NSW GOVERNMENT

Data Hub: Best Practices Review

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Contents

INTRODUCTION

The last two decades have seen an expansive proliferation of spatial data and more recently big data. This is set to continue with the emergence of the internet of things (IoT) where there is expected to be more than 50 billion IoT devices by 2020. Data proliferation and the digitisation of our cities is driving the Smart Cities agenda (Kitchin 2013).

The aim of a smart city is to "make better use of public resources, increasing the quality of the services offered to citizens, while reducing the operational costs of the public administrations" (Zanella et al 2014). The goals for smart cities are articulated further by Batty et al (2012 p.481):

- Develop new understanding of urban problems
- Develop effective and feasible ways to coordinate urban technologies
- Set models and methods for using urban data across spatial and temporal scales
- Develop new technologies for communication and dissemination
- New forms of urban governance and organisation
- Define critical problems related to cities, transport, energy
- Identify risk, uncertainty and hazards in the smart city

In the age of smart cities, governments are investing in the growth of data-driven platforms, services and analytics in order to improve the design, planning, management and evaluation of policies and projects for sustainable community development. It is in support of this endeavour that agencies like UrbanGrowth NSW need to play a critical role.

In order to achieve the aforementioned smart city goals, governing bodies must exercise organisational will and capacity to harvest intelligence from data and to translate this resource into policy formation and delivery, and new organisations of government. Effective data and information management (IM) is integral to this exercise, and perhaps the keystone to governance in the digital age.

It is useful to apply Lee's (1988) definition of Information Resource Management to describe the collection of activities and assets that comprise IM at an organisational level:

> *[It] is the planning, organising, controlling, securing, and integrating of the organisation's information resources, including; internal and external information; software; hardware; facilities; information systems budget; and information systems policies, procedures and methods.*

With the addition of information communication and dissemination to relevant external parties, this definition captures the various aspects of IM relevant to the scale and operation of agencies like UrbanGrowth NSW.

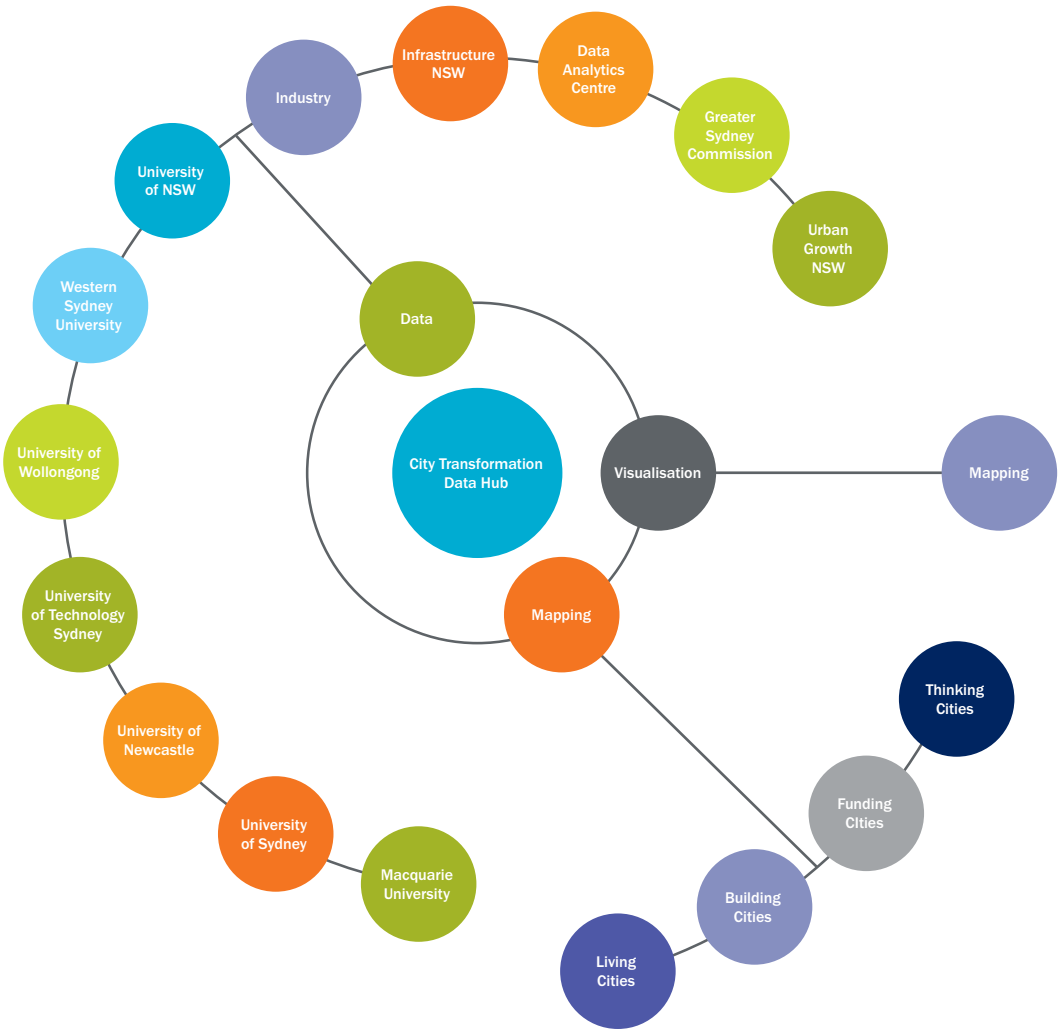
Purpose of Review

The business of establishing an IM system can be a challenge considering the variety of information assets and data formats, and the practical and legal conditions under which they may be acquired, shared, analysed, re-distributed and communicated. It requires an orchestration of the organisation's assets (e.g. ICT resources, personnel capacity and know-how, budget, and facilities) and operational procedures and policies.

This review is a complementary activity to the Connected City Data Hub Scoping Study and Roadmap, a project that supports UrbanGrowth NSW's City Transformation Lifecycle agenda by establishing a clear understanding of the digital ecosystem and user requirements needed to inform future forward investment in data delivery services.

The Connected City Data Hub Scoping Study and Roadmap is a collaborative project between UrbanGrowth NSW, University of New South Wales, University of Western Sydney, and University of Wollongong. The following diagram contextualises the project in relation to the components of UrbanGrowth's City Transformation Lifecycle initiative.

Figure 1: Context of the UrbanGrowth Data Hub in UrbanGrowth's City Transformation Lifecycle initiative



City Data Hub seeks to review existing datasets against UrbanGrowth's information management needs and assist in identifying where data agreements and partnerships with custodians may be beneficial for UrbanGrowth.

The diagram below maps a vision for an IM system to support UrbanGrowth's operations. The map summarises the components and functions of an IM enterprise.

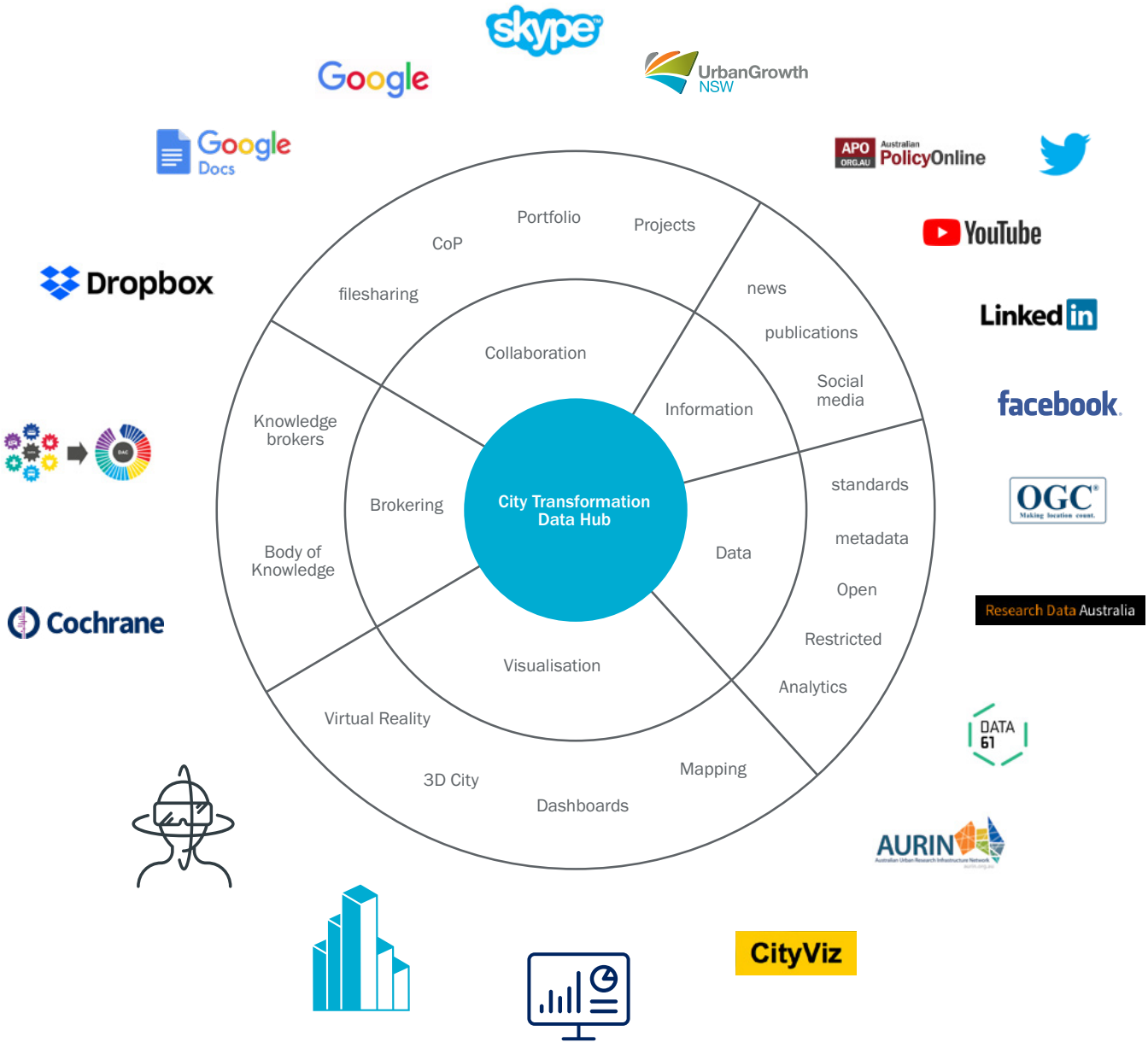


Figure 2: Components of UrbanGrowth's information management vision

This review will present case studies of IM system implementations deployed internationally and within Australia. It seeks to summarise best practices in information and data governance that would be applicable to UrbanGrowth NSW.

The next section provides a description of the framework and method used to produce this review. This is followed by a summary of best practices, and case studies that exemplify such practices in their IM implementations.

METHODS

Framework

Dimensions of Information Management system implementation

The review categorises activities related to the implementation of IM systems into three dimensions: People/Culture, Process and Technology. This categorisation is adopted as a summary of the IM facets discussed in literature concerning the integration of ICT into an organisation's business and operations (Weippert & Kajewski 2004; Cabrera et al 2001; Gold et al 2001):be transformative, as can be seen in the table below.

1. **People/Culture**

   This dimension addresses the 'human capital' part of IM; it includes the technical skills and competencies required, the fostering of good data management habits and sense of responsibility for data, and the provision of incentives for such behaviour; as well as presence of a collaborative culture at work to promote knowledge transfer. Komninos (2011) describes this aspect of IM as the dimension where 'amplification' can take place; where mechanisms are put in place to ensure that members of the enterprise or community that run, support and use the knowledge infrastructure have the skills or can upskill to be able to contribute and co-create information—thereby amplifying the capabilities of the information and data infrastructure.

2. **Process**

   This dimension is congruent with what Komninos (2011) has described as the capacity of an organisation for 'orchestration'. Orchestration is characterised by the coordination of institutions and human capital via political mechanisms and organisational protocol to effect collaboration, knowledge transfer, and produce innovative solutions. This dimension deals with putting proper protocols in place for maintaining data asset security, using standards for procuring and processing data across the enterprise, and establishing efficient practices for providing and controlling access to data assets.

3. **Technology**

   This dimension addresses requirement of ICT instrumentation to be able to collect spatial data, as well as the integration of data and metadata formats, and collaborative platforms/ software. The technology used to store, catalogue and make data accessible must allow for the data asset's interoperability between different platforms, across different agencies and perhaps even across different time periods. The system architecture must be able to provide contingencies for making existing data accessible and usable by other existing systems and other potential uses of the data in the future, as well as have mechanisms to allow the integration of data from various sources and accommodation for new types of data.

Capability Maturity Model

The review will apply the capability maturity model in recommending the order of best practices to apply. This kind of framework has been used by businesses in the IT industry to assess their organisational performance, as well as in other project management contexts. The authors believe that this kind of open-ended framework may be advantageous for organisations that are seeking a roadmap to incrementally optimise their IM program.

Given that the urban data landscape is subject to disruption in digital delivery services and that enterprises face risks associated with digital obsolescence—an open-ended framework that perpetuates continuous self-review and optimisation is practical. The descriptions for each stage of the capability maturity scale are summarised in Figure xx. The authors have inferred these descriptions from combining elements adopted from project management models (Yazici et al 2009), emergent collaborative organisation models (Morgan 2012), and ICT enterprise capability maturity models (Carcary 2013; Olutayo and Ekuobase 2015; Department of Finance 2015).

Exploration		Formalisation
	Ad hoc →	Opportunistic →
People/Culture	• Culture with regards to data openness is unaddressed • No established leadership • Intra- and inter-organisational departments' capacities with respect to supporting a KM enterprise are unknown • Intra- and inter-organisational departments' potential roles have not been discussed.	• Incorporation of openness in the organisation's objectives and change management strategy is discussed. • Leadership within the organisation is identified • Capacities and potential roles of departments within and without the organisation are identified • Potential collaborations (including the public) for data acquisition and analysis are identified. • Executive sponsorship is explored
Technology	• The organisation is unaware of technical standards that need to be adhered to for maximising data assets. • The organisation is unaware of tools and software solutions for managing information.	• Technical standards employed by local and international organisations are explored. • Available tools and software solutions are explored.

Figure 3: Framework for evaluating the maturity of an organisation's IM system, with respect to knowledge management dimensions

Implementation → **Consistency and Feedback**

Repeatable	Managed	Optimised
• Openness and the organisational and operational qualities that are entailed in such policy is communicated to every level of the organisation. • Leaders are engaged • Intra- and Inter-organisational departments' roles and responsibilities are defined • Agreements for collaboration are made. • Measures of success are defined • Executive sponsorship is secured	• Openness culture is modelled and championed • Consistency in fulfilling roles and responsibilities is observed • Training is provided to staff to ensure that protocols and standards are executed • Inter-organisational collaboration is implemented • Performance metrics are observed and reported • Executive sponsorship is continuous	• Openness policy is reassessed. Wider stakeholder engagement may be involved in this process. • Leaders' roles have grown/evolved • Strategies are in place to ensure the continuity of KM management and inter-organisational collaboration in case of leadership changes • Training of staff may be enhanced further • Collaborations with other organisations is evaluated and other potential collaborations are explored • Executive sponsorship is continuous, but other long-term funding options are also explored • Overall performance is evaluated • Performance metrics are reviewed in light of wider institutional strategy (i.e. city indicators)
• Appropriate technical standards, tools and software solutions are selected. • Targets are defined • Selected standards and technology are documented.	• Technical standards are implemented and adhered to throughout the organisation. • Staff routinely use selected tools and software • Upgrades and integrations are planned for and documented • Technical issues are reported, resolved, and documented • Performance against targets is monitored • Upgrades/integrations planned	• Implementation results are evaluated • Upgrades and integration are continuous • Technology adoption strategy is reviewed considering emergent technology and standards, and organisational capacity • Adequacy of targets is reassessed

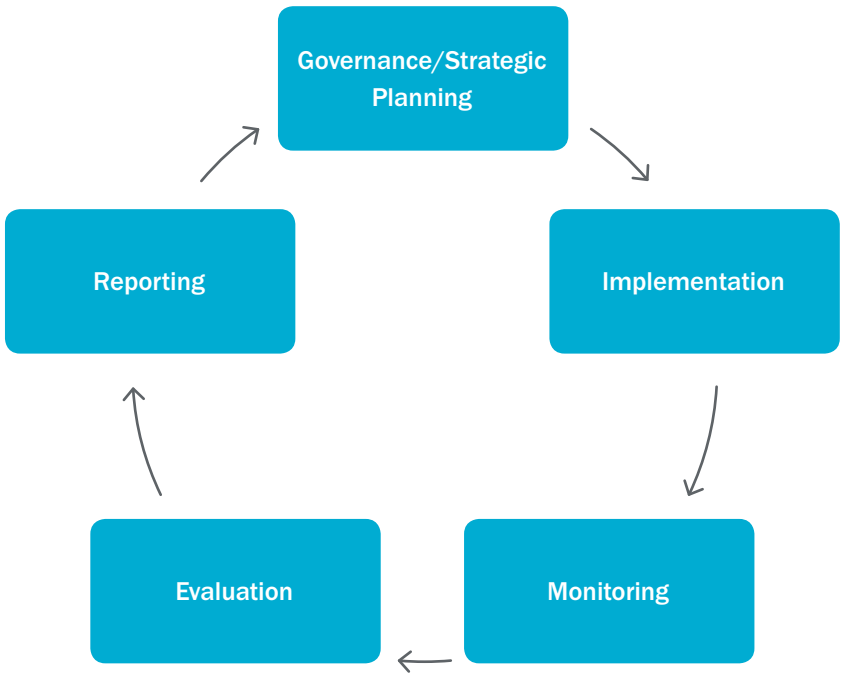
As various aspects of the IM system are improved—as threads of capabilities are interwoven—the robustness and integration of the IM system grows as it progresses along the maturity scale:

Figure 4: Dimensions of IM along the Maturity Scale

Although an enterprise's improvement within each of the three aspects of knowledge management may not occur concurrently (an enterprise may be advanced in Technology yet a step behind in putting up established procedures and protocol for Processes), the enterprise's performance is nevertheless determined by the dynamics of these three dimensions.

The progress of the IM enterprise towards maturity may be viewed as a cyclical exercise whereby standards for People/Culture, Process and Technology are planned and implemented, and thereafter monitored, evaluated and reviewed until the enterprise reaches optimisation. It is within this cycle that data governance is formed and improved, and where city indicators and benchmark measures may be further informed:

Figure 5: Knowledge Management Life Cycle



Literature search

The authors used the search phrases below to search for relevant literature on SDI and knowledge management best practices on ScienceDirect, Scopus, Web of Science, Directory of Open Access Journals, Scopus, and Taylor and Francis journals—specifically the International Journal of Geographical Information Science and Google Scholar. Google was also used to search for grey literature on the case studies taken up in this review.

Given time constraints in producing this review, the authors looked through the top two results page and consulted articles that seemed relevant to the guide keywords also listed below:

Search Phrases:

- Standards data sharing
- International data standards
- Urban data management
- Smart city data standards
- International data governance
- Knowledge Management Dimensions
- Knowledge management
- Information management dimensions
- Information management
- Spatial data infrastructure
- SDI
- National Spatial Data Infrastructure
- NSDI
- Information Infrastructure
- Knowledge management best practices
- Information management best practices
- Spatial data infrastructure best practices
- Spatial data infrastructure management
- London Datastore
- US National Spatial Data Infrastructure
- Australia National Spatial Data Infrastructure
- Europe INSPIRE
- Infrastructure for Spatial Information in Europe

Guide keywords:

- Smart City
- Best Practice
- Governance
- Urban data
- Spatial data
- Geospatial Information

BEST PRACTICE SUMMARY

People and culture

1. Establish an organisational strategy to implement a knowledge management system
2. Provide support for training and upskilling
3. Engage with internal staff and wider community to establish trust
4. Address leadership: establish information governance

Process

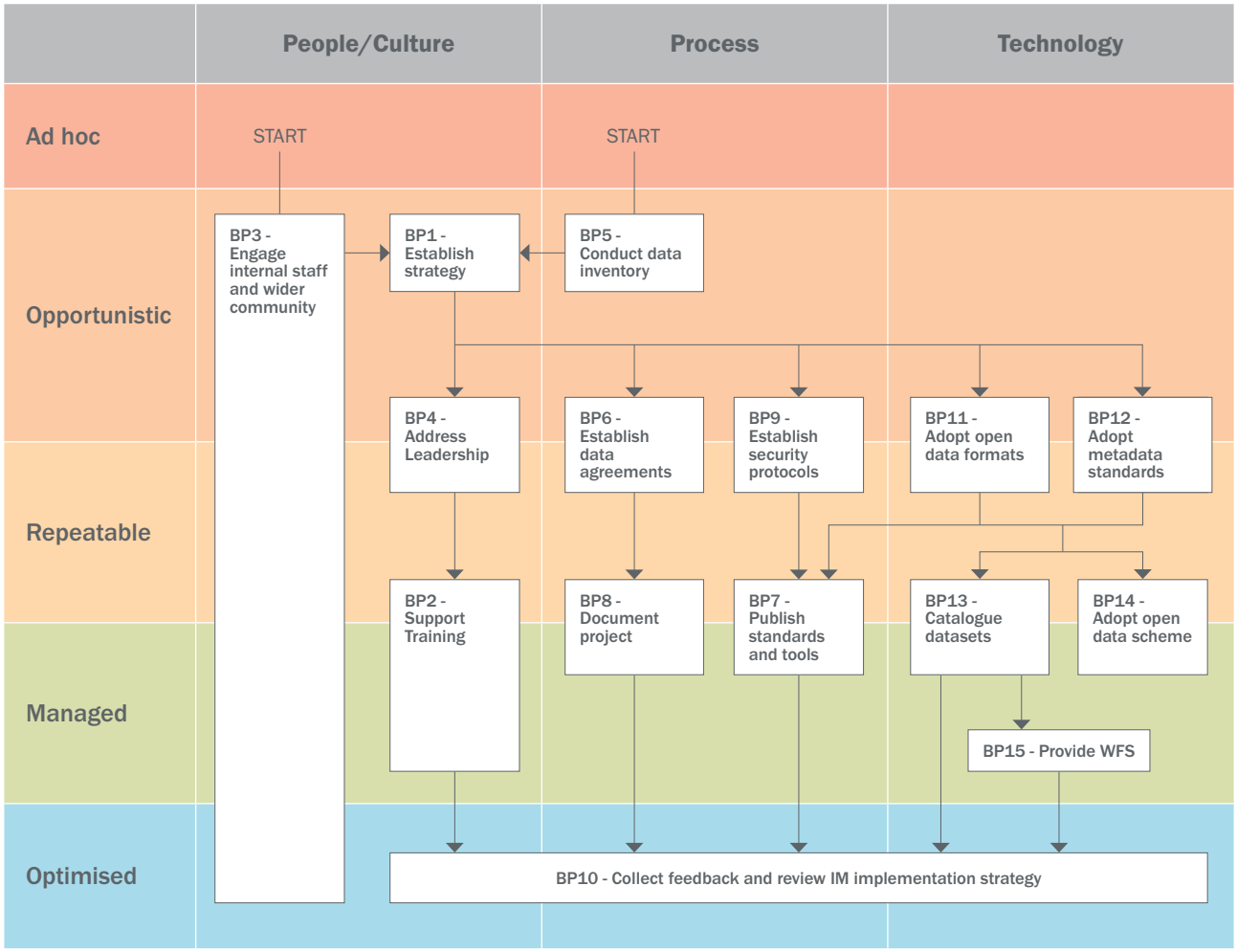
5. Conduct and communicate a data inventory
6. Establish data agreements
7. Publish standards and tools
8. Document and publish project information
9. Establish protocols addressing security and privacy concerns
10. Seek client feedback on the IM system and its implementation

Technology

11. Adopt open data formats
12. Adopt standards for metadata
13. Make datasets discoverable via catalogue
14. Adopt 5-Star Open Data Scheme
15. Publish web services for data visualisation and analysis

The diagram below proposes which best practices may be applied in each stage of the capability maturity model.

Figure 6. Best practices aligned to the capability maturity model



People and culture

Appropriate organisational structure and culture are fundamental to making the most from data.

1. Establish an organisational strategy to implement a knowledge management system

Implementing a knowledge management system requires the orchestrated effort of all levels of organisation that acquire, manage, produce, and use data. This requires direction in the form of an overarching strategy, addressing the organisation's goals for establishing a KM system and how this benefits its business.

Besides providing direction, an organisational strategy also lessens dependence of the KM system's implementation on a few passionate individuals or department champions. While leadership is necessary for KM implementation, having a strategy in place helps ensure that implementation is continuous beyond the leadership term of involved staff.

In this regard, the City of Greater Geelong's strategy for its open data program may serve as an example for similar place-based organisations. The strategy includes the council's vision for 'Digital Geelong', its benefits to the future economy of the city, and a set of 30 recommendations of changes that need to be applied to city's organisational culture and processes for its goals to be met.

→ *Case study 7. City of Greater Geelong*

Similarly, Western Australia's policy for its open data program specifies the authorities responsible for its implementation, which agencies are obligated under the policy, what the standards for data quality are, and guiding principles to be followed in the management and implementation of the open data program.

→ *Case study 4. Western Australia's Open Data Initiative*

London DataStore also published their implementation plan.

→ *Case study 9. London Datastore*

2. Provide support for training and upskilling

Human capital is as important as technological capacity to sustain and continually improve a IM system. Ensure those responsible for running the IM system, partners and collaborators and users know how to maximise the available tools and information. This will help sustain creativity in data-driven solutions and may put the people involved in a better place to identify where there is need for improvement in the system.

In the case studies, the degree at which government IM initiatives have provided training support varies. Most provide tutorial documents on their data portal to guide users and data providers. However, the EU INSPIRE case study is exemplar as it dedicates a coordinating body whose purpose is to assist members in improving their capacity.

3. Engage with internal staff and wider community to establish trust

Open data initiatives benefit by engaging staff, stakeholders and the wider community as early as possible to scope requirements and establish potential collaboration, even co-design. UrbanGrowth has already worked with Bang the Table on community engagement in its Newcastle project. They are a leading firm in this area and their website offers best practice examples and valuable insights on community engagement.

Within the case studies in this document, the City of Greater Geelong and the London Datastore program serve as good examples for this best practice. The City of Greater Geelong has incorporated staff consultation into its IM implementation strategy. It has also been active in engaging the wider community by organising hackathons, where it encourages developers to create applications using the city's open data.

→ *Case study 7. City of Greater Geelong*

The London Datastore is also a good example in the way it reached out to external stakeholders when it was scoping its strategy for its spatial data infrastructure (SDI) program.

→ *Case study 9. London Datastore*

4. Address leadership: establish information governance

Information management needs a leader. Information must be managed like any valuable asset, to generate the best return (such as better decisions) on the considerable investment made in its acquisition and management.

Identify where overall responsibility for information management lies in your agency, for example with the Chief Information Officer or equivalent. Next, identify each executive who has a responsibility for at least one of your organisation's core (or 'master') datasets. These people will be your 'data custodians'. You may find it easier to do this after performing a data inventory (BP 5): once you have identified your core datasets you can allocate each one to the appropriate executive.

Agreements and document custodianship responsibilities and reporting arrangements. Based on your business plan and priorities, executive custodians should determine the goals for their data assets (such as improved quality, coverage, or access) and take charge of achieving them. You may wish to map core datasets to business objectives: if a dataset is critical to achieving an objective, then the executive responsible for that objective may be the best candidate for custodian of the dataset (because they know what is needed).

The Data Custodian will probably need to delegate data management work to a 'Data Steward' who knows the data well, can answer clients' questions and lead the day-to-day work on improving the data as outlined by the Custodian. Data management responsibilities must be included in performance agreements and review. Data Custodians should probably meet in a formal committee chaired by the CIO to review progress on information management. You may formalise this into an Information Management Strategy and convene an Information Management Committee, or deal with it as a regular part of executive meetings. The key thing is to have some trigger that maintains oversight of information management at the executive level.

Process

Here we list a few key steps to implementing a successful data hub.

5. Conduct and communicate a data inventory

Take an inventory of your datasets as well as those you need or want. This will help reduce duplication of effort in data acquisition and can serve as a basis for better data planning. Focus on 'master' datasets: those which your organisation manages which are critical to your business. But also include 'reference' datasets: data created by an external party on which your business relies to a significant degree.

Communicating about the data inventory may provide an opportunity for organisations to identify commonality in the future datasets they need. Through collaboration, these organisations may be able to share data acquisition costs.

6. Establish data agreements

Use standard open licences where possible. Licensing agreements that allow users to reuse and share datasets can help reduce the volume of data requests for the same data, thus contributing to workflow efficiency.

The Creative Commons Attribution (CC BY) license is commonly used by data providers to enable users to redistribute, tweak, and adapt the data for their own purposes with the provision that they credit the source in their work.

The Australian Government's Open Access and Licensing framework (AusGOAL) offers a best practice framework for selecting appropriate open licences based on the Creative Commons suite. The approach starts with CC BY as the default licence, and steps through a series of questions to apply a more restrictive licence only where required.

Among the case studies included in this document, City of Greater Geelong and the Australian Research Infrastructure Network (AURIN) are noted for using CC BY. AURIN also has its own standard license template which is used in cases where some restriction is needed on what end-users can do with the data.

→ *Case study 5. Australian Urban Research Infrastructure Network – AURIN*

→ *Case study 7. City of Greater Geelong*

7. Publish standards and tools

Once you have selected standards and tools for data management (see Technology BPs below), publish and communicate them as guidelines and other documentation. Use seminars, executive messaging and other means to assist staff and partners such as data suppliers and developers to match your requirements. This will speed up the process of storing, managing and making data and information available. EU INSPIRE exemplifies this as communicating its standards to member states is essential to its operation.

8. Document and publish project information

Document the IM system implementation process to assist in future performance reviews, and to ensure continuity and coherence in its operation. The NSW State Archives and Records prescribes record-keeping principles and standards for government agencies to follow. These standards may be extended to the documentation of KM initiatives within the organisation.

Publishing information about the IM initiative (e.g. implementation strategy, technical updates, use case studies) opens up the project to the wider community. This can help foster trust among prospective data providers and end-users, and potentially start collaborations and partnerships. This will also contribute to literature on knowledge and data management, which can inform research and serve as reference for future IM system implementations. Several of the case studies included in this review demonstrate this best practice:

London DataStore's strategy and implementation plan is published on its website. On the same webpage, the project has an open message encouraging the public to collaborate with London Datastore. The project also maintains a blog to communicate project updates and other news related to smart cities.

→ *Case study 9. London Datastore*

AURIN's 'About' section has information on the project's governance and history. It also maintains a News and Events page that communicates research work that make use of AURIN, new data announcements, and the project's mentions in the media.

→ *Case study 5. Australian Urban Research Infrastructure Network – AURIN*

Western Australia has the SLIPStream Newsletter which communicates technological updates to the system.

→ *Case study 4. Western Australia's Open Data Initiative*

9. Establish protocols addressing security and privacy concerns

Government agencies, businesses, and non-government organisations with annual turnover more than $3 million must comply with the Australian Privacy Principles (APP) contained in the Privacy Act 1988. The Office of the Australian Information Commissioner (OAIC) has published guidelines and resources to help parties identify the activities they need to undertake to be compliant. This is especially applicable to parties whose business operations require the collection of personal information. These guidelines are available through the OAIC site.

The OAIC has a management framework that suggests practices and procedures that can enable organisational effectiveness in executing and maintaining information security and privacy. The following points are distilled from the items in OAIC framework:

- Conduct a review of the organisation's obligations with regards to the APP, and evaluate and adapt the organisation's privacy policy and management plan accordingly.
- On the level of organisational culture, it is important to establish leadership that holds key responsibility over the execution and review of the company's privacy policy and management plan. Accountability may be facilitated by further specifying leadership roles within different departments of the organisation.
- Consider the various kinds of information and data your organisation will acquire or has possession of. Evaluate and differentiate levels of sensitivity associated with these kinds of information in the organisation's privacy management plan.
- In creating a privacy management plan, address the handling of data and information throughout its life cycle; from when the data is collected, when the information is in the custody of the organisation, and when the information is no longer needed. The management plan must have protocols in place for securely storing information, maintaining back-ups, and destroying or archiving old information.
- Assess the methods your organisation uses or is planning to use in handling information (e.g. access, storage, back-up, deletion, archiving). Additional privacy considerations must be made when the organisation is to outsource such tasks.
- Promote privacy awareness among staff by communicating the company's privacy policy and management plan, outlining the privacy procedures that are especially applicable to each staff's work, and provide training.
- Document privacy procedures and protocols to support future re-evaluations.

10. Seek client feedback on the IM system and its implementation

Reviewing implementation of any program is necessary for its continuous optimisation. Collecting feedback from both the IM system's users and staff who are involved in its maintenance reveals the system's strengths and weaknesses, and opportunities for improving its implementation. This feedback should also inform the organisation's future development strategy, benchmarking and evaluation criteria.

Technology

At the heart of a data hub is data and the tools to manage, access and use it. An open standards-based approach facilitates collaboration and efficiency.

11. Adopt open data formats

Publish data and reports in machine readable formats that can be widely used and shared. This facilitates data reuse, redistribution and analysis by the wider community.

Data.gov.au has published recommendations of appropriate file formats to use for different kinds of data (e.g. tabular, spatial, and text). Data.gov.au has published a table summarising the uses and level of openness of different open data formats:

Tabular data

File type	Openness	Notes
CSV	High	The best format for opening structured data (e.g. as spreadsheets)
XLS or XLSX	Low	Limits machine reading and use on non-Microsoft systems)

Spatial data

File type	Openness	Notes
KML	High	An open standard developed for Google Earth. May not translate to other systems. KMZ is also available as a packaged set of KML files.
WMS	High	Standardised format for georeferenced map images
WFS	High	Standardised format for geographical features

Text

File type	Openness	Notes
TXT	High	Simple text format readable on most operating systems. No formatting is available
RTF	High	Simple text format readable on most operating systems which retains some formatting
ODT	Medium	Limits machine reading
DOC or DOCX	Low	Limits machine reading and use on non-Microsoft systems
PDF	Low	Useful for document exchange to preserve formatting, but has limitations for machine reading, character recognition and remixing.

File formats may also be used in tandem. For example; where a report is published in pdf, tabular and spatial information within the report should also be made available in separate CSV and KML files (e.g. maps).

Data.gov.au Toolkit's wiki page provides guidance on appropriate data formatting and publishing.

12. Adopt standards for metadata

Use standards for metadata to ensure that information about the data is complete, correct and ready to be catalogued. Consistency in metadata is fundamental to the technical implementation of SDI; helping ensure that datasets are discoverable and shareable across infrastructures and jurisdictions.

Metadata standards range from simple and generic to complex and highly specific. The Dublin Core Metadata Element set consists of 15 fields and is commonly used for describing web pages and non-spatial data:

Label	Definition
Contributor	An entity responsible for making contributions to the resource.
Coverage	The spatial or temporal topic of the resource, the spatial applicability of the resource, or the jurisdiction under which the resource is relevant.
Creator	An entity primarily responsible for making the resource.
Date	A point or period of time associated with an event in the lifecycle of the resource.
Description	An account of the resource.
Format	The file format, physical medium, or dimensions of the resource.
Identifier	An unambiguous reference to the resource within a given context.
Language	A language of the resource.
Publisher	An entity responsible for making the resource available.
Relation	A related resource.
Rights	Information about rights held in and over the resource.
Source	A related resource from which the described resource is derived.
Subject	The topic of the resource.
Title	A name given to the resource.
Type	The nature or genre of the resource.

Spatial data has its own metadata standard: ISO 19115 Geographic Information – Metadata. This standard covers the spatial aspects of metadata such as coordinate reference system, extent and resolution explicitly, as well as providing more structure for other aspects including data quality. Various profiles, or sets of mandatory elements and restricted code lists, have been created. The NSW Government has its own profile of ISO 19115 which we recommend UrbanGrowth use in your metadata catalogue. The mandatory elements of this set are:

1. Metadata File Identifier
2. Metadata point of contact
3. Title
4. Metadata date stamp
5. Topic Category
6. Keyword
7. Resource Language
8. Resource Reference Date
9. Resource Reference Date Type
10. Abstract
11. Purpose
12. Extent (name, polygon or bounding box)
13. Beginning Date
14. Ending Date
15. Progress Status
16. Maintenance and update frequency
17. Lineage
18. Access Constraints
19. Distribution Format
20. Distribution Contact
21. Metadata Standard Name

The practice of using metadata standards is exemplified across all the case studies discussed: Australian Spatial Data Infrastructure, USA – Roadmap to GeoPortal.gov, London Datastore, and European Union – INSPIRE.

13. Make datasets discoverable via catalogue

Establish a geoportal where all datasets can be easily discovered and accessed by members and partners of the organisation and the public. This is fundamental for collaboration. It will build trust with the community, increase efficiency in organisational workflows and may foster creativity and innovation in the application of data.

A number of software platforms are tailored towards building an open data portal. These are compared in the table below.

Software	Type	Pros	Con
ArcGIS Open Data	Hosted service	Good for ESRI users. Strong geospatial access	Propriety framework
CKAN/DKAN	Open Source Software	• Leading Open Source data portal: data.nsw.gov.au, data.gov.au, data.gov, data.gov.uk, data.gov.ca • over 300 open source extensions	Needs tech support, host server
Geonode	Open Source Software	• Spatial heritage, bundles GeoServer with OGC services • extensible CMS with python/Django	Needs tech support, host server
GeoNetwork	Open Source Software	• Full ISO19115 and flexible metadata schema support	Complex and aging source code
Mango	Hosted service	Easy and intuitive, no setup	Cost
Socrata	Hosted service	Visualisation, community building	Cost

An informative video from the Safe Software development team compares these data portal products.

14. Adopt 5-Star Open Data Scheme

In 1998 Tim Berners-Lee, inventor of the world wide web, proposed the development of a 'semantic web':

The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation.

In this decade, the semantic web has largely grown behind closed doors on the networks of online corporations like Facebook and Google. However Berners-Lee's vision is to bring this power to the public web by using standards to publish 'linked open data'. He proposed a 5-star open data scheme:

★	Make your stuff available on the Web (whatever format) under an open license	example
★★	Make it available as structured data (e.g. Excel instead of image scan of a table)	example
★★★	Make it available in a non-proprietary open format (e.g. CSV as well as Excel)	example
★★★★	Use URIs to denote things in your data, so that people can point at your stuff	example
★★★★★	Link your data to other data to provide context	example

15. Publish web services for data visualisation and analysis

Providing web feature services and other APIs that enable data visualisation allows users to preview the dataset on their web browser and make decisions on whether it suits their purpose before they download it.

Web feature services that enable basic data manipulation can also be valuable to users who need to carry out a certain degree of preliminary analysis (e.g. teasing out potential correlations between datasets such as neighbourhood walkability and prevalence of diabetes within a geographical area) without needing desktop software like ESRI ArcGIS nor the degree of technical literacy required to manipulate data on such desktop platforms.

Beyond that, web services are the foundation to grow an ecosystem of business and community services that support better planning and management.

Web feature services add value to the data available in the organisation as they potentially allow more users to generate insight from such data.

AURIN Map is a good example of a freely available web feature service that allows visualisation of national data layers. On the other hand, the AURIN Portal is also a browser-based tool that allows researchers to conduct a considerable degree of analysis on the datasets that belong to institutions partnered with AURIN.

→ *Case study Australian Urban Research Infrastructure Network – AURIN*

Other case studies in this document that also provide web feature services in their data portal are US NSDI, ASDI and Europe INSPIRE.

Appendix: ISO/TC211 Geographic standards lists highlights from the full suite of standards available for Geographic Information. Many of these relate to spatial web services.

CASE STUDIES

Here we discuss examples of publicly-accessible government Spatial Data Infrastructures (SDIs) and related data and information management systems.

1. USA – Roadmap to GeoPortal.gov

Owing to its relative maturity, the USA's experience in SDI has been used as a model in literature on government SDIs and open data endeavours. It is valuable to examine USA's roadmap to establishing its national SDI and federal geoportal, with particular interest in the People/Culture and Process dimensions.

First US NSDI

The 1990s saw a movement in the USA where federal government agencies began using the Internet as their primary means for disseminating public information (Tauberer 2014). In the previous decade there had already been a move to drive the coordination of federal digital cartographic data initiated by the White House's Office of Management and Budget's Memo 83-12 (Robinson 2008). It was in this context that the US Federal Geographic Data Committee (FGDC), under the leadership of the United States Geologic Survey (USGS), was tasked to be the coordinating body for the US National Spatial Data Infrastructure program (NSDI) by the President Clinton's Executive Order 12906 (Maguire and Longley 2005).

For this initial incarnation of the US NSDI, the FGDC could put together a set of nation-wide framework datasets including administrative boundaries and orthophotography. More importantly, the FGDC established standards for metadata and protocols for accessing and exchanging digital data. The coordinating body also developed the Clearinghouse network which served as a catalogue for metadata—making the metadata accessible and queryable (Maguire and Longley 2005).

In 1994, the FGDC executed the NSDI Cooperative Agreements Program (CAP), an annual funding program that seeded projects relevant to the implementation of the NSDI. The program was open to all levels of government, NGOs, academia and commercial projects. It was in effect until 2003 and by then it had supported over 700 projects—including implementations of the now internationally-adopted standards of OGC (Open Geospatial Consortium) Web Mapping Services. The NSDI CAP program objectives were focused on promoting the standardisation of metadata, enhancing a technical understanding of GI among different organisations that would be contributing to the US NSDI and expanding the implementation of geospatial services on the web (FGDC n.d.).

This earlier manifestation of the US NSDI could be considered a success in the technological dimension of SDI implementation. The FGDC laid the groundwork for helping ensure that there was capacity to fulfil the technical requirements of sustaining an effective NSDI (i.e. establishing standards and cataloguing protocols for metadata and supporting training efforts in such), and by encouraging the involvement of different geospatial organisations in the implementation of the NSDI.

However, even though the technical standards and protocols were established within the initial operation of the NSDI, there were other shortcomings in ensuring support for other key aspects of managing an SDI. These shortcomings undercut the NSDI's adoption in a wider community, subsequently compromising the infrastructure's endurance and longevity. "Although the program received backing at the highest political level in the form of an Executive Order signed by President Clinton in 1994 (Executive Order #12906), this Order only pertained to Federal agencies. It did not relate to other tiers of government, or to the private sector––both major participants in the GI community. Furthermore, the ideas encapsulated in the Order were not backed by financial control because there were no budgetary ties. This made it easy for people to ignore the suggestions of collaboration to create an SDI" (Maguire and Longley 2005).

The Geospatial One-Stop

Geospatial One-Stop (GOS) succeeded the initial US NSDI in 2001 and aligned with President George W. Bush's E-Government Act of 2002. In the roadmap to the current US national data infrastructure, GOS may be considered as the step where the US institutionalised the collaborative process to: (1) make geospatial data easily accessible to all levels of government and to citizens, which meant encouraging a wider range of providers and custodians (e.g. federal agencies, local governments, commercial entities) to share their geospatial data; and (2) ensure consistency

and quality in geospatial data and metadata (Maguire and Longley 2005; Goodchild et al 2007).

Building upon the initiatives seeded by the US NSDI, GOS created a 'one-stop shop' where users and providers can search, map and publish metadata for geospatial data. GOS made use of standards that OGC had developed: Web Feature Service, Web Map Service and Web Coverage Service. The GOS software also had an administrative functionality whereby GOS staff may screen the items that providers submit to GOS for publishing. This helped increase the consistency and quality of geospatial data and metadata available (Goodchild 2007).

Coinciding with the Bush Administration's E-Government Act was the release of OMB Circular A-16. This document outlined the importance of having an NSDI, its standards, and why it is beneficial to adhere to those standards. Furthermore, it clearly defined the FGDC's role as an interagency committee in charge of facilitating the implementation of the NSDI and stated that all agencies that are responsible for some geospatial data need to be members of the FGDC. It also defines the kind of organisations that may request membership into the FGDC and which activities related to geospatial information (GI) must adhere to FGDC protocol and NSDI standards (FGDC 2002). Furthermore, the Circular A-16 provides guidance to member agencies on their responsibilities to report spatial data assets against budget and performance review process. It also outlines a 'data themes framework' whereby agencies are assigned a lead role with respect to data pertaining to some geophysical, social and environmental concern (e.g. Climate, Demographic statistics, Buildings and Facilities).

In 2010, OMB released a memorandum addressing the heads of executive departments and agencies entitled A-16 Supplemental Guidance. This memorandum communicates any revisions or further clarifications to sections of the OMB Circular A-16. It appears to be issued as necessary changes arise, with the documents published on the FGDC website (fgdc.gov/policyandplanning/a-16).

GeoPlatform.gov

In 2006, the OMB initiated the Geospatial Line of Business (GLoB), which served as a framework for enhancing inter-agency coordination of geospatial-related investments. The GLoB aimed to minimise the costs of maintaining data assets by avoiding duplication of effort. It recommended the implementation of MOUs/SLAs/ELAs and improving technological and telecommunication infrastructure to facilitate sharing, rapid access and retrieval of GI assets from governmental and commercial repositories (OMB 2008). This push for cost-effectiveness through optimised inter-agency coordination also translated into improved geospatial services for citizens.

The GLoB would evolve into the formation of FGDC's current geoportal, GeoPlatform (geoplatform.gov). The website has some notable channels and features for promoting user awareness of the US's geospatial data and information assets:

- **GIRA (Geospatial Interoperability Reference Architecture)** – provides information of the governance framework behind GeoPlatform. Presents overviews of processes relating to the acquisition, management and development of geospatial technical architecture across government agencies.
- **GeoPlatform Dataset Search** – the website's search catalogue function. Users can search for data by geography, popularity, publishing organisation, organisation types, Tags, Topic Categories, data format and data status (i.e. completed, under development). This functionality is powered by CKAN.
- **Marketplace** – also a queryable catalogue with the same user interface as Dataset Search, the Marketplace lists datasets that are in the acquisition pipeline, so that users can determine if a GeoPlatform partner is already trying to acquire a dataset they are looking for.
- **GeoPlatform Communities** – this channel allows users to join a community of practice and learn about geospatial resources and tools relevant to that community.
- **GeoPlatform on ArcGIS Online and Open Application Services** – these applications allow users to exploit datasets available on GeoPlatform.

2. Australian Spatial Data Infrastructure

Following the US lead, the Australian SDI was conceptualised in the 1990s. The Australian New Zealand Land Information Council (ANZLIC), which serves as the coordinating body for ASDI, initiated the discussion for a national SDI with a formal paper commissioned from Price Waterhouse arguing that the economic benefit of establishing ASDI outweighed the cost of its development and maintenance by a ratio of 4:1 (Hall 2002). The aims of ASDI, as outlined by Hall, seem to invoke the principles that should make for an effective SDI program:

- Ensure the acquisition of complete and consistent datasets meeting the user's requirements, even if they are sourced from different jurisdictions.
- Increase high level political awareness and support.
- Develop a national directory system allowing users to identify and locate datasets (data.gov.au, formerly FIND)
- Promote a clear understanding of the ASDI and develop a practical implementation plan
- Identify key priority programs which will benefit from use of ASDI
- Provide a framework for development policies and standards which facilitates access to spatial information (p. 4).

The implementation model envisioned for ASDI is similar to that exemplified by the US NSDI:

- It would have an institutional framework that would generate policies and supporting administrative mechanisms for building and maintaining the SDI.
- ASDI would employ technical standards in providing fundamental datasets such as the cadastre and all datasets produced within the institutional framework would be compliant to standards. (Hall 2002)

Process-related barriers to ASDI implementation

While ASDI bears resemblance to the US NSDI in principle, its implementation has not been comparatively successful due to the barriers posed by cultural and process-related issues.

The first hurdle concerned legal protection of privacy. Major data suppliers were slow in sharing their datasets with ASDI to support an open data framework due to potential impact of privacy laws. ANZLIC needed to put a framework in place and an educational initiative for data agencies to support them in striking the balance between providing data and upholding confidentiality laws (Hall 2002).

The second hurdle was brought on by decentralised funding. Unlike in the US case study—the individual state governments who supply ASDI with data are responsible for financing their SDI projects. This has resulted in the ASDI becoming a collection of state government data put together, when "it is felt that it would be more coherent if a national SDI pool of funds was available (Hall 2002).

Technical Implementation of ASDI

While the ASDI implementation has been met with institutional barriers that have impeded its development, its technical implementation to date has potential for success if these problems can be addressed.

Australia's national standards for data capture and metadata are provided by ANZLIC and recommended to states for compliance. These national standards are based on ISO: ISO 9001 is applied for data capture while ISO 19115 provides the basis for the national standard for metadata (Najar et al 2007). ANZLIC provides the ANZMet Lite tool for creating metadata and has made it available together with PDF guides on its resources webpage (anzlic.gov.au/resources/metadata).

Cataloguing services were once provided by two separate catalogues: the Australian Spatial Data Directory (ASDD) maintained by Geoscience Australia, and the Environmental Data Directory, which was maintained by the Department of the Environment and Energy (Najar et al 2007). The ASDD was consolidated first into FIND and later into the data.gov.au portal powered by CKAN.

The ASDI geoportal catalogue lets users search through filters including publishing organisation, data theme/category (e.g. Environment, Civic Structure), tags, formats and licenses. Like the US GeoPlatform, the portal also enables users to visualise datasets on a map. The data.gov.au site also has a wiki with guidance for users to publish data or produce their own open data strategy, and a 'Use Cases' channel where it publishes applications that are based on ASDI data, submitted by developers.

Productivity Commission Report

In 2016 the Productivity Commission began to investigate ways to improve availability and use of public and private sector data. Their report on Data Availability and Use released in May 2017 recommends "significant change" aimed at "moving from a system based on risk aversion and avoidance, to one based on transparency and confidence in data processes, treating data as an asset and not a threat."

The central recommendation is to introduce a 'Data Sharing and Release Act' along with the appointment of a National Data Custodian; the identification, resourcing and sharing of National Interest Datasets; and the establishment of Accredited Release Authorities to provide data on behalf of government agencies. A new 'Comprehensive Right for consumers' would give individuals the right to access data held about them by government agencies and private companies, and to have this data passed to other parties, such as competing companies, at the individual's request.

3. New South Wales Government Information Systems

As a state-owned corporation, UrbanGrowth operates under NSW government legislation pertaining to information management. This includes provisions of the State Records Act, the Government Information Public Access (GIPA) Act and the Data Sharing (Government Sector) Act 2015.

The agency is also obliged to align its activities to whole-of-government information management and ICT policies and initiatives such as the Digital+ ICT Strategy, the Information Management Framework (IMF) and Location+ 2016 - 2017.

Legislation

State Records Act

The State Records Act requires CEOs of public offices to ensure compliance with the Act and public offices to make and keep full and accurate records and institute a records management program in accordance with standards and codes of best practice for records management.

GIPA Act

Defining government information broadly as "information contained in a record held by an agency", the GIPA Act aims to "open government information to the public by:

(a) authorising and encouraging the proactive public release of government information by agencies, and

(b) giving members of the public an enforceable right to access government information, and

(c) providing that access to government information is restricted only when there is an overriding public interest against disclosure."

Data Sharing (Government Sector) Act 2015

The DSGS Act authorises government agencies, State owned corporations and local government to share data and provide data to the NSW Data Analytics Centre (DAC – see below). It also authorises the Minister for Innovation to direct agencies to provide specific datasets to the DAC within 14 days. The DAC is authorised to share its analytics with government agencies only.

Policies

Digital +

Digital+ is the name given to the updated NSW ICT Strategy. The strategy includes:

- Establishing a whole-of-government Data Analytics Centre (DAC)
- Legislation to create a streamlined framework for data sharing between state government agencies, including sharing data with the NSW DAC
- Establishing a register of data assets and information sharing agreements between NSW agencies
- Publishing NSW government reports in a machine-readable format
- Integration between OpenGov NSW, Data NSW and the Digital State Archive
- Launch of a 'NSW Customer Dashboard' similar to the Australian Government Dashboard

Information Management Framework

The government's Information Management Framework is a set of standards, policies, guidelines and procedures to enable data and information to be managed in a secure, structured and consistent manner and appropriately shared or re-used.

Location+ 2016-17

The government's 'location intelligence' strategy Location+ focuses on key initiatives such as a single state cadastre and a comprehensive NSW Spatial Data Infrastructure.

Open data

The NSW Open Data Policy (PDF) expresses a vision that NSW agencies will:

4. Release better data in accessible, consumable formats with metadata and quality statements
5. Release data faster using automated processes, standard data categories and trusted user models
6. Release more data and make it discoverable through central portals

It requires agencies to manage data as a strategic asset to be:

- Open by default, protected where required
- Prioritised, discoverable and usable
- Primary and timely
- Well managed, trusted and authoritative
- Free where appropriate
- Subject to public input

The policy is supported by an Open Data Action Plan:

- Data Request Service (available on Data NSW)
- Open Data Innovation Scorecard
- Sustaining Open Data
- dMarketplace – a platform for linking data from government, industry and research, including ratings and comments from other users of the data
- Making Links with Data
- Incentivising Open Data & Fostering Innovation – investing in development of skills and capability
- Connecting Data and Stories

Data Catalogues

Data NSW

Data NSW (data.nsw.gov.au) is the main NSW government data catalogue. Powered by CKAN, it gives access to nearly 500 datasets across 66 organisations.

Spatial Data Catalogue

While Data NSW is the home for NSW government data, a separate catalogue exists for spatial data. Most datasets listed in the NSW Spatial Data Catalogue (SDC) are not covered by Data NSW. The SDC predates Data NSW, having grown from spatial metadata initiatives in the NSW government natural resource management sector during the 1990s.

The spatial data catalogue is more than five times the size of Data NSW, with 2515 records compared to 492. However the bulk of the spatial records are individual map sheets within a map series covering all or part of NSW.

In terms of currency, less than 10% of spatial metadata (245 records) have been modified in the last two years, compared to 483 records (98%) in Data NSW. Thus although larger and more mature, the metadata content on the spatial data catalogue is older and less well maintained.

Information Asset Register

The IAR allows NSW Government employees to find metadata and contact details for datasets and other information assets held by government agencies. The relationship between the IAR and Data NSW is unclear, however the information in IAR datasets is possibly more sensitive than those held in Data.NSW.

DAC Engagement Process

Working with other agencies

NSW Data Analytics Centre

The NSW Data Analytics Centre (DAC) was created in 2015 along with its enabling legislation discussed above. The DAC "aims to become a world leader in whole-of-government data analytics, to provide insights into complex policy problems, support greater evidence-based decision-making and improve service delivery for the community". They have undertaken 30 projects with 18 agencies[1] and are now entering a fifth round of project work.

Agencies may approach the DAC with a specific problem or a general inquiry. The DAC works with the agency to define the problem, identify and procure relevant datasets and undertake an analysis. By working together with the client agency, they are able to discover early insights from the data which may lead to reframing or focussing of the initial question.

The DAC has so far been centrally funded for projects but is expected to become increasingly self-funding. Funding arrangements are negotiated on an individual project basis and may involve a contribution from the requesting agency.

The DAC are working closely with NSW Department of Finance and Services in the establishment of the NSW Data Ecosystem, a platform for data sharing based on web services accessed via APIs. The dMarketplace (see above) will handle negotiation and compliance with licence conditions set by data custodians, which may be tailored to individual datasets or projects. Sensitive data may be provided within a secure environment that allows specific analyses but no download.

Data from UrbanGrowth could be ingested by the DAC for use in an UrbanGrowth project, or for more general access and use. If UrbanGrowth establishes its own online data hub, access could be automated through standards-based web service APIs. The DAC will also host data for agencies that lack this capacity.

1 Arts NSW, DFSI, DPC, DPE, DPI, Education, FACS, Fair Trading, Fire and Rescue, Health, Industry, Infrastructure NSW, Justice, OEH, SafeWork NSW, SIRA, State Library, TfNSW.

NSW Department of Planning and Environment (DPE)

The NSW Planning Portal supports information access for property development and related transactions. It also includes an Open Data hub with 19 key planning layers.

DPE has a corporate GIS system based around ESRI ArcGIS Server and ArcMap desktop software. Data are loaded to a central database managed from the Hurstville office and replicated to regional data stores.

Spatial metadata for around 1000 datasets is collected using the ISO standard for Geographic information – Metadata (ISO19115) and stored in a metadatabase accessed through the data portal.

The Knowledge Strategy sets priorities for knowledge that help OEH and its cluster partners to achieve its mission. It identifies priority knowledge needs across six themes.

NSW Office of Environment and Heritage has an open data portal holding 2,729 records. Of these 73% are PDF reports, leaving 739 actual datasets, of which 26 are available online as web services.

Transport for NSW

The Transport for NSW Open Data Hub provides API and download access to real-time public transport status, Opal monthly usage summaries and transport survey data. Data may be accessed via registered account, subject to the usual terms and conditions. Access must comply with a Data Licence, currently a Creative Commons Attribution 4.0 License.

Transport Performance and Analytics (TPA) is a business unit within Transport for NSW that provides public access to travel statistics and forecasts modelled on travel zones, which are also published as spatial data.

4. Western Australia's Open Data Initiative

Policy backing

Western Australia's (WA) SDI initiative is anchored by its Whole of Government Open Data Policy, which was published by the Department of the Premier and Cabinet in 2015. The policy indicates:

- Benefits of open data – The policy explains that well-implemented open data initiatives would allow efficient and improved evidence-based policymaking. It could also have broader social and economic benefits as open data offers opportunities for new businesses and supports research conducted by academic communities, non-for-profit organisations and enterprising citizens.
- Who the policy applies to – All WA public sector agencies as defined in The Public Sector Management Act 1994 are subject to the policy. Government enterprises, universities, local governments, courts and tribunals, government contractors, as well as recipients of government grants are also included in scope.
- Who is responsible for implementation – Landgate, the state's official register of land ownership and survey information, is in charge of implementing the initiative.
- Data quality – The initiative is to focus on making raw data available. It also stipulates that metadata and information on the data's purpose and quality be provided to users so that they may assess the data's suitability to their needs.
- Guiding principles for best practice – The policy provides guiding principles for management goals of the initiative. It emphasises that agencies be encouraged to make their data open by default, and free or with minimal cost to the end-user. Further to this end, one of the principles stipulates that the data be published in non-proprietary formats and licensed under Creative Commons Attribution (CC BY). Datasets should also be released in a timely manner and updated. The policy also requires agencies to carefully consider the costs of releasing data with privacy implications, and to take measures in securing such data when needed.

Landgate and WALIS

Landgate, formerly Department of Land Administration, is the government agency mandated to implement WA's open data initiative. The Western Australian Land Information System (WALIS) is a program within Landgate. It is through WALIS that Landgate coordinates and delivers geographic information under the custodianship of most WA government agencies (Department of Land Information WA 2005).

WALIS was established in the 1980s as a collaboration between government agencies to coordinate their efforts in electronic data capture. WALIS continues to serve as a forum and consortium of government agencies, and private sector organisations, academic institutions and community organisations that aim to improve WA's approach to geographic information management (WA Government 2012).

WALIS is governed by the Executive Policy Committee (WALIS EPC), which is comprised of chief executive officers of WALIS member agencies that are in custody of the bulk of WA's government spatial data.

The WALIS Spatial Management Group (WALIS SMG), is the strategic body for WALIS EPC. It is made up of Director-level representatives from WALIS member agencies. The SMG interacts with the WALIS community, including academic institutions and industry bodies, and plays an advisory role to the WALIS EPC.

WA's Shared Land Information Platform (SLIP)

The SLIP program is supervised by Landgate and WALIS. It was first launched in 2007 to serve as the platform through which government information systems would be linked, thereby serving as a single point of access to geographic information data from various government agencies. While SLIP's data cataloguing function has now been transferred to the new portal data.wa.gov.au, the SLIP website serves a number functions that support interoperability, and promote data accessibility and sharing:

- Data Dictionary
- Program updates via SLIPStream newsletter
- Tools for IT and GIS professionals
- Core dataset search – the SLIP website still has a search tool that enables users to discover datasets. Using the search bar on the SLIP website, the user is now directed to the new data catalogue site data.wa.gov.au
- SLIP Geodetic

The current data catalogue integrates all datasets that were available from Landgate's SLIP together with an additional 800+ datasets from different WA government agencies.

5. Australian Urban Research Infrastructure Network – AURIN

Although AURIN is geared towards catering to the research and academic community rather than the wider public, it is nonetheless a good example of SDI implementation. Born out of the Australian Government's National Collaborative Research Infrastructure Strategy in 2010, and with collaboration from federal, state, and local governments, educational institutions and industry partners, AURIN has strong backing for its continued operation and development.

The following aspects of AURIN's implementation make it an exemplar of several best practices mentioned in this review.

Governance

AURIN's governance structure is simple in that it comprises only three main bodies: the management board, a technical committee and a set of expert groups. Each body has a clear assigned task with regards to its contributions to the project.

The AURIN Management board is comprised of representative leaders from the project's main collaborating institutions. The board provides strategic oversight for the project.

The Technical Committee is responsible for overseeing the project's Technical Architecture and advising the Management Board on AURIN's technical operation and potential improvements.

AURIN also has several expert groups in place, with each group assigned a major theme in urban planning:

- Population and demographic features and benchmarked social indicators
- Economic activity and urban labour markets
- Urban health, well-being and quality of life
- Urban housing
- Urban transport
- Energy and water supply consumption
- Innovative urban design

The expert groups oversee identification of target data sets and open source research tools for their assigned theme.

Procedures and data policies

The AURIN website has a section on Compliance, which provides information on privacy policies, copyright and attribution, data terms and conditions.

AURIN prefers licensing through Creative Commons 4.0 framework (CC BY 4.0), a public license that allows users to redistribute, modify and adapt the data for their own purposes (including commercial) if they credit the source.

AURIN also has its own data licence template to accommodate data providers that cannot license their data through the CC BY 4.0. The agreement licenses AURIN to sub-license the data to its end-users. A main limitation however is that end-users cannot adapt the data for commercial purposes.

For prospective data providers, AURIN has a Data Release Form which functions as a checklist for metadata and licensing information. The website also has a dedicated page that details how data on AURIN is used, who the end-users are, how to process the data through AURIN's tools, the licensing arrangements and benefits for data providers.

AURIN emphasises that data providers benefit from feedback regarding data quality and delivery, usage statistics on their data and the potential for AURIN to help improve metadata and the dataset's usability.

Online data exploration tools

The AURIN Workbench has several tools that enable data discovery and quick analyses:

- **Data Discovery** – AURIN's data catalogue function uses a federated system wherein the data stays with the data custodian enabling users to browse the data before downloading. At the time of writing, AURIN had 2150 datasets from 90 organisations.
- **AURIN Map** – allows public users to visualise data layers on basemaps and embed the map onto the user's site.
- **AURIN Portal** – a browser-based tool that allows registered research users to load datasets from AURIN's catalogue and execute a large number of spatial analyses.
- **AURIN Decision-support** – AURIN's portfolio of more specialised data analysis products supporting planning and decision-making processes.

Project Documentation

The AURIN website makes project administrative documents available, not only fostering project transparency but also providing more information about the project to potential collaborators or to other organisations that are looking to build an SDI or IM enterprise.

The website also has a News & Events section where it communicates new project developments, newly highlights case studies and newly released data sets.

6. Australian Healthcare Data Linkage Systems

The Western Australian Data Linkage System (WADLS) and NSW's Centre for Health Record Linkage (CHeReL) enable researchers to link various health records relating to individual, family, place or event without disclosure of personally identifiable details (i.e. demographic data) to the researcher.

WADLS and CHeReL differ from the other case studies in that they do not hold custody over the data per se. Rather, their purpose is to connect various datasets held by different custodians and maintained in separate registers. Data interoperability is at the core of WADLS and CHeReL, and it is worth taking some best practice pointers from these systems in this regard.

The following sections will first explain how data linkage system works, and then discuss the data management methods worth noting from WADLS and CHeReL.

How data linkage works

Health researchers submit their project proposal to WADLS or CHeReL indicating which health and demographic data they need to be linked. The proposal must meet Ethics and Privacy requirements to be approved.

Once the proposal is approved, the relevant data custodians are contacted to provide the requested records to WADLS/CHeReL. The personal record identifiers (e.g. name and date of birth, other demographic data, original patient record number) are assigned person numbers that are specific to the research project. In this way, the data is de-identified.

These generated project-specific person numbers are then used in the linkage process where health records are automatically matched based on the probability that they pertain to the same individual. The researchers are only able to see the project-specific person numbers and the health records linked to that person.

Pointers for Interoperability

WADLS and CHeReL link various datasets held by different custodians through the use of technical standards in the way the datasets are structured and managed.

Both WADLS and CHeReL publish their data dictionaries on their website. The data dictionaries define the variables available in the dataset, and how entries for each variable are formatted (e.g. entries for the DATE OF BIRTH variable should be formatted ddmmyyyy).

These data dictionaries serve not only as a template for current data providers, but also as a basis for future data providers to select variables for inclusion in their dataset and to format their data for compatibility with the linkage systems. This is important for expanding the future of health research. Laying good foundations for data interoperability facilitates the generation of new insights from linking new kinds of data to existing core datasets. The history of the WADLS's development is worth noting in this regard.

Thanks to a number of data management initiatives throughout the years, WADLS has a history of benefiting the improvement of public health research and policy:

- In connection with the instigation of the Family Connections Genealogical Register in 2002, the WADLS went through a three-stage process whereby an inter-generational family linkage of data was achieved using electronic registrations of births, marriages, and deaths since 1974; a move was made to computerise and link earlier registrations; and a public appeal was made to fill in remaining gaps.

- Socio-demographic data from the state electoral roll was included as a core dataset, which improved the system's capacity to support migration-related health research.

Residential addresses on various hospital records were geocoded. This spatially referenced data enables further research into environmental factors and geographical distributions of illnesses. (Holman et al 2008).

In its earlier stage during the 90s, WADLS was able to secure funding to develop its infrastructure under the Lotteries Commission program. It was also during this time that the WA Data Linkage Unit struck an agreement with the State Health Department which enabled its academic staff to work closely with the core datasets under the department's custody (Holman et al 2008).

The Australian healthcare data linkage systems demonstrate the advantages of prioritising data interoperability, and that this can be achieved through incremental advances in the standardisation and encoding of data and formation of partnerships between data custodians. They also show that aiming for data interoperability enables the whole infrastructure to grow over time as it accommodates new datasets and facilitates the generation of new research insights.

7. City of Greater Geelong

The City of Greater Geelong's portal is a good example for other place-based organisations like UrbanGrowth seeking to make datasets and other informative documents publicly available in support of a digital economy.

Setting the strategy for a Digital Geelong

Geelong's open data initiative is part of the city's vision to become a nationally recognised leader in championing a digital economy, as expressed in its Digital Geelong strategy. The Digital Geelong strategy is underlined by the following key motivations:

- Maximising service delivery and efficiency by leveraging new methods of and best practices in communication (e.g. digital platforms) and civic engagement.
- Ensuring economic competitiveness by enhancing techno-literacy of the community and local businesses in line with the expansion of knowledge industries in the area. Geelong sees the relocation of government agencies such as the Transport Accident Commission and WorkCover in the area and the presence of tertiary education institutions such as Deakin University as strengths on which Geelong can build to attract new talent and grow its knowledge economy.
- Increasing the integration and effectiveness of public participation in decision-making through online engagement. Geelong is looking to enhance the relationship between the council and the community; sharing problem-solving through instant feedback loops enabled by digital technology.

Digital Geelong outlines a set of 30 recommendations to guide the council's course of action towards achieving its ambitions. Several of these may be relevant for agencies like UrbanGrowth to adapt in their strategic framework for implementing a knowledge management program. These are quoted below with modifications and further elaboration where necessary.

1. Treat staff (and the community) as part of a crowd-sourced online problem-solving network.
2. Continually improve the understanding of digital drivers in contemporary cities around the world and the role that they play in delivering a digital economy.
3. Build on the local strengths in the digital economy by embracing current and previous initiatives and their relevance to achieving the organisation's KM strategy.
4. Develop an implementation strategy that acknowledges the organisational culture changes required to align activities with the organisation's goals and ambition for a digital economy.
5. Endorse the overall strategy at corporate level, identify the champions who will lead the overall strategy and identify which department heads should lead implementation of each recommendation.
6. Partner with tertiary education institutions and relevant industrial entities to leverage their knowledge and capabilities in data analytics, visualisation and digital learning.
7. Ensure that a cross-department process of digitisation is led by the CEO with support from the CDO or other relevant officer.
8. Iteratively release all relevant datasets in machine readable format, with clear guidelines and policies on reuse. A progressive move towards making data available through Application Programming Interfaces (APIs) should also be explored. APIs enable connectivity between the organisation's datasets and creative applications which web developers can build when APIs are available.
9. Create a platform where users can view and interact with the organisation's open data. The platform should offer basic visualisation and data analysis capabilities, allow users to share the data, and provide guidance and examples of how data can be used creatively.
10. Use and promote benchmarking tools to assess digital awareness and participation within the organisation
11. Engage the wider community and local businesses with activities like 'hackathons' that incentivise users and developers to use the organisation's data to generate new insights and useful web applications.

Greater Geelong's Open Data

Geelong Council makes it datasets available on geelongaustralia.com.au/data. Two other local government areas, Golden Plains Shire and Surf Coast Shire have also contributed datasets to the catalogue. To date, the portal has 160 datasets available.

Geelong Council also uses the Australian Government's open data portal (data.gov.au). Datasets relevant to Geelong can be viewed by filtering for 'City of Greater Geelong' under Organization. The council also directs people who wish to publish datasets for Geelong to data.gov.au. They have provided a YouTube tutorial showing how users can upload the dataset onto data.gov.au, and how to use the portal's metadata editing tool.

Using data.gov.au's National Map feature, users can also visualise spatial data from Geelong on a base map. By making Geelong datasets publishable and accessible through data.gov.au, the council effectively leverages the portal's existing tools instead of building their own from scratch.

With regard to licensing, users can reuse Geelong datasets under CC BY 3.0 AU. This license enables users to copy and redistribute the data in any medium or format, and adapt the material for any purpose including commercial provided authorship is acknowledged.

Geelong 3D and hackathons: empowering the community to contribute

Geelong has started making its 3D data which includes terrain, building footprints and aerial imagery open to developers. In return, the council requires developers to return their building models. According to the council's website, more than 100 high quality models have been returned to the council through this initiative.

This is a good business case for making data openly available. It illustrates how engaging the community can directly contribute to expanding a data/knowledge management program.

Geelong Council has also become a two-time host of GovHack, a national open data competition held annually. The competition is led by IP Australia, sponsored by industry partners such as IBM and supported by various government agencies that are active open data publishers. The competition challenges developer teams to conceptualise innovative applications using open data for the benefit of the community.

Geelong Council's Open Data program is a good example of what an agency might do in the initial stages of setting up a knowledge management system. The council has set out clear strategic goals for its Open Data program. Through its participation in wider open data movements sponsored by the government, Geelong has taken steps to leverage existing tools and infrastructure that will support the growth of the initiative.

8. European Union – INSPIRE

Contemporary with the US establishment of Geospatial One-Stop, the European Commission launched its Infrastructure for Spatial Information in Europe (INSPIRE) initiative. INSPIRE has the distinct challenge of building and coordinating a spatial information infrastructure across 27 countries, each with their own sub-national components, and 23 languages. Such a feat requires a "very open and transparent model from the outset" (Craglia 2007).

Considering the potential incompatibilities in technological capacities, as well as political and bureaucratic structures of INSPIRE's stakeholders—it is valuable to examine how INSPIRE addresses technological barriers and governance issues.

An open and transparent legal initiative

INSPIRE was preceded in the late 1990s by GI2000, which aimed to progress the coordination and integration of geographic information (GI) across legal and administrative barriers so that businesses across Europe could exploit opportunities brought about by information. However, GI2000 did not become European policy and thus provided little to no impetus for adoption. INSPIRE, on the other hand, is a legal initiative that provides a framework for the eventual European Spatial Data Infrastructure or ESDI (Bernard et al 2004).

Before INSPIRE was put into effect, the European Commission undertook a process of stakeholder consultation and collaboration on determining the scope of the directive. Five working groups elaborated position papers on: (1) metadata; (2) standards and architecture; (3) datasets the user needs; (4) data policy; and (5) implementing structures and funding. Two expert groups with representatives from each member state were assigned to mediate the discussion and drive it to arrive at consensus (Vandenbroucke et al 2008, Annoni and Craglia 2005). The INSPIRE directive was put into force in May 2007 and was enacted in national legislation about two years later (Vandenbroucke et al 2008).

Consolidating and building on National SDIs

A key objective of INSPIRE is to address availability, quality, organisation, exchange and accessibility of spatial information that is pertinent to environmental policy-making. Within its initial clauses, the Directive expresses its recognition for GI infrastructure that already exist in member states and that these assets can be leveraged to achieve INSPIRE's objective by implementing rules, standards and procedures that would make them compatible and interoperable (European Commission 2007).

The European Commission publishes regulations to implement technical standards for metadata, data and service sharing specifications, network services, as well as monitoring and reporting requirements for member states. While member states must adhere to these regulations and transpose them into national law, this does not mean that countries implement INSPIRE on subnational levels in the same manner. Regulations are high level enough that countries can implement them in a way that is responsive to the structure of their NSDI. There is also variation in the completeness of implementation as some member states may have more capacity or more mature SDIs than others (Masser and Crompvoets 2015).

Given the varying capacity of member states to implement INSPIRE regulations, it is important for the initiative to have a mechanism for taking stock of member states' GI infrastructure capabilities and for monitoring progress of INSPIRE's implementation given such capacities. For this purpose the European Commission initiated INSPIRE State of Play, an annual assessment of status and development of NSDIs of member states (Vandenbroucke et al 2008).

In accordance with the commission's 2009 regulations, member states must report on indicators measuring implementation and GI infrastructure usage on a yearly basis. In addition, members are required to submit a report every three years detailing their NSDI's coordinating mechanisms, infrastructure and spatial information, data-sharing agreements and costs and benefits of their INSPIRE implementation (European Commission 2017). The INSPIRE website provides the template and guidelines for accomplishing such reports (inspire.ec.europa.eu/Library/Monitoring-and-Reporting/69).

Coordinating Bodies

Four main groups oversee, coordinate or lead implementation of INSPIRE directive:

- INSPIRE Coordination Team (CT) – The CT is the European Commission's main coordinating body for INSPIRE's implementation and further development. The team consists of staff from the commission's DG Environment, in charge of coordinating INSPIRE policy; the Joint Research Centre, which coordinates the evolution of INSPIRE's technical infrastructure; and the European Environmental Agency, which takes on tasks related to reporting and monitoring.

- INSPIRE Committee (IC) – The IC is made up of representatives from INSPIRE's member states. It supports the commission by providing opinion on proposed implementation rules.

- National Contact Points (NCPs) – These are public authorities designated by member states to communicate with the Commission on matters related to INSPIRE (e.g. reporting on their respective country's implementation).

- INSPIRE Maintenance and Implementation Group (MIG) – MIG is an expert group formed by the Commission in 2013. It consists of NCP representatives and works together with the CT and member states, providing support on specific implementation and maintenance issues. It also has a permanent sub-group focused on technical aspects of implementation. (European Commission 2017)

Technical Implementation guidelines

The European Commission provides technical specifications for data and metadata. These are summarised online (inspire.ec.europa.eu/node/57528).

Like the US NSDI, INSPIRE categorises data into themes and provides data specifications for each theme. Themes are further subcategorised into Annexes. Each annex has an appointed 'Milestone Date' for when its data, metadata and web service would be released, in accordance with INSPIRE's road map plan for implementation (inspire.ec.europa.eu/Roadmap/Data-Specifications/2892).

INSPIRE's metadata and service guidelines are based on ISO standards 19115, 19119, 19139 and 19143 (see Appendix: ISO/TC211 Geographic standards).

INSPIRE Geoportal

The INSPIRE Geoportal (inspire-geoportal.ec.europa.eu) has four main applications on its homepage:

- Resource Browser – for searching the catalogue. Among the usual filter options like the US GeoPlatform (e.g. spatial data themes, keywords, data types, publishing organisation), it is notable that users can search datasets by Resource language, metadata language, remote metadata identifiers and metadata point of contact organisations.

- Discovery/Viewer – allows users to search for datasets and allows data layers to be displayed on a map.

- Metadata Editor – a metadata editor with all fields required by INSPIRE standards. The editor also presents the option to enter metadata in 22 different European languages.

- Metadata Validator – allows users to copy-paste or upload their metadata to verify INSPIRE compliance.

9. London Datastore

In comparison to INSPIRE, the London Datastore is valuable as a case study of a more localised and bottom-up approach to SDI.

Initiation and leadership

The London Datastore was initiated in a climate that promoted the benefits of open data on a high level. In 2010, the UK Government had produced its Open Data White Paper and G8 Open Data Charter and Technical Annex, and the Open Data Institute was growing in influence (GLA 2010). Internationally, INSPIRE was in the works, the US NSDI had gained some maturity and the Obama administration had issued its Open Government Directive the year before. Furthermore, London Mayor Boris Johnson had committed to establishing an open data registry as part of his election campaign (Coleman 2013).

In 2010, the Greater London Authority (GLA) stated London Datastore's main goal, an updated 2014 version of which quotes:

The London Datastore has been created by the Greater London Authority (GLA) as an innovation towards freeing London's data. The aim is for citizens to be able to access the data that the GLA and other public sector organisations hold, and to use that data however they see fit – free of charge. The GLA is committed to influencing and cajoling other public sector organisations to releasing their data here too.

Releasing data is just half the battle. Raw data often doesn't tell you anything until it has been presented in a meaningful way. The project aims to encourage the masses of technical talent in London to transform rows of text and numbers into user-friendly apps, websites and mobile products. (Greater London Authority 2014)

Being open about Open Data

Emer Coleman (2013), one of the initial leaders and the architect of the London Datastore project stated that he was heavily influenced by a definition of open data described by David Eaves as follows:

1. If it can't be spidered or indexed, it doesn't exist.
2. If it isn't available in open and machine-readable format, it can't engage.
3. If a legal framework doesn't allow it to be repurposed, it can't empower (Eaves 2009)

In 2009, Coleman initiated the scoping process for the London Datastore. In the process, he recruited members of the GLA's Data Management Asset Group (DMAG) and the Technology Group (TG) and released an open call entitled "Help Us Free London's Data" to the city's developer community using the London Datastore's Twitter account. The invitation is quoted by Coleman as follows:

The Greater London Authority is currently in the process of scoping London's Datastore. Initially, we propose to release as much GLA data as possible and to encourage other public agencies in London to do the same, and we'd like your help! We want the input of the developer community from the outset prior to making any decisions on formats and platforms. We would, therefore, like to invite interested developers to City Hall, so that we can talk to you about what we want to do, get your views, and seek your input on the best way to deliver for London. (Coleman 2013)

This invitation led to an open workshop with over sixty developers from the technological community. Coleman and his team benefited from learning developers' expectations for open data services, as well as identifying potential barriers to releasing public data such as current government structures.

From the onset, Coleman and his team had recognised the importance of opening the process to the developer community, who are mostly ordinary citizens with the technical know-how and an interest in generating apps for public good. This community would not only be users of the released data—but also the very people who would be collaborators in turning that data into useful information. Coleman (2013) remarks that the initial feedback from the developers was that so long as the data was not in PDF—they would take it.

Negotiating Cooperation

In 2010, the GLA was taking the lead in convincing other agencies to share their data. Coleman recalls having numerous meetings with London's functional bodies together with members of the developer community. While the Datastore was seen as a good idea by many of the functional bodies, there was inevitable resistance from other agencies to release their data.

Bennet (1985) and Worthy (2008) point out that such a response reflects pre-established cultures of government secrecy. Resistance to making data publicly available may also stem from attempts to monetise state data (Burkert, 2004).

Coleman points out that leveraging the media's influence in helping to convince agencies to open up their data was essential in establishing the London Datastore. He notes that positive reinforcement from the media whenever an agency made progress towards sharing its data helped the process.

London's Open Data Charter and Datastore today

In 2014, the GLA released the second-generation London Datastore with the following principles:

- The intellectual property and technical specification of London Datastore will be non-proprietary.
- The second generation of London Datastore will be a place where organisations can publish their data in open format and where publishers may seek support and peer advice in doing so.

The London Datastore today serves as a focal point for the city's data strategy and smart city initiative, which is still unfolding.

CONCLUSION

In the wake of IoT and the movement towards data-driven decision-making, various institutions and organisations are looking to maximise on their data assets by implementing their own information management programs.

Since at least the 1980s, the ICT field has produced literature on data and information management. In conjunction with knowledge management insights from organisational learning, this base of literature can be leveraged by organisations like UrbanGrowth NSW in their endeavour to implement their own data hub. Frameworks such as the Capability Maturity Model can be adopted as a roadmap for the organisation's IM enterprise. In this document, the stages in this framework (from ad hoc to optimised) are elaborated on to describe progress in the three dimensions of IM systems: People/Culture, Process and Technology.

The case studies discussed in this document demonstrate that there is no single formula for building and maintaining a data hub. However, the similarities shared by how different case studies tackled elements related to either organisational culture, process, or technological methods may serve as general guidelines for forming and implementing an IM strategy. This document has summarised these similarities as a list of 15 Best Practices.

This is by no means a comprehensive list as IM implementation is a dynamic process, disrupted and evolved over time by technological, cultural, and organisational changes. IM systems also vary according to the needs and purpose of the organisations that implement them. It is advisable for organisations like UrbanGrowth NSW to treat this list as a guideline that can and should evolve as their experience in IM implementation matures.

There is also a need for further research into benchmarking practices in IM implementation, especially in the context of Smart City governance and performance indicators.

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APPENDIX: ISO/TC211 GEOGRAPHIC STANDARDS

ISO Technical Committee 211 is the peak body responsible for standardisation in the field of digital geographic information, with 96 standards either complete or under development (see standards catalogue). A listing follows of ISO/TC211 standards that have gained significant traction or are emerging in areas of interest.

ISO 19101-1:2014 Geographic information -- Reference model -- Part 1: Fundamentals

Defines the reference model for standardisation in the field of geographic information. This reference model describes the notion of interoperability and sets forth the fundamentals by which this standardisation takes place.

ISO 19110:2016 Geographic information -- Methodology for feature cataloguing

Defines the methodology for cataloguing feature types. This document specifies how feature types can be organized into a feature catalogue and presented to the users of a set of geographic data.

ISO 19115 Geographic information – Metadata

ISO 19115-1:2014 Part 1: Fundamentals

Defines the schema required for describing geographic information and services by means of metadata. It provides information about the identification, the extent, the quality, the spatial and temporal aspects, the content, the spatial reference, the portrayal, distribution, and other properties of digital geographic data and services.

ISO 19115-2:2009 Part 2: Extensions for imagery and gridded data

Extends the existing geographic metadata standard by defining the schema required for describing imagery and gridded data. It provides information about the properties of the measuring equipment used to acquire the data, the geometry of the measuring process employed by the equipment, and the production process used to digitize the raw data.

ISO/TS 19115-3:2016 Part 3: XML schema implementation for fundamental concepts

Defines an integrated XML implementation of ISO 19115-1, ISO 19115-2 and concepts from ISO/TS 19139.

ISO 19117:2012 Geographic information – Portrayal

Specifies a conceptual schema for describing symbols, portrayal functions that map geospatial features to symbols, and the collection of symbols and portrayal functions into portrayal catalogues.

ISO 19126:2009 Geographic information -- Feature concept dictionaries and registers

Specifies a schema for feature concept dictionaries to be established and managed as registers.

See also ICA wiki

ISO 19135-1:2015 Geographic information -- Procedures for item registration

Specifies procedures to be followed in establishing, maintaining, and publishing registers of unique, unambiguous, and permanent identifiers and meanings that are assigned to items of geographic information.

ISO/TS 19139:2007 Geographic information -- Metadata -- XML schema implementation

Defines Geographic Metadata XML (gmd) encoding, an XML Schema implementation derived from ISO 19115.

ISO/TS 19150:2012 Geographic information – Ontology

ISO/TS 19150-1:2012 Part 1: Framework

Defines the framework for semantic interoperability of geographic information: a high level model of the components required to handle semantics in the ISO geographic information standards with the use of ontologies.

ISO 19150-2:2015 Part 2: Rules for developing ontologies in the Web Ontology Language (OWL)

Defines rules and guidelines for the development of ontologies to support better the interoperability of geographic information over the Semantic Web. The Web Ontology Language (OWL) is the language adopted for ontologies.

It defines the conversion of the UML static view modelling elements used in the ISO geographic information standards into OWL. It further defines conversion rules for describing application schemas based on the General Feature Model defined in ISO 19109 into OWL.

It does not define semantics operators, rules for service ontologies, and does not develop any ontology.

ISO 19150-3 Part 3: Semantic operators (proposed)

ISO/AWI 19150-4 Part 4: Service ontology

Current status: Under development

ISO 19150-5 Part 5: Domain ontology registry (proposed)

The ontologies in this register shall be developed to serve as a basic framework for the definition of ontologies at finer level of granularity for application, shall allow mapping of concepts between application specific ontologies within a shared domain, and shall enable to interrelate concepts across domains.

ISO 19154:2014 Geographic information -- Ubiquitous public access -- Reference model

Defines a reference model for ubiquitous public access (UPA) to geographic information. This reference model uses standard concepts from both the Open distributed processing – Reference model (RM-ODP) in ISO/IEC 10746-1 and ISO 19101.

Defines:

- conceptual models for ubiquitous public access (UPA) to geographic information;
- a reference model and framework to support current and future specification development in this area;
- the semantics of information and processing within systems and services for the UPA of geographic information;
- the architectural relationship between this International Standard and other ISO geographic information standards.

Applicable to location-based services (LBS), ubiquitous computing environments, linked open data, and other domains that require a seamless public access to geographic information.

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