting season to optimize seed placement and precisely apply pesticides, herbicides and fertilizer.

Seeding and variable rate chemical application

GPS technology is integrated with prescription maps and spreading equipment for seeding, and variable rate application of fertilizers, pesticides and herbicides. Typical components of map-based variable rate systems include prescription maps on an in-cab computer, a GPS receiver that provides vehicle position, and an actuator that regulates material rates under the computer's direction. Strategies for varying inputs can be developed based on: soil type, soil color and texture, topography (high ground, low ground), crop yield, field scouting data, remotely sensed images, and numerous other information sources that can be crop and location-specific.

Agronomic decision-making

Farmers are deploying GIS technology to integrate field collected data with all kinds of other data, including base mapping, crop growth, weather, etc. for more effective agronomic decision-making. The powerful GIS analytical capabilities are used to examine farm conditions and measure and monitor the effects of farm management practices including crop yield estimates, soil amendment analyses, and erosion identification and remediation.

B.11 Renewable Resources

B.11.1 Forestry and logging

Forestry operations planning

Forestry companies use GIS in all phases of their forestry operations planning. They typically prepare management plans that outline cutting blocks for extended periods (e.g., 25 years, in five-year increments). The planning forester takes the five year ‘open blocks’ and groups them into an annual operating plan. Field staff then goes into the field with GPS data collectors and map out all the features that affect cutting in each block (e.g., stream buffers, protected habitat, etc.).

Harvesting operations

Harvesting machinery operators typically use onboard maps with block boundaries shown and GPS navigation that allows them to easily and efficiently discern harvest block boundaries and within-block critical features (e.g., wet areas, brooks, eagle’s nests, steep slopes, etc.) that factor into harvesting operations. The operator uses the system as his harvesting specs (e.g., when he reaches a stream buffer, it will flash on the system so that he knows not to harvest within that buffer zone). The system can also track the location of all machinery and the track logs can be used to update forest inventory and for operational quality control.

Materials transportation

GIS can be used to plan and design roads, track maintenance equipment, optimize wait times, keep track of shift change locations, harvesting machine operators, tree planting contractors, trucking contractors, etc. Logging trucks can be equipped with GPS to allow dispatch centres to monitor truck speeds so that contract trucking rates can be adjusted as necessary. If rolling speeds on routes are slower than average, grader operators can be dispatched to grade that stretch of road.

Mill operations

GIS and GPS can be used to support loading and delivering lumber and other wood products from warehouses and routing to customers. GIS is also used to help minimize wood costs to mills by optimizing which cut trees should go to each specialized mill (e.g., hardwood, softwood, etc.).

Reforestation

Plans for all the tree planting work orders can be made in the office using GIS. Quality control of planting can be expedited with mobile GIS applications and GPS data collection in the field. Similarly, data can be gathered for regeneration surveys, plantation survival surveys, permanent sample plots to measure individual tree growth, or inventory cruising.

Inventory updating

The inventory of felled wood can be compiled and tracked in GIS so that the people managing transportation of material know what kinds and volumes of wood are cut in each block. Dispatchers can provide truck drivers with instructions on how to get to a particular block to pick up a load, and the drivers can use in-vehicle navigation with GPS to optimize their routing.

Regulatory compliance reporting

Forestry companies have to submit geospatial data to the government at the block level (inside block boundaries they have to manage silviculture activities, writing site plans, etc.) as part of their business process to obtain harvesting approvals and update provincial forest cover data. They do different kinds of analyses with GIS to see how they are doing against regulatory targets (e.g., ungulate range, forestry impacts on stream flow, and directions on calculating equivalent clear-cut area, etc.).

B.11.2 Fishing, hunting and trapping

Fish finding

Commercial fishers are using sonars and echo sounders for fish detection, definition, and size distribution. There is typically a high degree of integration between the fishfinder system, marine radar, compass, and GPS navigation systems.

Monitoring fishing vessels

Fishing fleet operators use vessel tracking systems linked to major global satellite networks (Satellite AIS or Automatic Identification System technology) to accurately locate vessels and track their movements.

B.12 Non- Renewable Resources

B.12.1 Oil and gas

Exploration

Exploration work undertaken by petroleum geologists and geophysicists for conventional oil and gas extraction involves the use of a range of GI technologies. Areas considered to have potential are initially subjected to gravity, magnetic, passive seismic or regional seismic reflection surveys, where aerial or ground based platforms are navigated/positioned using GPS. Features of interest are subjected to more detailed seismic surveys, also involving positioning of measurement instruments. Mapping outputs are generated from the data collected in all cases and GIS is used to visualize data as digital terrain models of the surface and 3D models of the subsurface.

Development and production

Once a prospect has been evaluated and passes selection criteria, an exploration well is drilled to conclusively determine the presence or absence of oil or gas. Surveys of the wellsite location are required to produce the wellsite survey plans needed by regulatory authorities to process the application to drill. If the well is successful and a production well is established, surveys and plans are required for access roads and pipeline right-of-ways. GIS is applied by petroleum companies for many production purposes, including well and lease management, pipeline inspection and leak detection, directional drilling zone calculations, automating workflow processes using mobile technologies, managing production data, environmental monitoring, major incident management, etc..

Reclamation

Once a well has been abandoned, the company must return the land to its original state, which involves capping the well and removing equipment, cleaning up any chemicals, replacing soil and replanting native vegetation. There are often regulatory requirements to provide maps or plans of the reclaimed areas.

Regulatory compliance reporting

Under government regulation of the oil and gas sector, companies are required to undertake and report on environmental impact assessments, monitoring of sites and facilities, and major incidents such as gas leaks or oil spills. GIS is applied in integrating and analyzing the data and presenting the results of analyses for these purposes.

Land management

Geospatial tools are used to record and manage land inventory details and ownership history of land parcels (including mineral and surface ownership details). Use of GIS allows companies to see who owns the interest of various properties and monitor data about who owns what, who's acquiring what, and what and where they're drilling.

B.12.2 Mining

Exploration

Mineral exploration geoscientists use diverse types of datasets, ranging from geophysical and geochemical data to hyperspectral airborne and multispectral satellite imagery, to search for mineral deposits. GIS integrated with other specialized programs for image processing and CAD allows geoscientists to bring these datasets together and accurately calculate economic potential. Raster images, such as satellite or geophysical imagery, can be integrated and overlaid with vector data such as geology, faults, and sample information. GPS allows the positioning of conventional mineral location grids with greater speed and less impact on the environment by avoiding cutlines through forested areas.

Ore deposit definition

Mineralogical mapping uses hyperspectral imaging in a device called a core mapper to take an image every 2 nm of the visible and near-infrared spectral range to produce very detailed drill core mapping. Down-hole survey probes are employed to determine the orientation of the drill core so that 3D models can be developed. Software is then used to construct 3D models of mineral deposits to reveal their size and shape, so that optimum exploration and mining strategies can be devised.

Development and production

Mining companies use GIS to analyze mine data for engineering design and production management tasks such as seeing mines as 2D or 3D visualizations, generating reports and maps on site and keeping the corporate database current, and performing simple or complex analyses that helps stretch production dollars. Cavity monitoring systems provide 3D geometry of mine tunnels to help determine the shape and volume of rack that has been extracted.

GPS is also widely used for such functions as: mine site surveying; autonomous mining and operations control; remote control of vehicles and machines, including haul trucks and drilling equipment; vehicle tracking and dispatch; loading systems; material tracking along the supply chain; preserving areas of cultural heritage and high environmental value.

In underground mines, semi-automatic load-haul-dump (LHD) trucks are being employed in places like Australia and Chile (but not yet in Canada), which are tele-operated by a remote operator. Assisted navigation within mine tunnels from load to dump locations is accomplished with a combination of laser sensors and video cameras. Both active navigation, which relies on predetermined coordinates to establish the route a machine needs to take, and reactive navigation, which uses information gathered continuously by sensors (such as laser distance-measurement) mounted on the machine to determine its path, are employed. In Canadian mines, robots are employed that automatically take the drill-bit to where the hole is supposed to be on a pattern laid out by surveyors.

Reclamation

Proposals for a new mine typically include a mine closure and reclamation plan to return mine sites and affected areas to viable and, wherever practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities. Once a mine has been abandoned, the company must return the land to its original state, which involves removal or stabilization of any structures and workings remaining at the site after closure, and decommissioning tailings disposal facilities, quarries and open pits, pipelines and electrical transmission lines, etc. GeoRadar technology can be used to determine soil structure, particularly that of permafrost, or to monitor changes over time in underground contamination. With the availability of satellite imagery, mining companies can use GIS to show the size of tailing ponds, replanted areas, and how they are being monitored over months or years. There are often regulatory requirements to provide maps or plans of the reclaimed areas.

Regulatory compliance reporting

Under government regulation of the mining sector, companies are required to undertake and report on environmental impact assessments, monitoring of sites and facilities, etc. GIS is applied in integrating and analyzing the data and presenting the results of analyses for these purposes.

Land management

Geospatial tools are used to record and manage land inventory details and ownership history of land parcels (including mineral and surface ownership details). A spatially enabled approach enables: accurate plotting of land and mineral title data from corporate or government sources; visualization of competitor activity and potential stakeholder conflicts, tracking of regulations and obligations on active leases.

B.13 Retail

Planning store openings, closures and renovation, optimal locations and layouts, and product mix

Major retailers make extensive use of geospatial information and GIS applications in all operational areas. Common applications include:

- Real Estate/Store Development (e.g., site evaluation, market potential evaluation, trade areas analysis, competition analysis, customer profiling, store portfolio management, etc.)
- Marketing/Advertising (e.g., advertising effectiveness evaluation, focusing advertising campaigns, target promotion development, customer geocoding, etc.)
- Merchandising (e.g., ranking store locations by type and merchandise mix, analyzing market demographics, segmenting customers by lifestyle and product category, etc.)
- Retail Operations (e.g., analyzing markets, profiling customers, forecasting market potential, predicting consumer buying behavior, integrating in-store, catalog, and Internet market analyses, etc.)
- Supply Chain Operations (e.g., locating distribution centres (DCs), delivering/routing from DCs to store locations, enabling just-in-time scheduling, etc.)

These are good examples of the use of location intelligence.

Location-based services (LBS)

Location Based Services (or 'Location Services') can be defined as a service that delivers information about location to people who are using wireless, position-aware devices such as cell phones and PDAs; a wireless-IP service that uses geographic information to serve a mobile user; or an application service that exploits the position of a mobile terminal. The retail sector is a major user of LBS applications to drive customers to their outlets. Combining the location of customers with information about their previous buying practices, retailers can make targeted advertising (e.g., discounts, coupons, etc.) available to them on their mobile devices.

B.14 Financial and Insurance Services

Identifying and managing risk exposure

Geospatial information and GIS are being used primarily by insurance underwriters for accumulation management (i.e., helping to manage risk exposure by not insuring too many properties in one concentrated area). By bringing together the location of assets and hazards, insurers are better able to provide fair and competitive premium quotations, and at the same time evaluate the exposure to risk posed by their own insurance portfolios. Using spatial analysis, insurance underwriters can correlate natural hazard areas with historical claims to better determine an equitable pricing model.

Reducing auto insurance risk and rates

Telematics technology is being introduced with usage-based auto insurance plans by Canadian insurers as a means of more accurately assessing risk, and ideally, improving driver behaviour by providing an incentive for good driving. The technology involves some form of GPS tracking device that records driver behaviour, including such things as acceleration, braking and speed. In exchange for good habits, drivers get a discount, and accidents decrease and insurers have fewer claims to pay out.

B.15 Architectural, Engineering and Related Services

Engineering applications

GIS can support architectural and engineering services in numerous ways including identifying the best location of infrastructure projects, supporting geotechnical investigations, environmental impact assessments and other field studies. GIS helps manage the social, environmental and economic implications of different infrastructure projects (e.g., where best to locate wind turbines in a popular tourist destination in to minimize undue visual impact; most suitable location for a power transmission corridor taking into account geography, environmental factors, towns etc.) GIS assists in determining the most suitable location to build supported by 3D map analysis and soil samples. GIS also assists in developing an inventory of environmental flora and fauna to support regulatory requirements of environmental assessment. Base map data is overlaid with different data sets, related to the local habitat, and a visual representation of the area is then available to support informed decision making. GIS can also assist with reporting on environmental phenomena, and modeling the environment’s response to natural and man-made factors.

Surveying and mapping applications

Modern geospatial technologies are being applied routinely in survey practices to improve productivity and save costs. The use of GPS and electronic total station systems has dramatically reduced the amount of time for field data capture, and the use of mobile devices for storing and transmitting this information to the office has reduced the time necessary for data analysis and quality control checking, eliminating the possible necessity of returning to the field. GIS/CAD is used to speed up and improve the quality of plan preparation processes, and facilitates the submission of electronic plans where this is required. Planning of projects is also facilitated with the common use of open source data and tools like Google Maps/Earth. Mapping practices have also benefitted from modernization, with routine use of digital imagery (satellite, airborne, LiDAR, etc.) and photogrammetry for map production, reducing production time and increasing quality of outputs. Geomatics consultancy practices routinely use GIS and image analysis tools to produce a plethora of geospatial products and services, and sophisticated integrated information products and services that would not be possible without the availability of these tools and digital geospatial information.

B.16 Entertainment

Digital background production

Geospatial technology has become an integral part of the 3D entertainment industry. The availability of high-resolution stereo satellite imagery allows users to experience video games in a realistic 3D simulated world. 3D terrain models are used by game developers for map updating and creating 3D city models, a prerequisite for generating virtual reality environments. This lets users experience the thrill of racing on tracks through real cities, or to pilot fighter jets over vistas of cities, mountains, coastal regions and deserts. Similarly, 3D visualizations from geospatial images are being used in the film industry, with films such as The Matrix and Spiderman making extensive use of photogrammetry in constructing action scenes.

C. International Market

C.1 Europe

C.1.1 Supply-side

Geospatial Data Capture and Processing

NMCAs and Land Administration

All of Western Europe has well-established National Mapping and Cadastral Agencies (NMCAs) and organizations for land administration which have converted the majority of their paper records to digital and now operate fully digital processes for the maintenance of their data. The Dutch Kadaster has been particularly innovative in its maintenance of registers and provision of on-line access[281]. In Germany land administration is at the level of the Lander but records are fully digital[282] even though different systems are in use. Similarly in UK, although not strictly a cadastral system, all the records are digital and there is on-line access and a degree of automation[283].

In Eastern Europe the picture is patchier but all are moving in this direction with particular emphasis on land administration. Within the Western Balkans (Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, and Kosovo) there has been a major project INSPIRATION[284] funded by the EU to provide accurate, up-to-date, and accessible spatial data in local, regional and state administrative bodies in the region. In part this is to strengthen the land administration in these countries. This project is part of the INSPIRE initiative.

INSPIRE

INSPIRE (INfrastructure for SPatial InfoRmation in the European Union) is based on the existing infrastructures for spatial information established and operated by the 28 Member States of the European Union (EU)[285]. The European infrastructure has been enacted through the INSPIRE Directive which mandates 34 spatial data themes needed for environmental applications. Key components are specified through technical implementing rules. This makes INSPIRE a unique example of a legislative ‘regional’ SDI approach. So called *in-situ* (surface collected) spatial data is an essential underpinning for Copernicus, the earth observation and monitoring programme (see below). Given the fragmentation of spatial datasets, gaps in availability and lack of harmonization between datasets at different geographical scales across Europe, the European Commission realized the need for a European spatial data infrastructure.

The Directive is already having, and will continue to have, further impact on public bodies (e.g., central and federal government, government agencies and regional, local and municipal authorities) in all countries of the EU over the next few years. The geospatial data themes are as diverse as addresses, protected sites and transport networks and all are being supplied in a set of common data specifications to support European Union policy initiatives. The opportunity for improved interoperability and creation of shared web services, which it also provides, will be an influence on public sector growth but probably will not generate huge opportunities for commercial systems suppliers, particularly as INSPIRE is actively encouraging the use of internally developed open source solutions.

National Spatial Data Infrastructures (SDIs)

Many of the countries of Europe were already developing or had decided to develop national SDIs when the INSPIRE Directive came into European law. For example Denmark is actively developing a national SDI in tandem with INSPIRE. The development of the SDI is now covered by the Infrastructure for Spatial Information Act[286]. The Act, which came into effect in May 2009, transposes the regulations, principles and associated guidelines of INSPIRE into Danish law. It also empowers the Danish Minister for the Environment to extend the provisions of the Act to data other than those covered by the Directive where these can serve as a common basis for e-Government. Prior to the Act, the development of a Danish spatial data infrastructure had evolved through several stages involving bottom-up and top-down initiatives[287].

The United Kingdom has had various attempts at establishing elements of an SDI, but these did not really crystallize until the INSPIRE Directive was transposed into UK law. The UK Government published a strategy document at the time encompassing INSPIRE [288]. Economic conditions in UK subsequent to this have reduced the scope of the implementation to what is essential to comply with the INSPIRE Directive. Other opportunities highlighted in the strategy have not been pursued.

Open Data

The European Union Re-Use of Public Sector Information (PSI) Directive[289] was originally enacted in 2003 but recently revised to further open up the market for services based on public-sector information, by limiting the fees that can be charged by the public authorities (as a rule, at the marginal cost). Several member states have already made significant moves towards freeing up access to public sector data and in many cases this means online access, free at the point of use, under very simple and unrestrictive 'creative commons' licensing. States that have made significant moves in this direction with various types of geospatial data include Spain, Finland, Denmark, France and the United Kingdom[290].

Crowd Sourcing

Crowd sourcing is not a new concept. The names of neighbourhoods, roads and many other features have for many decades been provided by local people to surveyors who have then added them to maps. However, the social media revolution has changed the nature of the data that can be crowd sourced. Smartphones enable crowd sourcing of topographic features to accuracy levels comparable to the best efforts of NMCAs. The OpenStreetMap project[291] was initiated in the United Kingdom in 2004. The focus initially was on mapping the United Kingdom as a reaction to the Ordnance Survey, the NMCA which held a large amount of detailed geospatial data but restricted access to the data through the high charges it made. The OpenStreetMap Foundation was established in 2006 to encourage the growth, development and distribution of free geospatial data and provide geospatial data for anybody to use and share. The movement spread very rapidly across Europe and globally. The numbers of volunteers who collaborate in OpenStreetMap is very impressive as is the rate at which OpenStreetMap is being completed across the whole of Europe.

There is an element of this movement that is part of a wider counter-culture which is deeply suspicious of anything official. There is strong evidence that even where authoritative data is released for free and without reuse restrictions of derived copyright, the OpenStreetMap community would still often rather capture it themselves[292].

Imagery

Satellite and aerial imagery is widely available and widely used in Europe. There is an active space programme which is a major component of the Copernicus earth observation and monitoring programme that is coordinated and managed by the European Commission[293]. The space component is run by the EU funded European Space Agency (ESA) and the ground component by the European Environment Agency and the Member States. It has a budget of €3.8B for the period 2014 - 2020. Previously known as GMES (Global Monitoring for Environment and Security), Copernicus is primarily aimed at policymakers and public authorities to support: (i) the development of environmental legislation and policies; and (ii) emergency planning and management in the event of natural disasters.

Copernicus is made up of a number of systems which collect and process data from multiple sources such as earth observation satellites and *in situ* sensors which include ground stations and airborne and sea-borne sensors. The data is used to support a wide range of applications, such as environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism. As part of Copernicus, a whole series of Sentinel space missions are planned from 2014 onwards, for example:

> ***Sentinel 1*** *– all-weather, day and night radar imaging for land and ocean services for launch in 2014;*
> ***Sentinel 2*** *– high-resolution optical imaging for land services for launch in 2014; and*
> ***Sentinel 3*** *– ocean and global land monitoring services for launch in 2017.*

There is a strong commercial sector involvement in the manufacture of satellite imaging equipment as well the processing and distribution of imagery. Of these, Astrium[294], a subsidiary of EADS (Airbus Group) is the major European player with a turnover in 2012 of €5.8B and 18,000 employees in France, Germany, the United Kingdom, Spain and the Netherlands.

Geospatial Data Analysis and Presentation

The wide availability of geospatial data in digital form and the maturity of the market, especially in Western Europe, have meant that geospatial data analysis is widely used across the public and private sectors and, with ever increasing frequency, for consumer applications. There is an increasing demand for data analysis by sectors reliant on understanding consumer behaviour, such as retail, banking and insurance. These are increasingly turning to more comprehensive data analysis to support strategic direction setting, risk analysis, decision making and market differentiation. This demand is being met by an active and well-established software vendor community made up of a mixture of US-owned vendors (e.g., Esri and Pitney-Bowes) and European vendors.

Integrated Information Products and Services

There is increasing effort going into embedding location in the enterprise model, not just providing GIS solutions as an add-on (e.g., the Pitney-Bowes push on what they term 'Enterprise Location Intelligence'[295]). Google enterprise solutions are present in the market place with partners in most countries in Western and Southern Europe. There is less penetration in Eastern Europe however.

Location-Based Solutions

Mobile usage in the countries of Europe is very high. By 2009 there were 125 phone subscriptions per 100 inhabitants in the EU[296]. Smartphone adoption exceeds 60 percent in many European countries and is rising rapidly. Consumer mapping applications, such as Google maps, are heavily used and being incorporated into many travel and search applications. Total location-based services (LBS) revenues in the European Union reached €325M in 2012 and are forecast to grow to over €800M by 2017. At the end of 2012, it was estimated that about 40 percent of mobile subscribers in Europe were frequent users of at least one location-based service.[297] Mapping and navigation is the largest segment in terms of revenues, with local search and information services as the leading segment in terms of unique users.

The leading manufacturer of navigation systems in Europe is TomTom, a Dutch-based company. The company acquired TeleAtlas, another Dutch-based company, for €2.9B in 2008. TeleAtlas provides the digital maps and other dynamic content for TomTom and other devices[298]. Navteq, the Chicago-based company, is the other major data provider for LBS in Europe. It is now a wholly-owned subsidiary of Nokia, the Finnish communications and information technology company. Navteq and Nokia data is now being marketed under a unified brand 'Here'. Under 'Here' Nokia are moving to a cloud-computing model. Location data and services are stored on remote servers such that users have access to them regardless of which device they use. Location content is sold or licensed along with navigation services and location solutions to other businesses such as Garmin, BMW and Oracle. ‘Here’ also provides platform services to Windows Phone 8 smartphones and others running Android and FirefoxOS, but excluding iOS[299].

Geospatial Information Technologies

Major commercial GI technology players in the European market include EADS Astrium GmbH, Esri (through its regional distributors), Hexagon AB, and integrators such as BAE systems. As described at Geospatial Data Capture and Processing under Imagery, Astrium is a subsidiary of the European Aeronautic Defence and Space Company (EADS) that provides civil and military space systems and services amongst other services. Hexagon AB is a major technology group based in Sweden. Their main focus is on precision measuring technologies, including those for surveying and GPS. The Group employs about 12,000 people in 35 countries. Hexagon's products include GPS systems, total stations, sensors for airborne measurement and software systems. Its products are marketed under a number of brands including Intergraph, Leica Geosystems and ERDAS. All of these brands are wholly owned by Hexagon AB.

C.1.2 Demand-side

European Union

The European Commission and the agencies of the EU are large consumers of geospatial data. INSPIRE was initiated to promote, and gain the benefits from, a European-wide spatial data infrastructure. In particular, the need for environmental monitoring at a European level has meant that uniform and consistent thematic datasets need to be available.

There are a number of other major initiatives funded by the European Commission to foster the development and use of locational data. These include the European Union Location Framework (EULF) to create an EU-wide interoperability framework which is across all sectors[300]. This is mainly aimed at public administration to facilitate the use of INSPIRE data. There is also, somewhat confusingly, a European Location Framework (ELF) to deliver a pan European cloud platform and web services which will also build on the results of the INSPIRE programme[301].

Central Government

European central governments are major users of geospatial data, especially that produced by their own agencies, for the purposes of administration and the provision of public services. Many are developing spatial data infrastructures often in the context of INSPIRE as described previously.

Local Government

The local government sector in Europe has come under severe strain because of the Eurozone crisis, resulting in spending cuts which has driven the need for improved efficiencies and productivity. This has led to a stronger emphasis on self-service and self-assessment approaches to interactions with citizens and greater sharing of local area data amongst public sector organizations, including the voluntary sector.

In the UK, for example, the implementation of the Public Sector Mapping Agreement (PSMA) has made it easier to share data within the public sector and has tended to facilitate sharing of resources and services. The agreement[302] covers public sector organizations' use of geospatial data produced by the Ordnance Survey. The PSMA is centrally funded and available to any public sector body, including and primarily local authorities.

Building Information Modelling (BIM) and other 3D Initiatives

There is increasing interest in, and adoption of, Building Information Modelling (BIM) in Europe led by Finland globally with UK coming up a close second[303]. In June 2011 the UK government published its BIM strategy[304], announcing its intention to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on government projects by 2016. There remain many challenges, with interoperability of data and systems being the outstanding issue.

The EU is funding a number of projects for the development of 'Smart Cities' in the quest to make cities more sustainable and efficient[305]. Locational data, particularly 3D data, has a significant role in these projects

In the consumer market there is an increasing interest in, and demand for, 3D indoor mapping of buildings[306]. Applications for augmented reality are also creating a demand for 3D building information. Open Street Map (OSM) is beginning development of indoor mapping in Germany, Austria and France, for example[307].

Insurance

The insurance and re-insurance businesses are heavy users of geospatial data and tools, especially for risk management and accumulation management[308]. A diverse range of data sources are combined in the process of assessing risk (e.g., flood hazards[309]). With a 33 percent share of the global market, the European insurance industry is the largest in the world, followed by North America (30 percent) and Asia (29 percent). The largest insurance industry in Europe is in the United Kingdom. It manages investments amounting to £1.8T and contributes over £10Bin taxes to the Government. It employs around 320,000 people in the UK alone[310] about a third of the total European workforce engaged in insurance.

Within the General Insurance sector, at least in UK, the majority of firms use geographic products in some form at differing levels of granularity. A number operate at premise level with fully automated and integrated solutions sitting behind their own firewall while others use hosted or outsourced mapping visualization services to manage insurance underwriting and risk exposure. Point solutions may also be used within some departments such as marketing, claims processing, territory design, reinsurance and fraud management applications that combine software and data.

Within reinsurance, reinsurance broker and catastrophe modelling organizations, the use and take-up of location-based products is extensive and sophisticated. Primarily geo professionals create risk and catastrophe models, which are often published as web mapping services. The majority of location related activity is undertaken using desktop GIS and server technology along with geocoding and data services that are increasingly being delivered via the web.

Defence and Intelligence

Military expenditure in EU was over €190B in 2010, about 1.6 percent of EU GDP[311]. The most important military alliance is the North Atlantic Treaty Organisation (NATO), which co-ordinates military mapping activities between the 21 EU members of NATO. The requirements for geospatial data are clearly significant both from sources in the civilian sector and also from other military and intelligence sources.

Armed services across Europe are under pressure to do ‘more with less’[312]. Ironically, this is creating a growing market for geospatial products and services for defence, security and intelligence. Financial and operational pressures are producing a rapidly growing need to share information more quickly and accurately than ever before both within national forces and between NATO forces. Location information, through its pervasive nature, is a key enabler in allowing this to happen. Doing ‘more with less’ by sharing location information is accelerating the transition of the technology from what has traditionally been perceived as a particular specialization into general, mainstream, application. The effective user base for the technology is growing very rapidly.

While the market for geospatial data and systems in defence, security and intelligence is continuing to grow across Europe, it is very difficult to quantify and report. Much of the information about the use of the capability in this community is heavily classified. Practically every command and control, communications, intelligence, surveillance, search, analysis, reconnaissance, targeting, mission planning and training system currently in use has a location component. The increase in capabilities of mobile devices, maturity of Unmanned Aerial Vehicles (UAVs) and resolution of satellite imagery are all key developments for this sector.

One problem for the defence community is that systems have been acquired by many different departments and agencies through many different mechanisms. This creates challenges of interoperability and explains why the defence sector is at the forefront of work on international standards as part of the need to create a common operating picture (COP) for all units.

Land and Property

Depending on how Europe is defined, it has a population of about 500 million within the EU or over 700 million including the Urals and Caucasus in the east. Although there are no overall figures for the number of properties or land parcels in Europe, it is estimated run into the hundreds of millions. In most cases, except in parts of Southern and Eastern Europe, land is registered either at the municipal, administrative area or national level.

There is no European-wide conveyancing system for the buying and selling of property but there is a general trend to move to one-stop service portals that allow those operating in the property market to be able to find all information and government services that are relevant to a property transaction. Planning or building consents are handled differently in different European countries and are typically a local authority concern. However, in the UK (for England and Wales) a planning portal has been developed which allows the submission of electronic planning applications[313] albeit that they are still processed at a local level.

Telecommunications

3G coverage is still not as extensive or uniform as some mobile operators would claim. This means that there is still activity taking place analyzing the location of masts and understanding propagation models, which creates a demand for DEMs. 4G coverage is now being rolled out across Europe[314]. Setting up 4G networks requires new towers to improve coverage in rural areas and to support additional demand in city areas. Mobile companies are cash rich and are likely to find the money to invest in making smarter decisions on where to site additional towers for minimum outlay and maximum return. Such decisions require very detailed location data and complex spatial analysis. Cellular Expert, developed by a Lithuanian-based company, is an example of network planning software built on ArcGIS[315] that has been widely used in Northern and Eastern Europe.

The infrastructure providers for fixed telephony and broadband make extensive use of location solutions in asset management, to enable engineers to locate assets including underground ducts and overhead cables in relation to properties and road networks. The requirements for location data to support fixed broadband and telephony are largely similar to water and energy utilities in that they use it for asset management, including for fault response in control rooms but also for design of new schemes.

One example of the use of GIS software in the asset management of fixed telephony and broadband networks is by BT Group, the major UK telecommunications provider, which has around 15 million customers. BT uses Pitney Bowes' MapInfo integrated with BT's Oracle-based systems in the management of its networks and customer services[316]. Engineers using mobile applications are able to locate a property, view road networks and plant details, and then identify the location of underground ducts and individual cables within each site. Additionally, engineers are able to optimize routes between customers. The GIS component is also employed for emergency response, both for contingency planning and management and also in the location of callers to the emergency services.

Transport

Geospatial or location data, either sourced from data producers or generated by vehicles and mobile devices, is closely integrated into core business processes in the transport sector. Increased data volumes and a drive for greater integration are creating opportunities for improvements in spatial analysis to generate productivity gains and better tailor services to meet the needs of customers.

Following developments in the truck market, all the main car manufacturers are developing and equipping cars with inbuilt systems which will eventually provide a platform to support navigation, optimizing the performance of the car relative to the behaviour of the driver. This provides insurance telematics and processing of the information needed to make road charging viable. For example the German car manufacture Audi offers TMC Navigation[317]. In part, the requirement for these systems is being driven by the E112[318] initiative led by the European Commission, which involves the embedding of GPS-based devices to pinpoint the location of a vehicle in the event of an accident.

Road transport, and the associated logistical support, is by far the largest segment by value in Europe. However, it is important to recognize that air, rail and sea transport segments are also becoming increasing users of location information. For example, Poland has embarked on a programme of infrastructural development[319], a major part of this being transport infrastructure with particular emphasis on railway renewal and construction.

ETCS, the European Train Control System, is a signaling, control and train protection system that is replacing the many incompatible safety systems currently used by European railways, following the passing of several European Union Directives[320]. When fully realized, all line-side information will be passed to the driver electronically, obviating the need for line-side signals which at high speed are almost impossible to see or assimilate. As part of ETCS, train location will no longer be dependent on track-side transponders but will use satellite navigation and differential GPS based on EGNOS (see the Agriculture section for a description of EGNOS).

COSMEMOS (Cooperative Satellite navigation for Meteo-marine Modelling and Services) is another European initiative to use ships as distributed meteorological sensors to retrieve, via satellite or off-line, data on the sea surface[321]. This will provide an improved density of meteorological observations over the sea leading to improvements in the quality of local weather forecasting and 'nowcasting'. Loosely, this could be described as a form of ship-based crowd sourcing combining precision location with weather data.

Agriculture

Gross agricultural output of the EU in 2011 was over €15B[322], making this a key European industry. There is a great need to further improve productivity and increase European food security. Precision agriculture – the use of satellite navigation sensors, aerial imagery, and other location finding devices for optimum sowing density, fertilizer cover, spraying for diseases and pests and also crop monitoring and yield prediction – is set to play a key role in increasing food production and supporting greener agricultural practices across Europe. The benefits of using precision technologies include lower fertilizer costs, lower environmental impact, higher yields and time savings.

In its simplest form, Real Time Kinematic (RTK) systems based on GPS/GNSS and mounted in the cabs of farm vehicles provide accurate fixes for field boundaries and other features which can then be overlaid on maps showing, for instance, crop spraying patterns and yield statistics. Used most extensively at present by arable farmers, there is increasing use of RTK in field scale vegetables, and soft and top fruit.

Precision agriculture is also increasingly making use of remote sensed imagery from aerial and satellite platforms. These data can be used to manage application of fertilizers and nutrients, track the results of variable rates of seed application and provide soil moisture indicators. In addition, emerging applications include disease and plant stress detection, managing pesticides and invasive weed mapping. The availability of new satellite data with much higher resolution coming on stream over the next few years will offer further possibilities.

The European Geostationary Navigation Overlay Service (EGNOS) is a satellite based augmentation system (SBAS) developed by the European Space Agency and the European Commission. It supplements the GPS, GLONASS and Galileo systems by reporting on the reliability and accuracy of the positioning data[323]. It offers high precision (the horizontal positional accuracy is at the metre level) at low cost. EGNOS is free; signals are received in real time via three geostationary satellites. Equipment investment is small. Ten percent of tractors sold in Europe today are already equipped with GNSS receivers most of which are EGNOS-enabled. It has many applications in farming for both arable and livestock (e.g., livestock positioning)[324]. Other applications include for aviation, mapping, maritime and land transport (as discussed above).

C.2 United States

C.2.1 Supply side

Geospatial Information Capture and Processing

There are a very large number of relatively small geomatics companies in the US, involved in field capture of geospatial data for cadastral, engineering and many other purposes. The cadastral system in all states requires surveyors to be licensed and maintains a strong professional structure. Many are also involved in aerial imagery acquisition, which is still the only viable solution for large area project work. The United States is also home to some of the major worldwide players in data capture, including:

- **Trimble**, headquartered in Sunnyvale California, is one of the world leaders in positioning technology. It is best known for its GNSS products but also manufactures laser, optical and inertial positioning equipment and processing software. The group has a turnover of over US$2bn per annum[325]. Recent acquisitions include Sketchup, the popular 3D modelling software provider, and Gatewing, the UAV manufacturer. Trimble also has a joint venture with Caterpillar to develop advanced electronic guidance and control products for earthmoving machines in the construction, mining and waste industries. These diversifications are indicative of a trend for the larger US companies to diversify horizontally along the supply chain in order to gain greater market penetration.

- **Digital Globe**, which acquired GeoEye in 2013, is one of the key providers of commercial high resolution earth imagery products and services. This merger was one of necessity in the wake of the global financial crisis and cut-backs in federal spending. Digital Globe has its own satellite constellation of high-resolution commercial earth imaging satellites including IKONOS, QuickBird, WorldView-1, GeoEye-1 and WorldView-2. Together they are according to the company's own publicity capable of collecting over 1 billion square kilometres of imagery per year[326].

- **Faro,** with global headquarters in Florida, is a relative newcomer to the market, only formed in 2006, but the world leader[327] in the manufacture of laser scanning technology for geomatics and widely credited with making Lidar imagery capture affordable and increasingly widely deployed.

At the federal government level, the US Geological Survey is the national mapping agency for the United States. The agency has never produced large scale digital products on a national basis but focuses its efforts on relatively small scale products. The National Map data consists of elevations, orthoimagery, hydrography, geographic names, boundaries, transportation network, land cover and structures[328]. All these products can be viewed and downloaded for free.

Geospatial Information Analysis and Presentation

Information analysis and presentation is the mainstay of work by many commercial and public sector suppliers worldwide. Many of the products which sit on top of packages such as Esri and MapInfo (see below) can be categorized under this heading. These range from suppliers of tools for specific vertical market segments such as Accela[329] in government to horizontal technology enhancements for geographical search and metadata tagging such as Metacarta[330].

The US market is sufficiently large to support a range of companies operating in virtually all verticals. The needs of different organizations seem to be sufficiently diverse both functionally and geographically that there are few suppliers in any sector that seem to have achieved national dominance. One can also observe that most are relatively small because many organizations have chosen to invest in developing their own solutions using in-house staff.

The supply of horizontal technologies to perform particular functions is somewhat different. Many of the market leaders here operate on a worldwide basis. One of the most successful niche players is Safe Software. Although they are Canadian, they are worth mention as exemplars of this class of supplier. Safe's flagship product FME[331] uses the phrase 'connect, transform, automate' to describe its capabilities in taking data in a wide range of data formats, transforming it so that data structure and content can be efficiently manipulated and then output in an equally wide range of formats.

Integrated Information Products and Services

When looking at integration of geospatial with other types of information, some of the foremost exponents in the world are US-based companies:

- **AECOM** for instance is a US company that is one of the world's largest engineering, environmental, construction management and planning and design companies with a global turnover of US$7.3B. The company is large enough to have developed its own CAD and GIS best practice standards for use by its staff worldwide[332].
- **IHS** is the leading source of information, insight and analytics, headquartered in Colorado but operating worldwide. For the current year (2014) it has predicted revenue in the range of $2.17 billion to $2.23 billion. The company provides geospatial data products on a subscription basis to many large corporations across a wide range of industries but is particularly strong in the oil and gas market[333]. It is reported that a mid-range exploration company might typically spend $0.5M per annum with IHS for geological, cultural and well log data – much of which is available for free but from many disparate sources. Users pay for the convenience of the aggregation, analysis and quality control the company provides. The high value attached to such products contrasts strongly with the moves towards open and free data seen in some other sectors.
- **Critigen** is a major GIS consultancy company that advises businesses and governments worldwide on geospatial strategy and enterprise GIS implementation. This includes implementation of all aspects of a geospatial program, starting with data collection and working through geospatial processing, spatial analytics and intelligence, spatial application development, mobile solution development, hosting and cloud services.

Location-Based Solutions

The major player in this space is clearly Google, headquartered at Mountain View in the heart of Silicon Valley. In a recent discussion, a senior source within the Technology team at Google indicated that "about 30% of queries into the standard Google search bar are to find information about locations". This helps to explain Google's objective to create a spatial data infrastructure that is on a global scale and universally accessible. According to our source, Google's future direction will be centred on, amongst other things, wearable technology (Google Glass may by analogy be like the Wright Brothers' first plane), indoor positioning and solving problems surrounding online security. A major political concern is the 'balkanization of the Internet', with every country creating its own implementation of the Internet run by state controlled companies.

There are other global consumer mapping organizations headquartered in the United States, some of the strongest being Bing, Yahoo, Mapquest and relatively new entrant Apple. Bing (owned by Microsoft) has invested substantially in acquiring high resolution imagery, particularly for the largest cities in the world, in an attempt to distinguish its offering in location from that of Google. To further enhance its position it has licensed and now uses Nokia's mapping services[334]. It is also instructive to watch the development of Microsoft's relationship with OpenStreetMap (OSM), the crowd sourced alternative to Google for a consistent worldwide map base. Mapquest (wholly owned by AOL) is also a supporter and user of OSM[335]. The plays in this segment of the market come thick and fast. Apple Maps, an abject failure on first launch, appears to have some of the basics right this time and given the depth of their pockets, could invest very substantially in location, if they felt so inclined.

Turning to the applications market, it is estimated that there are about 100,000 geo-enabled apps on the Apple app store. The large proportion of these are designed and developed in the US. The variety of applications supported is the most impressive aspect of these examples:

- **Foursquare**, arguably the fastest growing location-based social networking business, is backed by Tim O'Reilly, the new media guru and publisher of many leading software titles. Foursquare describe their proposition as "check-in, find your friends, unlock your city". The idea of becoming the 'mayor' of your local Starbucks seems to have struck a chord with the wired generation and they claim 35 million users worldwide and over 10,000 developers using their API[336] . These volumes have allowed them to develop symbiotic relationships with Facebook and Twitter, so for instance, if you check-in on Foursquare, your friends are alerted to your location on Facebook.

- **ParkatmyHouse** is backed by BMW i Ventures with investment totalling US$100M[337]. The concept is simple; you are away from home and your driveway is unoccupied, you advertise this using this app and someone pays you to use it.

- **My Town 2 –** the producers, Booyah[338], claim 3.3M players for this app, which runs on a variety of mobile platforms. The concept is that you check-in (share your location) at real world places to 'unlock rewards'. You can also 'virtually buy and upgrade' your favourite shops, coffee outlets and collect rent when players visit them in the real world. Apparently it has been described by the New York Times as "location-based gaming meets Monopoly".

- **Location Labs –** this company provides a cloud-based API that enables developers to access, locate, and control mobile devices. Their main application is designed around knowing where your children are and controlling what they are doing[339].

Geospatial Information Technologies

As mentioned above, the largest GIS software suppliers are US-based, although they have global networks of distributors and subsidiaries. The main players[340] continue to prosper:

- **Esri** is very much focused on web GIS as its future direction. They see ArcGIS, the latest manifestation of their main product line, as being increasingly implemented as an online platform supported by basemaps and hosted user content. The Community Maps Program[341] includes a worldwide imagery layer available to users for free and Esri plans to increase the support for customers selling paid-for data layers through the platform.

- **MapInfo** – we understand that the product brand name, which has until recently been replaced by Pitney Bowes Business Insight (PBBI) in most geographies, may be set to re-emerge.

- **Autodesk** - appears to have positioned itself for a resurgence in the geospatial sector with its emphasis on it 3D, as indicated by its branding of their main product as AutoCAD® Map 3D. They are also placing a strong emphasis on intelligent-industry specific models and integration between GIS and CAD tools and data[342].

- **Bentley** – is a strong player in its core sectors of architects, engineers, and constructors (AEC) and utilities. Its solutions encompass the MicroStation platform for infrastructure design and modelling, the ProjectWise platform for infrastructure project team collaboration and work sharing, and the AssetWise platform for infrastructure asset operations[343]. $500 million is reported as its annual revenues.

Insiders tell us that, going forward, they see two very distinct parts to the location market:

i) GIS – this market is changing but it is essentially an evolution. The main trend is better access to data - making it easier to consume.

ii) Enterprise Location Intelligence - this is not GIS solutions for business but a much bigger 'prize' of embedding spatial thinking in the enterprise. Targets are Banks / Insurance /Pharmaceuticals / Manufacturers.

C.2.2 Demand-side

Federal Government

In 2011, revenues from the public sector led geospatial market growth and accounted for more than one-third of total revenue in the US according to the Department of Labor[344]. Its growing importance in federal programs is further underlined in the work coordinated by the Federal Geographic Data Committee (FGDC) referred to as the Geospatial Line of Business (GeoLoB)[345]. GeoLoB aims to refine the opportunities for optimizing and consolidating Federal geospatial-related investments to reduce the cost of government and, at the same time, improve services to citizens. There are 16 participating agencies; prominent amongst the leaders are the

Census Bureau, Environmental Protection Agency (EPA) and Department of Transport, and examples of their current status and future plans are summarized below.

The Census Bureau is arguably one of the largest users of geospatial information in the country. To paraphrase Timothy Trainor, US Census Chief of Geography, “the bureau produced 17 million maps in a single year to support the 2011 census – I think that gives us a right to talk on the subject of national mapping”. Geospatial information is used in many facets of their work such as for: creating reference and thematic maps to support censuses and surveys; developing standards and managing governmental units, administrative, and statistical boundary data; and building tools to help professionals and public users to visualize geographic data. Their Geographic Support System (GSS) project[346] is probably the most significant current initiative, focusing on ensuring a complete and updated address list for the country. This will contribute to improving the Master Address File/Topologically Integrated Geocoding and Referencing System (MAF/TIGER) in preparation for the 2020 national census.

The EPA has a wide ranging set of responsibilities including protecting citizens from significant risks to human health and the environment and ensuring environmental protection is an integral consideration in policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade. These factors are similarly considered in establishing environmental policy[347]. Geospatial information assists in understanding the complex interrelationships of natural resources and the human population. EPA has created a wide range of applications, many of which are available for public use[348]. These include:

- **AIRNOW** provides the Air Quality Index (AQI) forecasts as well as real-time AQI conditions for over 300 cities across the US;
- **WATERS** is an integrated information system for the nation's surface waters; and
- **EnviroMapper** is a tool that allows users to map various types of environmental information, including air releases, drinking water, toxic releases, hazardous wastes, and water discharge permits.

A recently released report by the Federal Highway Administration (FHWA)[349] explores the use of GIS for safety decision making and considers opportunities for FHWA to use this technology to improve highway safety. It found that while states are not generally using the full capabilities of GIS to support advanced safety data analysis, most are planning to enhance their use of GIS techniques in the future. The report also includes recommendations to help agencies through providing tools, marketing and training, and research.

State and Local Government

Much of the public sector activity which consumes geospatial information, technology and services is undertaken at the state or local level in the US. The number of enterprise-scale implementations, particularly at state and city level, is growing rapidly. The following are exemplars at each level to illustrate different approaches:

- **State of Hawaii –** The Office of Planning leads a multi-agency effort to establish, promote, and coordinate the use of geographic information systems (GIS) technology among Hawaii State Government agencies350. Significantly, the GIS program sits within the Department of Business, Economic Development and Tourism. The location of such coordinating offices tends to vary and this has a significant effect upon priority setting. In this case, the business focus of the parent department means that its performance is under corporate scrutiny by the Governor. There is a strong focus on elimination of redundant databases (generating efficiency savings) and the resultant data sharing improving decision making.

- **Kings County –** the County encompasses Seattle and has a population of 1.9m. It has long had a corporate approach to handling geospatial information and is instructive for its economic appraisal of the impact of geospatial information upon its operations. During the period measured from 1992 to 2012, total cost for GIS, including capital development, central operations and maintenance, and agency end-user costs were around US$200M but the overall net benefits of the GIS program were US$775 million. The study methodology devised by economic consultants Richard Zerbe and Associates[351] compared the costs to perform King County agency business functions both with and without GIS.

- **City of Philadelphia –** the City's focus on GIS is part of an orchestrated program designed to grow and support the City's innovation ecosystem. From a technology standpoint this is expressed as Mobile + Web + Social + Cloud + Open/Big/GIS Data. The centrality of GIS to the innovation strategy is manifested in a number of ways. Half of all data sets in the open data initiative OpenDataPhilly[352] are from the City's GIS; the Philadelphia redevelopment plan is underpinned by 3D GIS, and GIS is key to their plans to turn 311 centres into citizen engagement platforms with real-time mining of social media feeds to gauge community sentiment. Adel Abeid[353], the City's first Chief Innovation Officer, also highlights how other innovations over the next 5-10 years are expected to influence the City's growth and how geospatial information will play a part in them.

Defence and Intelligence

The Department of Defense (DoD) has been a long-time leader in the use of geospatial information. It was the main sponsor of work by Intergraph and Wild to develop very large structured databases, such a System 9[354]. Specialist system integrators such as Northrop Grumman[355] and Lockheed Martin were involved, for example, in their Combat Convoy Simulator[356].

As in other geographies there is little information in the public domain about their research activities; however, some high-level information is often shared at public conferences such as Geoint[357]. Sources suggest that investment in traditional operational and security focused applications is up but other areas are being cut. There is an emphasis on making geospatial 'pps' available as a 'commodity' with cloud as the preferred platform. The Snowden security breaches are expected to have an impact on information sharing in the community.

Social media trend analysis is a hot topic for federal agencies involved in homeland security. This is evidenced by the FBI issue of a Request for Information from industry on commercial tools to provide social media alert, mapping and analysis for their FBI Strategic Information and Operations Center (SIOC)[358]. The RFI reportedly requests "a secure, lightweight web application portal, using mash-up technology" with the ability to "quickly vet, identify, and geo-locate breaking events, incidents and emerging threats" and enhance its "situational awareness and strategic decision making."

Some less security-sensitive initiatives are where military and civilian activities interact. The DoD's Natural Resource Defense Council (NRDC) has released a proactive planning tool to help renewable energy site planning to avoid conflict with defence activities. NRDC's Renewable Energy and Defense Database[359] – or READ-Database – is a GIS database that captures essential DoD activities, including: DoD base, testing and training range locations; low-altitude high-speed military flight training routes and special use airspace; and an extensive inventory of weather and air surveillance radars within the United States.

Health

Health care is largely in the private sector in the United States and the largest companies work on a national basis. Most are GIS-enabled – integrating their 'Big Data' health and demographics databases with GIS tools to bring location into their predictive analytics.

Kaiser Permanente, one of largest health plan providers, is using GIS as part of their public relations in the Weight of the Nation campaign. As part of this web campaign for healthier living, they have created Community Commons[360], an interactive platform offering the nation's largest social determinants of health data engine, free GIS mapping capability, networking, and knowledge-building resources to encourage community activity.

Emergency Services

The Federal Emergency Management Agency (FEMA) mission is to support citizens and first responders to ensure that the nation works together to build, sustain and improve the capability to prepare for, protect against, respond to, recover from and mitigate all hazards. FEMA has defined a set of Emergency Support Functions (ESFs) which form a useful method by which to classify the use of geospatial information, systems and services. The main categories in which geospatial plays a key role and are not covered elsewhere, are:

- **Transportation** – this includes restoration/recovery of transportation infrastructure, movement restrictions, damage and impact assessment. By way of example, The MARVLIS system used by, amongst others, Lexington County, uses impedance and demand data to plan and monitor emergency vehicle deployment in real time.

- **Firefighting –** the use of GIS to provide a Common Operational Picture (COP) for sharing information between federal and local forces is critical. Recent wildfire response efforts in California[361] and Colorado[362] have brought the role of GIS into sharp focus.

- **Emergency Management** – some of the most critical aspects include coordination of incident management and response efforts, issuing mission assignments, resource and human capital identification and incident action planning. The New York Office of Emergency Management uses GIS amongst other functions to produce maps showing the distribution of non-English speaking residents to help plan where interpreters will be need in the event of an incident. After an emergency, GIS is used to help recovery workers make decisions about the priority order for demolition, plan reconstruction of an area, and determine which property owners qualify for grants or loan programs, among other recovery-related issues[363].

- **Search and Rescue –** includes life-saving assistance, mobilization of resources and operational management. Indicative of the state of the art here is the Search and Rescue Optimal Planning System (SAROPS) used by the National Coastguard service[364].

- **Public Safety and Security –** includes facility and resource security, security planning and technical resource assistance and support to access, traffic and crowd control. A study of the Ohio floods in 2008 showed that LiDAR data acquired for the whole state enabled one county to avoid having to evacuate its jail through accurately monitoring flood water levels and focused sandbagging effort, saving between US$4M and US$7.5M in a single incident[365].

Utilities

The US market is mature and in many cases enterprise-wide use of geospatial information has been in place for a number of years. The sector attracts a great deal of interest from all suppliers since implementations tend to involve significant volumes of assets, integration with other mission critical systems is essential, and consequently budgets tend to be large by comparison to many other sectors. Electric utilities tend to be the most demanding, due to the volume of assets, complexity of network structures and geographical extent. According to a recent US market research report[366] utility spending on GIS services, software, and tools will increase steadily over the next five years, reaching $3.7 billion worldwide in 2017. This report also provides an analysis of eight core GIS-related applications and their maturity:

- Applications already adopted by a majority of utilities, including automated mapping and facilities management, back office, and plant and facility design and construction systems;

- Applications experiencing wide-spread adoption over the next few years, such as asset, mobile workforce, and outage management; and

- Newly emerging GIS-integrated tools, such as advanced distribution management and advanced metering infrastructure (Smart Grid).

Intergraph and Smallworld have historically had the largest footprint in the sector, particularly Smallworld in the electricity market. More recently, improved support for network models in Esri's core functionality have resulted in greater penetration of their products, particularly through their partner Telvent[367]. Google has also started to increasingly appear in customer facing applications. The following case studies illustrate some significant aspects of the state of the market:

- **Duke Energy - Merger consolidation and integration of GIS into office functions –** The merger of Duke and Cineregy resulted in overlapping information technology organizations and systems. Duke commissioned multiple projects to consolidate the various systems into a single corporate standard based on the GE Smallworld Office Suite platform. The development partner was Ubisense[368].

- **Pacific Gas and Electric (PG&E) Mobile working –** PG&E wanted an Android-based mobile application for viewing their existing Gas and Electric Mapping System (GEMS) map files to support field crews performing pipelines inspections. Development partner Farallon[369] developed a customized mobile application capable of overlaying TIFF files onto Google Maps data to aid in utility location and demarcation for field crews locating and inspecting utility lines throughout California.

- **Texas - Water Utility Map Viewer-** The significance of this development is in sharing between utilities and other organizations involved in construction of public and private water assets. The Integrated Water Utilities Database (iWUD) Map Viewer[370] enables users to search and view retail water and sewer service areas for holders of Certificates of Convenience and Necessity (CCNs). The map viewer can search for boundaries of areas of responsibility or by a selected CCN number, water district name, city, county, zip code, address, intersection, and latitude/longitude. The site also provides links to other map viewers for individual utility providers.

- **San Jose Water – Mainstream integration –** This California utility is viewed as an industry leader in incorporating GIS data into its daily operations[371]. The data is stored in an Oracle Spatial database, which eases integration with the customer information system (CIS) and other mainstream applications, such as Google Earth. The system is also vital to regulatory reporting, reducing substantially the time spent on this activity and improving its quality.

Land and Property

GIS is fundamental to all parts of the land and property life cycle in the United States. Land records are managed and maintained as a local government function, with the notable exception of the Bureau of Land Management, which handles conveyancing of federal lands. Similarly, the management of planning control, referred to the US as zoning[372] is also a local government function.

The commercial sector is involved in all parts of the property life cycle and GIS is heavily used both for consumer sites and professional analysis. One of the longest established consumer property listing aggregators is Realtor.com[373] (established in 1996 and a GIS user from its inception), which claims to have the most accurate and comprehensive data in the industry, enabling consumers to search 98 percent of all for-sale properties listed in the U.S.

For real estate, GIS is most heavily used for functions including appraisals (valuation), managing inventory and market research. One of the largest providers of systems to this segment of the US market is Delorme[374].

Retail

Those concerned with what the retail world tends to call E-Commerce 3.0[375], suggest that the idea that everyone will in future use the 'bricks and mortar' store just as a showroom is fundamentally flawed. Jack Abraham, formerly with Ebay, divides the retail world into two fundamental types of products: bits and atoms[376]. Bits travel at near the speed of light, for atoms you have to go get the product or it has to come to you. The argument goes that disruptive technology, mostly generated by the Internet revolution, has biggest effect on products that can be transformed into bits:

- Music – file size is low, so it is fairly easy to download
- Video – bigger volumes but streaming allows you to start using almost immediately (10 percent of all internet bandwidth is used by streaming applications)
- Other 'bit' products include software and games
- Books – although this market is something of an anomaly, with ebook sales growth slowing in part because of price regulation by publishers[377].

The thesis is that: "any product that can be digitally transformed into bits will be – period, but any product that can't be transformed i.e. is inherently atoms (clothes being the most obvious example) will continue to be sustained by 'bricks and mortar' retailing." This is supported by eBay's research into where consumers spend their money. E-commerce is only 5 percent of total commerce and although it is predicted to rapidly grow, it will remain only a small proportion of the total retail market. However, cross channel commerce, characterized as online research but offline purchase is 30 percent of the total and growing much more rapidly.

The implications for geospatial information are enormous. E-Commerce 3.0 includes loyalty cards, check-in, self-scanning and check-out, in-store research, shopping lists, store locations, mobile commerce, promotions and coupons. Most of these innovations have a strong location element. Particularly important is that once a decision is made to buy, the consumer wants to know where they can buy it locally now. This is driven by the need for 'instant gratification'. It is also important to retailers to get people into stores as statistics show they spend on average US$150 more in-store than in an internet transaction.

Financial Services

For financial services organizations the most valuable asset is arguably their customer data, and consequently many of the solutions in this sector are focused primarily on being able to link this information to location and thereby make better decisions. Three key base-level applications are identified:

- **Analyzing local markets for targeted marketing –** this has traditionally been a desktop application but is rapidly moving to be a 'real time' app delivered to consumers on their smartphones.
- **Optimizing distribution networks –** looking at the entire supply chain in relation to customers and suppliers;
- **Enterprise-wide single view of risk –** primarily for the insurance industry, being able to aggregate risk based on location but also increasingly relevant to financial institutions particularly in relation to fraud detection.

According to one recent report[378] revenues for GIS in the sector are likely to grow over the period to 2016 by 5 percent worldwide.

Agriculture

The American Midwest was one of the areas where precision agriculture using location was pioneered. The latest generation of systems is being developed with backing from some of the largest US businesses in the market such as DuPont and Monsanto.

DuPont recently announced[379] that its customers will have access to an exclusive network of weather stations, including those positioned on growers' farms, for real-time local information, as well as environmental conditions in other regions and forecast data. Farmers will also be able to access electronic grain trading capabilities. The announcement comes three months after DuPont finalized a deal with farm machinery company Deere & Co that provides farmers a wireless transfer system for the data captured during routine ploughing, fertilizer spreading and other field activities.

DuPont is racing rival Monsanto Co. to capture market share in the precision agriculture arena. Monsanto sees farm-related data generating new profit streams by incorporating fungicide application timing, weather patterns and pest management into their analytics. Monsanto has also entered the meteorological data market by acquiring The Climate Corp, a weather data and modelling technology company.

Industry observers believe "*DuPont and Monsanto both see the future of farming and increased food production will be closely tied to sophisticated analyses of data to inform farmers on what types of seed work best in certain fields; where in a field they might want to plant more seed, or* *less; where they might have better moisture; more need for chemical treatments; and what type of weather events they might expect.*[380]"

Telecommunications

Geographical data is critical for network planning and management in the telecommunications sector. Major business processes and decisions that make heavy use of geospatial technology include:

- **Front office support –** service coverage area and store location insight. Visualization of service areas and store locations overlaid with availability of services such as 4G and local charges are essential, enabling sales staff to provide accurate information to potential customers.

- **Marketing –** customer profiling using demographic and location information helps find new high value prospects and optimize engagement with customers at the right time with better targeted offers.

- **Network planning** – providers need to overlay many different factors that are innately geospatial, such as demographics, planning, topography and meteorology, in making key decisions about expanding their networks or upgrading existing infrastructure.

- **Operational Network Management –** telecommunications providers need to monitor network performance and resolve outages quickly and easily. Seeing where assets are located and linking this to operational data from transmitters, switches and sensors helps optimize stability and uptime.

- **Tax jurisdiction/assignment management –** a particular issue in the US is the complexity of dealing with over 10,000 state and local tax jurisdictions. Geospatial information can help telecommunication providers meet this challenge cost-effectively by mapping subscribers and calls against these administrative area boundaries.

Games Software

The crossover between geospatial and games software, as typified by Grand Theft Auto and SimCity, has been long promised but can increasingly be seen as an important reality as illustrated by the following examples:

- **3D High Resolution Real World Data –** Real world location data is in many cases now cheaper to create and use in gaming than developing simulated environments. The game Driver San Francisco[381] for instance, claims one of the biggest driving infrastructure datasets currently available (with 208 miles of roads). Many areas were altered to make the driving experience more fun and more fluid, but it is described as "decidedly real-world San Francisco". It is likely that multiple real world environments will become available to players of many different types of games over the next three years. These environments may, as with Driver San Francisco, be separate products but are more likely to be available as in-game purchase options.

- **Gamification –** The concept of gamification is the use of the processes and techniques of gaming, sometimes referred to as game mechanics, to solve problems and engage audiences. Some of the key techniques used in gamification include:
- achievement badges – being the 'mayor' of the local coffee shop by being their most frequent customer over a set period;
- leader boards which indicate those users who 'check-in' most frequently;
- systems for awarding, redeeming, trading, gifting, and otherwise exchanging points, which for instance, extends the 'mayor' concept by offering them a free coffee on their next visit; and
- Direct peer to peer challenges.
- **Using GIS to Generate the Game Environment –** In some senses, this is a variation of the 3D real world data concept above and is illustrated by Esri's recent acquisition of a company called Procedural for their City Engine product. City Engine[382] is capable of producing large areas of realistic 3D cityscapes using a series of design templates rapidly with existing information such as a basic road network. The online demonstrations include a case study of creating a 'destroyed city' such as used in first person shooter (combat) games.
- **In Game Spatial Analysis –** Another developing area is the use of GIS to provide functionality to aid gamers in the virtual world, in the same way that high-end users employ spatial analysis. Massively multiplayer online role-playing games (MMORPG), such as World of Warcraft, with over 10 million subscribers worldwide, are played on a wide canvas with complex game mechanics and rule engines. The tactics required to be successful are analogous in many respects to those required in the real world and can be enhanced using the same tools. We anticipate that GIS-like functionality will start appearing in the next generation of MMORPGs.

Renewable Resources

Forestry is a well-established and sophisticated user of geospatial information and tools in both the public and private sector. Esri runs a dedicated conference for the sector[383]. Examination of the topics covered reveals the diversity of usage spread throughout the planning, production and business processes of a typical forestry organization, including:

- **Forest management –** Geospatial information and systems are becoming an essential part of a new generation of decision support tools for integrated forest management used in all business processes.

- **Logistics and Scheduling –** Sophisticated routing and tracking of logging vehicles, prioritizing haulage road grading, and optimized siting of equipment are all important geospatial applications. The effect upon the environment, particularly water sources, in these processes is of increasing importance.
- **Field mobility –** The use of geo-enabled tablets and smartphones for disconnected editing in the field is increasing.
- **Modelling, optimization and analysis –** The use of GIS to model the forest and of spatial analysis to optimize planting and harvesting is routine. The tools are also increasingly used to visualize the landscape effects for tourism impact assessment.

Non- Renewable Resources

The oil and gas sector has moved on from using GIS as purely a geological and seismic survey and mapping tool. The views of senior staff in some of the larger players in the market suggest that in upstream and midstream operations geospatial applications and information are used in most business units, with centralized data management provided by a dedicated team of GI analysts and specialists based in the IT function. Both analytic and presentation capabilities of GIS are used, with prospecting/exploration, appraisals, land management, drilling operations, asset locations and health and safety being at the forefront. The demands of increasingly important fracking[384] operations are similar to conventional operations with the exception of greater emphasis upon sources and transport of the large volumes of water required in the fracking process and the treatment of the waste produced.

Big data predictive analytics is the top research priority, along with 3D surface models using increasing quantities of LiDAR imagery. Outside the technology realm, information security is becoming a major concern with increasing numbers of external cyber attacks on data centres and data sovereignty restrictions. An increasing number of countries are unwilling to allow oil and gas industry data to be transferred outside their borders.

The United States has many large scale open pit mining operations for many different minerals. For a detailed treatment of this subject, see Australia.

C.3 Australasia

C.3.1 Supply-side

Geospatial Data Capture and Processing

Australia, New Zealand and many of the Polynesian islands have fixed boundary systems underpinning land tenure and so are relatively well endowed with cadastral surveyors who also undertake data collection for engineering and other property-related surveys. However, a recent study to determine future demand and skills gaps in Australia[385] identified an increasing shortfall of qualified staff due to forecast levels of construction activity and for the replacement of existing employees retiring.

There are a number of very well established and capable companies undertaking aerial (and LiDAR) mapping, many of whom are now offering Data as a Service (DaaS) access to up to date or time series large scale orthorectified image libraries combined with street and parcel overlays. A relatively new entrant into the market, Nearmap[386] is illustrative of this type of service, attractive to real estate and construction companies because of the transaction-based pricing model.

Neither Australia nor New Zealand has their own satellite imaging capability. Australia is a major user of Earth Observation Satellite (EOS) data, but has very little control over supply. In 2010 there were government programmes totaling more than AUD$1.3B in annual expenditure that had an explicit dependency on EOS. Most of the data utilized are sourced from public-good missions flown by major space-capable providers, such as USA, Japan, China and Europe[387]. New Zealand has recently discontinued funding of its Government-coordinated Kiwi Image[388] programme using imagery captured by DigitalGlobe using the Quickbird II satellite. However, it is known to be in discussion with other providers.

Particularly attractive to the regions are the stereo-capable constellations which offer high resolution digital elevation model (DEM) capabilities. The Pleiades-HR (High-Resolution Optical Imaging Constellation), two-spacecraft constellation launched by CNES (Centre National d'Etudes Spatiales - the Space Agency of France) with 50cm resolution[389], is illustrative of the capabilities of this latest generation of sensors.

In addition, the region has one of the most complete GNSS networks in the world. Geoscience Australia cooperatively operates and maintains a network of approximately 100 Continuously Operating Reference Stations (CORS) across the Australian region and the South Pacific[390].

Geospatial Data Analysis and Presentation

There are a significant number of companies offering specialist spatial analysis and data management services, either using software tools offered by the GIS, photogrammetric and image processing package providers or ‘in house’ developed software. The provision of services tends to be segmented by vertical markets with engineering consultancies, such as BECA[391] and Sinclair Knight Merz[392], well represented in mining, construction, transport and property sector, whilst specialist scientific consultancies tend to deal with environmental and geotechnical projects. However, many public sector and larger commercial organizations will tend to have a small ‘in-house’ team often as a corporate resource, undertaking analysis and presentation work for a variety of internal customers.

Integrated information products and services

The business systems that most organizations regard as mission critical are their Enterprise Resource Planning (ERP) package, of which SAP is one of the most successful examples and Customer Relationship Management (CRM) systems such as salesforce.com and Microsoft Dynamics. The third leg of this set of 'foundation' application types is business intelligence and analytics, which supports 'data mining' of actionable information from the growing volume of data (big data) stored by large corporations.

There are a number of organizations based in Australasia specializing in providing services for integration of geospatial information and business systems. One example is Cogha, based in Melbourne, which has not only achieved success working with large corporates in Australia but also penetrated the Chinese market, winning awards for its Digital City project in Xinjiang[393].

Pitney Bowes MapInfo is also repositioning itself in this market with what it dubs Enterprise Locational Intelligence[394]:

"By integrating customer data quality capabilities with rich location intelligence, you can apply sophisticated geocoding and spatial analysis to reduce risk, increase customer satisfaction and streamline operations."

The rationale for this focus on high integration / low geospatial functionality is recognition that for most enterprises, geospatial has to fit into the existing IT architecture, not the other way around.

Location-based solutions

The migration of the location-based app revolution from Silicon Valley to Australia and New Zealand has been relatively swift. Most of the more obvious mobile apps in personal navigation, retail and property have either been extended to cover the urban areas of the continent or re-implemented by local companies. One particularly innovative development studio based in Melbourne is Dreamwalk. One of their recent successes was working with Coca Cola on the Urban Treasure hunt promotion for their Pump water product launch[395].

Australia has taken on the concept of the now defunct Where 2.0 conference, by successfully staging a similar concept conference called Geonext. Geonext[396] is an 'alternative' conference now in its third year that features a hackfest, lightning talks from innovation start-ups, plus presentations from key opinion formers in the mass market geomatics field. The format is popular and attracts many delegates from developers and entrepreneurs with little knowledge of the field.

Google has a strong presence, particularly in Australia. Their model, as in other geographies, is to work with local business partners to supply large corporate customers with solutions based on the Google Earth or Maps platforms. Principal amongst these is GNIS, which has implemented several data platforms for state governments, such as Queensland spatial globe, based on Google Earth technology[397], as well as solutions for large utilities.

Geospatial Information Technologies

The mainstream GIS companies are all very active in Australasia. They normally have distributors or subsidiary companies based in Australia which service the whole region. Some, including Esri (Eagle Technology) and MapInfo (Crichlow) also have a permanent presence in New Zealand. Intergraph, now including ERDAS, tends to focus in this region on public safety and security, defence, government and utilities sectors.

However, in Australasia this segment is not just about distribution of European or North American developed software. Trimble, for instance, has one of their main research and development centres near Christchurch in New Zealand that employs a reported[398] 230 staff, and Esri's ArcPAD mobile software platform development team is based in Australia.

There are also plenty of new start-ups stimulated by the growth in open data. A good example of this is New Zealand-based Koordinates. Koordinates software is the technology base for the LINZ Data Service, the portal through which Government geospatial open data is made available. The founders of the company are also heavily involved in OpenStreetMap in New Zealand.

C.3.2 Demand Side

Central Government

Australia has a three-tier Government structure – federal, state and local. The federal government in Canberra, often referred to as the Commonwealth Government, is responsible for defence, immigration and other functions that are consistent for the whole country. A number of semi-autonomous public sector organizations such as GeoScience Australia and CSIRO are also controlled by the federal government. New Zealand and the Polynesian islands have only central government and local government structures, although New Zealand has regional councils with responsibility for environmental issues.

The use of geospatial information and technologies are widespread within central government. Geoscience Australia has a wide role in providing national base data, including national geographic information, but its remit also extends to natural hazards, environmental issues, vegetation monitoring as well as Earth observations from space[399]. The organization has been a pioneer in the supply of open data and a recent report[400] commissioned by the Australian National Data Service indicates that their open data initiative has an estimated benefit to cost ratio (in terms of lost revenue) of an impressive 13:1. They have also recently released a new data discovery and delivery system, based on Google Earth[401].

An important part of the central government infrastructure is the Cooperative Research Centre (CrC) program, an initiative for forming collaborative partnerships between publicly funded researchers and industry. The spatial industry in Australia and New Zealand has its own dedicated organization, Cooperative Research Centre for Spatial Information (CrCsi)[402], which conducts applied research focused particularly on addressing market failures and supporting the development of critical spatial data infrastructure.

ANZLIC – The Spatial Information Council[403] is the peak intergovernmental organization providing leadership in the collection, management and use of spatial information in Australia and New Zealand. ANZLIC's role is to facilitate easy and cost effective access to the wealth of spatial data and services provided by a wide range of organizations in the public and private sectors. ANZLIC has in recent years taken a lead in the development of common spatial data interoperability specification standards and in helping state and central government bodies define future strategy.

The final part of central government to recognize is the Office of Spatial Policy (OSP)[404], moved by the new Government elected in 2013 under the Department of Communications. It is a central policy unit, responsible for facilitating and coordinating spatial data management across Australian Government agencies.

The equivalent body in New Zealand is the Geospatial Office (NZ GO)[405], housed within Land Information New Zealand (LINZ). NZ GO is taking the lead in accelerating the creation of a regional Spatial Data Infrastructure (SDI) as part of rebuilding the Canterbury area following the devastating earthquakes in Christchurch during 2010 and 2011. The 3D cities element of this project is particularly impressive and GIS was heavily used in the creation of blueprints for reconstruction. The video fly through used to brief citizens and potential investors is worth viewing[406].

State Government

There are six states in Australia plus two Territories that operate in most respects like states. The states have large degrees of autonomy with law making powers and devolved control over a wide range of functions, including land registration and planning. The administration of land in Australia is founded on the Torrens system — where land ownership is based on a single title document registered with the government. While all State and Territory land ownership registration frameworks are based on Torrens, each jurisdiction maintains its own Land Registry with variable procedures and processes[407]. As a result of this, datasets are managed by diverse statutory agencies according to the needs of the local context and history. For example, land registries tend to be responsible for the cadastre but planning, land use and heritage datasets may be held by planning departments; and environmental datasets may reside within natural resource departments[408].

One of the best developed spatial information systems in the Australasia region is Landgate[409] in Western Australia. Landgate is a statutory authority with commercial powers and the primary source of land information and geographic data in the state. It was created to provide a single point of access for land related transactions by bringing together various land datasets such as cadastre, aerial photography and land ownership information. In addition to maintaining Western Australia's official register of land ownership and survey information, it is also responsible for valuing the state's land and property for government interest.

A comprehensive review of the state of the automation of the full property life cycle, including review of land administration, cadastral survey and planning systems can be found in the recently published LINZ report on Better Property Services[410]. In New Zealand, the Landonline[411] system for land administration has been in operation for more than a decade. It is well thought of by its users but is running on legacy hardware and software slated for replacement by a new platform referred to as the Advanced Survey and Title System (ASaTS).

Local Government

As in many other jurisdictions, the use of geospatial information in local government extends back many decades and is now a 'business as usual' core component of the systems of most authorities.

Auckland Council in New Zealand is an exemplar of local government best practice in Australasia. The council was created by the amalgamation of seven councils in 2010 and the use of geospatial information is underpinning the rationalization and integrated planning for the future of the city and its environs through the Auckland spatial plan[412]. The plan is designed to guide Auckland's future over the next 30 years and tackle issues such as transport and housing shortages; giving children and young people a better start; creating more jobs and protecting the environment. The geospatial team of over 70 staff delivers GIS applications, manages and procures geospatial data and provides high-end analysis and reports. They have developed the Auckland map viewer[413] to provide access to information including property and rates information, including valuation data, aerial imagery, property and road boundaries for both Council staff and members of the public. Further details of GIS developments can be found in the presentation by GIS manager, Ian Smith to the ALGIM conference in 2012[414].

The recent GIS in Local Government benchmark report[415] provides insight into the state of this market segment in Australia. The majority of participating councils in the survey on which the report is based are investing between AU$50,000 and AU$100,000 in GIS annually, with larger ones (7 percent) estimating spending of over AU$500,000 annually. Respondents indicated they use GIS technology for multiple business purposes, with almost 90 percent using it for asset management, customer service, and planning and analysis.

The report also cites development such as in Melbourne City Council, where field work activities are being transformed with 3D data collection. Staff now conduct a virtual 'fly through' of a property; pan up and down the street to examine assets; and understand how a proposed home extension or property development may impact the residential streetscape, without leaving the office. Not only does this produce time efficiencies, it also leads to greater levels of occupational health and safety.

Defence and Intelligence

As in other geographies, details of current developments and future direction are not normally publicly available. The defence forces of New Zealand and Australia are however heavily involved in working with a number of the smaller Polynesian states to help update their mapping and charting information. In particular, the growth of large leisure cruise ship activity between New Zealand, Australia and the island of Polynesia has increased the need for charts to be brought up to modern standards, particularly in the approaches to the ports. Hydrographic work, led by LINZ, is now being planned for a number of the islands[416].

Emergency Services

Australia has recently been badly affected by a number of natural disasters including forest fires affecting many areas and flooding, particularly in Queensland. The use of GIS by emergency services in responding to incidents is well established, with most police and fire services having enterprise-wide systems linking command and control centres to GPS-enabled vehicles and back office systems.

In the recent Queensland floods, Brisbane was particularly badly affected and the Brisbane City Council was recently recognized[417] for the contribution of its interactive, online flood map which was widely used before, during and after the Brisbane floods. The system compiled flood data from across the city and surrounding areas – such as flood peaks, road closures and evacuation centres – onto a map to provide a comprehensive, real time picture of the flood. This flood map was a key information source for emergency response teams guiding recovery operations and supporting critical decisions. It was also accessed by more than three million members of the public at the height of the crisis, to view the scope of damage and access important updates.

GIS has also been used in predictive analysis for forest fire spread. Project Vesta, led by the Department of Environment and Conservation Western Australia, is particularly innovative[418]. The toolbox combines many complex GIS operations into a single integrated process combining data such as vegetation, fuel age, weather, and digital elevation derived slope to calculate a potential fire rate of spread and potential fire intensity output that is adjusted for slope and fuel moisture content.

In New Zealand, the fire service has been one of the pioneers in the use of GIS for emergency services[419]. The range of systems they operate and interoperability with other services such as civil defence, police and ambulance services is truly impressive. It is currently building a 3D GIS for mapping of business in office blocks and individual households in order to improve knowledge for fire fighters arriving on-site during incidents.

Health

The Epidoros project in Queensland[420] is one of a number of health observatory projects that are currently underway in Australia that make heavy use of GIS data. Epidoros is a social enterprise led by Queensland's Griffith University, in partnership with the Logan-Beaudesert Health Coalition (LBHC), the Australian Research Council and Queensland Health. In 2011-12, Epidoros implemented an award-winning web-based tool, named the Health Decision Support System (HDSS), which is aimed at professionals in health policy and planning. The database they have created has recently been used to show the location of elderly people in relation to public transport, after hours GPs in relation to population in high risk, and the proximity of junk food outlets to schools.

Environment

Environmental protection is a particularly high priority throughout the region. The Secretariat for the Polynesian Regional Environment Programme (SPREP)[421] has been a particularly strong influence on spreading the use of GIS. It has established systems in many of the island nations designed to monitor biodiversity and climate change, protect coral reefs[422], and enhance waste management and pollution control.

In New Zealand, regional councils have been established to coordinate environmental management. These are amongst the most active users of geospatial technology, best illustrated by the IRIS project. IRIS is a collaboration between six of the 12 regional councils to manage core regional council functions, including the regulatory areas of consents, compliance, biosecurity and enforcement with GIS at its core[423].

Utilities

In Australia and New Zealand, water and wastewater are managed by public sector entities. One of the most advanced is South Australia Water, the first utility in Australia to fully capture and store the entire water and wastewater network on a GIS. They have detailed geospatial data for 32,000 kilometres of water and wastewater mains, together with water and wastewater treatment plants, reservoirs, pumping stations, tanks, valves and maintenance holes. This data has been integrated with records of more than 800,000 land parcels and over one million digital images of assets[424].

The electricity sector is equally advanced in their use of GIS technology, as illustrated by the GIS-enabled system recently installed by TransGrid. TransGrid is the owner, operator and manager of the high voltage electricity transmission network throughout New South Wales with over 12,000 kilometers (7,500 miles) of high voltage transmission lines. They rely on a range of third party information sources to access information on natural hazards affecting their infrastructure and have now installed a web-based hazard monitoring system that delivers real-time analysis of risks by integrating feeds from these sources. The system, called Indji Watch[425], predicts the future movement of threats such as storms and bush fires to determine when assets may be threatened. It automatically generates early warning notifications of approaching threats to asset owners on devices (including mobiles) and triggers automated responses to prevent or control damage resulting from a hazard based on pre-defined rules. For example, it can cut power supply to an asset, switch on sprinklers, sound alarms, or switch on emergency generators[426].

Retail

The use of geodemographic information by retailers both online and for 'bricks and mortar' in Australasia is similar to other developed nations. Typical uses include customer profiling and mapping, segmentation and modelling, prospect selection, customer database enhancement to understanding more about existing customers and consumer insight, understand market potential and use in strategic planning, setting sales targets and evaluating performance[427].

Transport

Logistics applications of route optimization are now commonplace in Australasia. The trend towards building such applications into the telematics of modern vehicles will ultimately mean this is no longer a GIS application, although there will probably still be work for Tom-Tom and maintaining the current data for the network for some years to come.

Ports and airports are also becoming heavy users of GIS recognizing that such systems offer them a platform for combining various sources of information more easily than CAD. The Westralia Airports Corporation (WAC), which runs Perth airport, is an example. WAC is a significant service provider, managing the power, gas, sewer, water, fuel, drainage and communications. The GIS administrator reported the change in workflows it has enabled:

> *"Before we implemented GIS, all spatial information requests were submitted to the Design Office (DO) to generate the relevant maps and data. This meant that departments did not have real-time access to information and the DO could become bogged down fulfilling the myriad of simple requests rather than utilizing their skills for design and spatial information management".*[428]

Architecture, Engineering and Construction

One of the most impressive Smart City initiatives in the world is the *Sydney Down Under* project. This brings together into a single database, utility infrastructure including water, wastewater, telecommunications, electric power, rail and subways, and roads and highways, together with buildings (above and below ground) including interior spaces and occupants. It integrates 3D BIM and geospatial and 2D data[429].

A 'Trans-Tasman' project with the potential to solve some of the institutional issues inherent in the smart cities arena is the Virtual Australia and New Zealand Initiative (VANZI). The objective of VANZI is to address both the technology issues and legal constraints implicit in the development of a new National ‘*infrastructure*’: a 3D computer model of the real world - for use in all ‘property-related’ activities. This ‘virtual’ infrastructure will deliver huge dividends in the form of $billions in productivity savings across the property sector by allowing all people engaged in it to work collaboratively, using ‘authoritative’ data, without duplication and re-processing – reducing errors, time and cost in the process. It will facilitate ‘workflow’ by eliminating ‘search’ and ‘validation’ of data – that will instead flow automatically to those who need it, when they need it[430].

Agriculture

The use of GPS and GIS to increase efficiency in agricultural production in Australia is not a new story and can be characterized on the Gartner hype cycle[431] as being on the plateau of productivity (i.e., it is an accepted tool which is widely adopted and routinely produces significant economic benefits).

CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency and one of the largest and most diverse research agencies in the world. It has a dedicated group which provides GIS software tools[432] to assist farmers to make better use of spatial information. The tools customize commercially available GIS to enable consultants and individual growers to estimate spatially variable achievable yields and to calculate appropriate fertilizer recommendations. The recommendations may also be fed to Variable Rate Technology (VRT) fertilizer application equipment.

Renewable Energy

The amount of sunshine received in most parts of Australia is very high. The assessment of suitability for solar panels is largely a geospatial problem and recently the Australian Renewable Energy Agency (ARENA) has sponsored the creation of a series of interactive map based tools[433]. The tools incorporate information on how much Photo Voltaic (PV) is currently installed in Australia including estimated electricity generated each year and in which locations (identified by postcode) and live performance data covering all main climate regions. The tools will undergo further enhancements during 2014, including the addition of a GIS-based tool for assessing PV potential in urban environments, accounting for available roof area, tilt, orientation and shading.

In New Zealand, geothermal is a significant part of the country’s sustainable energy policy. In 2014, the proportion generated from geothermal was almost 15percent, and overall 74 percent of electricity was generated from renewable sources[434]. The international engineering consultancy Arup are one of the most advanced in this field and make heavy use of GIS to evaluate the criteria to meet planning requirements for exploration and production boreholes and power plants. They also use GIS to assist in site suitability assessment and planning to aid stakeholder consultation and prevent project delays[435].

Non-renewables (Open cast Mining)

Australia is probably the world leader in open cast mining. Both BHP Billiton and Rio Tinto have facilities in the Pilbarra in Western Australia, which are practicing what is referred to as Next Generation Mining (NGM). The vision for NGM includes running standard processes and systems for production management (drill-hole to port), utilizing autonomous mining equipment operated from integrated remote operations centres, and using the most efficient mining methods[436].

From its purpose built operations centre located adjacent to Perth Airport, Rio operates some 14 mines, all rail and port infrastructure plus power and water distribution systems. BHP Billiton have introduced Caterpillar automated mining trucks with location telematics in their new Jimblebar iron ore mine, this autonomy is lifting productivity through higher utilisation, reduction of labour, greater predictability and less variability.

The use of high resolution terrestrial 3D laser scanners on potentially unstable slopes above coal seams is another area where large benefits are being realized. In one example, an additional 12,000-14,000 tons of coal was recovered with a recovery value AUS$1-2M after the slope had been resurveyed using this more accurate equipment[437].

C.4 Middle East

C.4.1 Supply-side

Geospatial Data Capture and Processing

The conversion of geospatial base data from paper records into vector form, where these exist, is largely outsourced abroad. Canadian firms like Terra Surveys, Kenting Earth Sciences, and MDA[438] [439] have historically played an active role in the manual and digital production of topographic base mapping, with major projects in United Arab Emirates (UAE), Qatar and Saudi Arabia. Within the region Egypt does have a reasonably strong capability and well-established set of commercial firms who undertake such work. The majority is however undertaken by Indian or other Asian subcontractors. The ability to work with the Arabic language strongly influences the ability of firms to break into the market both for capture and software development. The capture and on-going maintenance of 'foreground' data, such as oil and gas installations, planning application extents, transport street furniture, utilities infrastructure and other data requiring local presence is largely undertaken by migrant workers, particularly in the Gulf. Increasing use is being made of LiDAR to rapidly capture and extract existing features, particularly within the utilities and transport sectors.

Geospatial Data Analysis and Presentation

With a lack of up to date vector base data in many countries, the focus of data analysis tends to be based around aerial or satellite imagery. The production of ortho-rectified image maps continues to be the preferred presentation for topographic base products for all areas outside the major cities. Land classification and environmental applications, such as for pollution control, are the most popular thematic uses of remote sensed imagery in the region.

Integrated Information Products and Services

For clarity, here we cover integration of geospatial information with other types of business, statistical and other information through links to enterprise systems. These would typically include the 'mission critical' Enterprise Resource Planning (ERP)[440], SCADA[441] and asset management systems run by large organizations. This integration brings a geospatial dimension to decision-making and improved operational performance within organizations.

Many of the national systems are facilitating integration with other line of business systems by standardising on one software package. In Abu Dhabi Emirate, UAE, the technical interoperability has been facilitated by the use of Esri's ArcGIS package for all participants. It is the first country to have signed an Enterprise License Agreement with Esri, providing 'all you can eat' access to all the commonly required tools. These tools are not only used by government entities but also by state owned or joint venture organizations such as Al Hosn Gas, the public-private joint venture development company for the Shah gas field. Esri have engineered links to ERP systems such as SAP, and Maximo[442], IBM's asset management package, to provide out of the box solutions in this space.

Other suppliers, such as MapInfo, are now focusing on their location intelligence strategy within the region. This approach aims to leverage the penetration of their parent company, Pitney Bowes, into the supply chain of major corporations to geo-enable their operations. MapInfo is making headway through its heavy focus on business-focused geospatial information assets including demographics and transport network data. This is attractive to the international companies that tend to dominate (through local franchisees) insurance, real estate and telecommunications sectors in the region.

Location-Based Solutions

Mobile usage in most countries in the Middle East is generally high. Smartphone adoption tops 50 percent for both Saudi Arabia and UAE. As a result, consumer mapping applications such as Google maps are heavily used. Based on research conducted in 2012[443], Ipsos MediaCT reports that travel information apps that rely heavily on geospatial data have, for instance, been used for purchase decisions by over 50 percent of users in UAE. In contrast, the penetration of Google enterprise solutions into the market has been relatively slow. Appointment of the first enterprise Google Maps partner in the Middle East (Spatial Imaging) was as recent in 2011.

C.4.2 Demand-side

Central Government

As observed above, in most Middle Eastern countries funding of infrastructure development is controlled by Government as are many of the large commercial sector GIS consumers including utilities, energy producers and distributors. As a result much of the market activity could be included under this heading. For clarity here, we therefore focus on Spatial Data Infrastructure (SDI) initiatives.

It is perhaps unsurprising that Saudi Arabia, the largest country in the region, is a long-term user of geospatial technology. However, the picture is somewhat fragmented with different Ministries having chosen different solutions both in terms of architecture and technology, which are deeply embedded. Much of the early development was focused on oil exploration and infrastructure construction with central government (except defence) lagging somewhat behind. More recent efforts have sought to establish a more coherent national SDI[444] but collaboration has been difficult to achieve.

The most highly developed system that extends across government (i.e., can truly be regarded as providing a mature SDI) is probably in Abu Dhabi. Although the emirate is relatively small and the vast majority of the population live in one city, the progress based on a high level of executive-level ‘buy-in’ to the concepts and collaboration covering almost all the public sector is impressive. This can, in no small measure, be attributed to the early recognition of the need for a private-public partnership approach. Under the leadership of the UAE Military Survey Department, an SDI Business Plan was developed in 2006 under contract to a Canadian firm, Intelec Geomatics Inc. The Ministry of Information and Communications subsequently let a framework contract to lead SDI development to a American-led consultancy firm (GPC), who have brought to the project a wide range of expertise drawn from elsewhere in the Middle East, Europe and the United States.

Kuwait is emerging from a long period of limited investment in the sector (with the exception of the oil exploration field) with World Bank involvement in a new SDI initiative. Although at an early stage, it appears to be looking at a similar approach to that in Abu Dhabi.

Qatar, one of the earliest adopters of a national approach to GIS, has fallen somewhat behind other countries in recent years but seems to now be reasserting its interest in SDI. It recently hosted the UN GGIM knowledge exchange meeting in Doha[445] and is working in close collaboration with China on upgrading its capabilities.

Local Government

In common with many areas of the world, local government in the Middle East has many functions that cannot operate effectively without geospatial information but often lack the funds to deliver beyond very basic, often still largely paper-based, services. Exceptions are in the Gulf

States where municipalities can often be seen as an extension of central government and are relatively well funded.

Non-renewable Resources

Exploration activities for oil and, more recently gas, have led this to be a well-developed sector with most of the major players having full enterprise systems, providing services to the utility and asset management, environmental, community, terminal management functions in addition to the exploration activities. Saudi Aramco[446] has perhaps one of the most developed infrastructures – its emap division – which provides services to around 50,000 employees.

Utilities

The water and wastewater industries define this sector in the Middle East. The provision of both in the region is largely delivered by state owned or controlled entities. The priorities are asset management, where plans for management are often the determinants of funding. Large scale topographic and environmental mapping in connection with new pipeline and sewer construction is often project based rather than providing comprehensive cover.

Defence and Intelligence

Clearly a priority for all Middle Eastern countries, but understandably publicly available information is limited. We would observe however that the use of geospatial information in Saudi Arabia is particularly widespread and sophisticated in the defence sector. Intergraph have long held major contracts through their local partner, Atheeb, with the Ministry of Defence and Aviation (MODA) and the General Directorate of Military Survey (GDMS).In common with most countries, the main thrust has been for many years the realization of a Common Operational Picture (COP). The protection of the Saudi border, which is extensive, is an example. The scope of command and control systems with links to GIS to provide a common operational picture encompasses land, air and maritime data including high resolution satellite imagery (sub 1m resolution), DTED (elevation) and vector base mapping and charts[447].

Israel is known to have invested massively in the use of GIS in the defence sector working closely with the United States military. Information is scarce as to the actual uses but is thought likely to be focused on intelligence and weapon systems.

Land and Property

Sophisticated systems for land administration go back in the region to the 1980s, where Bahrain developed a comprehensive Intergraph-based GIS widely regarded as world leading. The current focus of land and property initiatives, particularly in the Gulf States, is the regulation of real estate transactions, where concerns about uncontrolled price escalation and corruption have led to establishment of real estate regulatory authorities. Geospatial referencing is vital to this function and in the densest urban areas 3D titles are a significant issue. A recent contract has been signed between Ordnance Survey and the Kingdom of Bahrain[448] to create a 3D-enabled data model.

The cadastral system in Egypt[449] has been recently revamped to simplify workflows and to more closely integrate registration and cadastral survey processes. The problems encountered here of lack of funding for data capture/conversion, legal issues resulting in the need to maintain parallel paper systems and the complex history of titles in urban areas, are typical of many Middle Eastern countries. However, the technology base of the Egyptian system does seem to be a successful model and a modification of this system was in the process of being implemented in Libya before the revolution.

While we have focused on property-related geospatial initiatives in the region, it is worth observing that some of the richer countries in the region are investing heavily in Africa and Asia in acquiring long-term land rights to provide food security. The Gulf States, with Kuwait prominent, are mostly focusing on land deals involving areas of rice production.

Telecommunications

Recent GIS conferences in the region have included a number of presentations on telecommunications, including network planning using detailed digital surface models (DSMs) to optimize coverage to population centres and transport networks. Oman telecom[450] is an example of usage evolving in the region from specialists to all staff and customers.

Transport

Worthy of mention in this section is the Israeli company Waze, recently sold to Google for a reported US$1.2B[451]. Waze is an innovative company specializing in passive crowd sourcing, particularly road network and related points of interest such as gas stations. It has been highly successful in capturing such data by ‘gamification’ (i.e., making it like a game for volunteers to participate in return for usually non-monetary rewards).

C.5 Africa

C.5.1 Supply-side

Geospatial Data Capture and Processing

The lack of good data is often cited as the reason why there is lack of progress on the continent. However, a new generation of high resolution earth observation satellites now pass over all parts of Africa with increasing frequency and South Africa is planning to launch its first earth observation satellite EO-SAT[452]. Furthermore, deals being brokered by, amongst others, the European Union allow cheap or free access to satellite data by the public sector[453].

In addition to satellite data, the advent of the Smartphone, with GPS capabilities, is putting location in the hands of millions of end users in Africa. Even the more pessimistic predictions suggest 40 percent of Africans will own a Smartphone in 5 years' time[454] and even the remotest parts of the continent have sufficient coverage of GNSS.

Geospatial Information Analysis and Presentation

While human resource capacity is still a problem in some parts of Africa, with the brightest students leaving to work in developed nations or not returning after education overseas, this trend is reversing in many countries. GIS software is more available in Africa than even 5 years ago. Large software companies such as Esri have been successful with programs to provide cheap access to academic and public sector organizations, and open source packages are much more widely available and understood. The availability of tools for spatial analysis, image processing, feature extraction and other previously expensive capabilities are becoming much more widespread and, when combined with the greater data content and accessibility outlined above, are leading to deployment in a much wider range of applications. The long and expensive process of producing topographic maps appears to be increasingly replaced by application-focused web mapping visualizations based on imagery base maps. Particularly significant in this respect are applications in agriculture, water management, land tenure and transport.

Integrated Information Products and Services

The majority of current development in Africa is around project-based initiatives. The exceptions tend to be around utilities and oil and gas, which involve infrastructure where the geospatial technologies are integrated with asset management or Enterprise Resource Planning (ERP) systems.

Location-Based Solutions

There are an increasing number of geospatial web services from global bodies such as the World Bank[455] and Southern African Development Community (SADC)[456] which provide metadata (data about data). While these are valuable resources, they often suffer from a lack of maintenance once the project which commissioned them is completed. There are few examples of mature commercial location-based services working on a large scale. Even Google, which operates worldwide, has comprehensive turn by turn navigation for only a small proportion of countries[457]. However, the growth of a community of 'neogeographers' building new apps is illustrated by the popularity of the WhereCamp Africa[458] and 'unconference', at which delegates decide their own agenda, the latest of which was held in Addis Ababa in March 2013.

Geospatial Information Technologies

The global software providers, such as Esri and Intergraph, have distributors on the continent but do little new software development there. There are a number of small but growing open source and independent developers, such as Afrispatial[459] based in South Africa, but these organizations do not have the critical mass to undertake large projects.

Worthy of mention is the Ushahidi project[460]. Ushahidi (meaning 'testimony' in Swahili) was a website that was initially developed to map reports of violence in Kenya after the post-election fallout at the beginning of 2008. It has now developed into a mapping platform based on open source software and a group of volunteer developers with a global reputation.

C.5.2 Demand-side

The demand-side is very variable, with the commercial sector still lagging behind the public sector and the aid programme of major donors being very significant. It is not possible to provide a comprehensive survey of all countries. Examples have therefore been selected to illustrate best practice and the direction of use of geospatial information and technology.

Central Government

The most coherent barometer of progress in central Government, particularly in respect of fundamental geospatial data availability and collaboration, is the status of SDI. Many countries are still facing challenges to put in place policies, resources and structures to make geographic information technologies easily accessible to decision makers and to user communities. The main challenges in implementing geomatics and SDIs remain limited financial resources and political support. However, there are starting to be notable exceptions.

The recent report (2010) "A Review of the Status of Spatial Data Infrastructure Implementation in Africa", [461] indicates that SDI activity currently is highly fragmented. Many SDI initiatives were stalled after management committees were set up. Limited human capacity and financial resources are identified as the major constraints. Furthermore, the study highlights concern that SDI does not often seem to have a policy framework that is pertinent to their country's development priorities (e.g., poverty reduction strategies). Only three countries expressed adequacy of funding for their SDI initiative (Gabon, Swaziland and Nigeria)[462]. The participation of stakeholders in SDI initiatives is generally not satisfactory. Only 6 out of the 29 countries expressed satisfaction in the collaborative goal of SDI with different stakeholders actively engaged in their SDI initiatives. The report notes that, while some SDI components appear to be in development, it is the handing over to local organizations that is often a critical missing aspect (e.g., Kenyan SDI after Japanese funding ended). A solid handover strategy is needed but the political and economic issues remain an important obstacle to achieving this goal.

In terms of political support, Rwanda and Uganda are among the countries that have a very high level of political support directly from the President's office. For Rwanda this has been a major milestone and the country has managed to get adequate funding for its SDI initiative[463]. Another relevant success story is Senegal, where Natural Resources Canada and Fujitsu Consulting (Canada) Inc. have been involved in the implementation of a SDI through the "*Projet d'appui canadien au Plan National de Géomatique du Sénégal*"[464], with funding support from the

Canadian International Development Agency. The program includes studies and projects relating to the geodetic system, training, metadata management and framework geospatial data management.

Apart from SDI initiatives, national mapping organizations and the academic community also represent key players in the sector, delivering geographical data and projects to other public organizations. Existing mapping institutes inherited legacy data and systems implemented by colonial administrations, mostly from France for West Africa and UK for large parts of East and Southern Africa.

In most cases, mapping is produced at 1:250 000 scale with partial 1:50 000 coverage. However, these base maps are not updated on a systematic basis. Taking Namibia as an example[465], their national mapping programme is driven by the political priorities including unemployment, limited access to land resources, limited food security, inadequate education levels and the effects of global warming (flooding, drought). The 1:250 000 topographical maps for Namibia have been revised recently (programme completed in 2006) and are in digital format. About one third of the 1:50 000 coverage of the country has been revised and are less than ten years out of date. In addition, digital colour aerial images of sub-meter resolution exist for the northern part of Namibia and full coverage is expected to be complete in 2014.

Maghreb countries (North West Africa) do fare a little better with more funding due to connections to the oil industry. However, few countries deploy national programs for aerial or space borne surveys. Data delivered within projects by and large does not find its way into national map series.

Local Government

Several countries have put forward decentralization programs but often failed to give regions the resources they need to really take charge of the responsibilities that the central government wish to hand over. State governments then suffer the same fate as local organizations: lack of funding, overcoming a huge bureaucracy, political instability and power struggles for money, and competing public organizations. What's more, local governments endure a lot of hardship for many reasons and IT is not a prime concern for most people. Demand from local governments is non-existent, at least from a business perspective. Political decisions are highly centralized, as are budget allocation and funding.

The lack of a culture of using geospatial information, restrictions being placed by governments on getting access to data, and a lack of awareness/support for its use in decision-making processes are other challenges to the implementation of geospatial programs. Unfortunately, data is typically scattered in several ministries and agencies, with no common standards. Access remains extremely difficult (e.g., inadequate policies, high fees, IP protection, lack of capacity) and most projects go unnoticed and will probably fail to deliver sustainable results once funding ends.

International Development Organizations

A great number of local and regional projects get funding from international development organizations, prominent amongst which are the World Bank, EU Commission, World Health Organization (WHO), UN Food and Agriculture Organization (FAO), African Union Commission (AUC) and UN Economic Commission for Africa (UN ECA), UN Habitat and UN Environment Programme (UNEP). As an example, the World Bank economic geography work[466] is a particularly valuable study showing how poverty reduction aid in Malawi tends to be clustered around good transport routes rather than targeting more remote communities where arguably need is greatest. Another valuable initiative is the use of geospatial information and GIS in the 2010 Round of the Population and Housing Census (PHC) led by the UN Economic Commission for Africa (UNECA)[467], which points to experience gained in several countries over the last decade in census mapping.

A focus in the next couple of years for these donor organizations will be helping all African countries to achieve their Millennium Development Goals (MDGs). These imply that core geospatial datasets for African countries need to be in place so that geospatial information can be used in the decision making processes for achievement of their MDGs.

National mapping organizations from developed countries and academia (research programs) also provide support. Historically, long-time partners like IGN France International are quite active in the French speaking countries (Senegal, Ivory Coast, Guinée, Burkina-Faso, Mali) and are more likely to develop agreements with African central governments. The Faculty of Geoinformation Science and Earth Observation at the Dutch International Training Centre (ITC), now part of the University of Twente, are particularly active in Africa and have a strong reputation for understanding the needs of students from developing countries.

Defence and Intelligence

Defence and intelligence represents a key sector, and in many African countries the national mapping agency is part of the defence department. In the remainder it keeps a high level of control on any IT implementation, based on security issues. The difficulty for geospatial suppliers is compounded by contracts often being handled at a political level with the preferred supplier often chosen on the basis of strategic national interests. For this reason, the African military sector is unlikely to be a significant opportunity for Canadian geospatial suppliers, with the possible exception of services for airborne or space borne imagery.

Emergency Management

The United States Agency for International Development (USAID) Famine Early Warning System (FEWS NET) is an important resource in the fight against poverty in Africa. Using GIS to integrate remotely sensed and on the ground survey data on climate, agriculture production, food prices and livelihoods, it forecasts changes in food security status six to twelve months in advance. The information FEWS NET produces is used by decision-makers and relief agencies to plan for food emergencies. FEWS NET was created in response to the 1984-1985 famines in Sudan and Ethiopia. Although it is a global system, it focuses primarily on Africa; 30 of the 38 countries that the system routinely reports on are in Africa[468].

The increasing availability of LiDAR data in many parts of Africa is also significant for, amongst other purposes, improved hydrological modelling to predict and obviate flooding. In northern Namibia a study of the Kavango river basin[469] showed that a 50m grid DEM produced from LiDAR data was effective in accurately modelling the effect of different levels of rainfall. As a result, local decision making in advance of major flood events has been enhanced. This is a good example of a system that could be deployed widely across Africa and elsewhere.

Non-renewable Resources

Africa has enormous deposits of natural resources, with the continent having a majority of the world's known resources of platinum, chromium, and diamonds, as well as a large share of the world's bauxite, cobalt, gold, phosphate, and uranium deposits[470]. In addition, oil and gas exploration and exploitation are important to the economies of Algeria, Nigeria and Angola, with both Sudan and Ghana set to become significant oil producers in the next few years[471]. The use of GIS in all aspects of the upstream and downstream processes of resource extraction is well established. The use of GIS in El Merk Oil field is typical[472] of the highest level of development that can be achieved when the technology is optimally implemented.

Although Africa is resource rich, these resources are often underexploited. There is an estimated US$130,000 of known sub-soil assets beneath the average square kilometre of countries in the OECD. In contrast, only around $25,000 of known sub-soil assets is reported to lie beneath the average square kilometre of Africa. This does not reflect fundamental differences in geology. It is likely that Africa has more, not fewer, assets but there has been only limited international investment in exploration[473].

The scale of this underinvestment indicates the huge potential for GIS to be applied as a tool for resource exploration in Africa, but it also begs the question why has Africa not attracted sufficient investment in exploration up to now? The answer is risk. African mining projects require larger than average investments in infrastructure[474] in what has historically been an insecure operating environment. The reasons for these insecurities are multifaceted, but the equation includes issues of land rights and security of tenure – another important area in which GIS can contribute to development in Africa (see Section 3.3.7).

The growth in commercial interest in a sector can often be gauged by the advent of conferences focusing on the subject. So the inaugural Geographical Information System in Mining Summit (GIS)[475] held in Johannesburg in October 2013 may be prescient.

Utilities

Utility companies (electricity, gas, water) are already important users of GIS in many parts of the continent. They collect revenue from their services and so have direct sources of income, which has allowed them to invest in geospatial technology. However, most are still under state control (being owned by public agencies) and larger investments still come mostly from public money via government transfers.

The predominant application is asset management. To this point most applications have been implemented on client-server architecture with usage largely limited to a relatively small number of professional users using desktop GIS software, but the advent of cloud GIS is opening up opportunities for much wider use by users in remote offices and field workers.

The future direction in which cloud GIS is the prevalent model is illustrated by work undertaken by the Kenya Electricity Generating Company on geospatial data management as part of their geothermal resource development[476]. A prototype system hosted on Amazon cloud servers was created using GeoServer, and the results in terms of performance and cost-effectiveness are encouraging.

Another example of ground breaking work in Africa is the use of Augmented Reality (AR) to extend current GIS used by the utility industries to smart devices[477]. The smart devices are aware of location, the compass direction and the inclination in relation to the horizon. GIS data is already spatially aware, and context-specific data can thus be fed to the mobile workforce. By integrating these two systems, data can be made available to the user in the field in an offline manner, exposing information that would otherwise be hidden by physical constraints such as buildings, natural vegetation and other obstacles.

Maghreb countries such as Algeria are also active in this space. Algeria recently launched a large project (*Société Nationale pour la Recherche, la Production, le Transport, la Transformation et la Commercialisation des Hydrocarbures* - SONATRACH) to manage its gas and water infrastructures[478]. The business objective is to improve surveillance and operational maintenance of 20,000 km of pipeline through database creation and loading, GIS system development and implementation.

The use of volunteered geographical information is worthy of mention under this heading. A valuable study in Kenya shows how tapping slum dwellers' knowledge can improve water supply delivery[479].

Land and Property

The issue of land rights is particularly contentious across large parts of Africa. Generally security of tenure is low and inequity of land distribution is high. The issue of security of tenure, particularly within slums, has been an element of Target 11 of Millennium Development Goal (MDG) 7 since the outset, however it was not until April 2011 that UN-Habitat put in place a methodology for measuring security of tenure[480]. The promotion of security of tenure to a measurable target has sparked renewed interest in this area. Although the MDGs are a global initiative, this development has particular relevance to Sub Saharan Africa due to the prevalence and prominence of the international development agencies and development finance in policy making in the region.

Rwanda is an example of an ambitious land tenure regularization project in Sub Saharan Africa. Before the project Rwanda had a dual tenure system with both written/statutory and unwritten/customary tenure systems operating simultaneously, with far-reaching legal and institutional changes being required. Once these were in place the regularization occurred through a nine step participatory process carried out by specially formed committees including processes of sensitization, demarcation, adjudication, mediation, and finally registration. The project relied heavily on GI technologies for the demarcation of parcels. The technique used was a participatory process of marking boundaries on RS imagery and subsequent digitization. By 2011 more than 3.3 million parcels were digitized. A 2013 study into the impacts of the Rwandan land regularization project found that 84 percent of households had a land title, and that titles had facilitated access to credit and reduced land related disputes[481].

A more bottom up approach to resolving land tenure issues has developed from a number of projects that have mapped urban slums. For example, the Map Kibera project used community volunteers and the OpenStreetMap platform to map Kibera, Nairobi's largest slum, which occupies an area of 550 acres and is home to between 200,000 and one million people. The project mapped all water points, toilets, clinics, pharmacies, schools, churches, mosques, and NGO offices. Although the project doesn't address issues of tenure directly, by mapping this informal settlement it at least gives some status to what is, according to Kenyan government records, a state owned forest[482].

Agriculture

Africa has a huge wealth of good farming land but the United Nations Food and Agriculture organization (FAO) is warning that land deals are undermining the continent's food security[483]. Large land deals have accelerated since the surge in food prices in 2007-08, prompting companies and sovereign wealth funds to take steps to guarantee food supplies to the Middle East, China and India in particular. Geospatial analysis represents one of the most powerful tools to identify the relationship between land tenure, agricultural production and economic welfare. In this section we look at some examples of how the technology is being used in agricultural research and decision making in Africa.

Many aspects of the state of the art were presented at the Africa Agriculture GIS week[484] held in March 2013. The promises of the relatively high availability of unused arable land in Africa, and the current under-exploitation of resources, both material and information resources, were highlighted in a keynote by Rolf de By, University of Twente[485]. Geospatial technology, as part of the wider digital revolution, will allow product-related information flows to inform better decision making. He used the 'last 10 km' as the metaphor of bringing information to individual farmers and equipping them with actionable information.

A practical example of applying spatial analysis and modelling on a regional basis is to drought resistant maize production[486]. The Decision Support System for Agrotechnology Transfer (DSSAT[487]) model was applied using climate, soils and historical crop productivity data in a 5 min of arc pixel grid to predict where newly developed crop varieties are most likely to thrive across the continent. The power of the work is that it can be applied to other crops and that it ties to other work being undertaken by FAO and others to refine soil type and climate data.

One of many local studies of note included a spatial analysis of livestock production patterns in Ethiopia[488]. The livestock sector is a large contributor to the Ethiopian economy and a mainstay in the livelihoods of many Ethiopians. This study links smallholder livestock population from agricultural census exercises with GIS data to assess livestock population, market access, and grazing land. This was combined with travel time data to calculate shares of livestock (cattle, sheep and goat) populations within defined travel time thresholds of major markets.

Renewable Resources

The wider availability of high-resolution multi-temporal (frequent return) imagery such as Landsat 8 and new software tools are beginning to make significant difference in applications such as monitoring deforestation. Google Earth Engine[489] for example, uses the organization's large-scale cloud computing infrastructure to build a powerful database out of the thousands of satellite photographs from the past 25 years. It has recently been applied to good effect in fire disturbance studies in Eastern Zambia[490].

Health

Making better decisions on health priorities is very important in Africa with the high rates of disease and relatively low levels of finance available to the sector. Amongst the many initiatives the following are a selection from around the continent.

The Malaria Atlas project involves an international consortium of academic researchers building a range of maps and estimates to support effective planning of malaria control at national and international scales. The group has assembled a unique spatial database of malaria case data which is openly shared and used for the group's own modelling of the distribution and prevalence of the malaria causing parasites[491]. Although the Malaria Atlas is a global project it is primarily focused on Africa where the majority of malaria deaths occur.

Another interesting global initiative that is making significant inroads in Africa is the Health Management Information System DHIS2. This is a project that originated in South Africa and is now the preferred health management information system in 30 countries and even more organizations across four continents. DHIS2 has an integrated web mapping option that allows users with minimal training to view health indicators on maps to inform decision making. The project currently does not incorporate a feature for detailed GIS analysis, but the project is open source and is therefore constantly evolving. With so many of the instances currently deployed in Africa and a core developer team in Tanzania, it seems probable that the system will develop solutions to African problems[492].

With often patchy and under resourced health care provision, analyzing the coverage and accessibility of health facilities is an area where GIS has the potential to have a big impact in Africa. GIS-based accessibility analysis modelling has been explored as an option in South Africa[493]. This technique used a combination of population data augmented by demographic information and combined with the locations of roads and health facilities to create a model of facility catchment areas and demand.

C.6 China

C.6.1 Supply Side

Geospatial Data Capture and Processing

The National Administration of Surveying, Mapping and Geo-information (NASG) of China, under the Ministry of Land and Resources of the State Council, has overall responsibility for supervision and management of surveying, mapping and geo-information work in the country. It is the central body in a tiered system with provincial, municipal and county level bodies underneath it. Local surveying and mapping departments manage and supervise surveying and mapping within their jurisdictions and submit the results to the higher level departments[494].

The administration system is established by the Surveying and Mapping Law of the People's Republic of China, which also outlaws private surveying and mapping activities in mainland China[495] and makes it illegal to produce or even possess a map that shows anything but China's official borders [496]. NASG adopted the China Geodetic Coordinate System 2000 (CGCS2000), a geocentric coordinate system, in July 2008. By 2012 the transformation of the national basic surveying and mapping results into the new coordinate system had already been accomplished[497].

In 2006 the NASG implemented the 1:50,000 Western China Mapping Project, which mapped 2 million Km^2 of western China at 1:50,000 resolution with major zones mapped at 1:10,000 resolution. A range of survey products were also produced, totaling 13.5 terabytes of data. Simultaneously the 1:50,000 National Fundamental Geographic Database Updating Project occurred. This project updated the existing 1:50,000 topographic map data covering 80 percent of China's land area. The results produced an additional 12.3 terabytes of data and updated the number of data classes from 101 to 437 with all data current as from 2005[498].

According to the Union of Concerned Scientists (UCS) Satellite database there are currently 107 Chinese owned/operated satellites in orbit[499]. This gives China the third largest total number of satellites behind Russia and the USA. The UCS database lists 33 satellites as Earth Observation or Remote Sensing satellites, however 20 of these are likely to be used for military purposes, despite official press releases to the contrary[500]. One is civil, the Beijing-1, operated by the Beijing Landview Mapping Information Technology Co. Ltd and built by a UK company, Surrey Satellite Technology Ltd[501]. The remaining 12 are state-owned. The most advanced of these is Gaofen 1 launched in April 2013. The first of a planned constellation of up to six satellites will be launched as part of China's high-definition Earth observation system (HDEOS)[502]. Gaofen 1 has a resolution of 2 meters for panchromatic images and 8 meters for multi-spectral images. As well as providing high resolution imagery HDEOS is designed to provide near real-time data[503]. China also has a long standing remote sensing joint venture with Brazil although none of the China-Brazil satellites are currently operational, and the most recent launch, of the China Brazil Earth Resource Satellite 3 (CBERS-3) on December 8, 2013 failed[504].

China has 15 operational 'Compass' satellites which currently form the Beidou regional satellite navigation system. Beidou is a three-phased project. Phase one was a local, to China, geostationary satellite navigation system. Phase two, which is currently operational, is a regional satellite navigation system using both geosynchronous and inclined geosynchronous satellites. Phase three, which will build on phase two, will include 27 medium earth orbit (MEO) satellites[505] forming a Global Satellite Navigation System. According to UCS there are currently five operational Compass MEO satellites, 19 percent of the planned constellation.

Geospatial Data Analysis and Presentation

China Information Technology Inc. (CIT) specializes in GIS, digital public security and hospital information systems. In a press release in Q1 2011, CIT announced US$36M in new contracts. All of the contracts listed in the press release were for government agencies including: Shuohuang Railway GIS, Shenzhen Traffic Police Mobile Law-enforcement System, and GIS platform in Jiaozuo and Hebi City[506].

Zondy Cyber produced its first GIS software product in 1991. The company is closely associated with China University of Geosciences (Wuhan) and the Research Center of GIS Software and its Application. The latest version of Zondy Cyber's flagship software platform MapGIS, MapGISK9, was released in 2009, with the dc-server version released in 2010[507].

GeoStar is a GIS software product developed by Wuhan Technical University of Surveying and Mapping (WTUSM) in 1992. It is now the flagship software product of Wuda Geoinformatics Co., Ltd. GeoStar is the exclusive domestic GIS platform for the China State Electricity Grid and the software platform and service provider for 'Map World', the Chinese state online map product[508].

Integrated Information Products and Services

China has a number of very large information technology companies that manufacture equipment and also provide a full service solution including GIS components. The largest of these are the telecommunication giants ZTE and Huawei. For example, the Huawei eSpace Emergency Command Solution uses GIS technology to enable emergency command centres to interact with on-site personnel to control accidents and disasters[509]. ZTE markets a similar product known as the Integrated Command and Dispatch System[510]. Other integrated product and service providers include China Trans Info[511], providers of transportation information products and services, and Dandong Dongfang Measurement & Control Technology, which provides scheduling management systems for open-pit mines[512], among other services.

Geospatial Information Technologies

China has become the world's largest manufacturing centre for electronic products[513]. All of China's large electronic manufacturers produce GPS devices, mainly for the mobile phone market. However there are several Chinese firms, for example ComNav[514], that specialize in surveying equipment including precision GPS devices. Many of ComNav's products are Beidou as well as Navstar (Chinese and US GNSS systems) compliant.

China has a thriving ecosystem of domestic GIS software developers. Generally these companies are spin offs from GIS research institutes within Chinese academic institutions. These institutions have been heavily involved in Chinese state GIS initiatives from the outset meaning that the 'spin off' software firms have been well placed to win government contracts, which account for the majority of the revenue of Chinese GIS software developers[515].

Beijing SuperMap Software Co., Ltd., founded in 1997, is currently the largest provider of GIS software in China. More than 70 percent of its sales come from the Chinese government[516]. SuperMap's latest product, SuperMap GIS 7C, includes cloud GIS, mobile GIS and 2D & 3D integration technologies[517]. Although the majority of SuperMap's sales are domestic it is increasingly looking to expand abroad (e.g., it provided a customized GIS application for Mauritius Police Force (MPF)[518] as part of an aid project funded by the Chinese government).

Location-Based Solutions

According to the latest official statistics from the China Internet Network Information Centre, China has 591 million internet users, of which 464 million access the internet via smartphones or other wireless devices[519]. This means that the Chinese web mapping market is highly competitive with an emphasis on mobile; according to the Quarterly Survey of China's Mobile Mapping Market there were 248 million mobile internet map users at the end of March 2012[520].

In 2010 China's State Bureau of Surveying and Mapping (SBSM) introduced licensing for online mapping services[521]. Initially SBSM granted licences to 31 service providers including several large Chinese Internet search companies, Baidu, Sina, Tencent, Sogou and Alibaba. Notable absences were Bing and Google. Nokia was able to obtain a licence as part of a joint venture with Chinese firm New Alliance.

In 2010 SBSM produced and released an online world map service called Map World[522]. Despite SBSM's best efforts Map World is not the most popular map service in China; the market leading online map API is Baidu Maps, a service provided by China's largest search engine Baidu, which in 2012 had a market share of 68.5 percent[523]. In the mobile mapping market the leader is a company called AutoNavi with a 25.9 percent share. AutoNavi also provides Chinese map data to a number of other significant players in the map market, most notably Apple Maps[524] and Google[525], and provides location based services to Sina, the creators of the popular micro blogging site Weibo[526]. In May 2013 Chinese e-commerce firm Alibaba paid $294 million for a 28 percent stake in AutoNavi[527]. A significant, but lower profile player in the Chinese mapping market is NavInfo, which does not produce a map product, but does provide data to Baidu and a range of other smaller players who when totaled account for 43.2 percent of the mobile mapping market[528].

With no licence for internet mapping and an already fractious relationship with the Chinese government it is likely that Google will not expand its Street View service to mainland China in the foreseeable future, leaving a space to be filled by domestic Chinese services. The first Chinese street view clone was launched by a small mapping company called City8.com in 2011[529]. This was followed by Total View, the Street View clone of Chinese search giant Baidu launched in 2013[530]. Baidu (and a number of other Chinese online mapping services) also provide a uniquely Chinese mapping style, best described as 3D pixel art. These maps are complete facsimiles of major Chinese cities rendered in colourful, clean, 3D graphics of the sort familiar to computer game players. They are also easier to manipulate than satellite imagery, allowing the Chinese authorities to control decisions on labelling of features[531].

C.6.2 Demand Side

Central Government

Central Government has paid significant attention to the development of the Chinese GIS industry. From the ninth Five-Year plan, the Ministry of Science and Technology has financed the development of domestic GIS software with special funds, and has previously developed the GIS industry in the high-tech fields. From policy, research and the technology orientation, the government's support plays a key role to the fast growth of the GIS industry[532]. Another example of central support for the industry is the construction of purpose-built geospatial industrial parks.

Local Government

In a November 2013 article for the BBC, Kerry Brown, professor of Chinese politics at the University of Sydney, analyzed the signals coming from China's third Plenum of the 18th Party Congress. She highlighted heavy references to the need to accelerate urbanization in order to achieve strong growth, a key driver being the achievement of a high level of urbanization by

2020. China's gamble is that it will be able to maintain growth through urbanization while answering some of the sustainability issues, and addressing inequality[533].

In line with the above strategy is the Geospatial Framework for Digital Cities (GFDC), a key component of China's national SDI. Since 2006, NASG has been implementing GFDC projects all over China. By August 2012 projects had been implemented in more than 270 prefecture-level cities and more than 40 county-level cities in various fields such as land management, urban planning, city management, public security, emergency response, environmental protection, public health, real estate, commerce and industry, water conservancy, meteorology and social services[534].

The pioneer of the digital city agenda was Shenzhen, China's newest major city, located in the rapidly urbanizing Pearl River Delta region adjacent to Hong Kong. In the academic journal 'Transactions in GIS', Wen Li (2008) writes that the establishment of the Shenzhen Urban Planning and Land Information Center (SUPLIC) in 1993 was the first step in developing and applying GIS in Shenzhen's government agencies. The initial motive for SUPLIC was more efficient land management. Over the last decade SUPLIC, in association with Chinese GIS research institutes and private sector organizations, has developed over 30 information systems along with a wealth of spatial and non-spatial data. SUPLIC's first significant success was a document processing information system designed to cover core business procedures such as land, planning, construction management, real estate registration, etc. SUPLIC also built a fundamental geographic information system incorporating land use data, cadastre, urban planning projects, transportation networks, and sewer networks. It is a database that has been frequently used by many other local government agencies and private enterprises[535].

Since Shenzen's GIS experience, the concept of the Smart City has gained considerable traction in China culminating in significant investment. Originally proposed by IBM, 'Smart City' is a synthesis of a range of technologies and concepts such as the Internet of things, cloud computing and GI technologies, particularly 3D GIS[536], and incorporates numerous sectors including transportation, healthcare and public security. Smart City initiatives are now occurring all over China. In 2012 the NASMG announced that over 100 Chinese cities had put digital geographic systems into full operation[537]. The NASMG has reported[538] that efforts to create digital cities have already resulted in 30B Yuan (US$4.86B) of value for the geoinformation service industry and China is planning to add additional cities to the Smart City pilot projects making available a fund of 440B Yuan (US$70.3B)[539].

The Suhou Industrial Park (SIP) in eastern China has implemented a Smart City concept that connects services such as schools, hospitals, hotels, public transportation and administration buildings to a smart grid. SIP's Geoinformation Services is taking data and building a map of the city that contains 660 layers of information ranging from power lines to green areas to population demographics[540]. Meanwhile the government of Nanjing has issued more than 5.4 million resident cards since the end of 2010 that serve as local social security cards, public transport cards and bankcards. The city's cloud computing program has completed databases for the population, corporations, government affairs and city services[541]. Shanghai is also undertaking a geographic census to capture the city's natural and built environment through 2015 as a means to establish their Smart City project. The Shanghai Institute of Surveying and Mapping will be collecting details on land features, vegetation, water resources, transportation and residential and commercial facilities[542].

Non-renewable Resources

The global commodities trade is dominated by exports to China. This has led to China investing heavily in the extractive industries of other nations. Chinese mining companies have traditionally preferred not to deal with projects in early stages of exploration. More recently however China's geological survey companies, such as the East China Exploration and Development Bureau, are becoming commercialized and venturing into new markets. The Central Geological Exploration Fund was established in 2005 to support the activities of such companies[543]. In February 2013 the Chinese state-owned company Citic Group signed an agreement with the Venezuelan government for prospecting and mapping that country's mining reserves[544].

The Chinese government mandates that investment by foreign investors who participate in mineral prospecting and exploration in China must be done through Sino-foreign joint ventures[545]. Domestically the largest mining sector in China is coal (although it has significant production capabilities for a wide range of resources). China uses nearly as much coal as the rest of the world combined (e.g., 3.5 billion tons in 2012), with the majority of China’s electricity supply being generated by coal[546]. China has a total proven coal reserve of 997 billion metric tons located mainly in the west and northeast, while China’s population is concentrated in the southeast coastal areas, so rail transport is used to move coal from west to east (see Section 3.8). GIS techniques are applied in many areas in the coal mining industry in China. For example coal mine information management systems that incorporate GIS, which are deployed widely in China, have been used with network analysis techniques to aid rescue operations in coal mine disasters[547] and remote sensing and GIS based decision support systems have been used to both monitor[548] and rejuvenate coal mine waste dumping grounds[549].

Renewable Resources

Between 2005 and 2007 the China Meteorological Administration carried out an onshore wind resource extrapolation, based on wind data collected at 2500 climate stations in 31 provinces, to create a general wind energy resource map of China. Under the project a wind resource database was set up. This was followed by further projects to develop a high-resolution wind map of an area 10 km inland and 30 km offshore from the coastline, plus meso-scale modelling and high-resolution wind mapping of Northeast China[550].

The National Forest Continuous Inventory (NFCI) is the first level of China's three-tiered forest inventory system and is part of China's effort to maintain a timely, reliable and accurate spatial database of current forest ecosystem conditions. The NFCI is administered by the State Forestry

Administration and new data is acquired every five years. Data sets include land type, forest classification, age class and group. Between surveys the system employs growth simulation models. In addition a 3D forest landscape virtual reality system has been developed to aid forest planning and design. The data is available for viewing by the public via an internet portal[551].

Utilities

In 2010 China spent US$7.3B on smart grid developments. These developments are in line with the smart or intelligent city schemes which have become part of the digital city concept (see Local Government section). In 2010 the State Grid Corporation of China exhibited a 4,000-square-metre pavilion named 'Magic Box' to showcase an integration of their diverse smart grid technology projects. Some of the features that incorporate spatial technologies included the Fault Restoration Management System and the Customer Energy Usage Collection System[552].

Defence and Intelligence

According to a 2013 TechNavio report on the GIS market in China the Chinese Defence industry has started to invest a large amount of money in GIS technology to enhance national security[553]. The exact nature of these investments is unclear; however, it is known that the Chinese government has at least 20 military remote sensing satellites[554], which are augmented by a drone-based emergency mapping system[555]. A clue as to how this data might be used by the Chinese military was provided in 2013 by Chinese GIS software vendor SuperMap's demonstration of a 3D military command and control system[556].

The People's Republic of China (China) has territorial disputes with India, Japan, Vietnam, Cambodia, The Philippines, Brunei, North/South Korea and Bhutan[557]; plus it maintains that the entirety of the island of Taiwan (The Republic of China) is an inalienable part of China's territory[558]. The contentious nature of China's border has resulted in the Chinese authorities being unusually strict about all aspects of map production to the extent that even inadvertent violations have resulted in censure. In 2011 Coca Cola was investigated for using GPS devices to monitor its delivery trucks in China[559].

Land and Property

In November 2013 the Third Plenum of the Chinese Communist Party's 18th Central Committee released a statement announcing their intention "to establish a unified land market in cities and the countryside" and "to give farmers more property rights"[560]. What this will mean in practice has been the subject of intense speculation; similar statements in the past have not resulted in material action, but other similarly vague statements have also heralded drastic changes. Deng Xiaoping's 1978 Third Plenum statement signaled 'reform and opening'; at the time of the statement China's real GDP was $187 billion, and in 2012 it was $4.5 trillion (prices adjusted to year 2000 USD)[561].

The present system dates back to the early days of the People's Republic and classifies all rural land as collectively owned, restricting farmers from selling the land they live on. While all farmland is state-owned, Chinese laws allow farmers long-term land lease rights under village collectives charged with oversight[562]. Two documents are supposed to record farmers' land rights, contracts and land-rights certificates. Research by land rights NGO Landesa found that only 36.7 percent of farmers have both documents as required by law[563].

There are two types of cadastral systems in China, one recording only land parcel information, the other integrating land and relevant building information together. Land in urban areas in China is state-owned while land in rural China is collectively owned. Most cities have established their cadastral systems for state owned land, including digital GIS data infrastructures (and made progress with 3D cadastre[564]), but not for collectively owned land[565].

Telecommunications

The two largest telecommunications companies in China are ZTE[566] and Huawei[567]. Both companies supply integrated GIS solutions alongside their core products of telecommunications equipment and network solutions. Both use GIS in their telecommunication network management. ZTE advertise a GIS network management service for managing, querying, and locating the network equipment, as well as providing coverage statistics[568].

Safety and Security

Following a number of high profile natural disasters China established a National Emergency Command Platform with an integrated GIS and a National Emergency Mapping Action Plan. The platform has 8 rescuing bases and 19 aerial emergency transportation service bases. It is capable of producing thematic maps within 2 hours of an emergency. It collects data from satellites, UAVs and integrated mobile mapping systems (minivans equipped with an array of surveying equipment). The Integrated Emergency Mapping System has been developed to deliver on demand applications based on cloud computing and cloud storage with the emergency command platform provided by the MapWorld web mapping platform. Maps are used for decision-making in the immediate aftermath of disaster and during the recovery period[569].

Transport

In 2011 China Information Technology subsidiary Wuda Geo announced a project with Shuohuang Railway for the Shuohuang Railway Geographic Information System. The system enables the simultaneous management of trains, automobiles, machines, labour and electricity. The project will be the first time GIS technology has been adopted by China's railway industry. The Shuohuang railway system is one of the main transportation channels for China's National West-to-East Coal Transfer project[570]. China TransInfo has installed intelligent GIS-based traffic management platforms in a number of Chinese cities, most notably Beijing in time for the 2008 Olympic Games[571], but also Wuhan[572] and Shanghai[573].

GIS techniques are also employed in highway planning and construction in China. GIS-based 3D visual highway construction schedule management systems display topographic, ecological and hydrographic data sets among others alongside a visual real time representation of highway construction progress. The system supports design, management and construction of highways[574].

C.7 India

C.7.1 Supply Side

Geospatial Data Capture and Processing

Survey of India (SoI) is the Indian national survey and mapping organization, producing a series of publically available digital mapping products at 1:250,000, 1:50,000 and 1:25,000 scales. These products can be licensed for a fee and are provided in vector format[575]. In the past SoI has practiced highly restrictive data access and still reserves its most detailed product, it's Defence Series, for the ministry of defence only[576]. However as part of India's new National GIS policy SoI data is due to become more freely available, at least to other Indian public institutions. The National Data Sharing and Accessibility Policy (NDSAP) mandates (with caveats) sharing of data sets generated through public investment[577]. Even when SoI data can be obtained, it may be difficult to use; although the Indian National Map Policy 2005 ruled that all SoI maps should be based on WGS 1984, as of January 2013 the SoI Topographic series was still based on Everest 1880[578].

India has a significant indigenous remote sensing capability. It launched its first experimental remote sensing satellite in 1979 and currently the Indian Space Research Organisation (ISRO) has a constellation of 11 operational earth observation satellites. Remotely sensed data is used for several applications covering agriculture, water resources, urban development, mineral prospecting, environment, forestry, drought and flood forecasting, ocean resources and disaster management. A large proportion of ISRO's datasets are available to view via the Bhuvan geoportal[579]. ISRO is also in the process of developing a Regional Navigation Satellite System and a Satellite Based Augmentation System for GNSS[580].

Other national level government organizations involved in geospatial data collection are: the Geological Survey of India, the Indian Naval Hydrographic Department, the Forest Survey of India, the Indian National Remote Sensing Centre, the Indian Space Application Centre, the Indian Meteorological Department, and the Indian National Bureau of Soil Survey and Land Use Planning.

Geospatial Data Analysis and Presentation

A number of independent Indian technology start-ups have invested in creating maps of India in an attempt to fill the void left by the restrictive practices of SoI. These companies have primarily focused on the in-car navigation market, but have since branched out and now provide a variety of GIS services. The most prominent of these are MapmyIndia[581] and a company called Sat Nav Technologies[582].

Other GIS services companies have developed out of the Indian telecoms sector. For example Genesys International Corporation Limited[583] is a Mumbai-based GIS services company that provides geospatial solutions to the utility, telecom, energy, government, oil and gas and petrochemical sectors.

Integrated Information Products and Services

India is a world leader in the field of IT services outsourcing and several of India's large outsourcing firms have GIS capabilities. These firms are known to frequently provide their services to foreign organizations and have offices around the world.

Globally, Tata and Wipro are the best known. However, there are many others, for example HCL Technology provided a fully integrated Road Asset System with Web interface and GIS functionality to the state of Victoria in Australia[584] and Infosys provided a GIS-based Information Management Portal for an Oil and Gas Major[585].

Rolta is an Indian company with offices in Europe, the Americas and the Middle East. It has a GIS services centre with over 2,000 GIS technicians in Mumbai[586], and carries out significant consultancy assignments (e.g., GIS services for the Abu Dhabi Sewerage Services Company in 2011/12[587]). These firms also deliver contracts within India, for example Cochin Port's GIS-based estate management system was implemented by Tata industries[588]. Numerous other GIS projects take place in India within the Indian offices of major western companies. For example IBM is now India's second largest private sector employer[589]. Other multinational corporations with a significant stake in the Indian GIS market are Autodesk Inc., GE Energy, Hexagon AB, Hitachi Zosen Corp., and MacDonald, Dettwiler and Associates Ltd[590]. Esri is present in India via a strategic alliance with one of the leading Indian IT services companies, NIIT Technologies, resulting in ESRI India[591].

Location Based Solutions

Indian starts ups have been most successful in the location based services market. MapMyIndia and SatNav, both Indian owned start-ups with accurate mapping products, dominate the in-car navigation market. Google, Bing and Nokia are all active in India; however, they have encountered problems navigating Indian bureaucracy. In 2013 SoI filed a complaint with the Delhi police force regarding a Google Maps competition to crowd map locations in India[592]. Google were then subsequently pre-empted in the Street view market by Indian owned Wonobo, which produced the first panoramic street level imagery of Indian cities[593].

C.7.2 Demand Side

Central Government

Included in India's 12th five year plan (2012-17) was a provision for the creation of a National GIS. Speaking at the 2013 ESRI user conference Sam Pitroda, adviser to India's Prime Minister for ICT and Innovation, described a customer- rather than technology-led system that focused on combating poverty of information. The planned system will include a national GIS platform including mapping at 1:10,000 scale, as well as city-level data at larger scales and targeted GIS applications to support government ministries, private enterprises, and citizens delivered through a National GIS portal[594].

The planned Indian National GIS is not the first project to attempt to synthesize India's geo-spatial data. The National Spatial Data Infrastructure programme was started in 2000. This cross-cutting initiative purports to bring together data from 17 government agencies. To date it has consulted on standards, agreed to adopt OGC standards, and created a geo-portal for viewing various government data sets (download not available)[595]. At the time of writing only a limited set of SoI Delhi data was available to view via the portal[596]. Canada played a leading role in providing advice to the Indian NSDI team, with several reciprocal visits between NSDI and GeoConnections officials facilitated by Natural Resources Canada and the Geomatics Industry Association of Canada[597] [598]. A Canadian industry team lead by CubeWerx Inc. completed a project to assess open-architecture, standards based, multi-vendor National Spatial Data Infrastructure following Canada's example[599].

Local Government

India is divided into states and union territories, with many States being more populated than most countries. The Indian state of Uttar Pradesh has a population of 199 million; equivalent to the population of Brazil, the world's fifth most populace country. The largest Union Territory is New Delhi, with a population of 22 million, the world's second most populous city.

The Indian National GIS is being piloted first at the state level. The most advanced examples are the union territory of Delhi and the state of Karnataka. Geospatial Delhi Limited (GDL) is the custodian of the data created by The Delhi State Spatial Data Infrastructure project. Since incorporation, this initiative has completed projects to record maintenance of water and sewage utilities, monitor property tax collection, track unauthorized settlements, map flood risk and create a drainage master plan[600]. Karnataka state has an active geo-portal[601] but access is currently restricted to government departments and selected NGOs, academies, industries and scientific organizations. There are plans to extend access to the public in the future, but the level of restriction imposed remains to be seen.

Non-renewable Resources

The Central Mine Planning & Design Institute, an Indian government enterprise, has a dedicated geomatics division where GI technologies are used for topographical survey, mineral exploration, land use planning, watershed management, excavation measurement to slope stability, ground subsidence measurement, coal mine fire mapping, environmental management, land reclamation and mine closure monitoring[602]. Coal India Limited, the world's largest coal miner with a production of 435 million metric tons in 2011-2012[603], uses GI operationally for real-time trip counting and truck monitoring systems at opencast mines. They also use GI in surveying and exploration and for creating environmental baseline and monitoring land reclamation projects[604]. Other developments in this field are a computerized register of mining tenements which could link in with the ongoing National Land Records modernization programme[605].

Utilities

India has implemented a wide ranging project to reform its electricity distribution network with the aim of reducing power losses, often from fraudulent tapping of the energy network, from around 30 percent to 15 percent. The project, which includes GIS-based consumer indexing and electrical network mapping, was initially launched in 2002, but has been beset with problems and is still ongoing following a complete re-launch[606]. Although the national scale project has run into difficulties there have been some significant successes at the local level. Reliance Energy, the private sector firm that took control of Bombay Suburban Electric Supply Ltd in 2002, won the 2008 Special Achievement in GIS (SAG) award for a project to GIS map its electricity distribution network. Location information was then incorporated into a number of other IT systems in order to locate faults and energy losses, improve planning of network growth, and assist in handling emergency situations[607].

Defence and Intelligence

India has ongoing territorial disputes with a number of its neighbours including significant disputes with China and Pakistan that have in the past resulted in wars. As such it is not surprising that India is secretive and sensitive to unrestricted access to geographic information. Failure to pay proper heed to Indian sensitivities can result in conflict. In 2005 India's then president APJ Abdul Kalam raised concerns about the availability of high resolution satellite imagery of sensitive Indian government sites on Google Earth. After a lengthy consultation Google agreed to blur and otherwise alter selected images[608].

The 2013/14 Indian defence budget was US$37.7B and it is predicted that India's defence spending will reach $65.4 billion in 2020, which would give India the fourth largest defence budget in the world[609]. Geographic intelligence will inevitably be part of India's strategic plans, but information about specific projects is difficult to obtain. However, one Indian defence equipment supplier, Tata Advanced Industries, has publically developed a range of seven Mini and Micro Unmanned Aerial Vehicles (UAVs)[610].

Land and Property

India is in the midst of a significant project, launched in 2008, to modernize land records – the National Land Records Modernization Programme. The project includes the digitization of all land records including creation of original cadastral records wherever necessary[611]. This huge project is still ongoing and is expected to run to beyond 2017.

Rapid urbanization in Indian has required the Indian government to explore techniques for better urban planning. One such technique is the National Urban Information System developed by the Indian Ministry of Urban Development and launched in 2006. This project brings together GIS mapping, remotely sensed data and statistical data to create a decision support system for planning and management of urban settlements. It includes a three tiered database of 1:10,000 maps based on remotely sensed imagery, 1:2,000 maps based on aerial photographs, and a 1:1,000 utilities GIS based on Ground Penetrating Radar. Phase 1 of the project is due to cover 137 priority towns, expanding to 1,500 and then all towns in phases 2 and 3. As of 2009 about 75 towns were complete[612].

Telecommunications

India's telecommunications revolution has put affordable mobile phone technologies in the hands of the masses. The rapid growth of mobile telephony in India was driven by the private sector who efficiently adopted GI technologies. In 2010 Indian telecoms giant Bharti Airtel implemented an award winning Unified GIS system (UGIS)[613]. Bharti UGIS integrates maps of India's land base (incorporating satellite imagery, field surveys and census data), and Airtel's network inventory with a number of business applications to aid in fault localization, network analytics, network planning and maintenance. A similar system was implemented by Reliance Infocomm, another large Indian telecoms provider, as far back as 2003[614].

Transport

India's road network is the third largest in the world with over 4 million km of roads and 70,000 km of national highways. With a 10 percent annual increase in traffic, India is carrying out a huge upgrade of its road network to cope[615]. In line with this objective India's Central Road Research Institute is currently piloting a GIS-based National Highways Information System[616].

Indian Railways is state-run and has the fifth largest railway network in the world and the largest under single management[617]. Indian Railways have embarked on an ambitious project of creating a GIS-based database of its network and assets. The system will also be used for disaster management, providing the location and accessibility of accident sites, availability of resources for rescue operation, location of medical relief facilities, etc.[618].

Indian Railways have trialed a number of train tracking initiatives. The first attempt to track trains using GPS, project SIMRAN, was a failure and was scrapped in 2012. Subsequently a very popular service called RailRadar was developed using information from the official Indian

Railways' train running operational dataset, which provided pseudo-live running status[619]. The information was viewable on a Google map and was available via a smartphone app. However this project was also scrapped and replaced with a tabular search interface[620]. To use the new service the user must complete a captcha, presumably to prevent third party services scraping the data and creating unauthorized Rail Radar style apps.

The Airport Authority of India in conjunction with ISRO successfully operationalized in January 2014 a constellation of three geostationary satellites that broadcast GNSS corrections for India and the region. The system is known as SBAS-GAGAN[621]. Although primarily for aviation, SBAS-GAGAN has significant spin-off benefits for the geo-spatial industry in terms of increased accuracy of GNSS measurements**.**

C.8 Rest of Asia

C.8.1 Supply Side

Geospatial Information Capture and Processing

A number of East Asian countries have active remote sensing/earth observation satellites, including Japan, Malaysia, Pakistan, Singapore, South Korea, Taiwan, Thailand and Vietnam. All except one are projects of national space agencies; the Japanese PRISM project is led by the ISSL (Intelligent Space Systems Laboratory) at the University of Tokyo. Launched in 2009, PRISM was a pioneer of the concept of low earth orbit nano-satellite technology for the capture of high resolution imagery[622].

Japan also has an active satellite-based GPS augmentation system, the Quasi-Zenith Satellite System, which works in conjunction with a comprehensive GNSS ground-based Earth Observation Network. Currently the system has one active satellite, but there are plans for three more. The system will deliver cm level positioning accuracy[623]. Since the enactment of new legislation in 2007 called ‘The Basic Act on the Advancement of Utilizing Geospatial Information’ significant progress has been made in opening up Japan’s geospatial data. Fundamental datasets were either created or updated including: all city planning zones at scales greater than 1:2,500; all other areas at scale of 1:25,000; and a 5m resolution DEM for more than half of Japan. In addition, observation data collected at each of the 12,000 base stations in the GNSS Earth Observation System was made open for public and private uses in Japan[624]. All of this information was made available to the public via a web mapping service.[625]

South Korea is embarking on an ambitious cadastral reform project. The project is set to run from 2012 to 2030 and has a budget of US$1.7B. It will resurvey 38 million parcels with an accuracy of +/- 7cm, integrate the newly surveyed information into a digital database, and create a 3D cadastre[626].

Geospatial Information Analysis and Presentation

Pasco Corporation is Japan's largest provider of digital maps. In addition to being an authorized Esri distributor it has a range of products including software and data (distribution as well as generation). The company has a fleet of 42 aerial survey aircraft[627], and also provides cloud hosting, consulting, implementation, and end-to-end solutions[628].

Samboo Engineering is a leading Korean geospatial solution company that provides a range of geospatial information services including aerial photography and digital map production. Samboo is also involved in software development and GIS R&D and has carried out projects both domestically and internationally[629]. Another Korean provider, GeoC&I, is a firm of GIS consultants that produces a range of information management systems for agriculture, environmental management, disaster prevention and facilities management[630].

Integrated Information Products and Services

The Hitachi Zosen Corporation is a major Japanese industrial and engineering corporation. It also manufactures and deploys a range of equipment based on high precision GPS technology. These include an electronic datum point network that monitors tectonic movement and offshore wave meters capable of observing tsunami in real time[631].

InSpace is a Korean certified Venture Company that specializes in research and development, spun off from the Korea Aerospace Research Institute, operating in the field of remote sensing and image analysis. They develop hardware and software solutions for the collection and processing of satellite imagery as well as providing consultancy services in the application of satellite imagery to solve real world problems[632].

Location-Based Solutions

Leading Japanese mobile telecoms provider Docomo has partnered with Pioneer, an in-car navigation systems company, to create an intelligent transport network. The system will use data gathered from Pioneer's car-mounted navigation units and Docomo smartphones in moving vehicles to process detailed traffic information in Pioneer's cloud platform[633].

In November 2013 the Singapore Land Authority launched the geo innovation fund to spur innovation in the use of GI in Singapore. The fund offers up to $50,000 for projects that are deemed innovative, sustainable and feasible. So far two apps have been launched; the first helps find public toilets and then rate them on cleanliness; the second allows users to locate nearby recycling bins, check-in to bins and gain community 'credits'[634].

In 2012 a study of the Korean smartphone market found that there were 30 million smartphone users in the country. Of all mobile phone users in Korea, 58.5 percent were found to be using smartphones[635]. The widespread penetration of smartphones into the Korean mobile market presents many opportunities for location based services. The Korea Communications

Commission, noting a rise in the number of location based businesses registering, has initiated a "plan for the activation of use of locational information", which includes informative videos and workshops to help new start-ups avoid legal pitfalls[636].

Geospatial Information Technologies

The mainstream GIS companies are all very active in Asia, with distributor companies in most territories and there are a few notable domestic companies as well. For example, Multi Agent Knowledge Orientated Cyber Infrastructure (MAKOCI) is an innovative Taiwanese Geographic Information Services cloud computing platform. It brings together GIS systems and data from a variety of online sources and provides a graphical interface to allow the creation of workflows to analyze the data[637].

An example of an Open Source Asian start up is Mango Maps, a Cambodian online mapping provider that produces highly customizable pre-rendered maps. It is based entirely on Open Source mapping software and is very user friendly. It is a competitor to services such as Mapbox, and buthas (a more user friendly graphical interface, as opposed to Mapbox), which requires some knowledge of programming languages[638].

C.8.2 Demand Side

Central Government

The Singapore Geospatial Collaborative Environment (SG-Space) aims to create an environment in which the public and private sectors and the communities can collaborate on a wide range of applications and services using geospatial information. SG-SPACE is a cross-government initiative driven by the Singapore Land Authority (SLA) and the Info-communications Development Authority of Singapore (IDA) with the aim of implementing Singapore's NSDI. As at June 2012, over 370 layers were available from 33 public agencies[639]. The data is available to 77 agencies under 15 ministries via the GeoSpace portal, and can also be accessed by the public via the onemap.sg web mapping service, or the data can be accessed directly via the data.gov.sg website. The GeoSpace portal is a powerful collaborative cloud based system that allows data selection, query and analysis with both vector and raster geo-processing, and a 3D modelling function. The platform also allows the integration of spatial and non-spatial data, as well as live data (such as weather information) via geo-rss feeds[640].

The One Nation One Map project is a geo-portal project in the Philippines. It is an e-government project designed as part of the Philippines National Spatial Data Infrastructure Plan. The aim of the project is to establish a web portal. The Philippine Geoportal intends to hold and serve to the general public the basemaps and fundamental datasets created by the National Mapping and Resource Information Authority (NAMRIA). This will then be used as a basis to integrate thematic data from other stakeholder agencies. As at 2011 NAMRIA had uploaded the available topographic base maps namely, 1:250,000 (whole country), 1:50,000 and 1:10,000 (selected areas), LiDAR and orthophotos (Greater Metro Manila, 2011), geodesy, hydrography, forest cover, and land classification. Key government stakeholder agencies also provided their fundamental datasets to the Philippine Geoportal and these include data on agriculture, environment, health, education, national roads and infrastructure, tourism, transportation and communication, climate and natural hazards[641].

Indonesia used the Esri ArcGIS Online platform to create a geo-portal of geospatial data, which allows the various Indonesian government agencies and the public to search, analyze, share and publish geospatial data online[642]. The portal and accompanying SDI will form an authoritative source of geospatial information for the country when completed. The country has encountered difficulties with conflicting datasets for important issues on for example, forest coverage, or even the location of administrative district boundaries. Using the geo-portal framework, ministries work together to input a number of thematic layers, with forest area being of upmost importance as part of a national programme to halt deforestation[643].

The Malaysian Centre for Geospatial Data Infrastructure (MacGDI), an agency under the Ministry of Natural Resources and Environment, has launched MyGOS (Malaysia Geospatial Online Service), an integrated portal for geospatial services and information. Information available via the portal includes: The 1Malaysia map, Air Pollutant Index and Management System, 2013 General Election, Malaysian standard geographic information and Road Networks[644].

Local Government

In November 2012 Thailand's Geo-Informatics and Space Technology Development Agency opened a new Space Krenovation Park. The new centre will focus on meeting global demands for Geo-Informatics and Space Technology as well as stimulating new businesses and acting as a centre for training in remote sensing and mapping[645].

Makati City in the Philippines has developed its own Land Information System and produced a coordinate-based cadastral map. The City uses the system to produce thematic and analytical maps, which are being used for: land use planning, disaster risk reduction, environmental management, real property and business tax mapping and social services monitoring[646].

Utilities

Manila Water in the Philippines is a public/private water company serving 6 million people. The current ownership began in 1997 and inherited a water system with many problems. GIS was implemented for asset management in order to optimize planning for renewal investment. Since 1997 the service has improved significantly. In 2012 24 hour water coverage was at 99 percent up from 26 percent in 1997 and the proportion of the water produced that was lost before reaching the customer was at 11 percent, down from 63 percent in 1997. The company also pioneered an innovative integration of the GIS database with the customer relationship management database[647].

Pengurusan Aset Air Berhad (PAAB) is a Malaysian water asset management company with responsibility for Malaysia's water infrastructure in Peninsular Malaysia and the Federal Territories of Putrajaya and Labuan. PAAB recently undertook a project to standardize the various water distribution spatial data models from the various Malaysian states. The new standardized model provided PAAB with a standard platform for spatial analysis, data management, and digital mapping. The model was also used to create a web dashboard application to provide a high level view of PAAB's operations and assets including: operational and maintenance information relating to assets; customer consumption and customer service information and reports on breakdowns and service disruptions[648].

Land and Property

The Sarawak Land and Survey Information System (LASIS) holds digitized versions of all land and cadastral data for the state of Sarawak. The data is used for surveying, planning, valuation and conveyancing and the system is used to administer land tenure, land value, land use, land development, enforcement of land laws, collection of land-related revenues, and any other land matters. The system allows the processing of applications online without physical documents, reducing the length of time taken to register a property to just one day. Currently the US$35M system is being used to maintain up-to-date records of over 950,000 land parcels and provide authoritative land information to over 3,000 staff[649].

However, the top down approach to digital land administration systems has not been as successful throughout Asia. In Sri Lanka a digital land information system was introduced in 2003, but by August 2012 only 500,000 (out of 12 million) parcels were registered[650]. The potential benefit of a more innovative approach using crowd sourcing and low tech might be usefully repeated here[651].

Transport

The Land Transport Authority of Singapore has created a Land Transport GIS Hub that incorporates information on public transport, road infrastructure, traffic, engineering and transport planning. The system is used to design, build, manage, analyze and inform the public on transport issues. The public facing website is achieving over 10 million hits per month and includes a range of apps for download including an app that allows the public to crowd source maintenance requirements such as the location of potholes[652].

The East Japan Railway Company, the largest railway corporation in Japan, developed a series of GIS systems in conjunction with SuperMap the Chinese GIS software supplier. The systems are used to manage all of the company's railroad facilities throughout Japan[653].

Agriculture

The Indonesian Agriculture Field Survey System uses Supergeo's[654] mobile, desktop and server applications to obtain and manage spatial information about farmland. The system collects data on crop types and conditions and precisely measures farm size in each district. The data is collected using rugged mobile GIS systems that use GPS for measurements while the GIS server provides a platform for data synchronization, management, and sharing. The system allows the Indonesian Ministry of Agriculture to visualize and analyze field data and make decisions on grant funding and subsidy policy[655].

The Land Cover Database of Farmlands of Taiwan was constructed based on supervised and unsupervised multi-temporal classification of remote sensing technology (satellite and aerial photographs), aided by the necessary ground trothing. The project maps the distribution of crops three times per year. It started in 2008 in Tainan County and expects to be able to map the whole of Taiwan, three times a year, by 2015. More than 50 species of crops including major staple food, upland crops, vegetables, fruits and bamboo distribution layers were mapped. This information is used for making agricultural and other natural resources management decisions, and is also available to the public via a web mapping interface[656].

Safety and Security

The Asia Pacific region is particularly vulnerable to natural disasters. According to the United Nations Economic and Social Commission for Asia and the Pacific, from 2001-2010, on average, more than 200 million people were affected and more than 70,000 people were killed by natural disasters annually[657].

The Sentinel Asia initiative is a collaboration between space agencies and disaster management agencies, applying remote sensing and Web-GIS technologies to support disaster management in the Asia-Pacific region. Sentinel Asia provides disaster related information, such as satellite imagery and satellite data products, on its website[658].

The Japanese authorities have a well drilled GI disaster response procedure which was deployed following the Great East Japan magnitude 9 Earthquake and Tsunami in 2011. The response started before the earthquake through thorough planning and lasted for several months after. In the emergency response stages, less than one hour after the disaster, small scale (1:500,000) were provided to government offices, ground service movement was assessed and an aerial survey took place. In three days the Tsunami inundation areas were delineated and aerial photos interpreted. Within 2 months victims were issued with disaster building damage certificates. After two months geodetic control points were re-surveyed and damaged areas were mapped at 1:2,500 scale for reconstruction planning[659].

Malaysia has launched an emergency response smart phone app. The app is aimed at disabled people and particularly those with difficulty verbally communicating such as the deaf and mute, but could also be used by others having difficulty communicating, such as those having a heart attack. The app uses the user’s location information. The app can summon immediate assistance and allows the user to enter supplementary information including photographs[660].

The Taipei City Fire Department has developed a GIS-based Incident Command System. The system integrates spatial information derived from digital maps, building and block maps, aerial photographs and water resource maps to enable the city's Emergency Dispatch Centre to manage and mobilize rescue operations. It also provides local authorities with a heightened situational awareness in emergency situations[661].

C.9 Latin America

C.9.1 Supply side

Geospatial Information Capture and Processing

The Latin American region is making important advances in SDI, particularly for aspects such as legal framework, policies, geospatial data and services accessibility and data production. Data content includes geodesy, transportation networks, elevation, imagery, topography and administrative boundaries. Colombia and Ecuador have made important progress in term of data and metadata. In addition, approximately 80 percent of the countries publish Web Map Services. Countries that use a legal framework and established financing models offer more geospatial data and metadata.

Regionally, new partnerships and outreach efforts have also been prominent, such as the 2013-2015 Joint Action Plan to Expedite the Development of Spatial Data Infrastructure of the Americas, signed in November 2012

The Brazilian Institute of Geography and Statistics (IBGE) is the Federal Government institution responsible for producing, analyzing and disseminating statistical information as well as geodetic, cartographic and geographic information. Brazil also has the National Institute of Space Research (INPE), responsible for the development and application of space technologies, including remote sensing, which has made all of its data available on the Internet free of charge. This initiative has been further supplemented by also providing free Open Source software SPRING. CONCAR, the Brazilian National Commission of Cartography, sets technical standards and specifications for the production of geospatial data for the National Cartographic System[662].

Brazil's remote sensing community has been in partnership with China since 1984. The partnership has resulted in the China–Brazil Earth Resources Satellite program (CBERS). The programme has deployed three successful satellites, all of which have come to the end of their life span. CBERS 3 was launched in December 2013, but malfunctioned and was lost. CBERS 4, due to launch in 2014, will carry four sensors able to obtain imagery in a wide range of bands, up to a resolution of 5m (panchromatic)[663].

SSOT (Satellite for Earth Observation) is an optical high-resolution microsatellite controlled jointly by the Chilean space agency and air force. The satellite was built by EADS Astrium and was launched in December 2011 in French Guiana. The on-board sensors provide imagery of 1.5 m resolution in Pan 6m resolution for multispectral images[664].

VRSS-1 is Venezuela's first remote sensing satellite. The spacecraft was designed and developed by the China Academy of Space Technology of Beijing and was launched in September 2012 at the Jiuquan Satellite Launch Centre in China. This satellite is equipped with both high-resolution cameras and wide-swath cameras. The high resolution cameras are able to obtain imagery of 2.5m resolution in pan and 10m resolution for multispectral images[665].

Geospatial Information Analysis and Presentation

The GeoSUR Portal provides an entry point to spatial data published by Latin American and Caribbean agencies. More than 90 institutions from 25 countries in the region are actively involved in the Program, and over 10,000 digital maps are available from its regional portal. Access to services offered by GeoSUR is free and requires no special software[666].

Integrated Information Products and Services

Santiago & Cintra Consultoria is a Brazilian consulting company specialising in geospatial solutions. It is the largest supplier of satellite imagery in Brazil and has developed unique Web-GIS based solutions, serving a wide range of markets. It won a number of awards at the 2013 MundoGeo conference.

Location-Based Solutions

There are apps starting to emerge in Latin America but the lack of geospatial base data is generally constraining development.

Geospatial Information Technologies

The market is very software oriented and Esri acts as the leader. GE Energy, SPOT Image, Hexagon AB, MacDonald Dettwiler and Associates, Bentley Systems, Autodesk and AEROTERRA are also present. The Canadian geomatics software sector is also the most active.

C.9.2 Demand side

Central Government

The Mexican National Institute of Statistics and Geography (INEGI) generates statistics on drinking water management, sanitation and urban solid waste through census surveys. This information is combined with 24,000 geo-referenced objects of environmental interest such as sources of water catchment, treatment plants, disposal sites and utilities. The information is integrated in a web-based geoportal for comprehensive visualization of water and waste management. The system is used for decision making, such as locating municipal dumping grounds[667].

The Infraestructura de datos geoespacial de Peru (IDEP) includes geospatial data sets such as elevation data, transportation networks, hydrography, political and administrative limits, toponymy, orthoimagery and land parcels. It is a collection of separate and disparate web sites, catalogues, maps and tools developed and maintained by Peruvian ministries with ten specific nodes in the fields of health, education, justice, statistics, disaster prevention, environment and mineral exploration.

The INDE (Infraestructura Nacional de Datos Espaciales) of Chile relies on a network of fifteen regional geospatial data infrastructures that offer interoperable services based on OGC standards. Each region has its own approach to building and promoting its data, and viewers, tools and strategy vary greatly. For instance, the Santiago area offers only web links to static map products in pdf format while the most recent Los Rios' SDI is trendier and more dynamic, with tools to view, download or search data. Overall, only small scale data is available. All major national agencies participate in an Integrated Cadastral Information System[668].

Infra-estrutura Nacional de Dados Espaciais (INDE), the Brazilian spatial data infrastructure[669], creates, implements and maintains the SIG Brasil Web geoportal, which should provide access to all of INDs geospatial data and services. The portal hosts the central data catalog (Diretório Brasileiro de Dados Geoespaciais - DBDG), and data is provided at no cost to any registered user. INDE also has an open access policy regarding its extensive library of remote sensing images. It enables independent verification of deforestation numbers. Brazil extensively uses open software, particularly PostGreSQL, MapServer and a Web-based viewer a solution called i3Geo).

The Simón Bolivar Institute acts as the leader of geospatial data infrastructures in Venezuela (IDEVEN). The Simón Bolívar National Geoportal is a project for the distribution and use of official geospatial data in Bolivia. The portal gives access to the usual base data layers through a browser – Land Management and Planning, Coastal zone management and Hydrographic Geoportal.

INEGI, the Mexican National Geographic Agency, is the key actor in the development and implementation of the Mexican Geospatial Data Infrastructure (IDEMEX). IDEMEX is generating a minimum of seven data groups: geodetic reference framework; coastal, international, state and municipality boundaries; continental, insular and submarine relief data; cadastre, topographical and natural resources and climate data, as well as geographical names. INEGI publishes Web Map Services for DEM, topography (1:1,000,000, 1:250,000, 1:50,000), administrative boundaries, toponymy, transportation networks, geodesy, some information related to natural resources, land parcels and imagery. However, it is not possible to download data online[670].

There are also Open Data movements developing across Latin America[671]. One of the earliest adopters of Open Government policies was Brazil where a strong civil society movement

'Transparência Hacker' has sprung up. The group has developed mapping mash ups showing young adult education resources and the consumption of rain forests[672].

Local Government

The Secretary of Finance of Rio de Janeiro invested US$10M in georeferencing the asset data base in the City of Rio de Janeiro. The system includes a GIS application for visualization and planning. The benefits of the system include: cost reduction, optimization of resources and increase in municipal tax revenue[673].

The ICDE (Infraestructura Colombiana de Datos Espaciales) is part of Colombia's Smart Cities strategy. The project's aim is to reinforce production, exchange, access and use of geospatial information between government agencies. The ICDE offers many WMS services through 9 major agencies. Fees charged for data sets depend on the production agency but costs are being kept low in order to ensure the update and maintenance of data[674].

Defence and Intelligence

Defence and intelligence represents a key sector, as it generally operates the national mapping agencies in Latin America. However, this sector keeps a high level of control on any IT implementation, claiming security issues. For this reason, the South American military sector cannot be considered a market for geospatial Canadian suppliers, except maybe for acquisition of airborne or space borne imagery and image analysis software.

Safety and Security

In Chile the Regional Plan for Territorial Ordering (PROT) is an emergency management system for assessing threats, vulnerability and risks of natural hazards. PROT was utilized during the eruption of the Hudson volcano in the Patagonian Andes in October 2011, when it provided information on the areas at risk of lava, lahars, and pyroclastic flow and fall. The information supplied by PROT resulted in the authorities evacuating a 40 km radius area without injury or loss of life[675].

Several Brazilian states have adopted GIS-based Integrated Public Safety systems. The Brazilian state of Amazonas invested US$150M to map major cities and implement a GIS crime mapping system integrating monitoring cameras and GPS navigation for responders. The result was a 10 percent reduction in police incidents and 13 percent reduction in homicides in May 2012 compared with May 2011. The Brazilian State of Bahia used a similar system to monitor events and optimize decision-making and planning during the Salvador Carnival in 2011.

Authorities in Brazil[676] and Colombia[677] are also using GIS and satellite imagery to map areas at high risk of landslides.

Health

The Mexican National Council for Science and Technology funded the development of a web based, geographically-enabled, dengue integral surveillance system (Dengue-GIS). The system manages the nation-wide collection, integration, analysis and reporting of geo-referenced epidemiologic, entomologic, and control interventions data. Dengue-GIS provides the geographical detail needed to plan, assess and evaluate the impact of control activities. The system is beginning to be adopted as a knowledge base by vector control programs. It is used to generate evidence on impact and cost-effectiveness of control activities, promoting the use of information for decision making at all levels of the vector control program[678].

Education

The principal country advancing education in GIS in Latin America is Brazil, with the Instituto Nacional de Pesquisas Espaciais, São José dos Campos providing recognized graduate programmes. Brazil offers more than 20 graduate programmes in which GIS is a significant component. Other courses have been offered with a variety of GIS perspectives by: the Geographical Institute 'Agustín Codazzi' of Colombia, UNCPBA and UNLU in Argentina, and Universidad Autónoma del Estado de México and Toluca in Mexico[679]. In addition, UNIGIS in Latin America offers distance education programs in GISciencia and Geographic Information Systems from Ecuador, in partnership with the University of Salzburg (Austria)[680].

Environmental Conservation

The Brazilian MMA Project provides geospatial information to support government decision making and technical teams plan the sustainable use of natural resources in Brazil. The system incorporates satellite data at a range of spatial, spectral and temporal resolutions and performs analysis to support a number of different programmes, particularly the Rural Environment Cadastre. MMA data is available via a web based geoportal. The thematic database generated by the project has been used to support legalisation of property rights as well as environmental monitoring projects[681].

The International Center for Tropical Agriculture (CIAT) based in Colombia is lead partner in the Terra-i project. This is an effort to detect, using remotely sensed satellite imagery, land cover changes resulting from human activities in near real-time, producing updates every 16 days. The system is based on the premise that natural vegetation follows a predictable pattern of changes in greenness from one date to the next brought about by site-specific land and climatic conditions over the same period; the system marks areas as changed where the greenness suddenly changes well beyond these normal limits[682].

In Argentina, very high resolution satellite imagery and image processing software has been used to conduct tests on automated whale counting techniques. The system was used to count the number of Southern Right Whales in a section of the Gulf of Nuevo and was able to find 90 percent of Whales identified in a manual search[683].

Utilities

The State Company for Water and Sewage of Rio de Janeiro has implemented a geo-referenced energy monitoring system. The system allows real time online viewing of asset electricity consumption allowing faster reaction for necessary cost reduction actions[684].

The Prefeitura da Cidade of Sao Paulo has developed a project called GeoCONVIAS that integrates data from 20 to 30 utilities operating in the city. The project organises underground infrastructure to prevent accidents and reduce inconvenience and costs. The Prefeitura da Cidade do Rio de Janeiro also has a similar project called GeoVias, part of the motivation for which was a spate of manhole explosions caused by the hazardous proximity of underground electrical and gas facilities under the city[685].

AES Eletropaulo, the largest electric distribution company in Latin America and based in Brazil, invested in a large project starting in 2008, to develop a corporate asset management system to support design, construction and maintenance of electrical network. The system integrated the network technical cadastre with the accounting system, avoiding rework and operational difficulties, improving network management, and maintaining a permanent and automatically updated network data base.

The Brazilian National Water Agency has produced the Atlas for Urban Water Supply for metropolitan areas, for Northeastern and Southern Brazil. The atlas includes population forecasts and demand estimates, evaluation of water sources, availability and quality, diagnosis of water producing systems and a proposition of technical alternatives for the water supply until the year 2025[686].

Land and property

A numbers of projects have been undertaken across Latin America in cadastre and land registry. These projects faced major challenges relating to data acquisition and update, government acknowledgement and funding.

MuNet Cadastre (Efficient and transparent Municipalities) is a project of the portfolio initiatives of the Government of Canada aimed at strengthening municipal cadastre information and institutional capacity building. The MuNet Cadastre Project had 2 phases; phase I began in 2006 and included implementing five comprehensive GIS cadastre projects and providing GIS software and support to five additional ones. The countries where the 10 projects were implemented are: Venezuela, El Salvador, Costa Rica, Ecuador, Chile and Paraguay. Phase 2 began in 2008 and is ongoing. Phase 2 aims to strengthen municipal cadastral capacity jointly with central governments in El Salvador, Ecuador, Bolivia, and Guatemala[687].

Microsoft has started mapping Brazil's informal settlements, known locally as Favelas, in a move designed to reduce the digital divide[688]. This interesting development replicates the outcomes of crowd sourced mapping projects that are ongoing in a number of African slums.

Transport

Brazil is planning a high speed rail link between its two major cities: São Paulo and Rio de Janeiro. CPRM, the Brazilian government agency for geology mapping was appointed to carry out the geological and geotechnical mapping for the project. The mapping was completed in less than three months using field crews collecting data using electronic notebooks with GIS software and thematic mapping data. The data was integrated onto a central server and combined with orthophotos and vector data, generating new layers of information for mapping[689].

Brazil has developed a geographic database for waterway transportation (inland, long haul and cabotage[690]) and for its port facilities. Vector maps of water transport routes were prepared from satellite imagery and combined with existing vector data in Brazil and from neighbouring countries. In addition, information was added about road and rail transport. The resulting integrated network was used to simulate demand and identify new areas for waterway terminals. The study indicated 41 potential areas and projected demand of 458 million tonne cargo to the water ways by 2030[691].

Communication

Oi (formally Telemar) won the 2011 Latin America Geospatial Forum Geospatial Excellence Award for implementing geospatial technology for business intelligence[692]. Oi have implemented JMap[693], a geospatial tool developed by Canadian geospatial company K2 Geospatial, which is designed to provide for access to rich geospatial information by non-technical decision-makers.

Agriculture

Brazil's Sugarcane Technology Center produces bioenergy from sugar. The Center uses GIS to produce thematic maps of sugar production areas using satellite images, which are combined with field surveys to identify the causes of problems, and to monitor the result of the actions taken. The system allows early diagnosis of problems and planning and rationalization in the application of agrochemicals. The results are reduced costs and environmental impacts, better and more uniform productivity, and better long term planning[694].

Renewable Resources

The South American Development Bank (CAF) has sponsored hydropower assessments in a number of Latin American countries. Most recently in December 2013 CAF finished a project to evaluate the hydroelectric potential of the State of Sao Paulo, Brazil in cooperation with the Energy Secretariat of Sao Paulo. As a result of the first phase of the study, a digital map was generated with the theoretical hydropower potential of each 1 km. river segment, estimating a total theoretical available potential of 3.5 GW for the State[695].

In May 2013 CAF completed the first phase of a hydro power assessment for Peru. This initiative leveraged the SRTM level-2 dataset (30 meter resolution) and hydrological data from Peru to undertake a detailed GIS analysis of the hydro power potential of more than 1,000,000 stream segments in that country[696].

Geospatial information is also used by Suzano, one of the world's largest paper and pulp companies. The company uses several GIS systems which incorporate satellite imagery and aerial photography to monitor their forest base compromising 770 000 hectares, divided over 7 states in Brazil. As well as asset management, the systems monitor forest age, stage of afforestation, and help with control of permanent preservation areas[697].

Non Renewable Resources

While Venezuela's massive oil reserves dominate this market, other countries are also interesting, such as Cuba, Colombia (large oil and gas reserves), Trinidad and Tobago (world-leading exporter of ammonia, methanol and liquefied natural gas), Ecuador and Guyana.

In Bolivia the YPFB Transporte S.A., a major hydrocarbon transportation company, has 6,200 kilometers of natural gas and liquid pipelines. Some of this transportation infrastructure was built over 60 years ago and a strict maintenance regime is required to ensure continuous operation. In 2009 the company transitioned from an old CAD-based system to a new interactive GIS-based mapping system for data maintenance, mapping and reporting, and integrity management[698].

Brazil has world-class resources of minerals including silver, copper, nickel, niobium, zinc, iron ore, manganese, bauxite, tin and gold, plus 12.2 billion barrels of oil reserves. Companhia de Pesquisa de Recursos Minerais (CPRM) is the Brazilian state owned company responsible for geological mapping. In the year 2000 the company launched a vigorous programme of modernisation culminating in a fully digitised data bank accessible via an online portal GEOBANK[699].

Codelco, a Chilean state owned copper mining company, used GIS analysis of satellite data for exploration of the copper provinces of Brazil to identify some common characteristics associated with porphyry copper ores.

Brazilian energy company Petrobras has had a GIS system for supporting the engineering division in the design and management of gas pipelines since 2003. More recently they have implemented a 3D GIS environment for management of equipment including manifolds, pipelines and platforms.

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