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'Evidence-informed' metropolitan planning in Australia? Investigating spatial data availability, integration and governance

Final report

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We acknowledge the traditional custodians of the land on which we conducted this research. We pay our respects to ancestors and Elders, past, present and future. The University of South Australia is committed to honouring Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to society.

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Executive Summary

The research presented in this report was guided by the following two research objectives:

1) to identify current gaps and potentials in addressing spatial data requirements for metropolitan planning; and

2) to investigate the limitations and potentials of available spatial data to inform metropolitan planning policies, using the example of Greater Adelaide, and to discuss the current challenges affecting the provision of comprehensive and integrated spatial data for urban and regional planning in Australia.

In response to the first research objective, a review of the published academic literature indicates while planning research has given limited attention to conceptualising and analysing spatial data in planning processes to date, debates in the spatial science literature have identified a fragmentation of spatial datasets across the different government levels, but have only on occasion considered the implications for the specific application of urban planning. Overall, there appears to be an important gap between the producers of data, and the users of spatial data, such as urban planners. Challenges in relation to spatial data for urban planning are often not the result of missing data *per se*, but rather that data are not in the required formats, timescales, resolution, or are compatible with other datasets.

Bridging the gap between data providers and data users, especially in relation to the requirements of urban planning, will be important if progress towards sustainable development and low-carbon cities is to be made. This will, however, first require a political acknowledgement of the important role that spatial planning has in achieving positive societal outcomes - something which may be difficult to achieve given the current emphasis on facilitating economic investment and consequently the scaling back of planning regulation. For public sector planners therefore, the current course of action may be a more pragmatic one, by seeking to have a voice in discussions on SDI initiatives in Australia as an important user of spatial data, and by engaging with public sector data providers within their states to explore avenues for accessing spatial data that are ‘fit for purpose’. The considerable number of geoportals and map viewers now available can be useful for Australian planning departments seeking greater transparency on datasets available. However, reviewing their content and reflecting on the usefulness of the sources to complete their planning tasks will require capacity and technical skills. Within state and local planning departments there is therefore a need to overcome the ‘division of labour’ between planning policy officers, spatial data analysts and GIS technicians. Providing public sector planners with at least basic skills in GIS and spatial data analysis will be important to allow an informed discussion with GIS technicians, and for urban planners to be able to express their data requirements clearly.

In terms of SDIs and related initiatives in Australia, the analysis presented in this report has shown that stronger leadership at federal and state levels will be required for agreement at national level on data standards and meta-data standards to ensure better data integration and coordination across the nation and across different levels of government. There would also be value to improve the involvement of local governments in discussions on SDIs at state level as well as across Australia, given the important role of local councils in land use planning and development control.

The second objective of the research was achieved by focusing on a pilot analysis of metropolitan spatial planning policies for Greater Adelaide, as set out in the most recent ’30-

Year Plan for Greater Adelaide – Update 2017' (Government of South Australia 2017). This was done by selecting two of the policy themes set out in this metropolitan strategy, with a view to illustrating what spatial datasets would ideally be needed to develop and monitor metropolitan planning policies, and compare these with the actually available spatial datasets.

The analysis showed a considerable disconnect between the comprehensive and integrated planning policies (such as for activity centres or healthy neighbourhoods) presented in the metropolitan strategy, and the limited number of narrowly defined 'high-level' targets with their only marginally considered data needs. For the future metropolitan strategy for Greater Adelaide, which will be prepared under the PDI Act 2016 by the SA state government, it would be useful to consider data needs from the outset of the policy-making process and for the different stages of the policy cycle, so as to be in a better position to analyse spatial trends, develop spatial policies in response, and to set up monitoring arrangements early on. The considerable number of data initiatives over recent years, notably in relation to high-resolution and frequently updated remote sensing (2D) and LiDAR (3D) data, will offer great opportunities for urban planners. However, it will be important to engage with these data collection and data analysis initiatives from a planning perspective early on to make sure such datasets are accessible and can be tailored to the needs of the specific planning tasks.

The analysis of the spatial data implications arising from the 2017 Update of the 30-year plan for Greater Adelaide showed some important gaps in data availability, e.g. in relation to information on the mixed-use of land and buildings. It also highlighted some important 'blind spots' in current data collection and availability, notably in relation to 'flow data' (infrastructure usage) of cyclists and pedestrians, given that traffic flow data is still heavily focused on only measuring motorised road traffic use. Aside from challenges of harmonizing different spatial datasets, important gaps in data availability therefore also exist because of political preferences and resource decisions, resulting e.g. in a structural distortion towards representing 'hard' infrastructures and an overemphasis of road traffic data over other transport modes. Existing challenges in relation to spatial data availability and harmonisation for metropolitan planning will likely be exacerbated by the on-going privatisation of data collection in parallel to shrinking public budgets.

1. Introduction

1.1 Context for research

In many Australian states, major reforms of urban and regional planning systems have been initiated over the past years. Common trends in these planning reforms have been observed across the states, relating to a simplification of rules and speeding up of decision-making to facilitate economic investment (Goodman et al. 2013). At the same time, and often in contradiction, there are long-standing expectations for planning to support the transition to sustainable and liveable urban environments. Over recent years, there has also been renewed attention to metropolitan-regional planning for Australia's capital cities as an approach to coordinate urban development and infrastructure investments and reduce negative impacts from congestion and increasing inequalities (Hamnett and Freestone 2018; Tomlinson and Spiller 2018).

Over recent years, there has been much emphasis on government policy to be evidence-based, and this has placed the spotlight on the availability and compatibility of geo-referenced data to inform urban plans and metropolitan spatial strategies. Archived multidimensional spatio-temporal data with rich semantic information are crucial inputs for developing spatial plans and to monitor the effectiveness of urban and regional planning policies. However, the rapidly changing context for urban and metropolitan planning in Australia also places new demands on spatial data availability. New data may be required to analyse trends and develop policies in response to the broadening scope of planning. The attention to the metropolitan scale as the suitable arena for coordinated planning responses for the urban region raises questions about the definition of these regions and about the coordination of spatial data across neighbouring jurisdictions and across different government levels.

It has been noted that metropolitan governance in Australia is fragmented, and so is the approach to collecting and collating spatial data (Jacoby et al. 2002). This can present challenges for public sector authorities when preparing spatial strategies or trying to monitor the implementation of planning policy. While there are initiatives underway in Australia to develop geoportals and Spatial Data Infrastructures (SDIs) at different scales, aimed at coordinating the exchange and sharing of spatial data (Sinnott et al. 2015), in comparison to the European Union (EU) and other advanced economies, Australia is trailing behind in providing consistent, comprehensive, interoperable and readily accessible spatial data across jurisdictions (Rajabifard et al. 2006). In the context of a greater interest in metropolitan planning for Australia's capital city regions, this report seeks to contribute to a better understanding of the challenges facing public sector planning authorities in relation to spatial data availability and coordination for 'evidence-informed' metropolitan planning in Australia.

1.2 Research objectives, research questions and methodological approach

The research presented in this report was guided by two research objectives, as follows:

1) to undertake a comprehensive review of the academic literature and of policy initiatives to develop geoportals and spatial data infrastructures at national, state and local levels in Australia, with a view to identifying current gaps and potentials in addressing requirements for urban and especially metropolitan spatial planning; and

2) to investigate, from a university researcher's perspective, the limitations and potentials of available spatial data to inform metropolitan planning policies, using the example of Greater Adelaide, and to discuss the current challenges affecting the provision of comprehensive and integrated spatial data for urban and metropolitan planning in Australia.

This research comprised was a desk-based review of the academic literature and of relevant policy documents and legal frameworks. In response to the first objective, a comprehensive analysis of the academic and policy literature was undertaken, looking into spatial data needs for collaborative spatial planning across administrative boundaries and reviewing initiatives to develop spatial data infrastructures. The geographical focus of this analysis was on Australia, with other democratic federal nations and international organisations (notably the EU) offering points of reference. The second objective of the research was achieved through a pilot study of metropolitan spatial planning policies for Greater Adelaide, as set out in the current '30-Year Plan for Greater Adelaide – Update 2017' (Government of South Australia 2017). While South Australia's new planning legislation foresees the preparation of a new metropolitan strategy, to replace the 30-year plan, work on the new policy document will not commence until the end of 2020. For the purposes of the analysis presented in this report, therefore the existing planning document provides a 'real-world' example of an adopted metropolitan spatial strategy. The 2017 Update of the 30-Year Plan for Greater Adelaide was analysed by selecting two of the policy themes set out in this metropolitan strategy as examples; comparing which spatial datasets would ideally be needed to develop and monitor these metropolitan planning policies against the spatial datasets that are actually available; and identifying issues related to their ownership, timescale and resolution. The findings from the desk-based analysis were discussed in the project team and with external partners in order to identify the challenges and potentials for metropolitan planning in Australia in relation to spatial data availability and data harmonisation.

The research presented in this report was undertaken between January and June 2020. The study was financially supported by the UniSA AHURI Research Centre, and undertaken by UniSA researchers Prof. Stefanie Dühr, Dr. Hulya Gilbert and Dr. Stefan Peters. Mr. Bert Bruijn from the Department of Planning, Transport and Infrastructure (DPTI) and Prof. Jane Hunter from AURIN provided guidance on the research from their respective professional perspectives, and their constructive engagement with the research is herewith gratefully acknowledged.

1.3. Definitions

Spatial data are defined as 'data with implicit or explicit reference to a location relative to the Earth' (European Commission 2020), and consisting of both topographic information and thematic attributes. In this report, the term *spatial data* is used as synonymous with *geo-referenced data*. More specifically, the focus of the research was on those spatial datasets that are of relevance to urban and regional planning, that is, geo-referenced data on topics such as settlement structures, population trends (and their location), data on economic activity, on transport and mobility, and on environmental and on social matters (Indrajit et al. 2019; Siddiqui et al. 2019; Zwirowicz-Rutkowska and Michalik 2016).

Different types of spatial data can be differentiated. Spatial data can be in the form of vector data (represented as points, lines, polygons, triangulated irregular network (TIN), and 3D models) or be in the form of raster data that provide information in a cell-based manner (such as remote sensing data from satellite images). Spatial data can refer to a fixed location on a continuous surface (with a continuous or categorical value), or they can refer to objects (points, lines or areas) located in a discrete geographic space, such as a building, a road or a town centre (Haining 2003). While most spatial data available is quantitative, there is also an increasing attention given to qualitative data in urban and regional planning, such as for example the EU's surveys of quality of life as perceived by citizens in different European cities (see Dühr et al. 2010 for an overview).

Spatial data provided by public authorities is ideally accompanied by a metadata file, that is, a file that contains data about the specific dataset. *Meta-data* would usually include information about data type, format, dimension, coverage, collection (time/creator/method), topic/keywords (e.g., 'housing density' or 'traffic volume'), data updates ('what', 'when', 'how', 'by whom', and frequency of updates), attributes, topology, and so on.

A Spatial Data Infrastructure (SDI) is 'an enabling platform for data sharing. It is based on a dynamic, hierarchic and multi-disciplinary concept that includes people, data, access networks, institutional policy, technical standards, and human-resources dimensions, which aims to facilitate and coordinate the exchange and sharing of spatial data between stakeholders in the spatial data community' (Rajabifard et al. 2006, p. 727). Davis (2009) emphasises that SDIs present a number of challenges at various levels of interaction. Firstly, at a societal and organisational level, the community of producers and users of spatial data need to agree on common rules in order to enable that data can be exchanged between different producers and can be accessed by users. Secondly, standardization needs to be achieved, which according to Davis (2009) is increasingly guided by the technology standards and standards for the key elements of SDIs as proposed by the Open Geospatial Consortium (OGC). Thirdly, there are specific concerns related to the integration of data from different sources and often presenting specific aspects in relation to scale, level of detail, accuracy and uncertainty. Integrating data from different sources requires attention to semantics, because data produced by different organisations and for a variety of uses are not necessarily compatible, and meta-data standards are needed to clarify the content and technical details of the different datasets (Davis 2009).

The exchange of information included in SDI's requires attention to technological aspects and easy access. Geoportals have therefore been identified as important building blocks of SDIs (Bernard et al. 2005). The possibilities offered by the Internet have prompted an increasing use of Web services for online *geoportals*, defined as entry points for 'users to discover, understand, view, access and query geographic information' for a range of uses, including land use planning (Bernard et al. 2005, p. 15). Increasingly, SDIs and their associated geoportals go beyond simple discovery tasks and the download of geographic information, and besides map viewers now also increasingly offer online Geographic Information Systems (GIS) that allow spatial analysis and visual representation of multiple and distributed sources of information (Davis 2009).

1.4 Structure of report

The report is structured as follows. Chapter 2 presents the results of the review of the academic literature on spatial data initiatives and SDIs, and on the role of spatial data for metropolitan spatial planning tasks, as considered in previous research. Chapter 3 analyses the main producers of spatial data with relevance for urban and metropolitan spatial planning in Australia, and discusses the current arrangements for their coordination. Chapter 4 presents the results of an analysis of those datasets that would be readily available to support the implementation and monitoring of existing policies of the metropolitan strategy for Greater Adelaide, as set out in the '2017 Update of the 30-Year Plan' (Government of South Australia 2017), versus those that would be ideally available for the policies presented. Chapter 5 discusses the key findings of the study, presents conclusions and makes suggestions for further research.

2. Spatial data for metropolitan spatial planning: a review of the academic literature

2.1 The economic and societal value of spatial data

The economic value of spatial data is increasingly recognised by governments and commercial organisations around the world. The past few decades have seen rapid advances in the generation of geo-referenced data as a result of computers being embedded in everyday objects such as mobile phones (Batty 2013; Geertman et al. 2019), and with spatial data becoming more readily available and transferable through the Internet. Increased computation speed, particularly in World Wide Web (WWW) infrastructure technologies, has enabled the development of geoportals with an increasing range of functions (Maguire & Longley 2005). Online geoportals have greatly facilitated access to spatial datasets and visualisation techniques, including through map viewers and online mapping systems, for a wide range of users across governments, private companies and the general public.

There is an increasing recognition of the economic value of spatial data in Australia. For the period 2006-2007 it has been estimated that the contribution of spatial data to Australia's productivity accounted for 0.6% to 1.2% of Gross Domestic Product (GDP) (equivalent of AU$6.43 billion to AU$12.57 billion) (ACIL Tasman 2008). For remote sensing data alone it is estimated that their economic value will grow from AU$496 million in 2015 to AU$1,694 million in 2025 (ACIL Allen Consulting 2015). Investments in remote sensing technologies (such as the opening of the Australian Space Agency in Adelaide in February 2020) are expected to have important implications for the Australian spatial sector through the streamlining of data supply chains and facilitating new economic uses (2026 Agenda 2019). For example, satellite-based data, providing high-resolution and up-to-date earth observation (EO) information, are expected to play a greater role in emergency management in future (Department of Industry, Science, Energy and Resources 2018). Other key sectors where spatial data will become more important have been identified as including: agriculture, aviation, tourism and recreation, petroleum, mining, water, property, and insurance (ACIL Allen Consulting 2015). These applications of spatial data, besides their estimated impact on economic productivity, are also expected to have considerable environmental and social relevance (Woodgate et al. 2017).

More recently, attention has been given to the economic value of spatial data in the built and natural environment, and technological advances such as 'digital twins' which comprise 'highly advanced digital representations of the real world' (ANZLIC 2019a, p.4) will also be relevant for urban and regional planners in the public and private sectors. It has been estimated that by 2028 Australia could realise economic benefits of up to AU$ 10 billion from adopting data-driven urban management technologies that incorporate building information modelling (BIM) (AlphaBeta 2018). This value is calculated based on the anticipated reduced cost of various practices in Australia such as infrastructure planning and management as well as for opportunities for Australia to export these technologies to other Asia-Pacific cities (AlphaBeta 2018).

Estimates about the increasing volume and socio-economic significance of spatial data explain the increasing focus on SDIs over recent years in many countries and at different scales. For example, the EU's INSPIRE Directive[1], adopted in 2007, is a framework legislation specifically aimed at overcoming problems of fragmentation of spatial datasets, gaps in data availability, and lack of harmonisation between datasets collected by different providers in the EU member states and available at different geographical levels in the European Union (Council of the European Union 2007). The focus of INSPIRE is on ensuring compatibility of different national and regional data sources. This is achieved by setting out common rules and standards that EU member states have to comply, both in relation to the types and formats of spatial data but also in relation to protocols for meta-data that document the content of datasets (cf. Dühr et al. 2010). The INSPIRE Directive required EU member states to transpose the regulations of the EU law into their national legislation by 2009. An important aspect of these national frameworks is the involvement and collaboration of local and regional government authorities in the context of national SDIs. In total 34 spatial data themes are defined (Council of the European Union 2007; European Commission 2020; see Appendix A for an overview), and this framework ensures that all levels, from the EU institutions down to local authorities, follow the same standards for spatial data and meta-data.

While a better coordination of spatial data will be important for policy-making in the EU, economic benefits have provided important arguments for establishing a comprehensive SDI such as INSPIRE. Thus, while the cost of the INSPIRE initiative was assessed as being €200-300 million annually for 10 years, the projected savings were estimated to be in the range of €1.2-1.8 billion per year (Masser, cited in Alvarez León 2018, p. 164).

2.2 Potentials and challenges of Spatial Data Infrastructures: a review of the academic literature

Spatial Data Infrastructures (SDIs) are sets of policies, technologies and standards that support the production and management of geographic information and that enable a community of spatial data users to access this information (Davis 2009). The scale of an SDI can vary from the local level to a regional or state, national and international scale. Accordingly, and as the EU's INSPIRE initiative shows, SDIs can require very complex governance arrangements (Maguire & Longley 2005; Basaraner 2016). The benefits of SDIs can be summarised as supporting governments and external stakeholders in their policy and decision making, cost-effectiveness, and enabling easy and equal access to high-quality data (Maguire & Longley 2005).

Woodgate et al. (2017) have noted that over the past years the focus of SDIs moved from the initial central concern with data management to a broader understanding, which places the use of the data and the specific needs of the users at the core. The increased focus on

[1] INSPIRE stands for 'Infrastructure for Spatial Information in the European Community'

user needs has been referred to as indicating a transition from spatial data infrastructures (SDIs) to spatial knowledge infrastructures (SKIs) (Woodgate et al. 2017). Technological advances have accompanied the shift to a user focus. Woodgate et al. (2017) explain that while SDIs are characterised by static, 2D data, expert-driven, push-based spatial data supply chains with duplication of data across multiple agencies, SKIs are characterised by 3D and 4D data and visualisations, pull-based data supply chains that enable consistent and seamless access to data for a wide range of users (including non-experts). The migration of data from 2D platforms to 3D/4D platforms, and the intricacies of updating 3D and 4D datasets as compared to the process for 2D datasets, can reportedly present considerable challenges (Woodgate et al. 2017).

In parallel to the increasing complexity of technological aspects of SKIs, governance arrangements have also become more involved due to a greater role of non-government organisations as the producers of spatial data. This has been exacerbated by a reduction in the capacity of public sector departments to collect and publish spatial data, as a consequence of deregulation and the liberalisation of public services in many Western democracies (Rajabifard et al. 2006; Alvarez León 2018). The result has been a growing number of stakeholders aside from public authorities who are now involved in spatial data collection and use, including private companies, user communities and the general public. This raises important questions associated with legal agreements to regulate data quality, data reliability and data access, for data collected by non-governmental actors, especially if these data are to be used in public policy-making (Alvarez León 2018). Challenges have also been identified in relation to the coordination and integration of spatial data in multi-level systems and across territorial jurisdictions (Steuer et al. 2014; Dühr & Müller 2012), and with ensuring the interoperability of heterogeneous datasets provided by an increasing number of organisations (McMeekin & West 2012).

While SDIs, meta-data standards and geoportals play an important role in coordinating data collected by different organisations and facilitating access, some researchers have called for a more fundamental review of practices related to data collection and use. Woodgate et al. (2017) for example have argued that data producers often do not know the needs of the end users, resulting in challenges for users to identify and access datasets required for their specific tasks. A move from 'static query systems' to 'open query interfaces' might help overcome such problems. This would imply that users, as opposed to trying to match the existing data to their specific tasks, are allowed to ask open questions to data producers. According to Woodgate et al. (2017), this could initiate a two-way dialogue between the producers and users, resulting in better opportunities for matching the data with tasks.

Moreover, the technological developments supporting spatial data infrastructures (SDIs) and the ease of preparing and sharing spatial data and maps over the Internet have arguably led to a 'democratisation' of how maps are prepared and used, with the previous boundaries between cartographer and map user becoming increasingly blurred (Dühr 2007). While this raises questions for the reliability of cartographic products and their underlying datasets, and consequently how such products might be used for public policy-making, there are also deeper epistemological issues to consider in the types of data collected and maps produced. For years, cartographic scholars have emphasised that maps construct, rather than reproduce, the world (see e.g. Crampton 2011). However, there is an acknowledgement that Geo-Information Systems (GIS) and the increasing reliance on remote sensing data in many areas of public policy may actually strengthen the belief that 'unbiased' and 'objective' spatial representations are possible. After all, as Pickles (1995, p. 12) noted, 'the epistemology and method that underpins GIS emerged in the 1960s under the auspices of positivist and empiricist versions of science and re-emerged as a result of the collaboration between, and a revitalization of, spatial analysis, cybernetics, and computer development of the 1970s'. The reliance on GIS technology therefore means that a filter is applied at every step from data collection to the final map product, ensuring that data continues to be mostly used in raster or point/line/area formats, rather than allowing for fuzzy boundaries and the representation of qualitative data. Most types of data, including soil, vegetation and land-cover classes, would neither show clearly recognizable boundaries nor the spatial homogeneity that their translation into datasets and subsequent cartographic representations would suggest. However, given the technological filters applied to data collection, storage and representation, and in spite of more recent developments to enable the representation of network space and fuzzy boundaries, it remains challenging to represent 'the uncertainty which is associated with most geographical phenomena' (Dühr 2007, p. 31).

2.3 Spatial data in metropolitan planning processes

In the context of pressing national and global challenges such as climate change, population growth and rapid urbanisation, spatial data play a critical role in informing policies and decision making. Since the 1990s, Geographic Information Systems (GIS), defined as 'software systems for capturing, storing, managing and displaying spatial data' (Haining 2003, p.7), have become important tools for urban and regional planning professionals. Craglia (2014, p. 367) has argued that SDIs are 'the extensions of GIS in the Internet age' as they allow users to work with a wider range of data on the Internet as opposed to only using their own data in a 'normal' GIS.

Despite the increased attention to spatial data as key aspects of economic growth and as an important basis for public policy making (including for land use planning), uncertainties remain over how public sector planners might benefit from technological developments and greater data availability in the context of decreasing capacities in the public sector and an 'outsourcing' of many planning tasks to private consultancies. While there seems to be a common acknowledgement among Australian planning researchers and 'reflective practitioners' that 'sound evidence and reasoning is useful, if not essential, to inform good planning practice' (Taylor & Hurley 2016, p. 118), this has not resulted in clear pathways for 'research to practice' nor prompted a large body of research on the role of spatial data and emerging technologies that utilize 3D and 4D spatial data in planning tasks undertaken by both public sector departments and commissioned consultants (the exceptions are discussed in the next section). Even internationally, including in the UK where planning policy is now explicitly expected to be based on a sound evidence base (Lord & Hincks 2010), a critical analysis of the availability and use of spatial data and other evidence, such as urban research more generally, remains rare.

Moreover, the research available invariably focuses on the very specific contexts within which urban and regional planning is undertaken and the distinct institutional context for spatial data availability and harmonisation (cf. Dühr & Müller 2012; Indrajit et al. 2019). The few available studies on the preparation and monitoring of Australian metropolitan strategies have been noted to rely often on untested political assumptions rather than spatial analysis and a sound evidence base to inform policy formulation (Elliott 2009; Taylor

& Hurley 2016). According to Randolph (2013, p. 131), Australia's 'metropolitan strategies are bedevilled by a lack of understanding of how the cities being planned actually work'.

Outside of public sector departments, there is likely much work going on with spatial analysis and evidence-informed policy-making, which has not yet been the focus of academic research. It is beyond the scope of this study to analyse the use of spatial data in planning consultancies, and how the private sector work informs public sector planning policies and practice. The focus, rather, is on different types of plans at different scales, and the role of spatial data in spatial planning policy processes, as explained in more detail in the following sections.

2.3.1 Levels of spatial planning and types of plans

There is considerable variation internationally in how planning systems are organised. Within the European context alone, considerable research effort has been extended over the past years to categorise different approaches and to identify 'traditions of planning' (CEC 1997, ESPON 2018).

In Australia's federal system, the six states (New South Wales, Victoria, Queensland, Tasmania, Western Australia and South Australia) and two territories (Northern Territories and Australian Capital Territory) have their own urban planning laws and procedures. The nationwide Australian Government's involvement in urban planning is limited, although based on the Constitution the Commonwealth government is able to use existing powers to pursue environmental objectives and set out national environmental policy which has relevance for land use planning, and federal governments have at times been influential in setting directions for urban policy and infrastructure investments.

The traditionally limited role of the federal government in spatial planning and the strong interest of state and territorial governments to exercise their constitutional rights has resulted in distinct systems of urban and regional planning in the different states, each with their own arrangements for administrative departments to oversee and regulate planning and land use activities. The different states and territories are also responsible for legislation to establish a devolved tier of local jurisdiction, including setting out the role of local government in urban and regional planning (Gurran 2011). Aside from providing the legislative and policy frameworks for planning, state government and its administration has also always had a direct role in local land use planning, notably through the design and implementation of major infrastructure proposals and the designation of large areas for urban expansion and (more recently) urban renewal.

In many Australian states, planning reforms have been implemented over previous years, aimed at streamlining decision-making and facilitating economic development (Goodman et al. 2013; Hamnett & Maginn 2016; Ruming & Gurran 2014). In South Australia, a major reform process of the planning system was launched in 2008 with the aim to make planning 'cheaper, faster, simpler' (Government of South Australia 2009; see also https://www.saplanningportal.sa.gov.au/). The *Planning, Development and Infrastructure Act* (PDI Act) 2016, which is still being implemented at the time of writing, is the legal basis for the reformed South Australian planning system. The influence of the property industry on shaping the proposals of the reform has received considerable criticism (Kellet 2014; Leadbeter 2019). Consequently, other concerns such as environmental sustainability and climate resilience were likely lost with this drive for speed and an increasing emphasis on supporting economic investment (Gurran 2011).

Needham et al. (1997) have defined a spatial plan as a document that states the policy for the physical development of an area. Spatial planning, then, describes all the activities taken by the planning subject of preparing the plan, launching it, and following it through. While the purpose of every spatial plan is to guide future decisions and measures, in most planning systems a variety of plans that differ with respect to subject matter, scale, status, time horizon and comprehensiveness can be found (Mastop & Faludi 1997). In most democratic countries, including Australia, two spheres of spatial planning exist, often in a hierarchical or mutually influential relationship.

Within the Australian states and territories, the local land use planning process is usually characterised by two stages, namely policy-making (developing plans), and development control. Development control refers to the assessment of development proposals that were submitted by a private or public developer, against the provisions in the local land use plans, and 'issuing a decision to approve (usually with conditions), refuse or negotiate to further modify the proposal' (Gurran 2011: 44).

In terms of planning policy, local land use plans set out planning policies, which 'are usually expressed through legally enforceable guidelines or controls on land use and on the dimensions of development contained with a planning instrument or instruments' (Gurran 2011: 44). Local land use plans, or development plans (as they were referred to in South Australia until recently), can be guided in their content and direction by supra-local plans, such as metropolitan planning strategies which have been prepared over recent years for many of Australia's capital city regions (Tomlinson and Spiller 2018; Hamnett and Freestone 2018). Such metropolitan plans are intended to offer a long-term (usually 20-30 years) framework for the spatial development and to guide the local land use planning, which is concerned with offering planning certainty over land use allocations.

The different types of spatial plans also have different mechanisms for implementation and consequently for the approach taken to evaluating plan outcomes. The distinction offered by Mastop & Faludi (1997) between what they refer to as 'strategic plans' and 'project plans' is useful to explain this. In this distinction, a local land use plan (or: development plan) would be considered as a typical *project* plan, that is, a blueprint type plan. Its success is evaluated on the extent to which outcomes conform to the plan. Local land use plans are usually statutory planning instruments, meaning their form, content and processes of preparation and implementation are guided by clearly defined rules set out in planning law and other relevant legislation (Mäntysalo et al. 2015). A *strategic* plan on the other hand provides a framework for decision-making, without being prescriptive or binding, and therefore is not *implemented* so much as rather *applied* (Faludi 2000).

Internationally there are few examples of institutionalised metropolitan governments with responsibility for spatial planning at this scale. Consequently, metropolitan strategies are usually prepared through collaborative governance arrangements, given that the region they cover is comprised by a number of local authorities that are each responsible for planning in their territory. The situation in Australia is different to that of many other Western countries, in that local governments have no constitutionally assigned powers to conduct land use planning and state governments are therefore dominant actors in urban and regional planning. In many states, with the exceptions of metropolitan-scale governance bodies in South East Queensland and Greater Sydney, it is also the state government that is responsible for metropolitan spatial planning for the capital city regions (Hamnett & Freestone 2018; Dühr 2020). According to Tomlinson and Spiller (2018), sometimes quickly changing state governments have used metropolitan strategies as political tools to communicate their agenda, rather than allowing them to function for the time period intended and to perform as long-term spatial development frameworks to guide local level planning decisions. Moreover, because state governments have also maintained a strong role in development planning (with recent planning reforms further centralising local land use planning, see Goodman et al. 2013), there is a tendency to conflate the role of supra-local planning and development planning, with the purposes of these planning instruments at the different scales not always clearly evident in the policy directions at the two scales (cf. Dühr 2020).

2.3.2 The role of spatial data in planning processes: a conceptualisation

Aside from clarifying the differences between strategic spatial planning and local land use planning, for the purposes of this research it is also useful to reflect on the role spatial data could play at different stages of the planning process. In policy studies, the public policy-making process is often conceptualised as a policy cycle, consisting of several subsequent and interrelated stages from agenda-setting over policy formulation, decision-making, policy implementation and policy evaluation (with the ideal process then starting again with agenda-setting informed by the evaluation of the policy). Spatial data can have varying roles in the different stages of the policy cycle for the preparation of metropolitan strategies. Such requirements for spatial data are ideally considered from the beginning of the policy-making process (that is, once the decision to prepare a new metropolitan strategy has been taken) as this would allow due consideration to be given to data needs and monitoring arrangements. Table 1 below offers a conceptualisation of the role of spatial data at different stages of the process of preparing and applying a metropolitan strategy.

Table 1: Conceptualisation of the role of spatial data and data requirements at different stages of spatial strategy-making

Stage a spatial strategy process	Role of spatial data at different policy stages
1) **Agenda setting** (problem recognition / policy needs)	***'Framing the policy problem'*** • Spatial analysis of current situation and trends, assessing problems and identifying their causes (analysis)
2) **Policy formulation** (Proposal of a solution / policy goals and plan-making)	***'Constructing the meaning of policy issues'*** • Understanding and framing of how the identified challenges should be addressed and visualisation of spatial focus of policies
3) **Decision-making** (Choice of a solution / adoption of plan)	***'Deciding and communicating policy choices'*** • Decisions on policies and instruments, e.g. instruments to manage urban growth and protect open space (green belt, urban growth boundary etc.), clarifying the spatial focus of

	policies and their anticipated effects
4) **Policy implementation** (putting solution into effect / arrangements for planning implementation and development assessments)	***Monitoring plan implementation / application*** • Spatial data to assess whether plan objectives have been met, e.g. in relation to monitoring land use changes, changes to spatial and socio-economic structure in plan area etc.
5) **Policy evaluation** (assessing the performance of a strategy or the conformance of plan outcomes to initial intentions as set out in plan)	***Arrangements for evaluation*** • Targets, indicators and corresponding spatial data requirements for evaluation of plan achievements

Source: authors' own based on Howlett 2019

In international planning scholarship, there has been some discussion about the role of spatial data at different stages of the policy process. Previous studies have usually focused on the specific planning context within which the research was undertaken. Because of the differences in the organisation of planning in different countries (and sometimes even within countries), the findings will not be fully transferable to the Australian context. However, the existing research nevertheless allows a discussion about the role of spatial data for different types of spatial planning and at different stages of the planning process.

Over the past years there have been several academic contributions that have acknowledged the relevance of spatial data and geospatial technologies in urban and regional planning processes. For example, Nedovic-Budic et al. (2004) in their assessment of the effectiveness of SDIs in Australia and USA identified planners as the most obvious beneficiaries of SDIs, with benefits however yet to be fully realised (Nedovic-Budic et al. 2004). Rajabifard et al. (2002) observed greater difficulties in the arrangements and effectiveness of an SDI in federal systems (such as Australia). The fact that there is no formal mandate to develop sub-national SDI initiatives in federal countries has been noted to present 'many obstacles to supporting urban management and planning, due to a high number and variety of jurisdictions and stakeholders involved in decision-making' (Nedovic-Budic et al. 2004, p. 346-347).

Siddiqui et al. (2019) in their research on planning in India have shown how geospatial technologies allow advanced spatial analyses that can inform strategic spatial planning through the development of scenarios, and can also support plan monitoring and evaluation. They further highlight the value of spatial modelling when managing urban growth and to inform decisions over the provision of future services and infrastructures in quickly developing urban contexts, such as India. Pfeffer and Verrest (2016) have noted that high spatial and temporal granularity achieved by the Earth Observation (EO) technologies afforded planners with opportunities to undertake spatial analysis such as natural hazard management, urban sprawl and urban density monitoring. They outlined how these technologies are particularly useful in the identification of individual objects such as slum housing in Indian cities. For the Belgian region of Wallonia, Stephenne et al. (2016) have discussed the importance of spatial data for analysis and policy development in strategic spatial planning. Indrajit et al. (2019) have shown how more attention to spatial data can improve public participation in urban planning processes in Indonesian cities.

2.3.3 Challenges to the use of spatial data in urban and regional planning processes and suggestions for improvements: a review of the international academic literature

While previous research has begun to clarify the role of spatial data in all stages of the policy process and in different planning contexts, there has also been discussion of the challenges for a better utilisation of data in urban and regional planning processes. Nedovic-Budic et al. (2004) in their assessment of the effectiveness and use of SDIs in local planning in Victoria (Australia) found that local government planners often considered the spatial data made available through federal and/or state SDIs as being of insufficient detail for local planning tasks.

Due to their multi-scale and multidisciplinary nature, urban and regional planning issues require a wide range of spatial data on different themes and for different scales. This often requires cooperation between different stakeholders to allow the integration of spatial data, as Steuer et al. (2014) have illustrated with the example of rail infrastructure planning. Chen et al. (2018) have shown how even the analysis of specific phenomena, such as urban density, requires a wide range of data and indicators relating to population, land use and building specifications. Based on their analysis of planning in Australia they have argued that because the compatibility of data from different sources is critical for multi-disciplinary policy questions (such as those inherent to urban and regional planning) placing domains of knowledge at the core of data collection and coordination would offer benefits. Thus, rather than the currently dominant focus on single-issue datasets, the use of ontology-based frameworks such as indicators required to analyse and assess urban density could offer advantages. Although such proposals are widely supported, Woodgate et al. (2017) have warned that a wider application of domain-based ontologies would likely create further challenges that would need to be addressed by new standards.

For the Australian context, inconsistencies in terms and conditions for access to spatial data have been identified as presenting significant barriers (Sinnott et al. 2015). Others have criticised the lack of shared unique identifiers for data collected by multiple agencies (Car et al. 2019) and the fragmentation and limited accessibility across both the public and private sectors for urban data (O'Donnell et al. 2019). This highlights the need for agreements on data standards as well as meta-data protocols. It has been noted that the lack of uniform definitions or approaches for measuring often complex planning concepts, such as 'accessibility', makes it difficult to clearly identify data needs to support spatial analysis, policy-making and implementation (Curtis & Scheurer 2010; Reis et al. 2014). Data heterogeneity (lack of standardisation and common language) used to present considerable challenges for Australian SDIs because different data providers use different standards to collect, store and process data (McMeekin & West 2012). Woodgate et al. (2017) also noted the need to address issues related to the intellectual property rights for data sourced from multiple agencies. There are indications that such concerns may be less acute in future as technologies and software systems are increasingly adopting data open standards. For example, ANZLIC (the Australia New Zealand Land Information Council, discussed in Chapter 3) is currently working on ISO level metadata standards[2].

The shortcomings of available spatial data to implement, measure and monitor integrated policy objectives have been put in the spotlight recently with the requirements of international policy agreements, such as the UN's Sustainable Development Goals (SDGs) (United Nations 2015). Although Australia has a single reporting platform to track progress on the implementation of the SDGs, challenges have been reported as a result of the diversity of data providers across different jurisdictions and the absence of aggregated data at the national level (Department of Foreign Affairs and Trade 2018). Sabri and Rajabifard (2020) have argued that SDI initiatives in Australia are still hampered by the heterogeneity and fragmentation of data collected and that this presents considerable challenges for attempts to monitor progress on SDGs. In order to support the implementation and monitoring of such comprehensive sustainable development goals at the local level, Rajabifard et al. (2020, p. 247) have emphasised the importance of 'integration, harmonisation, connectivity and scalability of multi-source urban datasets'.

There have been a number of suggestions in previous research for how spatial data availability and accuracy for urban and regional planning purposes might be improved. Mudau et al. (2019) note that addressing increasingly complex urban problems will require a better utilisation of advanced technologies and tools, such as 3D Geovirtual Environments and virtual reality technologies. Such developments are supported by the greater availability of 3D data, such as LiDAR[3]. The possibilities that an increased volume and variety of remote sensing data collected through satellites, planes and drones offer for urban analysis are frequently highlighted (Thakuriah et al. 2017; Long & Liu 2016). For example, for metropolitan planning in Western Australia MacLachlan et al. (2017) have argued that EO data would offer considerable advantages to static and aggregated census data as a more accurate method for urban growth management and to monitor infill development and urban density.

Through its use of 3D and 4D data and linking to real time data to create a virtual representation of physical environments at different scales (ANZLIC 2019a, Guo et al. 2020), digital twin technologies also offer a much-needed alternative to 2D data-based systems. These platforms have the potential to improve a range of urban and regional planning activities such as transport network planning, development assessment and emergency management (ANZLIC 2019a).

There are first examples of the use of digital twin technologies in Australia that show the potentials and challenges of such comprehensive virtual city models. For example, CSIRO's[4] Data61 initiative presented a Spatial Digital Twin for the Western Sydney region (NSW) in early 2020 (CSIRO 2020). Although this type of platform offers several advantages to inform decision making and policy development, in light of the challenges related to data availability and consistency across different jurisdictions it is unclear how long it would take to extend its scale from Western Sydney to the rest of the state of NSW and then to other states and territories across the nation.

[2] ISO is the International Organisation for Standardisation, see www.iso.org

[3] Lidar (light detection and ranging) is a remote-sensing technique that uses laser light to capture surfaces of the earth or built structures, producing highly accurate x,y,z measurements.

[4] CSIRO is the Commonwealth Scientific and Industrial Research Organisation

While acknowledging the overall benefits of spatial data and geospatial technologies for the profession of urban and regional planning, Pfeffer et al. (2015) called for a critical reflection on the long-term requirements for maintaining and updating these technologies. They note the resource-intensive nature that requires an institutional capacity and commitment in the form of budget allocations, time and expertise. These demands, combined with institutional barriers and potentially changes in the political support for comprehensive data initiatives often prevent planning professionals from deeply engaging with the possibilities, or limit them to focus only on selected features (such as mapping). Moreover, Pfeffer and Verrest (2016) note that the resource demands and the reliance on expert knowledge to update, maintain and use SDIs may be exacerbated between larger (mostly urban) and smaller (often rural) local authorities, as only urban authorities may have the ability to buy in data and services from private companies.

Over recent years, much of the discussion on spatial data in urban and regional planning has focused on their relevance in achieving 'smart cities' objectives (cf. Rajabifard 2020; Geertman et al. 2019). There is a close link between these policy debates and increased attention given to 'big data' that allows access to real-time information and enables new forms of analysis regarding urban design, traffic management and environmental management (Taylor & Richter 2015). Such developments and debates are not immune to criticism. Pfeffer and Verrest (2016, p. 155) have for example criticised the over-emphasis of technology in smart city discourses, which ignore 'the location-specific individual dimensions and processes and actors behind it'. They further question 'the capacity of the technology to actually develop relevant knowledge on urban issues to feed strategic planning and long-term visioning processes' (p. 155), beyond the mere provision of real-time data to monitor the functioning of urban infrastructures (e.g. in relation to traffic flows). Also, while Taylor and Richter (2015, p. 180) acknowledge the potential of 'big data' to improve urban governance processes through addressing inequality issues in access to data, they note inherent problems with 'embedded power dynamics' given that most 'big data' is collated and owned by private companies.

2.3.4 Types and themes of spatial data for urban and regional planning: towards an analytical framework

Spatial planning is a comprehensive public policy area that requires diverse spatial data that are integrated from various sources to address key planning considerations related to land use and urban development, economic development, public health, environmental protection, housing, and the provision of transport and utilities infrastructures (Nedovic-Budic 2004). Table 2 below lists the types of data that urban planners use on a regular basis. Academic analyses of spatial data in urban and regional planning often only provide a partial insight into the complexities of data needs, data availability and data integration from these different sources in planning practice. For example, Nedovic-Budic et al. (2004, p. 335) noted that the 'process of integration often involves the use of data represented in scales ranging from large (e.g. 1:5000) to small (e.g. 1:25,000) and with boundaries derived through various institutional, administrative, or analytical processes (e.g. planning jurisdiction, districts, census tracts, neighbourhoods or subdivisions, traffic analysis zones, blocks, and parcels) as well as those defined ecologically (e.g. critical areas, watersheds and drainage basins, air sheds, and habitats).

Table 2: Common data requirements for local land use planning

Type	Content
Population	Totals; by gender; by race; by ethnicity; by education
Housing	Number of dwelling units; by dwelling type; by quality; homeless population; housing vacancies, supply and demand
Transportation	Roads by capacity and use; traffic counts; public transit; rail lines; bus lines; airports; helicopter ports
Economics	Household income; employment by type; by location; unemployment; poverty; commercial volume; industrial production
Utilities	Water; electricity; natural gas; sewage/storm drainage; solid waste; telephone; cable TV
Facilities and Services	Libraries; recreation centers and activities; schools by type and by attendance; day care centers; hospitals by type, number of doctors and beds
Health and safety	Police stations; crime statistics; fire stations
Environment	Topography by elevation, slope, and exposure; soil types; water bodies; floodplain; air quality; water quality; hazards by incidence and location; ecosystems/natural habitats
Land	Property cadastre and titles; property assessed value; land use by type—residential, commercial, industrial, recreational and open space, institutional, etc.; by density/intensity; ownership; land supply/demand; development potential
Urban development	Buildings by type, quality and value; development permits and application status; aerial photography
Plans and policies	Master/comprehensive plans; zoning and subdivision ordinances; capital improvement programs and budgeting; emergency preparedness and hazard mitigation; building codes

Source: Nedovic-Budic 2004, p. 335

In a more recent study, Indrajit et al. (2019) assessed spatial information themes required for participatory urban planning in Indonesia. They note that the availability of spatial data for planning tasks is often the result of the data producers' perspective, which can result in a mismatch with the requirements of the users (planners and citizens). While 3D city models, 3D cadastre, and spatial topology models would be useful to support urban planning processes, Indrajit et al. (2019) have argued that such spatial datasets and data models are not always available, meaning that planning often continues to rely on two-dimensional data and maps. In their analysis of participatory urban planning in Indonesia, Indrajit et al. (2019) discuss the spatial data layers that would ideally be available to support participation and monitoring processes from three angles: first, in relation to the requirements as set out in urban planning regulations; second, in relation to the availability of relevant spatial information (as provided by data producers) and their potential uses in urban planning; and third, in relation to the perspective of users (defined as 'internal users' – e.g. local councillors, public sector planners; and 'external' users - non-government institutions, private sector actors, and citizens). Using urban planning monitoring in Indonesian cities as a case study, at a map scale of 1:5000 or better, Indrajjit et al. (2019) identified 15 spatial data layers that they consider essential for urban planning tasks, as listed in Table 3.

This categorisation provides the basis for analysing the requirements and availability of spatial data for the investigated policy theme examples as discussed in chapter 4.

Table 3: Spatial datasets identified as relevant in urban planning processes in Indonesia

Score	Spatial dataset type
1	Digital Elevation Models/ DEM (include Contour lines)
2	Satellite Ortho-Imageries or Aerial Ortho-Photo
3	Toponym (place name) and Point of Interest
4	Coastline
5	Building
6	Public facilities
7	Transportation (include Roads, Runways, Ports, etc.)
8	Utilities (including, cables, pipes, hydrants, etc.)
9	Land cover (including, vegetation, water etc.)
10	Land Use
11	Urban Zonation (include administration boundaries, permissions, restrictions, etc.)
12	Land rights (tenure)
13	Land value/suitability
14	Soil
15	Geology

Source: Indrajit et al. (2019)

2.4 Summary and discussion of findings from the literature review on the role of spatial data in metropolitan planning processes

Spatial data are essential for a wide range of urban and regional planning activities including land use planning, social and physical infrastructure planning, climate change adaptation and mitigation, natural resource management, heritage protection, housing supply and property management and development activity tracking. They play a role in spatial analysis and policy-making as well as in the monitoring and evaluation of planning outcomes, and are needed to inform participatory processes. However, despite the general acknowledgement of the importance of spatial data for urban and regional planning, there have only been a limited number of analyses of the barriers and potentials for spatial data in planning processes in different contexts to date.

The available research suggests that there are a number of challenges for planning practitioners in accessing and using spatial data to inform their planning policies and monitor their implementation. Overall, the reasons why urban planners may not use spatial data more have been identified as referring to data availability, data heterogeneity and lack of coordination of spatial data provided by different organisations (Sinnott et al. 2015; Chen et al. 2018). Setting up comprehensive SDIs can be particularly challenging in federal systems due to dispersed responsibilities and the need for stable cooperation and coordination agreements (Nedovic-Budic 2004).

Indrajit et al. (2019) contend that available spatial data are often collected for a wide range of possible applications, which can make their application to specific uses, including in participatory planning processes, difficult. In a similar vein, Evans (2007) has argued that the challenges for urban and regional planning are not a result of a lack of availability of spatial data as large volumes of data exist, but rather a lack of data that are appropriate for specific planning purposes and that meet technical requirements in relation to timescales, resolution and so on.

Importantly, however, the challenges for urban and regional planning in relation to the availability of spatial data that are also 'fit-for-purpose' are not restricted to the technological domain. Institutional issues are often more difficult to address than technological barriers (Rajabifard et al. 2006; Geertman et al. 2019). Reconciling top-down approaches to harmonising data standards in SDIs with the often diverse demands from different stakeholders, and meeting the needs of a wide range of applications can be problematic, especially in multi-level or federal systems (Rajabifard et al. 2006). Previous research has, however, identified essential datasets for urban and regional planning tasks (Nedovic-Budic 2004; Indrajit et al. 2019), which will provide a useful basis for the analysis presented in chapter 4. First, however, the following chapter will discuss the current governance arrangements for spatial data in Australia.

3. Spatial data providers and data governance arrangements in Australia

In an era of fast paced urbanisation and digitisation, accompanied by the production of large volumes of data on a daily basis, the importance of being able to access high quality and reliable spatial data is arguably greater than ever (Sinnott et al. 2015). SDIs play an important role in assisting with knowledge generation as they standardise and streamline the production and distribution of spatial data and make them accessible for a wide range of sectors, including urban and regional planning (Alvarez León 2018, Yang et al. 2010).

In the Australian context, the growing importance of spatial data, including for economic development, has been recognised in the '2026 Agenda', first published in 2016. The '2026 Spatial Industry Transformation and Growth Agenda' is a whole-of-sector initiative of business, government, research, academia and spatial-user organisations that aims to transform and realise the potential of the spatial industry as an important component of the Australian digital economy. An initial action plan of the 2026 Agenda was released in 2017, and on the basis of a nation-wide consultation with the key stakeholders on the needs of the spatial industry an updated version was published in 2019. The action plan identifies the key initiatives to realise the social and economic potential of the spatial sector in Australia and sets out a 10-year roadmap.

The working group behind the development of the 2026 Agenda includes representatives from a wide range of organisations including ANZLIC, SIBA, CSIRO (Data 61) and Geoscience Australia. These key organisations for spatial data coordination in Australia will be discussed in the remainder of this chapter. ANZLIC is the Australia New Zealand Land Information Council, and has since the 1990s been the driving force for SDI initiatives in Australia.

3.1 Governance bodies for spatial data coordination in Australia

The federal system of Australia means that the different states and territories have developed their own systems for public sector data coordination as well as for urban and regional planning. For example, in South Australia, the government body responsible for the provision of infrastructure and services for geospatial data to the government and the general public, and to support data sharing across government departments in the state, is Location SA. Location SA is located within the Department for Planning, Transport and Infrastructure (DPTI).

The dominant role of the states and territories in data collection presents challenges for the Australia-wide coordination of SDI initiatives, given that different systems have been conceived and have evolved within the specific political and institutional settings of the states and territories. Since the 1990s, SDI initiatives have been launched across Australia, spearheaded by the 'Australia and New Zealand Land Information Council' (ANZLIC) (see Nedovic-Budic 2004). This organisation was originally established in 1986 as the Australian Land Information Council (ALIC), but in 1989 expanded to include representation from all state and territory governments. The current name was adopted in 1991 when New Zealand became a full member (ANZLIC 2020a). ANZLIC is the peak government body in Australia and New Zealand for spatial information, and according to its website (ANZLIC 2020a) responsible for:

- providing leadership and direction to achieve a standardised approach for the provision of foundation spatial data and services within jurisdictions and at the national level.
- developing a strategic plan and annual program of activities that support accessible, innovative and integrated spatial data and services.
- leading collaboration and sharing solutions to common spatial issues between jurisdictions and amongst the wider spatial industry and research sector.
- promoting and advocating on spatial priorities of strategic importance with key stakeholders and decision makers in government and across the spatial industry and related sectors.
- coordinating the Intergovernmental Committee on Surveying and Mapping (ICSM) as ANZLIC's delivery arm, in the delivery of spatial data initiatives.

The 'Intergovernmental Committee on Surveying and Mapping' (ICSM) is the body responsible for coordinating and promoting the development and maintenance of key national spatial data including geodetic, topographic and cadastral data, street addressing, tides and sea level and geographical names (ICSM 2020). ICSM was established by then Prime Minister Bob Hawke and the State Premiers in 1988. In 2002, ICSM became a Standing Committee of ANZLIC, with representatives from the Australian Defence forces and from the governments of all the Australian states, territories, the Commonwealth and New Zealand.

ANZLIC has four key partners: PSMA Australia Limited, FrontierSI, the Spatial Industries Business Association (SIBA)/Geospatial Information & Technology Association ANZ (GITA), and the Surveying & Spatial Sciences Institute (SSSI).

PSMA Australia Limited is a for-profit company, which is jointly owned by the nine governments of Australia (PSMA 2017). It is accountable to its shareholders who set the policy objectives for spatial data. PSMA Australia Ltd. is responsible for sourcing spatial data from various government agencies and consolidating these datasets on a national scale. These datasets include G-NAF (Geocoded National Address file), Administrative Boundaries (e.g. electorates, suburbs, statistical areas), Transport and Topography (transport infrastructure and topography), Postcode Boundaries and Cad-Lite (land parcel level spatial representation and information) (PSMA 2020). While G-NAF and Administrative Boundaries are openly available through an agreement between the Australian Government and PSMA Australia Limited, the other datasets are subject to a fee-based subscription. PSMA Australia Limited uses a large number of 'value added resellers' in disseminating these databases, whereby PSMA's datasets are combined with other data and embedded in various products (Christensen et al. 2014). While government agencies only pay an access fee, private companies are also required to pay royalties based on revenues generated from the sale of products using PSMA's datasets (Christensen et al. 2014).

Other key partners of ANZLIC are FrontierSI and SIBA/GITA. FrontierSI was launched in 2019 following 16 years as the Cooperative Research Centre for Spatial Information (CRCSI). It is a not-for-profit company that undertakes spatial research and provides advice on mapping, infrastructures, positioning, geodesy, analytics and standards (FrontierSI 2020).

The Spatial Industries Business Association (SIBA)/Geospatial Information & Technology Association ANZ (GITA) are a joint organisation that represents a range of companies and organisations in the spatial industry (both in Australia and New Zealand). These organisations include 'the businesses who supply surveying and spatial services, as well as educational institutions and government agencies who provide critical services and support, and organisations who use spatial information in the public and private sector' (SIBA/ GITA 2020). The responsibilities of SIBA/GITA include promoting the recognition of the economic value of the spatial industry; facilitating research and development; and ensuring access to a skilled workforce for their member businesses. SIBA/GITA also provides a range of professional development opportunities for employees in the spatial industry through a range of local and national conferences (e.g. the annual Locate Conference, which in 2021 will be held in Brisbane).

The Surveying & Spatial Sciences Institute (SSSI) 'represents the interests of surveying and spatial science professionals, combining the disciplines of land surveying, engineering and mining surveying, cartography, hydrography, remote sensing and spatial information science' (ANZLIC 2020a). SSSI is also the body responsible for certification of the surveying and spatial science professionals (SSSI 2020). Their partnership with ANZLIC enables the representation of the professional community in the development and maintenance of spatial data management policies (ANZLIC 2020a).

In addition to the coordination of spatial data as undertaken by ANZLIC and its partners, Geoscience Australia as the national mapping agency provides geospatial data on the geology and geography of Australia and advises on the potentials for EO in Australia (Commonwealth of Australia 2020). GeoScience Australia has also been major drivers of the use of spatial data standards in Australia, as will be discussed later.

3.2 SDI initiatives, geoportals and map viewers in Australia

The collection of spatial data in Australia is characterised by a large number of agencies. This leads to interoperability issues due to high levels of data heterogeneity (Sinnott et al. 2015) and increased cost due to data duplication (McMeekin & West 2012).

Such issues are being addressed through the 'Foundation Spatial Data Framework' (FSDF), which provides a common reference for the assembly and maintenance of Australian and New Zealand foundation level spatial data, to be delivered in open access formats and with national coverage. ANZLIC is the body responsible for the management of the national Foundation Spatial Data Framework (FSDF) (Box et al. 2015). At federal level, the FSDF comprises more than 1000 datasets that are organised according to ten spatial data themes (see Table 4). These themes include: geocoded addressing; administrative boundaries; positioning; place names; land parcel and property; imagery (as an analytic source and a background layer for other datasets on land cover and land use changes); transport; water; elevation and depth; and land cover and land use (ANZLIC 2020b). These datasets are owned by different government and non-governmental agencies. These 'data custodians' have the responsibility for the development and management of individual datasets and for decisions regarding the conditions of distribution and use.

Table 4: FSDF spatial themes and sub-themes

FSDF theme	FSDF sub-themes	Description
Administrative Boundaries	• Australian Statistical Geographical Standard Boundaries • Jurisdictional Boundaries • Australian Electoral Boundaries • Maritime Jurisdiction Boundaries • Native Title Boundaries	'Foundation datasets', which define the spatial extent of legislative jurisdictions and regulatory, electoral, statistical and maritime geographic areas.
Geocoded Addressing	• The Geocoded National Address File	Connection between a physical address with location information which shows up as a 'place' or 'spot' on the Earth. This makes the information able to be mapped and connected to other location information. An address is a structured label usually containing a property number, a road name and a locality name.
Place Names	• Gazetteer of Australia	Foundation datasets for the names of cultural and physical features and their location and extent.
Positioning	• National Geospatial Reference System	Australia's spatial referencing system. The positioning service defined under this theme includes the coordinates and their uncertainty of all location-based data promulgated from or related to, the Australian Fiducial Network (AFN) and the defining Australian Height Datum tide gauge stations.
Land Parcel and Property	• Land Parcel Boundaries • Land Tenure	Foundation datasets for the land boundary system. The term Land Parcel and Property can be interchangeable with cadastral, land administration and property systems. Land Parcel and Property contains a record of interest in land.
Imagery	• Low Resolution (>80m) High Temporal Coverage (>weekly) • Medium Resolution (>10-80m) Medium Temporal • High Spatial Resolution (>2.5-10m) Low Temporal Coverage (>Quarterly) • Very High Resolution	Foundation data that captures images of the Earth's surface, from many different sensors and cameras. These data is often the base layer over which many other datasets are used.

FSDF theme	FSDF sub-themes	Description
	(<2.5 m) Very Low Temporal Coverage (>annual)	
Transport	• Roads • National Crossings • Railways and Railway Stations • Traffic Control Devices • Airports and Airfields • Navigation Aids and Obstacles	Foundation datasets for moving people, goods and freight, and other services from one location to another.
Water	• Surface Hydrology • Catchment Boundaries • Hydrological Obstructions • Flow Direction Grid • Groundwater • Groundwater Bores • Groundwater Dependent Ecosystems (GDE)	Foundation datasets for surface and groundwater and excludes atmospheric, industrial or oceanic water processes.
Elevation and Depth	• National Digital Elevation and Depth Model	Foundation datasets that measure the Earth's surface (wet or dry) above or below a vertical datum to obtain either the height of the land or a bathymetric depth.
Land Cover and Land Use	• Dynamic Land Cover • Fractional Ground Cover • National Topographic Data • Forests of Australia • Australian Collaborative Land Use and Management Program • National Vegetation Information System	Foundation datasets for Land Cover and Land Use. Both land cover/use are often very interrelated datasets. Land cover shows the natural cover on the Earth's surface including trees, shrubs, grasses, soils, exposed rocks and water bodies; as well as human elements such as plantations, crops and built environments; Land Use refers to the ways in which land cover is used by humans (e.g. residential, industrial, commercial, agricultural, forestry, recreational).

Source: http://fsdf.org.au/

The FSDF 'imagery' theme includes four aerial/satellite imagery datasets. With Landsat and Sentinel multispectral satellite imagery time series, the low and medium resolution FSDF imagery datasets (10-80 Metre) are provided free of charge by Europe's and America's space agencies (ESA and NASA). While it is relatively easy to use these imageries as base maps, advanced GIS and RS skills are needed to utilize the spectral information of these data. This spectral imagery information, however, could be converted into time series of natural and built environment data including built-up areas, land use, vegetation health and soil moisture, i.e. data sets which are frequently missing for urban planning tasks. Spectral information of the high and very high resolution FSDF imagery datasets (>10 Metre) would provide even more detailed information of the above-mentioned layers, but such finer-resolution data are proprietary and only available as paid services.

In order to achieve some level of coordination across the different organisations and their datasets, the data custodians regularly consult with their allocated 'theme sponsor' under the FSDF (see Table 5). Five such sponsors have been set up under the ANZLIC governance structure, which are responsible for different themes covered by the FSDF, liaising with other sponsors, consulting with the community of their data users, and coordinating activities with the relevant data custodians.

Table 5: Theme sponsors under the FSDF

Sponsor	Theme
Commonwealth Department of Industry, Innovation and Science	Geocoded Addressing
Intergovernmental Committee on Surveying & Mapping	Positioning, Place Names, Land Parcel and Property, Imagery, Transportation, Elevation and Depth, and Land Cover
Australian Bureau of Statistics	Administrative Boundaries
Bureau of Meteorology	Water

Source: ANZLIC 2020b (https://www.anzlic.gov.au/resources/foundation-spatial-data-framework/governance)

As part of its five yearly strategic initiatives, ANZLIC recently announced that the FSDF will be modernised to enable all datasets to be used in 3D and 4D formats and to improve its quality and accessibility by a broader range of end users (ANZLIC 2020c).

Geoportals are important to enable access to these various datasets, and are therefore an important building block of SDIs. A large number of geoportals have been set up over recent years, and it is impossible to provide a comprehensive overview across Australia. Table 6 (below) lists some of the most prominent geoportals at national scale, and Table 7 shows important geoportals for South Australia. As the central source of Australian national data data.gov.au is accessible for anyone as a result of the federal government's public data policy that requires all government agencies to make non-sensitive data openly available. It is important to note that geoportals, including data.gov.au, only facilitate access to data but do require coherent data standards. This means that data available through these portals are a collection of a wide range of multi-levelled datasets from several sources that are not necessarily compatible (Warnest et al. 2002).

In addition to government-provided geoportals, there are a number of geoportals operated by universities and supported by government funding. An example with a dedicated focus on supporting urban research is the 'Australian Urban Research Infrastructure Network' (AURIN), established in 2010. AURIN's Portal incorporates spatial data from 139 government and non-government agencies such as the Australian Bureau of Statistics (ABS), various local governments and PSMA Australia Limited, and also offers online tools to facilitate spatio-statistical analysis and visualisation (AURIN 2020). Access to the AURIN Portal requires either an academic institutional login (via AAF) or registration and VHO login for non-academic users. For users associated with any levels of government and for university students or staff that conduct non-commercial activities, access to the AURIN Portal is free of charge. For users from the private sector and commercial uses, different licencing terms apply to those datasets that are not open access (CC-BY).

Table 6: Geoportals at national scale in Australia provided by government and non-governmental organisations
(in alphabetical order; numbering in first column refers to Table 10)

No.	Geoportal	URL
1	ABS – AGSG digital boundaries	abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.001July%202016?OpenDocument#Data
2	ABS – Census data	abs.gov.au/
3	ALA – Atlas of Living Australia: national portal supplying biodiversity data and species information	ala.org.au
4	AODN – Portal which provides access to all available Australian marine and climate science data and provides the primary access to IMOS data including access to the IMOS metadata	portal.aodn.org.au/
5	AURIN – Australian Urban Research Infrastructure Network covering all aspects of Australia's human settlements including population and demographics, transport and infrastructure, health and well-being, housing and property, energy and utilities, education, economy and built environment.	data.aurin.org.au/dataset
6	Data.Gov – Australia's open data portal	data.gov.au/
7	ELVIS – Elevation Information System: LiDAR point cloud and derived DEM	elevation.fsdf.org.au/
8	Geoscience Australia (GA) – Satellite imagery products such as ALOS 2.5m panchromatic reference image (AGRI), Landsat multispectral bands (ARG25), Water Observations from Space (WOfS), Fractional Cover (FC25) and DEA Hotspots.	ga.gov.au/scientific-topics/earth-obs/accessing-satellite-imagery
9	NNTT – National Native Title Tribunal and Registrar's spatial data incl. Native Title applications, claims, determinations, outcomes, agreements, representative body areas, and bodies corporate	nntt.gov.au/assistance/Geospatial/Pages/DataDownload.aspx
10	Residential tenancy databases (TICA)	tica.com.au/
11	Sea Map Australia – Australian seabed habitat classification scheme and spatial database	seamapaustralia.org/map

Source: authors' compilation

Aside from the geoportals provided by governmental and non-governmental organisation at national scale, there are also portals provided by state governments across Australia such as Location SA, a branch of the Government of South Australia, or by DATA VIC (State Government of Victoria), which are freely accessible to any users and provided through web-based geoportals. Location SA is a collaboration (SDI) that has nearly all (19) state agencies collecting from source of truth systems nightly, monthly or weekly and supplying to a central data depository (Data.SA with 602 datasets, see Table 7) for sharing across all agencies. Moreover, street basemaps are built weekly to incorporate new developments; shared imagery is collated into a topographic basemap and into a street basemap; and data web services are supplied to agencies with their own web maps (Location SA, 2020). Portal cross-platform infrastructure allows agencies to build their own spatial mobile solutions and web maps.

Table 7: Geoportals of the South Australian government
(in alphabetical order; numbering in first column refers to Table 10)

No.	Geoportal	URL
12	Data.SA – South Australian Government Data Directory	data.sa.gov.au/data
13	SA DEW – Department of Environment	data.environment.sa.gov.au/
14	SAILIS – South Australian Integrated Land Information System	sailis.lssa.com.au/
15	SAPPA – South Australian Property and Planning Atlas	maps.sa.gov.au/SAPPA/
16	SARIG – South Australian Resources Information Gateway	energymining.sa.gov.au/minerals/online_tools/free_data_delivery_and_publication_downloads/sarig

Source: authors' compilation

The spatial data available through the above listed geoportals are also generally available for direct visual exploration through a web mapping application or 'map viewer'. Table 8 gives an overview of currently available map viewers in South Australia. The South Australian government's e-planning portal refers to several geoportals relevant for urban and regional planning at different levels (https://www.saplanningportal.sa.gov.au/interactive_tools). Besides SAPPA and the Location SA Map Viewer the next most important web map for planners and developers is the SA Investment Atlas. There are some overlaps with the previous tables, because the websites for AURIN, ALA, Location SA Map Viewer, NatureMap, SARIG, as well as Sea Map Australia, not only offer 'map viewers' but are also geoportals and allow data query and download options. AURIN and ALA even offer advanced web-cartography together with web-GIS analytical tools, such as overlay and statistical data analysis. In recent years, advances in Internet technology, web cartography as well as in Web-GIS interoperability have enabled many map viewers to now function as visual explorative platforms that can provide users an insight into spatial data as well as basic options to analyse and to download filtered datasets. For example, Data61's NationalMap even allows exploring multidimensional spatial data in a 3D geo-virtual environment with the option for users to upload their own 2D or 3D data.

Table 8: An overview of map viewers (interactive web mapping applications) with relevance for metropolitan spatial planning in South Australia

Map viewer[1,2]	purpose / content	URL
ABS	Statistical data by region map interface	Abs.gov.au
AgInsight SA	Agricultural mapping and economic data	aginsight.sa.gov.au/
ALA	ALA's spatial portal focuses on where a chosen species was located, what species were found in a defined area and what are the environmental conditions in that area.	spatial.ala.org.au/
AURIN	Map and portal with research data covering all aspects of Australia's human settlements	map.aurin.org.au/ portal.aurin.org.au/
Carer Support	DHS - Carer Support Finder	dpc.geohub.sa.gov.au/portal/apps/webappviewer/index.html?id=0afae0db41224affbf58ca4c1da2576a
CFS Geohub	Country Fire Service online maps (Bushfire Management Area Plans, Bushfire Safer Places and Bushfire Last Resort Refuges, CFS Public Incidents and Warnings Map)	cfs.geohub.sa.gov.au/portal
Community	Community Impact Assessment Portal assists	cbs.sa.gov.au/ciportal

Map viewer[1,2]	purpose / content	URL
Interest Portal	licensees in collating the information required to complete a community impact submission	
Cycle Instead	Cycling planner along roads, paths, bikeways in Adelaide	maps.sa.gov.au/cycleinstead/
Development tracker 3D	Adelaide's Development activity tracker - 3D web map app	saplanningportal.sa.gov.au/interactive_tools/Development_Activity_Tracker
Enviro Data SA	Gateway to data and information relating to the science and monitoring of SA's environment and natural resources	data.environment.sa.gov.au/
Geoscience Australia	interactive maps and public web services offering decision-making relevant information about marine jurisdiction, geology, geophysics, hazards, coastlines, water, topography and other earth observation and satellite imagery information	maps.ga.gov.au/interactive-maps services.ga.gov.au/
Hiking trails	Interactive web maps for hiking and walking trails in SA	southaustraliantrails.com
Housing SA	Housing SA Office Finder	dcsi.maps.arcgis.com/apps/MapTour/index.html?appid=3befd1c1dc3948e0a1d96dc38c509c5e
Hydrochemistry Atlas	GSSA Hydrochemistry Atlas SA	energymining.geohub.sa.gov.au/portal/apps/View/index.html?appid=d3116cb265eb4073a9b6e1718292b107
ITLUP	SA's Integrated Transport and Land Use Plan	maps.sa.gov.au/ITLUP/
Living in SA	points of interest and further information on living, working, studying, doing business and visiting SA	maps.sa.gov.au/French Engagement/
Location SA Map Viewer	Public-facing application to enable citizens to visualise much of the state government data in the Location SA repository	location.sa.gov.au/viewer/
LookNorth	Businesses and projects focused on creating jobs and empowering local communities in northern Adelaide	northernadelaidemap.sa.gov.au/
NationalMap	Easy access to spatial data from Australian government agencies through a 3D map viewer	nationalmap.gov.au/
NatureMaps	Maps and geographic information about SA's natural resources	data.environment.sa.gov.au/naturemaps
Open council data	Local government shared data viewer and data sharing portal	opencouncildata.org/
Outback Roads Warnings	South Australian Outback Roads Temporary Closures, Restrictions and Warnings	dpti.sa.gov.au/OutbackRoads#map
RAVnet	Approved heavy vehicle route networks in SA	maps.sa.gov.au/ravnet
Renewable Energy	South Australia's Renewable Energy Resource Maps	renewablessa.sa.gov.au/topic/investor-information/renewable-energy-resource-maps
SA Investment Atlas	South Australian Investment Atlas: access property, infrastructure and social information, enabling you to find the perfect place to land.	dti.sa.gov.au/investment/south-australian-investment-atlas
SAPPA	SA Property and Planning Atlas	maps.sa.gov.au/SAPPA/
SARIG	SA Resources Information Gateway delivering	map.sarig.sa.gov.au/

Map viewer[1,2]	purpose / content	URL
	state-wide geological and geospatial data	
Sea Map Australia	Australian seabed habitat classification scheme and spatial database	seamapaustralia.org/map
Traffic SA	Roadworks, incidents and planned events impacting traffic	traffic.sa.gov.au/
Urban Heat Map	Urban Heat Mapping of Adelaide Metropolitan Area South: 22/2/2016, West: 9/2/2017, East: 23/3/2018	spatialwebapps.environment.sa.gov.au/urbanheat/?viewer=urbanheat
WaterConnect	Latest information about SA's water resources	waterconnect.sa.gov.au/

[1] *Map viewers highlighted in light blue contain national spatial data while all others include content located in SA*
[2] *Map viewers in bold include spatial data which are* **not** *available through data.sa*
Source: authors' compilation

3.3 SDI initiatives in Australia: potentials and challenges

Several technological, legal and financial considerations for SDIs are important to ensure that spatial data are efficiently and effectively circulated between the producers and end users (Crompvoets et al. 2018). Both government and non-government providers produce spatial data of relevance for metropolitan planning. Legal frameworks are fundamental to the development as well as the effective governance of SDIs (Alvarez León 2018; Crompvoets et al. 2018). The regulation of both the production and use of data is needed to address issues surrounding individual privacy, intellectual property and freedom of information (Alvarez León 2018).

Furthermore, it can be expected that an increasing use of digital technologies will present additional legal challenges related to security and data management practices, hacking and other cybercrimes, and will require regulations such as anti-trust and anti-competition laws to control the influence of private companies on public policy- and decision-making (Onsrud 2020). Moreover, government regulations are important also to create an 'open, free and competitive' market (Onsrud 2020, p. 139).

Spatial data collected by government, whether at federal, state or local level, are openly accessible to all users for government or research purposes as set out in state public sector data sharing legislation for New South Wales (2015), South Australia (2016), and Victoria (2017). Proposals for Australia-wide legislation on public sector data sharing are currently being debated. They have come in response to the Productivity Commission's findings in 2016 that Australia is falling behind in realising the potential of public sector data, resulting in the establishment of the Office of the National Data Commissioner in 2018 (Commonwealth of Australia 2019). The primary role of the National Data Commissioner is to oversee the development of a legislative framework to assist with data sharing activities between the Commonwealth agencies (Commonwealth of Australia 2019). Although this initiative enables participation from all levels of government, its scope is currently limited to Commonwealth data (Commonwealth of Australia 2019).

Yet agreements on a binding legal and administrative framework that applies to the multiple (public and private) actors across Australia and that regulates across the levels of government, comparable to comprehensive legal frameworks such as the EU's INSPIRE Directive (Council of the European Union 2007), seem far off, and as a result there is considerable diversity in how spatial data are governed across the different government levels and between states and territories.

Moreover, different conditions apply to the sharing of data of private providers. For example, as explained above, PSMA Australia Limited makes Geocoded National Address File (G-NAF) and Administrative Boundaries datasets available through geoportals such as data.gov.au. However, fee-based subscriptions and licences are needed to access other databases provided by PSMA Australia Limited, for example on buildings (e.g. outline, height, planning zone) and trees (e.g. height). Other datasets produced by PSMA Australia Limited are distributed through their private partners (value added resellers) such as Aerometrex, Pitney and Bowes, Deloitte and OneMap (PSMA Australia Limited 2019). A range of new markets are created through these partners as the raw data from PSMA Australia Limited are enhanced, embedded into other data, and tailored towards software solutions for users from various sectors (e.g. engineering, real estate) (PSMA 2019).

Over recent years there have been calls to work towards a culture of sharing and collaborating, ensuring equitable access to high-quality data and standards (ANZLIC 2020c; Commonwealth of Australia 2019). ANZLIC's 2026 Agenda is one of the most recent initiatives aimed at improving the availability and coordination of spatial data in Australia in a context that is frequently described as characterised by fragmented governance arrangements. A recent survey undertaken by the Government of South Australia for example highlighted the difficulties that industry representatives are reportedly facing when trying to find and access government-owned data (Government of South Australia 2018). The reasons are a lack of coordination and transparency of available data held by a range of organisations, but also a result of data heterogeneity that restricts the integrated use of these data (Chen et al. 2018).

The effective governance of SDIs is critical for their successful implementation and the full realisation of the benefits they offer. However, in complex multi-level systems that cover numerous stakeholders and jurisdictions, agreeing on standards and rules is often characterised by major challenges (Crompvoets et al. 2018). Pashova and Bandrova (2017, p. 106) have noted that developing an SDI 'requires a delicate balance between public, private, and personal interests while taking into account the complex interplay among technological, legal, economic, and institutional issues in achieving such balance'. Previous research on SDIs has highlighted the importance of collaborative governance arrangements and the availability of institutions that can coordinate cooperation and collective decision making (Crompvoets et al. 2018).

In Australia, ANZLIC, ICSM and Geoscience Australia are currently the main bodies in a position to conduct such tasks across Australia. ANZLIC is responsible for the management of the national Foundation Spatial Data Framework (FSDF), for which a range of ISO standards has been adopted. While these standards facilitate the coordination and exchange of spatial data across the nation in some areas, they arguably fall short of offering a comprehensive framework for coordination of diverse datasets collected by different organisations and across scales, given inconsistencies in standards across different jurisdictions (Woodgate et al. 2017). Moreover, Finney (2007, p. 86) has noted that ANZLIC does not act as 'a national standards registration authority', and that there is reportedly considerable uncertainty among stakeholders about ANZLIC's role in reaching agreement on data standards. This has recently prompted calls for ANZLIC to have a more 'authoritative voice in senior decision making' (ANZLIC 2019b, p. 6).

Similarly, the critical need for the Commonwealth Government to provide leadership in ensuring seamless access to nationally consistent data has been emphasised. For example, the *Building Up & Moving Out* report, a result of an Inquiry into the role of the Australian Government in the development of cities (Commonwealth of Australia 2018), emphasised the importance of data in the holistic planning and development of Australian cities and regions. Although this report did not distinguish spatial data from non-spatial data, there were several references to spatial data in the context of land use, urban sprawl and transport planning. In the absence of a nationally consistent approach various stakeholders, who were consulted for the report, highlighted issues associated with the fragmentation in data collection and management in Australia. A specific issue in relation to the inaccessibility of data after a project or a contract has been completed was reported, as most government departments now outsource their data collection and analysis activities (Commonwealth of Australia 2018). Other than recommending the continuation of funding for AURIN and CSIRO's urban living labs, the report did not include any suggestions for the establishment of a national body for data collection and sharing but rather noted that these matters were being dealt with as part of the response to the Productivity Commission's findings (e.g. the appointment of the National Data Commissioner) (Commonwealth of Australia 2018).

As mentioned above, the '*2026 Spatial Industry Transformation and Growth Agenda'* as a collaborative whole-of-sector (i.e. industry, government, universities and various end users) initiative was launched in 2017 with the aim to transform the Australian spatial sector and enable it to realise its full economic potential. The 2026 Agenda presents a framework for a 10-year period for the spatial industry in Australia. Six key areas for development are defined, namely: public infrastructure and analytics, innovation and entrepreneurship, outreach, research and development, education, training and capacity building and representation. These six areas are supported by a range of specific actions. For example, under *Public Infrastructure and Analytics*, the agenda sets out nation-wide actions such as 'prioritising the collection of and access to public datasets of national importance, and supporting analytical capabilities' (*2019 Action Plan – Accelerating Change*, p. 4). The actions refer to a range of different sectors (e.g. telecommunications, robotics) and do not specifically divide tasks and responsibilities amongst different stakeholders. Rather, they set out nation-wide strategies to promote the growth of the Australian spatial industry across all relevant sectors. However, this also means that there is a level of uncertainty regarding how these tasks will be achieved by different sectors (and at different scales), including the built environment sector.

Current SDI initiatives in Australia are organised at state level or federal level, with limited involvement by local governments in their development and coordination of SDIs. Local governments have been hindered by lack of individual resources, varying technological consistency and lack of support from state LGA's in dealing with geospatial data (Alvarez León 2018). However, Australian local governments play an important role as producers of local level datasets and as users of other spatial data (Jacoby et al. 2002), and the current top-down approach to SDIs has therefore been criticised as a 'paradox' (Alvarez León 2018, p. 160). Local level spatial data display higher levels of accuracy and granularity, which makes them relevant for local land use planning activities (e.g. in relation to detailed parcels and zoning layouts, development control, neighbourhood development) and other applications. Given the small geographical size of many of the 'urban' local governments in Australia, the need for cooperation in land use planning and for the provision of services and infrastructures across local boundaries should be self-evident, and this would consequently require the availability of compatible datasets between local jurisdictions to enable coordinated planning. However, Jacoby et al. (2002) have noted a lack of consistency in the availability and management of spatial data across local governments in Australia.

Moreover, they observed a gap between the GIS teams (often organised as extensions of ICT departments) and local government's planning departments as users of these services (Jacoby et al. 2002). The challenges of spatial analysis and mapping for land use planning may be exacerbated by the lack of expertise in GIS and spatial data analytics and modelling among local government planners. It has been observed that in many Australian university courses on urban and regional planning, Geospatial Science, in particular GIS and spatial data analytics, is given insufficient attention (Karuppannan 2009).

3.4 Discussion: Spatial data governance and issues of urban and metropolitan planning in Australia

The overview of SDIs and related initiatives presented in this chapter has highlighted a number of challenges for spatial data governance in Australia. Although national organisations such as ANZLIC, Geoscience Australia, CSIRO/Data61 and ICSM play an important role in leading on the development and implementation of spatial data infrastructures, the decentralised nature of spatial data collection and provision by states and the increasing role of the private sector present considerable challenges for agreements on comprehensive SDIs. In relation to the strategic management of different stakeholders' activities, although ANZLIC holds an important position in uniting the interests of both producers and users of spatial data, the fragmentation of the data supply chain is evident. The involvement of both government and non-government agencies in the production and distribution of spatial data, combined with the absence of a centralised legal framework to regulate access to data means that significant variation remains in how data can be accessed and integrated across agencies and jurisdictions. Regarding data and metadata standards, some agencies (e.g., Geoscience Australia) have adopted the ANZLIC metadata profile that was developed to facilitate the interoperability within and between Australian and New Zealand agencies and jurisdictions and is based on the ISO 19115 international standard (ANZLIC 2020d). Some agencies have also adopted the Open Geospatial Consortium (OGC) standards The agreement on the '2026 Agenda' raises hopes that progress towards a more collaborative and network-based structure for data provision across Australia might be emerging, and that this might also help with reaching agreements on standards.

In terms of the legal frameworks that constitute a critical condition for the successful implementation of SDIs (Alvarez León 2018), there are currently no comprehensive legal frameworks for SDIs comparable to the EU's INSPIRE Directive. One of the main objectives for the newly created role of the National Data Commissioner is to oversee the development of a new legislation for the better management of public sector data. However, the initial scope of this proposal suggests it will be limited to the Commonwealth agencies. As only three states currently have laws on public sector data sharing in place, a federal legislation initiative would however ideally facilitate access to data between the three levels of government and their agencies and other public institutions (such as universities) across the country.

Moreover, as a private sector data provider, PSMA Australia Limited is not bound by the public sector data sharing legislation, and this can present challenges for urban and regional planners looking to access relevant information (e.g. building, trees). Alvarez León (2018) has argued that reliance on privately owned data poses risks to users as the long-term sustainability of data is not warranted. The situation in Australia may therefore hold considerable challenges for the future given the increasing involvement of private companies in data collection. For urban and regional planners, weak regulation and increasing privatisation should be of particular concern given the complexity of urban and regional issues that transcend multiple domains, scales and jurisdictions (Chen et al. 2018; Sinnott et al. 2015).

4. Spatial data requirements for metropolitan planning in South Australia

In spite of advances on SDIs and geoportals, existing spatial data may not always be sufficient for complex or newly defined planning tasks. For analysis, policy development or monitoring in urban and regional planning, available spatial data usually need to be processed and possibly combined with other datasets. This may involve GIS-based spatial analysis to convert data into meaningful and relevant information or indicators that can support trend analysis, policy formulation and decision making. Spatial analysis requires a comprehensive knowledge about the planning task, question or problem on which basis spatial criteria will need to be defined (e.g. based on regulations, such as required distance from a protected area). From these criteria, a *data needs assessment* has to be carried out to identify a list of required spatial data and their attributes. In doing so, the following data features need to be considered: data model, accuracy, format, dimension, coverage, timestamp, quantitative and qualitative thematic information, target scale, Level of Detail (LoD), Level of Abstraction, Coordinate Reference System, and Map projection (Heywood et al. 2011). The actual spatial analysis can then be performed, which includes planning and preparation, execution of GIS processing tools, and the evaluation of results (Longley et al. 2005). Therefore, advanced knowledge and expertise in GIS data processing and spatial analysis tools is required to support urban and regional planning tasks. Previous research has already shown that increasingly there is a separation of the tasks of GIS analysis and those developing planning policy and related tasks, and that this ‘division of labour’ can result in communication problems and present challenges for evidence-based spatial planning (Dühr 2007).

While the previous chapters considered the perspective of data providers and how data collection is governed, in this chapter the focus is on asking what spatial data would ideally be available to support and monitor metropolitan-level policies, and which of these datasets are actually available to planners. This analysis was undertaken by choosing two examples of planning policies from the current metropolitan strategy for Greater Adelaide (SA), the ‘2017 Update of the 30-year Plan for Greater Adelaide’ (Government of South Australia 2017). While an evidence-based understanding of policy-making emphasises the need for policies to be grounded in an analysis of spatial trends and perspectives, this phase of policy-making was not subject to the analysis presented here, given that the document has already been adopted and a new planning strategy for Greater Adelaide is expected to be prepared only later in 2020. Therefore, the focus of analysis was on a hypothetical policy evaluation or policy monitoring phase of the policy process, as set out in Table 1 above.

4.1 Formal requirements for spatial data in metropolitan planning in South Australia

Until the new planning legislation for South Australia, the 'Planning, Development and Infrastructure Act' (PDI Act) was adopted in 2016, urban planning and development assessment was regulated by the 'Development Act 1993' and the accompanying 'Development Regulations' of 2008. The '30-year Plan for Greater Adelaide' and its '2017 Update' (Government of South Australia 2010, 2017) were also prepared under this legislation.

The Development Act 1993 did not specifically address spatial data requirements, but Division 3 was dedicated to public infrastructure, and this provided some information about the relevant spatial data categories required to inform infrastructure planning (even if not urban planning more generally). Public infrastructure in the 1993 Development Act was defined as:

(a) the infrastructure, equipment, structures, works and other facilities used in, or in connection with, the supply of water or electricity, gas or other forms of energy, or the drainage or treatment of wastewater or sewage

(b) roads and their supporting structures

(c) ports, wharfs, jetties, railways, tramways and busways

(d) schools, hospitals and prisons

(e) all other facilities that have traditionally been provided by the State (but not necessarily only by the State) as community or public facilities.

The Development Act 1993 required the preparation of a South Australian Planning Strategy by the state government, in order to provide state government direction on land use and development. The 2010 '30-Year Plan for Greater Adelaide' (Government of South Australia 2010) and its 2017 'Update' (Government of South Australia 2017) are a 'volume' of the South Australian Planning Strategy, and intended to provide a strategic (30-year) planning horizon for the Adelaide metropolitan region. The Development Plans of local councils were required to be consistent with the overarching policy objectives as set out in the metropolitan strategy. Although the preparation of the metropolitan strategy documents was a legal requirement under the Development Act 1993, the adopted policy documents are of non-binding status.

The *30-Year Plan Update* includes six 'strategic high-level targets' for 2045, in relation to residential development, mobility and tree canopy in the CBD and inner suburbs (see Table 9). Geospatial data matters are addressed primarily in the third chapter of the strategy where plan implementation and monitoring are discussed (South Australia Government 2017, p. 138-153). For each high-level target, required spatial data and the spatial analysis method are discussed very briefly and in rather general terms in the document, and an overview is provided of how progress towards each target will be measured. Table 9 shows a compilation of these analysis methods and monitoring arrangements towards progress on achieving the targets. In addition, for each of the targets no. 1 to 5, a map product is provided which gives further information of which GIS data layers (e.g. boundaries, topography, infrastructure) are of importance for the required analysis method.

It is important to note that the targets only partially correspond to the much broader policy themes as set out in the 30-Year Plan for Greater Adelaide (2017 Update). They are overly selective, especially considering the complexity and integrated nature of the policy objectives proposed. In order to better understand the actual implications of comprehensive policy objectives for spatial data requirements, the analysis presented in this report focused on two of the policy themes presented in the metropolitan strategy to identify which spatial data would be ideally be needed to allow a comprehensive spatial analysis and monitoring of these policy themes. This assessment was then compared to the datasets readily available to urban and regional planners in South Australia.

Table 9: Targets, analysis methods and monitoring approaches as proposed in the 2017 Update of the 30-year plan for Greater Adelaide

Target	Description	Analysis methods using spatial data	Implementation plan: Target measuring details
1	**Containing our urban footprint and protecting our resources** a) 85% of all new housing in metropolitan Adelaide will be built in established urban areas by 2045 b) 90% of all new housing in the Outer Greater Adelaide will be built in established townships and designated urban development areas by 2045	Annual dwelling count data	Annual dwelling count data prepared by DPTI. Each year new dwellings will be attributed to infill, fringe or township locations within the ABS Greater Adelaide Capital City statistical area
2	**More ways to get around** 60% of all new housing in metropolitan Adelaide is built within close proximity to current and proposed fixed line (rail/tram/O-Bahn) and high frequency bus routes by 2045	GIS analysis of dwellings built and proximity to public transit	Use of annual dwelling count data prepared by DPTI. Each year new dwellings will be attributed to the defined catchments and then calculated as a proportion of the total dwellings built in metropolitan Adelaide (urban area). Any additions to the public transport network that meet the high frequency criteria of this target will be added annually and included in the analysis
3	**Getting active** Increase the share of work trips made by active transport modes by residents of Inner, Middle and Outer Adelaide by 30% by 2045	ABS data	Use of Census data and set separate targets for Inner, Middle and Outer Metro areas
4	**Walkable neighbourhoods** Increase the percentage of residents living in walkable neighbourhoods in Inner, Middle and Outer Metropolitan Adelaide by 25% by 2045	Multi-criteria analysis (through GIS)	Each of the spatial data layers developed for this target is based on the criteria identified. The walking distance from each criteria was measured using network analysis rather than 'as the crow flies'. The higher the rating, the more walkable the

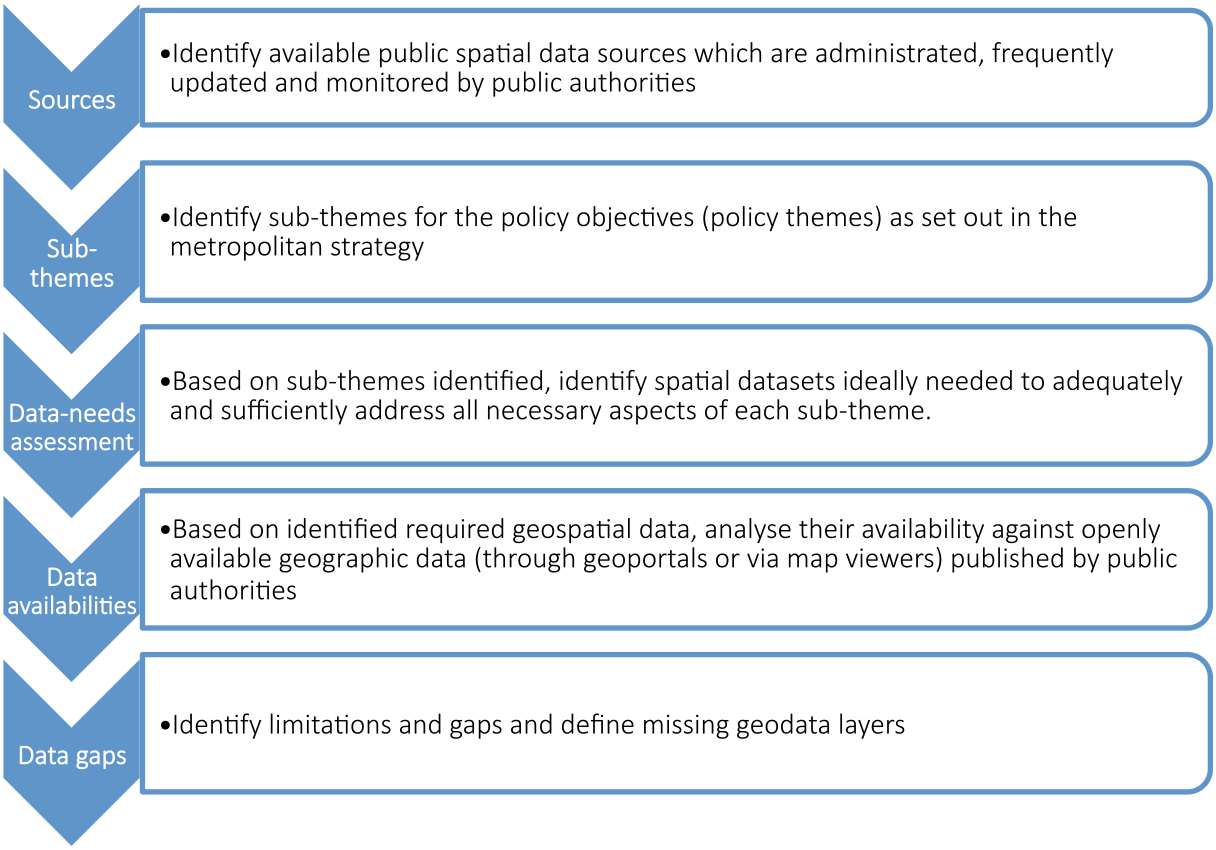
			neighbourhood. Population data at the ABS mesh block level (approximately 30 to 60 households) was overlaid to estimate the population within each walkability category.
5	**A green liveable city** Urban green cover is increased by 20% in metropolitan Adelaide by 2045	Survey/aerial photography	Through GIS software the following is proposed: For council areas with less than 30% tree canopy cover currently, cover should be increased by 20% by 2045. For council areas with more than 30% tree canopy cover currently, this should be maintained to ensure no net loss by 2045.
6	**Greater housing choice** Increase housing choice by 25% to meet changing household needs in Greater Adelaide by 2045	Analysis of dwelling count data (rolling 5-year average)	Using annual DPTI dwelling count data to track the number of dwellings built by type. It will use a rolling five-year average to calculate the ratio of detached to non-detached dwellings. Investigation will be undertaken to determine other ways to measure diversity of housing types. Currently data is extracted in the following five categories only: detached, semi-detached, flats/ apartments, home unit/townhouses and retirement village units

Source: compilation of information provided in: Government of South Australia 2017, pp. 138-153

4.2 Analytical approach

Figure 1 below summarises the approach to the analysis of spatial data requirements and data availability for two of the policy themes defined in the 2017 Update of the 30-year plan for Greater Adelaide. The results of the analysis will be presented in the following sections. The analytical approach was as follows: first, all available sources (geoportals) for spatial data in Australia provided by public authorities were identified and their content clarified (Table 6 and 7, see section 3.2.). Taking two policy themes from the '2017 Update of the 30-year plan for Greater Adelaide' as examples, sub-themes of the comprehensive policy objectives were determined. For each sub-theme a data needs assessment was conducted to identify spatial data that would ideally and realistically be needed to fully analyse and monitor the aspects of the comprehensive policy objectives and their sub-themes. The methodological approach is informed by the work of Indrajit et al. (2019), as explained in section 2.3.4 above, in relation to the selection of relevant spatial data for urban planning. As a next step, the desirable datasets for the selected policy objectives were compared to the availability of relevant spatial data layers as identified in the first step. Finally, by comparing available with required spatial data limitations and gaps in available datasets, as well as identify missing spatial data layers could be determined.

Figure 1: Workflow applied to the analysis of spatial data requirements and availability for policy themes as set out in the 2017 Update of the 30-year plan for Greater Adelaide



Source: authors' own

Due to the restrictions of the Covid-19 pandemic, which prevented engagement with stakeholders in focus group meetings and through interviews as was originally envisaged, the analysis presented in this chapter is based on a desk study assessment by the researchers undertaking this study. It is acknowledged that this approach has limitations. The assessment by researchers, rather than practising planners working on the metropolitan strategy and monitoring arrangements, presents an 'outsider's view' to what are often complex policy-making and plan-implementation processes which may also rely on information not openly accessible. It is acknowledged that the selection process of spatial data layers relevant to the examples of planning tasks considered for this research would have been more robust if a range of practising planners, spatial data experts and data contributors could have been involved in the discussion of research findings. In spite of these limitations, the approach presented here is a systematic analysis, which allows now only a reflection on gaps in relation to a discussion of data needs and monitoring requirements in the policy document under study, but also gives insights into the challenges of compiling relevant spatial data sets for what are often complex policy objectives that may carry internal tensions.

The two policy objectives from the 2017 Update of the 30-year plan for Greater Adelaide that were selected for the analytical approach as presented in Figure 1 were:

- 'Transit corridors, growth areas and activity centres', and
- 'Health, Wellbeing and Inclusion'.

There are altogether 15 policy objectives set out in the metropolitan strategy, with some focused on specific geographical areas (Adelaide City Centre, Barossa Valley and McLaren Vale) and others are more sectorally-focused on transport, water or heritage. The selected examples are comprehensive policies, which require responses, and measures that are integrated while at the same time place-specific (because achieving these objectives will require different responses for different areas of the Greater Adelaide region). The selected policy objectives therefore seemed particularly fruitful examples to investigate the spatial data implications for metropolitan-level planning.

In response to step 1 of the analytical model presented in Figure 1, Table 10 lists all identified GIS data layers relevant for the selected two policy objectives. For every dataset, details such as data type (point/ line/ polygon/ raster/ excel spreadsheet), updating frequency (ad hoc/ nightly/ weekly/ monthly/ yearly etc.), availability (available/ restricted/ missing) and source is given. The latter category, 'source' refers to the geoportals through which the data are openly available, as listed in Tables 6 and 7. The focus was on geospatial data provided by public authorities through nation-wide and South Australian geoportals. Open source spatial data provided by private companies, Non-governmental organizations or Volunteered Geographic Information initiatives, such as data from OpenStreetMap[5] were not considered.

Table 10: Relevant geospatial datasets for selected examples of policy themes from 30-Year Plan for Greater Adelaide (2017 Update)

Acronym	Dataset*	Type	Update	Availability1	Source
ASGS	Statistical areas defined by Australian Statistical Geography Standard (ABS 2011) including MB, SA1-4, SUA etc.	polygon	adhoc	available	1
DePlMaI	Development Plan Map Index	polygon	adhoc	available	12
GAPR	Greater Adelaide Planning Region	polygon	adhoc	available	12
HoRe	Housing SA Regional Boundaries	polygon	nightly	available	12
LGA	Local Government Areas	polygon	nightly	available	12
MeBou	Metropolitan Adelaide Boundary (Development Act 1993)	polygon	adhoc	available	12
GovRe	SA State Government Regions	polygon	adhoc	available	12
Sub	Suburbs	polygon	nightly	available	12
M-AcCe	Activity Centres: 17 in total (30-year plan '2017 page 43)	point	-	missing	-
M-AcCeBa	Activity Centre Barriers (accessibility information for persons with physical impairment disabilities)	point	-	missing	-
Acc2H	Accessibility to health/ public transport/education services	polygon	once off	available	6

[5] OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. Map data is collected from scratch by volunteers performing systematic ground surveys using tools such as a handheld GPS unit, a notebook, digital camera, or a voice recorder. The data is then entered into the OpenStreetMap database. https://www.openstreetmap.org/

Acronym	Dataset*	Type	Update	Availability1	Source
Acc2PT Acc2E	2015; five different accessibility classes based on Metropolitan Accessibility/Remoteness Index of Australia (Metro ARIA)				
BiDiNe	Bike Direct Network	line	weekly	available	12
Bld	Building footprints	polygon	adhoc	*restricted*	12,13
M-Bld_3D	Building models (3D) – Level of Detail (LoD) 3 or 4	3d model	-	missing	-
M-Bld_u	Usage of buildings and building parts/floors	polygon	-	missing	-
BuUpA	BuiltUp Areas (derived from Lidar and aerial imagery)	polygon	adhoc	*restricted*	12,13
M-CCELCD	Community Centres and Events supporting Cultural Diversity	point	-	missing	-
Census	Census of Population and Housing (2016, 2011, 2006…)	polygon	5 years	available	2
CSISC	Communities and Social Inclusion Service Centers and Office Locations	point	adhoc	available	12
DEM	Digital Elevation Model (5m)	raster	adhoc	available	7
M-ECECC	Early Child Education and Care Centres (incl. childcare, day care, early learning centres, kindergarten, Montessori etc.)	point	-	missing	-
EmSe	Emergency Services	point	adhoc	available	12
FUGA	Future Urban Growth Areas	polygon	adhoc	available	12
Ho2BlSz	Mean house to block size ratios by SA1 – available for 1990, 2010, 2010, 2014	polygon	once off	available	6
LaCo	SA Land Cover (25m pixels, every 5 years 1990 – 2015) 11 main classes: built-up, urban,… (extracted from Landsat imagery)	raster (tiff)	5 years	available	12
M-LaPa	Land parcels (parcels can be viewed through SAPPA but there is no option to download polygon files)	polygon	-	missing	-
LaUg	parcel-based Land Use Generalised 2019, 17 classes (see example 1)	polygon	adhoc	available	12
LDA	Land Division Applications / Proposals (since 1989)	polygon	nightly	available	12
LDZ	Land Development Planning Zone Categories	polygon	weekly	available	12
MOSS	Metropolitan Open Space System Study Area	polygon	adhoc	available	12
M-Mus	Museums and Exhibitions	point	-	missing	-
M-NeiQI	Neighbourhood Quality Index (incorporating air quality, noise, safety, aesthetic, avg income, health etc.)	raster or polygon	-	missing	-
PDFIP	Planning and Development Fund Investment Projects	point	adhoc	available	12
PeCr	Pedestrian Crossings	point	weekly	available	12
M-PSCRF	Public Sporting, Community and Recreational Facilities data.sa only provides sporting locations for Adelaide City	point	-	missing	-
PrReRe	Private Rent Reports (xls): median private rent in SA by suburb, postcode, State Government Regions and LGA	xls	3 months	available	
M-PrSc	Private schools (incl. primary and high schools) (data via addresses/ webmap available at privateschoolsguide.com)	point	-	missing	-
PUL	Planned Urban Lands to 2045 (Urban Boundary)	line	adhoc	available	12
M-PuTrBa	Public Transport Barriers (accessibility information for persons with physical impairment disabilities)	point	-	missing	-
PuTrSt	Adelaide Public Transport Stop Data	point	weekly	available	12
RaNe	Rail Network	line	adhoc	available	12
Rd	Road Network (statewide, complete)	line	adhoc	available	12
ReBrLa	Residential Broadhectare Land	polygon	annually	available	12
ReTr	Recreation Trails - formed pathways	line	adhoc	available	12
RoCrLo	Road Crash Locations in SA	point	4 years	available	12
RTD	Residential tenancy databases	xls	adhoc	*restricted*	10
SAGES	SA Government Education sites (schools and preschools)	point	daily	available	12

Acronym	Dataset*	Type	Update	Availability1	Source
SAILIS	South Australian Integrated Land Information System	pdf	adhoc	*restricted*	14
SAPPA	South Australian Property and Planning Atlas	web map	weekly	available	15
SeSA	Service SA: office locations for Service SA in South Australia	point	weekly	available	12
SiUrGr	Small regions with significant urban parcel growth based on cadastral parcel change between 8/2011-8/2014	polygon	once off	available	6
M-TeEdu	Tertiary Education locations	point	-	missing	-
M-Trees	Tree type, age and location data.sa only provides street tree locations for Adelaide City	point	-	missing	-
TrIn	Transport Infrastructure Lines	line	adhoc	*restricted*	12,13
TrVo	Traffic Volume daily estimates: sum of vehicle traffic travelling in both directions on a two-way road passing a roadside observation point over the period of a full year divided by the number of days in the year.	line	weekly	available	12
M-WaCyFD	Walking and Cycling Flow Data (use of pedestrian and cycling infrastructure)	line	-	missing	-
M-WaPa	Walking paths (in urban areas)	line	-	missing	-
WATER	Layer group including multiple datasets related to the total water cycle and water from all sources, including rainwater, storm water, groundwater, mains water and wastewater: - Groundwater (Prohibition Area, Monitoring Stations) - Coastlines; Shallow Standing Water Level - Soils Watertable Depth and Waterholding Capacity - Storm Water Drains - Surfacewater Basins and Catchments - Water and wastewater network a.o. data - Water Abandon, Water Bodies, WaterSources - Prescribed surface water-/ water resource / wells areas - Reclaimed water assets a.o. data - SA Water Land Holdings and Easements - Watershed Priority Areas - *and others*	point line polygon	adhoc	*some are* available, *some are restricted*	12

Source: authors' compilation

* *first 8 datasets (highlighted in light-red) are administrative and statistical boundaries*

[1] *If a number is provided, the dataset is available.*
The number refers to the respective number in Tables 6 and 7.

Spatial datasets categorized as 'restricted' in the table refer to available data with restricted access. As explained in chapter 3.3, such restricted datasets are produced and shared by private providers (e.g. PSMA Australia Limited) and require a fee-based subscription and licence for access. 'Missing' spatial datasets are those which do not exist, or which are not provided by public authorities through their geoportals.

4.2 Example 1: Policy theme on 'Transit corridors, growth areas and activity centres' as presented in the 30-Year Plan for Greater Adelaide (2017 Update)

The analytical approach described in the previous section was applied to the policy theme on 'Transit corridors, growth areas and activity centres'. A description of this policy theme with definitions of relevant terms is provided in Appendix B. The plan specified twelve policy objectives in support of the policy theme, as set out in Box 1. The 2017 Update of the 30-

year plan for Greater Adelaide identifies targets 1, 2, 3 and 4 (see Table 9) as relevant for this policy theme and its policy objectives.

For this first example of a policy theme from the 30-Year Plan, eight sub-themes could be identified. Each sub-theme aligns with one or more policies defined within the policy theme as indicated through the corresponding policy objective, as shown in Table 11. For each sub-theme, the required geographic data (layers) that are needed to support the policy requirements were analysed. Three groups were identified for these ideally required spatial datasets, namely: (I) available and appropriately detailed datasets; (II) available datasets but with insufficient level of detail; and (III) overall missing spatial data. Table 11 lists the acronyms of the spatial datasets identified as being required to support the policy theme for all three groups. The ‘coding’ of the spatial datasets refers to the acronym as shown in Table 10.

Box 1: Policy theme on 'Transit corridors, growth areas and activity centres' as presented in the 30-Year Plan for Greater Adelaide (2017 Update)

Policy objectives P1-P12:

P1 Deliver a more compact urban form by locating the majority of Greater Adelaide's urban growth within existing built-up areas by increasing density at strategic locations close to public transport. (Map 2)

P2 Increase residential and mixed-use development in the walking catchment of:

- strategic activity centres
- appropriate transit corridors
- strategic railway stations.

P3 Increase average gross densities of development within activity centres and transit corridor catchments from 15 to 25 dwellings per hectare to 35 dwellings per hectare.

P4 Ensure that the bulk of new residential development in Greater Adelaide is low to medium rise with high rise limited to the CBD, parts of the Park Lands frame, significant urban boulevards, and other strategic locations where the interface with lower rise areas can be managed.

P5 Encourage medium rise development along key transport corridors, within activity centres and in urban renewal areas that support public transport use.

P6 Promote urban renewal opportunities and maximise the use of government-owned land to achieve higher densities along transit corridors.

P7 Focus government services in higher-order activity centres that are well-serviced by public transport to support viable clusters of activities and minimize car trips.

P8 Provide retail and other services outside designated activity centres where they will contribute to the principles of accessibility, a transit focused and connected city, high quality urban design, and economic growth and competitiveness.

P9 Develop activity centres as vibrant places by focusing on mixed-use activity, main streets and public realm improvements.

P10 Allow for low-impact employment activities in residential areas, such as small-scale shops, offices and restaurants, where interface issues can be appropriately managed.

P11 Ensure new urban fringe growth occurs only within designated urban areas and township boundaries and outside the Environment and Food Production Areas, as shown on Map 3.

P12 Ensure, where possible, that new growth areas on the metropolitan Adelaide fringe and in townships are connected to, and make efficient use of, existing infrastructure, thereby discouraging "leapfrog" urban development.

Source: Government of South Australia 2017, p. 42

In Table 11, available and appropriately detailed spatial datasets (I) with restricted access (as defined in section 4.1) are shown in ***bold and italics***. A data layer is categorized as 'insufficient' (II) if it is considered that a GIS-analysis would be required to address the corresponding sub-theme, but based on the data such analysis would not be possible. This is the case if one or more of the following data features are inadequate: spatial or temporal coverage, Level of Detail, spatial resolution, or semantic information.

The administrative boundary layers MeBou, GAPR, GovRe, Sub, LGA, DePlMaI and HoRe, as well as ASGS as defined by ABS (2011) are listed in Table 10 but not included in Tables 11 and 12. This is because for each sub-theme within the two examples of policy themes from the metropolitan strategy it will depend on the area of interest for a decision on which of these spatial boundary layers to include.

As presented in Table 11, for the policy theme on 'Transit corridors, growth areas and activity centres', altogether 29 different required GIS data layers can be considered as needed to support the policy objectives. In the analysis presented here, 15 of these datasets can be considered to be readily available and appropriate, with access to four of these 15 layers restricted. Seven out of 29 layers can be considered insufficient, and eight datasets that would be important for the policy objectives set out are not available (i.e. 'missing').

Table 11: Identified sub-themes and required spatial data for policy theme on Transit corridors, growth areas and activity centres

Sub-themes and Policy objectives — *required spatial data*[1]:	*available*		*Missing data*
	Appropriately detailed data	*Insufficiently detailed data*[2]	
Urban consolidation / higher densities; urban infill (location of development in specified locations of the urban area, shift to higher density development – apartments, townhouses; increase density to 35 dwellings per hectare in activity centres and across transit corridors) Policy objectives P1, P2, P3, P11	- Rd, LDA - PUL, LDZ - FUGA - ReBrLa - *Bld** *BuUpA**	- LaUg - LaCo - Census - Ho2BlSz - SiUrGr	- M-Bld_u - M-Bld_3D - M-WaPa - M-WaCyFD
'Activity centres' across Greater Adelaide: City of Adelaide and other centres (see map p. 43) / 'Higher-order centres' (scale question, incl. connections between designated activity centres and within these centres to facilitate accessibility) Policy objectives P7, P8, P9	- Rd, PeCr - PuTrSt - BiDiNe - *TrIn** - *Bld**	- TrVo	- M-AcCe - M-AcCeBa - M-PuTrBa - M-Bld_u - M-Bld_3D - M-WaCyFD
Locate government services in higher-order activity centres with good accessibility Policy objective P7	- PuTrSt - *TrIn** - *Bld**	- TrVo - SeSA	- M-AcCe - M-Bld_u - M-PuTrBa - M-WaPa - M-WaCyFD
Mixed use (Residential development near or integrated with commercial etc. uses) Policy objectives P4, P10	- *Bld**	- LaUg	- M-Bld_u - M-Bld_3D
Urban renewal: brownfield redevelopment, re-use of major previously used sites (e.g. old-industrial areas), re-use of buildings etc., upgrading of areas / neighbourhoods with new infrastructure investments etc. to offer improved residential areas Policy objectives P5, P6	- *Bld**	- LaUg - LaCo	- M-Bld_u - M-Bld_3D - M-WaPa - M-WaCyFD
Accessibility / Access to public transport (rail, tram, bus) and walkability Policy objectives P5, P7, P8	- PuTrSt - RaNe, Acc2PT - *TrIn*, Bld**	- TrVo	- M-PuTrBa - M-WaPa - M-Bld_u - M-WaCyFD
Transit corridors and key transport corridors, accompanied by medium-rise developments along these routes	- Rd, LDA - PUL, LDZ	- LaUg - TrVo	- M-Bld_u

Sub-themes and Policy objectives	required spatial data[1]: available		Missing data
Policy objective P12	- FUGA, RaNe - ***TrIn*, Bld* BuUpA****		
Restrict development on greenfield lands / on urban fringe / outside built-up area Policy objective P11	- Rd, LDA - PUL, LDZ - FUGA - ***Bld*, BuUpA****	- LaUg	- M-Bld_u

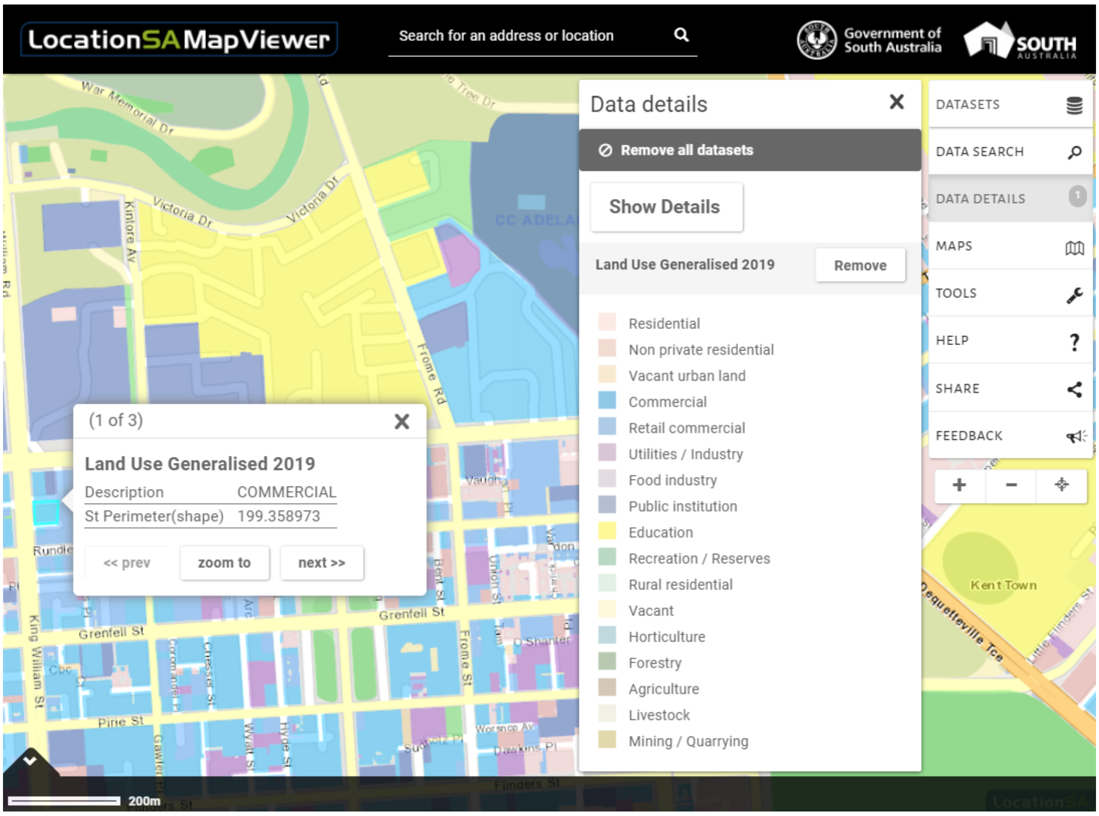
[1] *only data acronym listed; for details one each dataset refer to Table 10*
[2] *scale / Level of Detail insufficient to undertake GIS-analysis necessary for sub-theme*
* ***bold and italics*** denotes ***spatial data with restricted access***
Source: authors' analysis

The challenges of achieving comprehensive spatial data availability can be explained with the following illustration. One of the sub-themes identified as part of the analysis and shown in Table 11 is 'mixed use', which refers to the integration of different types of land use in a neighbourhood or even a plot /building (e.g. residential development near or integrated with commercial uses). The 2017 Update of the 30-year plan for Greater Adelaide does not specify any requirements for geospatial data or spatial analysis for mixed-use developments, and the only publicly available dataset for a GIS based analysis related to this sub-theme is '*LaUg'* as identified in Table 10. This layer is a general parcel-based land use dataset derived from parcel valuation information. The land use code from the valuation has been categorised into the following 17 broad classes:

agriculture, commercial, education, food industry, forestry, horticulture, livestock, mining, residential, non-private residential, rural residential, public institution, recreation/reserves, retail commercial, utilities/industry, vacant, vacant urban land.

Figure 2 illustrates, through the use of Location SA MapViewer, the Level of Detail of this layer's defined land use classes. Since 2017, this dataset can be downloaded as an ESRI shapefile from data.sa.gov.au and is updated annually, thus temporal changes at the provided Level of Detail (LoD) can be explored as well.

Figure 2: Land Use Generalized 2019 ('LaUg') data layer



Source: authors' compilation, generated with the use of Location SA MapViewer

However, to address the sub-theme 'Mixed use', the '*LaUg'* data layer is insufficient as boundaries are based on cadastral land properties and the data layer's land-use related attribute 'Description' does not consider mixed land use. Land parcels had been aggregated based on common and shared 'overall' land use characteristics. Consequently, it is not possible to spatially investigate mixed uses on sites. Furthermore, the '*LaUg'* is not based on buildings, and therefore does not include any detail if the use of one or more buildings on a plot differs from the uses of the rest of the site. Likewise, there is no detail included about multi-storage buildings, which may comprise different types of use, such as retail on the ground floor and apartments above. Through data.sa.gov.au a '*building'* layer (***Bld****) is available, but its information is restricted to the building footprint. GIS overlay analysis would allow to join the respective land use attributes from '*LaUg'* to a building polygon, but again, if in reality the building has multiple types of uses, this could still not be fully analysed.

This reflection on data implications for 'mixed use' allows the identification of two missing data layers to fully address this sub-theme: first, a 2D polygon layer with high 'Level of Detail' (LoD) about the use of buildings and of different parts of a building. Second, in order to also be able to differentiate between the uses of different levels in multi-storey buildings, another data layer of a 3D building Model of at least LoD 3 or even LoD 4 would be useful. This should comprise the same semantic information as the before mentioned 2D building usage layer, but in addition include the vertical dimension. Both layers are listed in Table 11.

4.3 Example 2: Policy theme on ‘Health, wellbeing and inclusion’ as presented in the 30-Year Plan for Greater Adelaide (2017 Update).

The same analytical approach was applied to a second example of a policy theme from the 2017 Update of the 30-year plan for Greater Adelaide, namely the theme ‘Health, wellbeing and inclusion’ with the mission to ‘Create healthy neighbourhoods that promote cycling, walking and public life’. A description of this policy theme together with definitions of relevant terms is provided in Appendix C.

The plan specified eight policy objectives in support of this policy theme, as set out in Box 2. The 2017 Update of the 30-year plan for Greater Adelaide identifies targets 2, 3, 4 and 5 (see Table 9) as relevant for this policy theme and its policy objectives.

Box 2: Policy theme on ‘Health, wellbeing and inclusion’ as presented in the 30-Year Plan for Greater Adelaide (2017 Update)

Policy objectives P47-54:

P47 Plan future suburbs and regenerate and renew existing ones to be healthy neighbourhoods that include:

- diverse housing options that support affordability
- access to local shops, community services and facilities
- access to fresh food and a range of food services
- safe cycling and pedestrian-friendly streets that are tree-lined for comfort and amenity
- diverse areas of quality public open space (including local parks, community gardens and playgrounds)
- sporting and recreation facilities
- walkable connections to public transport and community infrastructure.

P48 Create greenways in transit corridors, along major watercourse linear parks, the coast and other strategic locations to provide walking and cycling linkages.

P49 Encourage more trees (including productive trees) and water sensitive urban landscaping in the private and public realm, reinforcing neighbourhood character and creating cooler, shady and walkable neighbourhoods and access to nature.

P50 Provide diverse areas of quality public open space in neighbourhoods (especially in higher density areas) such as local parks, community gardens, playgrounds, greenways and sporting facilities to encourage active lifestyles and support access to nature within our urban environment.

P51 Facilitate and support the value of local ownership by supporting communities and businesses to help shape and look after their local open spaces and streetscapes.

P52 Support a diverse range of cultural initiatives, such as public art, to stimulate the revitalisation of communities and social cohesion.

P53 Encourage the integration of green infrastructure in the public and private realms to support positive physical, mental and social health outcomes.

P54 Prioritise Planning and Development Fund grants for improved access to quality public realm (such as playgrounds, linear paths and new open space purchases) at strategic locations.

Source: Government of South Australia 2017, p. 74

Using the same analytical approach as described in chapter 4.2), the following sub-themes and required geographic data were identified for the policy theme on health, wellbeing and inclusion (see Table 12).

Table 12: Identified sub-themes and required spatial data for policy theme on Health, wellbeing and inclusion

Sub-themes and Policies — *required spatial data*[1]:	*available*		*missing*
	Appropriately detailed data	*Insufficiently detailed data*[2]	
Diverse housing options Policy objective P47	- MOSS - ***Bld****	- Census	- M-Bld_u - M-Bld_3D
Affordable housing Policy objective P47	- ***Bld****	- Census	- M-Bld_u
Safe cycling options Policy objective P47	- Rd, PeCr - BiDiNe, RoCrLo - ***TrIn****	- TrVo	- M-WaPa
Safe walking options Policy objective P47	- Rd, PeCr - BiDiNe, RoCrLo - ***TrIn****	- TrVo	- M-WaPa
Tree lined streets / tree cover Policy objectives P48, P49	- Rd	- LaCo	- M-Trees
Easy access to services, retail, community facilities (Up to 10 minutes walk (800m) to an activity centre which includes local shops, services and community gathering places such as libraries.) Policy objective P47	- Rd, PeCr - BiDiNe - Acc2PT, Acc2H - ***TrIn*, Bld****		- M-Bld_u - M-AcCe - M-AcCeBa - M-PuTrBa - M-WaPa
Local access to Sporting facilities Policy objectives P47, P50, P53	- LaUg - Rd, PeCr - BiDiNe - ***TrIn*, Bld****	- ReTr	- M-PSCRF - M-WaPa
Local access to Recreation facilities Policy objectives P49, P50, P53	- Rd, PeCr - BiDiNe - ReTr, MOSS - ***TrIn*, Bld****		- M-PSCRF - M-WaPa
Easy Access to Frequent Public Transport (Up to 5 minutes walk (400m) to a high frequency bus stop or 10 minutes walk (800m) to a train station, tram or O-Bahn stop). Policy objective P47	- Rd, PeCr, PuTrSt, BiDiNe - ***TrIn*, Bld****	- Acc2PT	- M-PuTrBa - M-WaPa
Nearby Access to Schooling and Childcare (Up to 15 minutes walk (1km) to a primary school, childcare centre or kindergarten). Policy objective P47	- SAGES, Rd, PeCr - BiDiNe - ***TrIn*, Bld****	- Acc2E	- M-ECECC - M-PrSc - M-TeEdu - M-WaPa
Close Access to a Range of Employment Centres Up to 20 minutes cycle (5km) to employment zoned land. Policy objective P51	- Rd, PeCr - BiDiNe, - ***TrIn*, Bld****		- M-Bld_u - M-AcCe - M-AcCeBa - M-WaPa
Local access to Quality public open spaces (A diverse range of public open spaces with all dwellings having at least one option within a 5 minute walks	- Rd, PeCr - BiDiNe - ***TrIn*, Bld****	- MOSS	- M-Bld_u - M-AcCe - M-AcCeBa

Sub-themes and Policies *required spatial data*[1]:	*available*		*missing*
	Appropriately detailed data	*Insufficiently detailed data*[2]	
(400m)). Policy objectives P47, P50, P51			- M-WaPa
Water-sensitive urban landscaping Policy objective P49	- WATER - ***WATER****	- ELVIS	
Neighbourhood character and amenity Policy objectives P47, P50	- ***Bld****	- Acc2H - Acc2PT - Acc2E - LaUg - LaCo	- M-Bld_u - M-NeiQI
Offer of cultural initiatives Policy objective P52	- CSISC		- M-Bld_u - M-Mus - M-CCELCD
Governance: identity and local sense of ownership Policy objective P51	- SAPPA - ***SAILIS****	- RTD	
Governance / Instruments: priority funding for improvements to public realm Policy objective P5	- PDFIP		

[1] *only data acronym listed; for details one each dataset refer to Table 10*
[2] *scale / Level of Detail insufficient to undertake GIS-analysis necessary for sub-theme*
* ***bold and italics*** denotes ***spatial data with restricted access***
Source: authors' analysis

As presented in Table 12, for the policy theme on health, wellbeing and inclusion altogether 43 different GIS data layers can be identified as being necessary for a comprehensive analysis and monitoring. Altogether 19 of these datasets are available and appropriate, although four of those have restricted access. Ten out of 43 layers are identified as insufficient, and 14 out of 43 as missing.

The challenges of comprehensive spatial data availability can again be illustrated with a specific example (see Figure 3). This was done by analysing in more detail the seventh sub-theme on 'Local access to Sporting facilities', as identified in Table 12. As with the previous example, the 2017 Update of the 30-year plan for Greater Adelaide also does not address any requirements on geospatial data or GIS analysis in regard to these issues. There is also no adequate dataset available containing location information of local sporting facilities within the Adelaide metropolitan area.

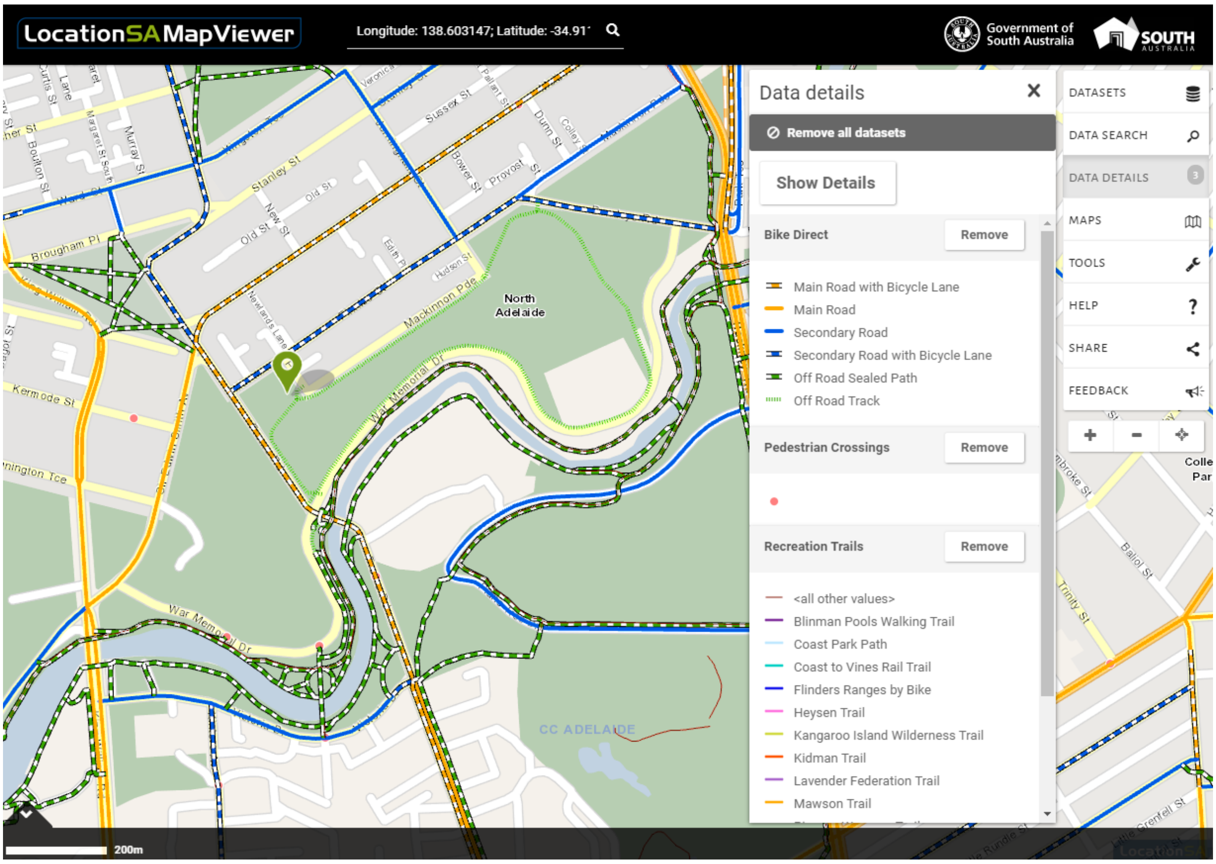
Therefore, a missing layer – called 'M-PSCRF' – 'Public Sporting, Community and Recreational Facilities' – was identified. This would for instance include public outdoor gym facilities, but also locations of parklands fitness events, such as regular public/community exercising activities (e.g. yoga, gymnastics). Another important missing GIS layer for this sub-theme is a Walking path line network (here denoted as '*M-WaPa*'). This should include detailed urban walkable paths that can be connected to a bicycle paths network layer ('*BiDiNe*') as well as to any other roads ('*Rd*') not included in the bike layer.

Furthermore, an available yet for the purposes of this task insufficient layer is the Recreation Trail dataset ('*ReTr*'). Only portions of some long-distance trails that coincide with vehicular tracks or constructed roads, or that exist only as a natural ground surface are included in the existing dataset.

A further important dataset is the available Land Use layer ('*LaUg*'). Unlike in the first example of 'mixed use', for the example on 'access to sporting facilities' this dataset can be considered sufficient. However, in order to analyse and on that basis identify the need for the planning of further sporting facilities with the help of GIS, also data on geo-located addresses or buildings ('*M-Bld_u*') would be needed. Such a dataset, which ideally would be combined with usage and address attributes, a road line network with consistent topology ('*Rd*'), and pedestrian crossings ('*PeCr*'), is currently not available. In order to support 'local access' through use of public transport, also a Transport Infrastructure Line network layer ('*TrIn*') would be needed for the analysis and monitoring of this policy, but access to this dataset is currently restricted.

Figure 3 illustrates, through the use of Location SA MapViewer, the available layers 'Bike Direct', 'Pedestrian Crossing', and 'Recreation Trails'. To avoid visual overload, the layer 'LaUg' has not been included in this illustration but can be seen in Figure 2 above. The green pin indicates, as a demonstration of the approach, an outdoor fitness location where gym facilities are provided (at Mackinnon Parade, North Adelaide).

Figure 3: Available GIS layers related to example 'Local access to sporting facilities'



Source: authors' compilation, generated with the use of Location SA MapViewer

It should be noted that there are a number of additional spatial datasets available through Adelaide City Council of relevance to these themes. However, these only cover the local council area of the CBD, North Adelaide, and the Parklands. These datasets are: Park Land

Parks, Park Land Sporting Facilities, Bike and Pedestrian Paths, Park Land Path Ring Route, and Park Land Playgrounds.

4.4 Discussion and conclusions: challenges for metropolitan spatial planning in South Australia from a spatial data perspective

The examples from the 2017 Update of the 30-year plan for Greater Adelaide were analysed in relation to spatial data needs versus data availability, and they confirm observations of existing important limitations with regard to availability and content of data to support comprehensive metropolitan-level policy-making and plan evaluation. Supporting a shift towards more integrated land uses and sustainable mobility is hindered by a lack of available information on mixed-use of land and buildings, and a lack of relevant information to measure accessibility and connectivity, notably in relation to infrastructure for walking and cycling and their use (in terms of volume of users across certain routes). Where traffic flows are measured, the corresponding datasets are strongly focused on motorised road traffic use, and consequently present an important blind spot for presenting information on alternative forms of transport. Likewise, the available datasets on land uses are limited by only showing single or dominant uses of land parcels and buildings. Given the policy emphasis on mixed use, the lack of data seems particularly concerning, and not being able to analyse different types of uses on a site may present additional challenges for planners trying to monitor progress on overcoming unsustainable land use patterns. It has been noted in earlier research that there is a lack of available spatial datasets required for specific planning tasks (Evans 2007), and that data producers often do not know enough about the needs of end users (Woodgate et al. 2017) – in our case metropolitan planners. It would be important to reconcile producer and user perspectives so that comprehensive spatial data are available to support integrated spatial planning concepts related to activity centres, transit-oriented development, and denser yet more sustainable urban neighbourhoods more generally.

Moreover, although general spatial datasets, maintained and distributed at SA state level, cover basic topographic layers as presented in the FSDF themes, several important datasets required to inform metropolitan planning are the result of project-based or 'one-off' data collection efforts by local governments. As such, they are not systematically maintained and updated, and neither can they be combined with datasets from other jurisdictions to allow sufficient spatial coverage, thematic or geometric level of detail for metropolitan-level planning.

Other notable limitations in available spatial data for metropolitan planning tasks include:

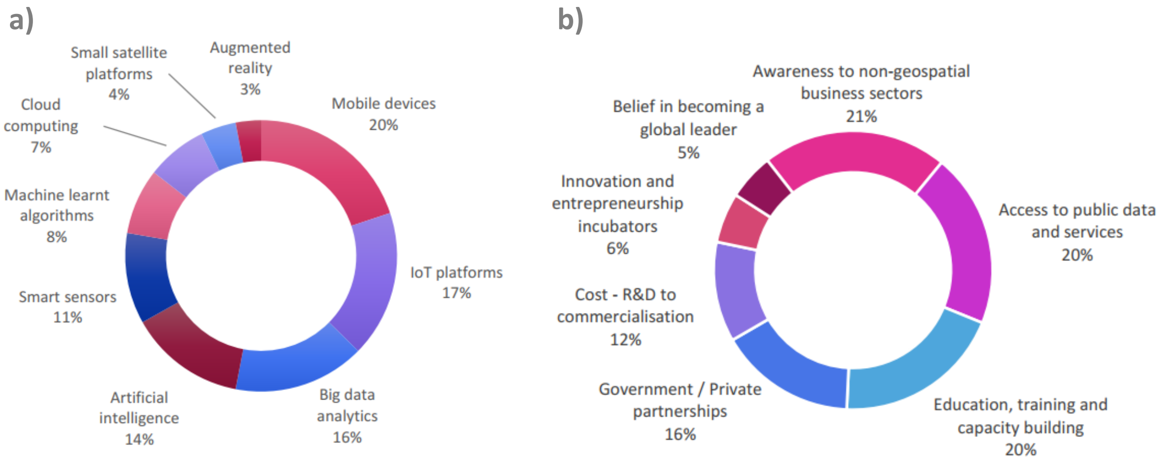
- restricted access, absence, or partiality of 3D building models[6]
- missing detailed semantic information of natural environment and built structures
- missing 'flow data' which would reveal insights into spatial patterns of people walking and cycling tracks, in particular inside or around activity centres
- missing archives of change-sets storing any attributive or geometric change
- non-physical semantic information which relate to location (opinions, trends, collaborations, communications, flows of goods/services/people/capital)

[6] Lidar data is being utilised for communicating 3D models of larger developments through displaying building profiles and height limitations.

- missing topological relationships between datasets
- lack of suitable ontologies and ontology-based meta-data
- difficulties in collecting data in a consistent and spatially enabled manner; including the ability to classify and license the data (providing the permission required to get the data, use or share the data for multiple purposes); and getting or creating appropriate meta-data[7]

There are a number of on-going initiatives in Australia that might address at least some of these limitations. ANZLIC is currently working on ISO level metadata standards. The South Australian government is currently working on a geospatial strategy to utilize strengths, identify opportunities and advance leadership in the state's geospatial industry (Department of the Premier and Cabinet 2018). As part of the engagement activities with the South Australian geospatial community, the Office for Data Analytics (ODA) of the Department of the Premier and Cabinet (DPC) had organized in 2018 a series of co-design workshops with leaders from business and industry, government, and research and education. Figure 4 summaries which main potentials of future technologies were identified, and the challenges to geodata capacity in South Australia that to a significant degree arise from a lack of awareness, challenges in relation to access to data, and education, training and capacity-building.

Figure 4: Potential future technologies (a), and challenges to geodata capacity in SA (b)



Source: SA Geospatial Strategy (Department of the Premier and Cabinet 2018)

7 personal communication with Bert Bruijn (DPTI)

5. Summary of findings and conclusions, and suggestions for further research

5.1 Key findings and conclusions

The research presented in this report was guided by the following two research objectives:

1) to identify current gaps and potentials in addressing spatial data requirements for metropolitan planning; and

2) to investigate the limitations and potentials of available spatial data to inform metropolitan planning policies, using the example of Greater Adelaide, and to discuss the current challenges affecting the provision of comprehensive and integrated spatial data for urban and regional planning in Australia.

In response to the first research objective, a review of the published academic literature indicates that there have been only a few previous analyses on the role of spatial data in Australian urban and regional planning processes. There may be other analyses, undertaken by government departments or the private sector, which are not publicly available and therefore have not been reviewed. Over recent years, there has also been an increasing focus in Australia on data and indicators for policy domains other than urban planning, such as in relation to public health (see e.g. Fortune et al. 2020), but the relevance for urban and regional planning processes is at best implicit in these analyses. There has been limited discussion in planning scholarship on the role of spatial data for regions with a size and composition that may vary over time, such as metropolitan regions. This is remarkable, considering the increasing emphasis in policy debates on the need for 'evidence' to inform spatial policy-making and assessing planning outcomes. While planning research has given limited attention to conceptualising and analysing spatial data in planning processes to date, debates in the spatial science literature have identified a fragmentation of spatial datasets across the different government levels, but have only on occasion considered the implications for the specific application of urban planning.

Also, in policy development and planning practice there appears a disconnect between the producers of data, and the users of spatial data, including urban planners. Challenges in relation to spatial data for urban planning are often not the result of missing data *per se*, but rather that data are not in the required formats, timescales, resolution, or are compatible with other datasets. The discussions in Australia about the economic value of spatial data, such as set out in the '2026 Agenda', have initially considered only the private sector as potential beneficiary of spatial data in order to contribute to economic growth and job creation. Societal benefits from 'better urban planning', and consequently the needs of public planning authorities in accessing spatial data, are only now beginning to receive political attention, for example in relation to the UN's Sustainable Development Goals, as discussed in chapter 2.

Bridging the gap between data providers and data users, especially in relation to the requirements of urban planning, will be important if progress towards sustainable development and low-carbon cities is to be made. This will, however, first require a political acknowledgement of the important role that spatial planning has in achieving positive societal outcomes - something which may be difficult to achieve given the current emphasis on facilitating economic investment and consequently the scaling back of planning regulation. For public sector planners therefore, the current course of action may be a more pragmatic one, by seeking to have a voice in discussions on SDI initiatives in Australia as an important user of spatial data, and by engaging with public sector data providers within their states to explore avenues for accessing spatial data that are 'fit for purpose'. The considerable number of geoportals and map viewers now available can be useful for Australian planning departments seeking greater transparency on datasets available. However, reviewing their content and reflecting on the usefulness of the sources to complete their planning tasks will require capacity and technical skills. Within state and local planning departments there is therefore a need to overcome the 'division of labour' between planning policy officers, spatial data analysts and GIS technicians. Providing public sector planners with at least basic skills in GIS and spatial data analysis will be important to allow an informed discussion with GIS technicians, and for urban planners to be able to express their data requirements clearly.

In terms of SDIs and related initiatives in Australia, the analysis presented in this report has shown that Australia will have some ways to go to achieve a comprehensive framework comparable to the EU's INSPIRE Directive. Given the nature of the federal system in Australia and the strong (federal and state) political leadership required to achieve a comprehensive and multi-level legal framework, this may not even be an ambition with a chance of realisation in the future. However, reaching agreement at national level on data standards and meta-data standards would be important, because the current decentralised approach to spatial data collection and provision by states with little coordination at the federal level presents considerable challenges. There is also a need to improve the involvement of local governments (and their own data collection efforts, which are often not coordinated with neighbouring or higher-level authorities) in discussions on SDIs at state level as well as across Australia. Particularly considering the opportunities for public sector urban planners to become more closely involved in the discussions on SDIs in Australia would be important, to ensure constructive communication and cooperation between data provider and end-users (planners). Woodgate et al. (2017) have suggested organising a two-way dialogue to improve the data situation for end-users, with users being able to ask open questions to providers and make suggestions based on their current and future needs. This might be a governance model that could be considered for urban and regional planning in Australia

However, while the focus on public sector data coordination is important, it will only be part of the solution. There are an increasing number of private sector spatial data providers, data analysts and modellers, who are not bound by existing legal frameworks such as public sector data sharing legislation. The privatisation in data provision will therefore present additional challenges for data governance. The often-considerable costs attached to access datasets, indicators and models collected and generated by private companies will make them prohibitive for many urban planning tasks, even though the datasets could be of considerable value to inform public policy.

The second objective of the research was achieved by focusing on a pilot analysis of metropolitan spatial planning policies for Greater Adelaide, as set out in the most recent '30-Year Plan for Greater Adelaide – Update 2017' (Government of South Australia 2017). This was done by selecting two of the policy themes set out in this metropolitan strategy, with a view to illustrating what spatial datasets would ideally be needed to develop and monitor metropolitan planning policies, and compare these with the actually available spatial datasets.

The analysis showed a considerable disconnect between the comprehensive and integrated planning policies (such as for activity centres or healthy neighbourhoods) presented in the metropolitan strategy, and the limited number of narrowly defined 'high-level' targets with their only marginally considered data needs. For the future metropolitan strategy for Greater Adelaide, which will be prepared under the PDI Act 2016 by the SA state government, it would be useful to consider data needs from the outset of the policy-making process and for the different stages of the policy cycle, so as to be in a better position to analyse spatial trends, develop spatial policies in response, and to set up monitoring arrangements early on. The considerable number of data initiatives over recent years, notably in relation to high-resolution and frequently updated remote sensing (2D) and LiDAR (3D) data, will offer greater opportunities also for urban planners. However, it will be important to engage with these data collection and data analysis initiatives from a planning perspective early on to make sure such datasets are accessible and can be tailored to the needs of the specific planning tasks.

The analysis of the spatial data implications arising from the 2017 Update of the 30-year plan for Greater Adelaide showed some important gaps in data availability, e.g. in relation to information on the mixed-use of land and buildings. It also highlighted some important 'blind spots' in current data collection and availability, notably in relation to 'flow data' (infrastructure usage) of cyclists and pedestrians, given that traffic flow data is still heavily focused on only measuring motorised road traffic use. Aside from challenges of harmonizing different spatial datasets, important gaps in data availability therefore also exist because of political preferences and resource decisions, resulting e.g. in a structural distortion towards representing 'hard' infrastructures and an overemphasis of road traffic data over other transport modes. Epistemologies that favour the representation of quantitative data (shown as points, lines and areas) over qualitative information, and that are biased towards static information over 'flow' data, are deeply ingrained in data collection processes (Dühr and Müller 2012). They have shaped the dominant understanding of what 'valid' data are, and (in often subtle ways) determine which spatial analyses can be undertaken. Existing challenges in relation to spatial data availability and harmonisation for metropolitan planning will likely be exacerbated by the on-going privatisation of data collection in parallel to shrinking public budgets (Pullar and Hayes 2019).

5.2 Suggestions for further research

This research was undertaken as a desk analysis only focussing on the published literature, and initial plans to engage with stakeholders from both the data provision side and from the user perspective (urban planners in government agencies, NGOs/NFPs and the private sector) could not be implemented as a consequence of the Covid-19 pandemic restrictions. In terms of future research, undertaking an analysis of the work of urban planners in Australia in relation to their understanding and use of spatial data, and their anticipated data needs to inform future planning tasks would therefore be important. This could also consider the challenges inherent in the 'division of labour' in state and local planning departments, between those officers involved in planning policy and plan implementation on the one hand, and those responsible for data analysis and mapping on the other, and how this division could be overcome to give planners a stronger voice in expressing their data requirements.

More research could be undertaken on possible approaches to establish a dialogue between the producers and users of spatial data in Australia and in different contexts. This could focus on communication and collaboration arrangements to ensure constructive debates, but also on the role of existing tools and platforms (such as geoportals) to improve the 'ready-ness' of spatial data from the perspective of users, including urban planners.

Given far-reaching changes to planning systems in many Australian states over recent years, including in South Australia, there is also a need to further investigate how the changing understanding of spatial planning in relation to its scope, instruments and links with other spatially-relevant policy sectors (such as environment, transport, economic development, health) will impact on (future) spatial data requirements. Aside from structural reforms, the past years have also seen an increasing attention to metropolitan-scale governance arrangements for Australia's capital cities to coordinate infrastructure investments and achieve more social cohesion. More research would be beneficial on the different types of metropolitan governance arrangements emerging (such as the Greater Sydney Commission, as compared to the South Australia where the state government is responsible for metropolitan planning) to analyse how metropolitan governance affects the requirements for spatial data to inform spatial planning at this scale. A future study could ideally involve a comparison between spatial data requirements for metropolitan planning in different Australian states.

Moreover, further research would be useful to better understand the implications of the 'outsourcing' of both planning tasks (from public sector departments to private sector consultancies) and the increasing privatisation of data collection and analysis on the ability of public sector planners to undertake evidence-based urban and metropolitan planning. A comparison of existing spatial data and map viewers with missing but relevant spatial data and geo-analytical tools for selected metropolitan planning tasks could help to understand current gaps, including those arising from on-going privatisation, and can help to highlight the benefits of addressing these gaps as well as demonstrate the importance of public sector planning and planners in acting in the interests of the public.

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Appendices

Appendix A: INSPIRE spatial data themes

INSPIRE ANNEX: 1

1. Addresses
2. Administrative units
3. Cadastral parcels
4. Coordinate reference systems
5. Geographical grid systems
6. Geographical names
7. Hydrography
8. Protected sites
9. Transport networks

INSPIRE ANNEX: 2

10. Elevation
11. Geology
12. Land cover
13. Orthoimagery

INSPIRE ANNEX: 3

14. Agricultural and aquaculture facilities
15. Area management / restriction / regulation zones & reporting units
16. Atmospheric conditions
17. Bio-geographical regions
18. Buildings
19. Energy Resources
20. Environmental monitoring Facilities
21. Habitats and biotopes
22. Human health and safety
23. Land use
24. Meteorological geographical features
25. Mineral Resources
26. Natural risk zones
27. Oceanographic geographical features
28. Population distribution and demography
29. Production and industrial facilities
30. Sea regions
31. Soil
32. Species distribution
33. Statistical units
34. Utility and governmental services

Source: Council of the European Union (2007); European Commission (2020)

Appendix B: Example of policy theme 1 – description and definitions

Example of policy theme: 'Transit corridors, growth areas and activity centres'

Description as provided in the 2017 Update of the 30-year plan for Greater Adelaide (Government of South Australia 2017, p. 41):
'Deliver a new urban form: Greater Adelaide's new urban form will support jobs and services in accessible locations and provide more housing options close to public transport. The city, mixed-use activity centres and transit corridors will be the focus of renewed activity and will be supported by rejuvenated neighbourhoods linked by integrated public transport systems and cycling networks. Townships and new fringe growth areas will be planned to ensure residents are connected to necessary infrastructure and services. Metropolitan Adelaide's population density is currently among the lowest in Australia, with an average of fewer than 1400 people per square kilometre. This makes it difficult to support investments in new public transport infrastructure through, for example, higher service frequencies such as the network of trams (AdeLINK) envisioned in the ITLUP. Cities around the world with light rail and/or underground trains have an average population density of at least 3000 people per square kilometre across their metropolitan areas and, as a result, have higher public transport use. Greater use of public transport, including walking and cycling infrastructure, can be achieved through a more compact urban form, mixed land uses and increased population density'.

Definitions as provided in the 30-year plan (Government of South Australia 2017, p. 171-178):

- **Transit corridors:** "are the walking catchments of light rail mass transit and high frequency bus routes. They are well serviced with infrastructure and when fully developed will contain a mix of housing including medium to high density and mixed-use developments". (p. 178)
- **Growth areas: "**These areas have been identified for urban expansion. They will be subject to further intensive investigations and public consultation". (p. 174)
- **Activity centres: "**are concentrations of business, administrative, civic, retail, residential, entertainment, employment, research, education and community uses. The purpose of activity centres is to cluster commercial and employment activity to improve accessibility, productivity and the efficient use of infrastructure. The Capital City centre, encompassing the central business district, is the pre-eminent activity centre in the Greater Adelaide region. Other more traditional activity centres are located in the metropolitan area and will be instrumental in the inclusion of residential development adjacent transit corridors over the life of the 30-Year Plan**".** (p. 171)
- **Urban renewal:** "This is the process of improving the economic, social and environmental sustainability of a particular urban area. It typically involves urban redesign, infrastructure renewal and investment, and the creation of more attractive residential environments" (p. 178).

Appendix C: Example of policy theme 2 – description

Example of policy theme 2: 'Health, wellbeing and inclusion'

Description as provided in the 2017 Update of the 30-year plan for Greater Adelaide (Government of South Australia 2017, p. 71):

'Create healthy neighbourhoods that promote cycling, walking and public life: Healthy, walkable neighbourhoods are places where people can afford to live, learn, work and play. They offer a wide range of services that can easily be reached on foot or by bicycle, including schools, health care, shops, parks, sports facilities and public transport. They also provide streets and public spaces that support diverse and vibrant public life, biodiversity and physical activity opportunities. They connect people with nature, support social interaction, are multi-functional and will better meet active and healthy lifestyles as Adelaide's new and more compact urban form evolves. Healthy neighbourhoods also have access to affordable and diverse housing options which meet Greater Adelaide's varied household and family structures. Creating compact mixed use communities ('the new urban form') is essential to supporting increases in walking, cycling and public transport. Higher residential densities are needed to create vibrant neighbourhoods by ensuring that there are enough people to support local shops, services, public transport and community facilities within walking distance. The better integration of transport and land use planning is a critical component of this'.