The social, technical, environmental and economic benefits and opportunities of accessing and sharing geodetic data.

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Key words: Geodesy; Data Sharing; Policy development; Capacity building

SUMMARY

The geodetic measurements observed over 2000 years ago, by the famous Greek mathematician and astronomer Eratosthenes, established the spheroidal shape and size of Earth. Since then geodesy has grown into the science of observing and understanding Earth's time-varying shape, gravity field, and rotation. Modern geodesy targets the study of processes as diverse as deformation of Earth's surface, redistribution of mass within and on the surface of the solid Earth, and changes in sea level. It provides the spatial framework that underpins positioning, navigation and timing, to better understand the world we live in, thus:

- contributing to hazard mitigation;
- facilitating better decision making;
- enabling spatial data interoperability;
- allowing for safer navigation by air, land and sea; and
- enabling more sustainable management and development of earth resources.

However to realise these benefits geodetic data should be shared and made available with minimal restrictions. Exchanging geodetic data should also consider international data sharing principles, so that as far as practicable the data is:-

- complete and comprehensive;
- timely, useable and accessible;
- interoperable
- machine readable and operable;
- non-discriminatory;
- non-proprietary; and
- available under an open licence or agreement

This paper discusses the argument for sharing geodetic data, the benefits that flow from accessing this data, and the need for a geodetic data sharing policy and strategy.

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1. INTRODUCTION

The geodetic measurements observed over 2000 years ago, by the famous Greek mathematician and astronomer Eratosthenes, established the spheroidal shape and size of Earth. Since then geodesy has evolved into the science of observing and understanding Earth's time-varying shape, gravity field, and rotation. Modern geodesy targets the study of processes as diverse as deformation of Earth, and rotation of and redistribution of mass within and on the surface of the solid Earth, and changes in sea level. It also provides the spatial framework that underpins positioning, navigation and timing.

Historically from a national perspective the geodetic system provided a local datum that formed the basis for national mapping and land development. Countries were concerned with developing local datums that were a best fit to their position on the globe and typically little consideration was given to connections to and contributions to global reference frames and data sharing.

However, with the advent of global positioning systems in the 1950s such as Long Range Navigation (LORAN) and more latterly Global Navigation Satellite Systems (GNSS), countries have progressively updated their national local datums to global geocentric datums and vertical datums accessed using ellipsoidal heights with a geoid model to derive sea-level heights. This shift has been realised in large part over the past four decades by the easy and free access to GNSS signals and data that enable accurate positioning anywhere, anytime. This has also led to a proliferation in the use of GNSS data to the extent that it is now regarded as a new "enabler" that is used in many aspects of our every day lives.

The success of these global systems is dependent on the provision of a well-distributed ground segment and provision of data that enables the accurate definition of these global reference frames to be refined, including the accurate determination of GNSS satellite orbits. In part it has been the support of relatively few countries that provide the global framework which enhances the accuracy and interoperability of GNSS systems from which all of society benefits. The United Nations (UN) recently recognized the importance of geodesy and geodetic systems as critical infrastructure, and the need for modern Global Geodetic Reference Frames (GGRF). In 2017 the UN established a sub-committee on Geodesy to promote better coordination of national geodetic activities, and establish accurate GGRFs that are sustainable and accurate. The important factors to facilitate this is the concept of open data and / or the sharing of geodetic data between countries.

An essential element to modernise geodetic frameworks or geospatial reference systems, and to make them critical infrastructure, is to warrant their relevance to the key decision makers and stakeholders within government. To be relevant geospatial information and geodetic data must be acknowledged and supported as integral components or foundations for government outcomes, outputs and operations. For some countries however, it is recognised they do not have the capability to provide all geodetic services or develop and maintain "state of the art" operational geodetic infrastructure and systems. In either situation, working collaboratively and in a unified manner, to exchange or share geodetic data is a mechanism that will allow countries, both developed and emerging, to achieve their social, economic and geospatial objectives or mandates in a fiscally constrained and competitive environment.

2. BENEFITS OF DATA SHARING

The use and benefits of geodesy and geodetic data extend far beyond what was initially envisaged. It provides the geospatial framework that underpins positioning, navigation and timing to enable decision makers to have a better understanding of the world we live in.

In October 2009, 76 scientists met near Salt Lake City to discuss the future of geodesy (UNAVCO undated). It was identified by these experts that geodesy was a key component to resolving or addressing global issues, including:

Where is the Water? - focusing on the distribution of water in the Earth system, in oceans, glaciers and great ice sheets, in the atmosphere, and on continents.

- Will the global population have enough water to sustain itself?
- How will Earth change as sea level rises?
- How do glaciers and great ice sheets change on timescales of months to decades to centuries?

Earth the Machine? – focusing on the dynamics of solid-Earth systems.

- How do tectonic plates deform?
- What physical processes control earthquakes?
- How does Earth's surface evolve?
- What are the mechanics of magmatic systems?

Beyond that they also perceived geodesy benefiting society as a whole by:

- Improvement of geodetic methods and accuracy leading to a host of benefits to society in non-scientific realms such as commercial and civic planning;
- Early warning for natural hazards – tsunami, earthquakes and volcanic eruptions;
- Rapid recovery from natural events;
- Facilitating better decision making;
- Enabling spatial data interoperability;
- Allowing for safer navigation by air, land and sea; and

- Enabling more sustainable management and development of earth resources.

To attain these and the many other benefits, the geodetic community (and others) require open access to and the sharing of geodetic data and associated information. Of recent times, there have been numerous publications, articles or reports which describe these benefits from a holistic perspective. As a consequence, the commentary in such sources should be considered or referred to by countries or agencies justifying the need for open data or data sharing. For example the information in the following reference material could be useful - "USGS–Why Share Your Data"; the Open Data Handbook–Why Open Data? ; the European Data Portal–Benefits of Open Data; and the World Bank Group–Data .

Contributing to a system from which all can benefit: As noted above, geodesy and geodetic data contribute too many aspects of our everyday life; in ways that could not have been imagined. Access to the "system" of GGRFs and GNSSs is essentially delivered through open access and free of charge. Subsequently, the greatest benefits can be gained if (a) participants contributed to the system by providing data to enhance or value add to the system itself; and (b) there is a well distributed ground segment of GNSS ground stations contributing data to analysis centers to enhance GNSS satellite orbits. It then follows that such data should be:

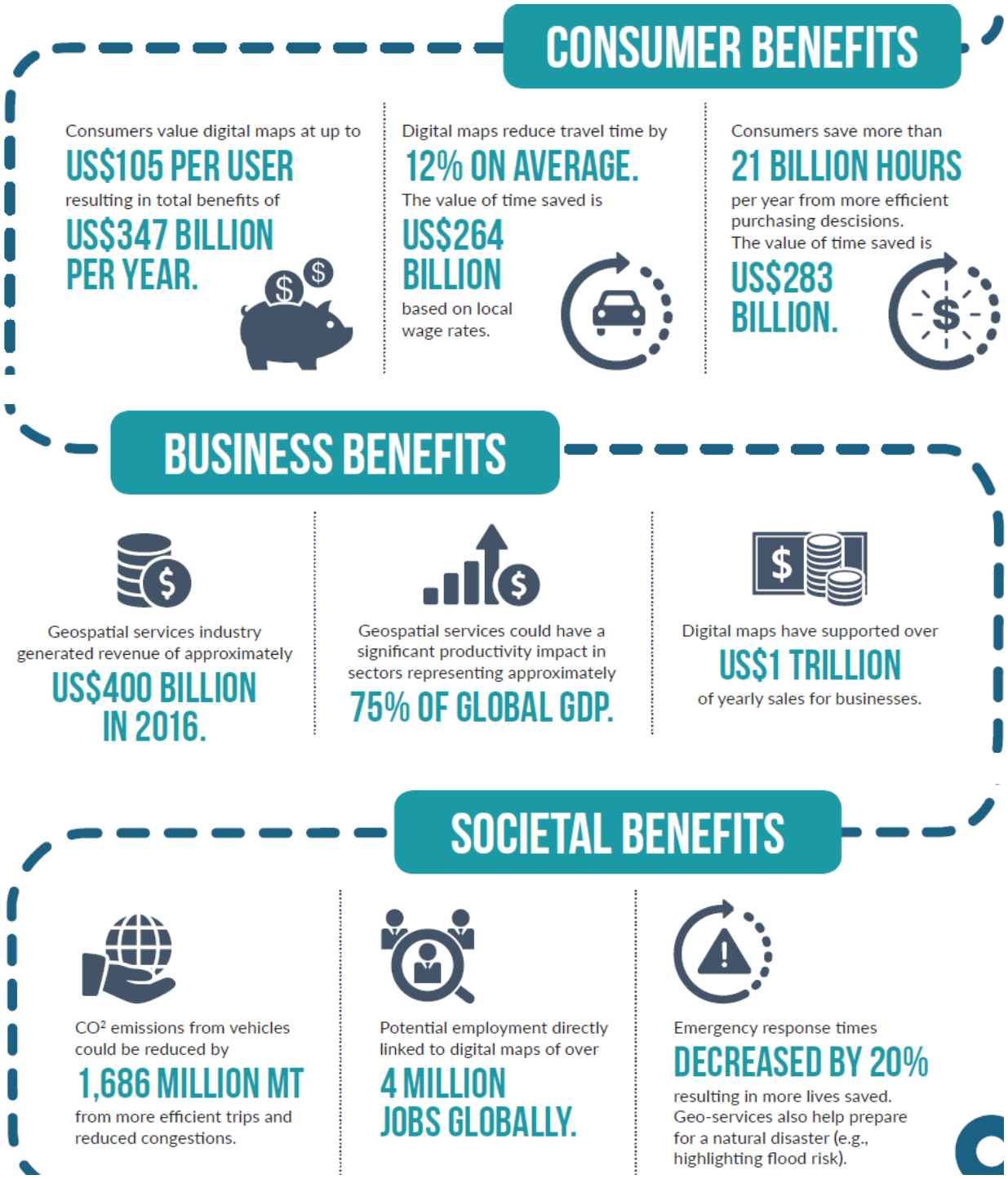
- Transparent, being clear as to origin, processing etc.
- Verifiable
- Discoverable

Risk mitigation and global change: Geodesy is a key tool in understanding and mitigating the effects of many natural hazards such as earthquakes and sea level rise. And yet the impacts of these risks do not stop at the borders of countries and at the very least are often regional in nature. For example global climate change and sea level rise is inevitable but to better understand the risk, the impacts and to mitigate this problem, sharing our data openly and freely is necessary to enable:

- Unification of observations for better decision making
- Cross checking of data from different disciplines
- Due diligence and review of any critical decisions

Innovative Applications: The use of GNSS data has far exceeded the expectations of the developers of those systems, and thus sharing geodetic data openly should also enable more innovative uses and applications. It should also be noted that any barrier to access will stifle innovation and can lead to duplication of effort and hence cost (MBIE, 2017). From a GNSS data from CORS (both real time and static) perspective, it is now regularly used by meteorologists for better weather forecasting; by scientists to better monitor the environment and geo-hazards (tsunami early warning system); and by positioning providers that underpin location based geospatial services. With respect to the latter, recent analytical research has estimated the "global" benefits and impacts of location based geospatial services in terms of consumer, business and societal (refer to the table on next page).

Re-use and return on investment: The value of data increases with the potential number of users. Reuse of data enables the reduction of redundant and costly repeat observations, leading to a greater return on investment. It also opens up opportunities for business to collect, curate and share geodetic information. For example in Australia and New Zealand data from the national GNSS CORS network is made freely available to all users for a variety of purposes. This also includes to private CORS suppliers who in turn supply their CORS data for (a) enhancement or validation of the geodetic reference frame or datum, (b) scientific research, and (c) for general public benefit, use and common good.

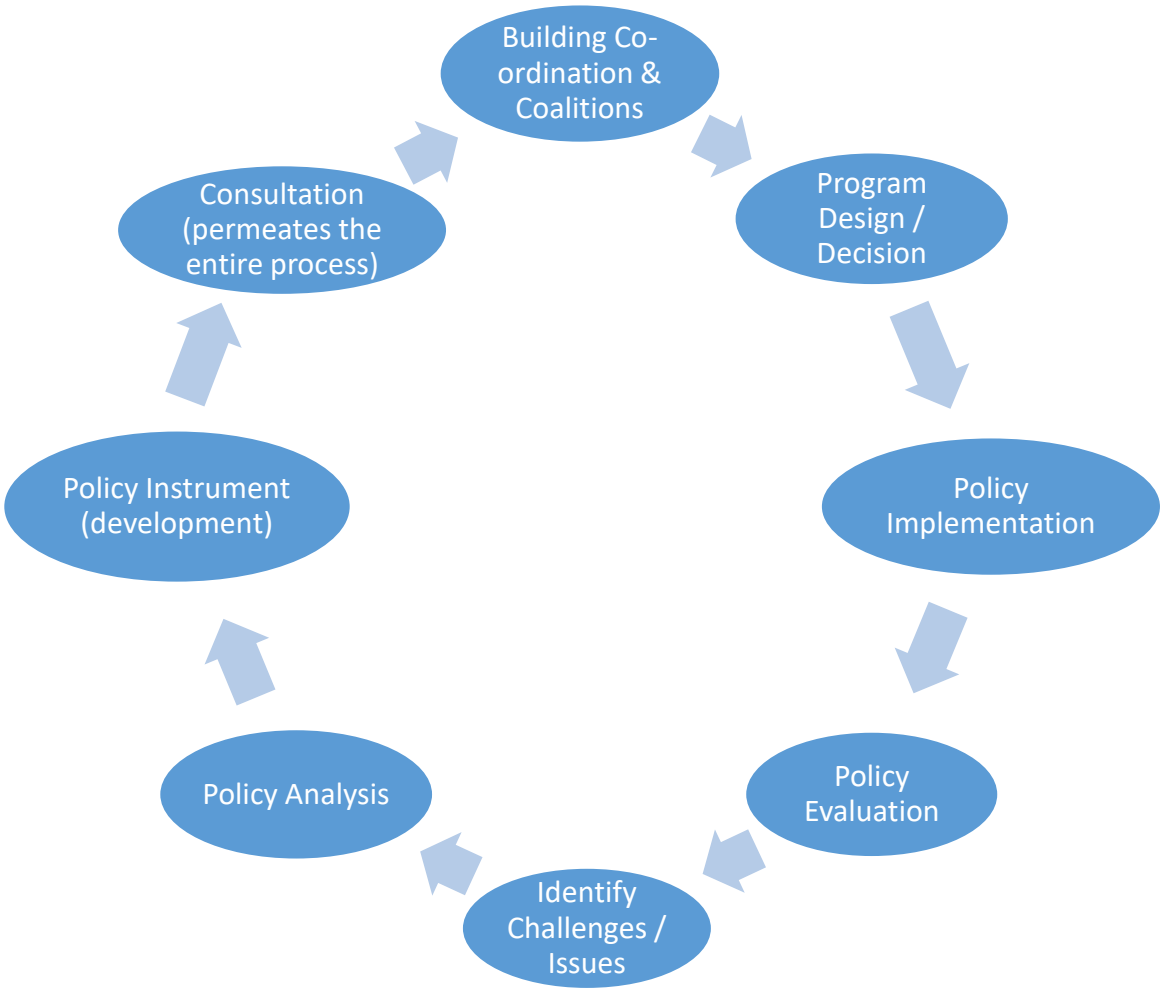


Source – AlphaBeta Strategy & Economics (2017)

3. GEODETIC DATA POLICY

In most countries the geodetic (or geospatial reference system - GRS) framework is controlled by a government "surveying and mapping" agency to administer the related legal, institutional, infrastructure, data, standards, people and technological matters. To perform this role government agencies often develop geodetic strategies, business plans to direct, guide and advocate a purpose to stakeholders and users. An integral part to the implementation process of government strategies is the development of relevant government policies, and administrative orders.

Briefly, a policy can be defined as a statement or an announcement of a government's activities, plans, intentions, and guiding principles relating to issues / challenges of the day. It often describes and declares how a government agency implements legislation, changes law, instigates a public or community initiative or makes decisions. To achieve this the following policy cycle could be employed –



Althaus et al (2012)

Accordingly, creating a geodetic data policy on accessing, exchanging or sharing is ultimately a decision for government and their respective agencies. Nevertheless such authorities need to consider the "why" and the "benefits", as previously articulated, but also acknowledge that there is a global trend amongst geospatial organisations, agencies and authorities to embrace, create or consider "shared or open" data policies, so as to contend with modern day social and economic challenges.

When contemplating a geodetic data policy (or strategy) a simple strengths, weaknesses, opportunities and threats (SWOT) analysis should be performed so as to identify and understand the internal and external factors or key issues affecting geodetic data. Although this type of analysis does not necessarily offer solutions it does provide the opportunity to align other key strategies and initiatives associated with the geodetic framework. There are also other questions

relating to geodetic data sharing which should be asked or considered during the initial stages of the analysis or brain storming, and they are –

- Why do you want to share geodetic data?
- What is the primary purpose or driver for sharing?
- What is your government's position or opinion on geodetic data sharing? On data sharing generally?
- What geodetic data can be shared and what are the formats?
- Who is the owner and / or data custodian of the subject geodetic data?
- How will the geodetic data be accessed?
- Who should be involved – internally and externally, traditional and non-traditional?
- Do you have the capacity to share geodetic data? If not, what needs to be done and changed?
- Are there impediments, restrictions or challenges (real or perceived) associated with sharing geodetic data? – Technical, political, legal, social, economic? How will these be resolved?
- What is the status of your geodetic data: "closed" or "opened" or "shared"?

With respect to the last point it is important that the terminology use in a geodetic data policy is understood, consistent and aligned with internationally accepted definitions. According to the Open Data Institute (https://theodi.org/what-is-open-data), the exchanging of data can be classified into three types –

- ***Open Data*** – data that can be accessed, used, and shared by anyone without restrictions. Examples are - Weather records, earthquake monitoring data, and particle physics information has been opened up for research to develop solutions or assist risk management
- ***Closed data*** - data that only people in an organisation can see. Examples are - National security data, mobile phone use, confidential business reports
- ***Shared data*** (a hybrid of both) – data that can be use by a specific group of people for a specific purpose with "conditions"; broad term that is often used to cover data that is collected every day. Examples are - Supermarket shopping habits, electoral register

Essentially the difference between these classifications is about ***who can use data and how***! From a geodetic data perspective the questions that should be asked are –

- What classification is your ***geodetic data***?
- Is it closed? If so, why?
- Can it be open? If yes, then is it being implemented and how?
- Can it be shared with expressed permissions on how it shall be accessed, used, re-distributed and published? If yes, then what can be improved?

4. FUNDAMENTALS OF A GEODETIC DATA POLICY

Based on research of various government data policies, globally and in the Asia Pacific region, (refer to Bibliography section) there are several rudimentary elements that should be included in a geodetic data policy. These elements, if expressed in a clear and concise manner, should define the agency's position and obligations with respect to disseminating (publishing), sharing and using geodetic data. They should also guide the agency on what data shall be shared / released, inform external stakeholders on how and when such data will be made available, and more importantly, how they can contribute to the data sharing process itself and to achieve the "outcome" of sharing geodetic data.

In the first instance the policy needs to state why government wants such a policy and its significance to industry, stakeholders, users and the community. It is vital this statement also articulates the benefits, purpose, vision, and drivers for the policy. The reasons for such a policy can emanate from a need, an issue, obligation or expectation that has a scientific, economic, technical, environmental, and social or community basis. For example to -

- Foster transparency, accountability, a more efficient, effective and responsive government
- Stimulate research outcomes, and innovation
- Improve management (interoperability) of geospatial datasets, assets, service delivery
- Support initiatives with respect to disaster risk management, mitigation, monitoring
- Create economic opportunities
- Enhance development of fundamental data for SMART cities
- Facilitate capacity development
- Deliver or measure Sustainable Development Goals (https://theodi.org/supporting-sustainable-development-with-open-data)
- Empower governments, society, public and private sector organizations to work toward better outcomes

It is important for the geodetic data policy to declare the principles which guide the implementation of the policy itself. These principles could also be the core values, ideologies or standards that are associated with the release and reuse of geodetic data. It is apparent that many present day data policies use or have adopted a hybrid of the "six" principles espoused by the "Open Data Charter", which was formulated through a collaboration of numerous governments and experts advocating and working to open up data. The six principles are –

1. Open by Default
2. Timely and Comprehensive
3. Accessible and Usable
4. Comparable and Interoperable
5. For Improved Governance and Citizen Engagement
6. For Inclusive Development and Innovation

For more information about these principles and the "Open Data Charter" refer to https://opendatacharter.net/principles/ .

The geodetic data policy must describe to whom the policy will apply, and what geodetic data is be shared. It should provide a scoping statement that expresses what the policy will do and what geodetic data it applies or refers to such as – GNSS, gravity, height, tidal, and other data sources. When considering this section of the policy, the list of stakeholders, parties and agencies should not be confined to just who is directly involved but it should also consider who else will be affected, who will be responsible for certain aspects, who can collaborate and assist with implementation, and who will need to be engaged to ensure sustainability. Note, as geodetic observations and geospatial systems are now more universal, space and internet based, consultation about data sharing should not be limited to local or traditional sectors, so views from non-traditional stakeholders, who are regional or global and from different scientific, academic, commercial, professional, and industry sectors, need to be sought.

Another aspect of a geodetic data policy that needs consideration is management and governance. This may include an explanation of the framework to release, receive, process, store and record geodetic information, and the authority responsible for such activity. It would also be prudent to refer to any applicable legislation or other relevant policies that may affect geodetic data sharing. For example, statutes or administrative orders pertaining to copyright, intellectual property, privacy, freedom of information, national security, records / information management etc.

From a technical perspective it will be necessary to ensure the geodetic data policy describes and references the "standards and practices" required to acquire, deliver or submit geodetic data of a specified integrity, quality and type; alternatively in more general terms data publishing standards. Using GNSS data as an example, presently the requirement for static and real time data streams (in a machine-readable format) is RINEX or RTCM respectively; the metadata must comply with IGS log files; and data collection to be in accordance with industry best or acceptable practices.

It also needs to be noted that policies of this nature need to be "agile and flexible" due to the ever changing technology, the trend to automate processes, and the demand for 3-dimensional visualisation in near real time. For example in the future the sharing of geodetic data (and metadata) will be through web services, cloud based systems, and via an Extensible Mark-up Language (XML) based standard for geodesy, known as GeodesyML. Briefly, this concept of storing data in a structured way, which is both human and machine readable, allows for optimal transference and validation of data and metadata; facilitates the requirements of geospatial web based databases; and enhances dataset interoperability. Presently the data exchange format only accommodates GNSS data and is aligned with international standards, thus supporting a broad spectrum of government, industry, science and societal applications. Refer to website for more information - http://geodesyml.org/geodesyml-information/ .

For some countries there will be a necessity to place restrictions or conditions on the use of geodetic data, and in this instance the policy will need to explain such requirements. This situation is often expressed though a data licensing or sharing agreement, which should outline the geodetic data to be transferred, along with the limitations on use, access, sharing, publishing. To gain a better understanding and for general information about licensing geospatial information, from a surveying professional and non-legal perspective, navigate to the website to view the document "Compendium on Licensing of Geospatial Information" - http://ggim.un.org/meetings/GGIM-committee/7th-Session/documents/Agenda%208%20-%20Compendium%20on%20Licensing%20of%20Geospatial%20Information.pdf

Depending on the agency's organisational culture or mode of operations geodetic data sharing policies may also outline the process for the various phases of implementation and associated timeframes. In some cases the policy may provide details of how the relevant agency will interact with external and internal stakeholders; roles and responsibilities of stakeholders; the method of obtaining feedback; and how the success of the policy will be monitored and measured (for more detail refer to section – Implementation of a Geodetic Policy).

There are also other elements that could be incorporated into a geodetic data policy, through additional sections or appendices, such as –

- Definitions and terms used in the policy document. Note for data sharing terminology and definitions refer to website - https://opendatacharter.net/resource/definition-key-terms-charter-principles/
- More detailed explanation of the "principles"
- Specifications of the geodetic data to be shared – quality / formats / standards / metadata
- Examples of an "open data" or "data licencing or sharing" agreements
- References to geodetic data sharing "toolkits", guidelines
- Frequently asked questions
- Who to contact

Overall there is no right or wrong way to prepare a geodetic data policy; however policy writers are encouraged to review the following websites –

- https://theodi.org/guides/writing-a-good-open-data-policy - a check-list to make sure a data policy is clear, useful and has the best impact
- https://theodi.org/maturity-model - a way to assess how well an organisation publishes and consumes open data, and identifies actions for improvement.

5. IMPLEMENTATION OF A GEODETIC POLICY

From experience, the successful implementation of any new initiative, idea, or policy will often depend on the strategy to change the mind-sets or paradigms and culture of the organisation(s) and stakeholders involved. The publication "Open Data in government: how to bring about

change" (https://theodi.org/open-data-in-government-how-to-bring-about-change) suggests a variety of change management initiatives to implement data sharing. Using these perspectives the following should be considered by policy developers with respect to sharing geodetic data.

- Articulate the policy vision, with clear examples of benefits the geodetic data sharing will bring.
  - Is there a challenge that sharing geodetic data can resolve?
  - What are the benefits of sharing – tangible / specific / universal / non-geospatial?
  - What value will geodetic data sharing bring to the community?

- Secure support for the geodetic data sharing initiative from both senior government officials within the agency, and political leadership before declaration.
  - Create a campaign / initiatives to advocate / educate government officials about geodetic data sharing.
  - Fostering support for the change will help encourage early uptake and on-going ownership.
  - Develop a resourcing plan (with time frames) to implement and sustain geodetic data sharing

- Find "champions" of geodetic data sharing at all levels within government and key external stakeholders.
  - This is essential for the implementation and sustainability of geodetic data sharing.

- Create an accessible and simple mechanism to deliver information and receive feedback about geodetic data sharing.
  - Use whatever means and opportunities that are available to engage stakeholders, participants and users.

- Need to have "quick wins" for your geodetic data sharing initiative to assist the momentum for change.
  - Release a certain number of complementary or subgroup datasets for geodetic data sharing; set up data sharing processes for internal agencies.

- Be agile, flexible and responsive to the strengths and needs of different agencies and work units.
  - Have clear data sharing transitioning objectives and practices. Ensure geodetic data sharing principles are aligned with internal data policies and future reforms.

- Consolidate change management efforts
  - Support staff to be educators and innovators so as to build on "quick wins" and identify gaps the strategy

- Ensure the all members of geodetic data sharing team have open, frank, regular communication.
  - All parts (and people) of the geodetic data sharing are important to the sustainability of the initiative.

- Locate stories that reflect the value of geodetic data sharing.
  - Need to be tailored or aligned, depending on who the audience is.

- Gather and encourage ongoing support and demand for geodetic data sharing from external sources - traditional and non-traditional sectors.
  - External support can help to maintain the political will to support geodetic data sharing, and be a source of ongoing learning and dialogue.

- Have learning programs to create opportunities for other government employees to be part of geodetic data sharing.
  - Training sessions, secondments to teams or working groups.

- Develop formal metrics to monitor and evaluate geodetic data sharing activities.
  - To measure progress, benchmark success and identify areas for improvement.
  - To demonstrate the return on investment.

6. OPEN DATA CASE STUDY: PositioNZ GNSS DATA

Land Information New Zealand (LINZ) is the New Zealand government department responsible for land titles, geodetic and cadastral survey systems, topographic information, hydrographic information, managing Crown property and a variety of other functions. LINZ in partnership with GNS Science, through the GeoNet project, collects Global Navigation Satellite Systems (GNSS) data from a network of 37 continuously operating stations throughout New Zealand. The purpose of the network is to monitor New Zealand's official datum, New Zealand Geodetic Datum 2000 (NZGD2000), by measuring the effects of tectonic plate motion and earthquake displacements on it. This network is called PositioNZ.

The New Zealand Government and LINZ have a policy to open up government held data and release it free of charge under an open licence. LINZ releases two forms of GNSS data from the PositioNZ network; static data and real-time data. The real-time data is streamed via the internet to users in the field to allow for accurate positioning in real-time. Both the static and real-time data are utilised for surveying, construction, asset management and scientific applications.

The static data is provided in an open format. This open format allows the data to be used with many different GNSS receiver brands and models. This data is available in hourly or daily data files and can be downloaded from http://www.linz.govt.nz/positionz .

The real-time (PositioNZ-RT) service also provides GNSS data in an open format designed for streaming data via the internet. Users registered for real-time services include private cadastral survey companies, engineering firms, local and regional councils, and university and research facilities, as well as groups engaging in emergency management and aerial imagery rectification activities. Both datasets are licensed for re-use under the CC-BY 4.0 NZ license.

The GNSS community can benefit from this open and freely available data. Several private CORS operators in New Zealand use this data to supplement their private networks. In return they supply data to LINZ from their network which is used to enhance the national datum without compromising the private operators' commercial operations. Following recent major earthquakes in New Zealand these operators have also been willing to share their data with responding government agencies which has been critical in earthquake response and recovery. Being willing to share data openly brings benefits to many and reciprocal agreements that may otherwise not have been possible.

7. CONCLUSION

The use of geodesy and geodetic data goes far beyond what was initially envisaged. It provides the geospatial framework that underpins positioning, navigation and timing to enable decision makers to have a better understanding of the world we live in. The key elements of the system, such as the GGRFs and GNSS, can provide a wide range of benefits. To realise and maximise these benefits it is important that users also contribute to the system through the provision of open data and exchanging data to enhance the system of applications. By opening up and sharing the data we also encourage innovation; the broad use of the data for many applications; and help solve many of the global issues and natural disasters that affect us all.

This paper has presented the argument and a guide for a geodetic data policy to assist countries to open up their geodetic data for reuse and sharing.

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BIOGRAPHICAL NOTES

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Robert Sarib obtained his degree in Bachelor Applied Science – Survey and Mapping from Curtin University of Technology Western Australia in 1989. He also holds a Graduate Certificate in Public Sector Management received from the Flinders University of South Australia. Rob was registered to practice as a Licensed Surveyor in the Northern Territory, Australia in 1991. Since then he has worked as a cadastral and geodetic surveyor, and a land survey administrator.

Mr Sarib has been an active member of the FIG since 2002, and is now Chair of the FIG Asia Pacific Capacity Development Network. Rob is presently a Board member of Surveying and Spatial Sciences Institute; the Chair of the Surveyors Board of Northern Territory; and member of the Inter-governmental Committee on Survey and Mapping – Australia.

Graeme BLICK, Group Manager Positioning and Resilience in the Location Information Group of Land Information New Zealand.

Graeme obtained his Bachelor of Surveying from Otago University in 1980. He worked for the then New Zealand Geological Survey (now GNS Science) in their Earth Deformation Section using geodetic techniques to measure, monitor and study crustal deformation across New Zealand.

In 1992-1993 he received a visiting Scientist Award to work at the University NAVSTAR Consortium in Boulder Colorado. In 1995 he moved to Land Information New Zealand (LINZ), New Zealand's National Survey and Mapping agency. He is the Group Manager of the Positioning and Resilience Group where he continues to work on and manage the development and implementation of the geodetic system in New Zealand, including management of its semi-dynamic datum and oversee their resilience programme focused on natural hazard mitigation. Graeme has also been an active member of FIG Commission 5, Positioning and Measurement.

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