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How are Australian cities preparing for Autonomous Vehicles? A systematic review of transport and planning policies

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Abstract

Autonomous vehicles (AVs) are predicted to be occupying a high proportion of urban roads over the next few decades. While having a wide range of benefits such as safe navigations and efficiency in road use, AVs can have negative impacts including pollution. Many of those benefits and impacts are still unknown. Lack of comprehensive awareness of the potential impacts and consequences of using AVs have prevented the development of relevant policies and strategies. Instead of waiting for arrival of AVs into common roads, urban policies and strategies can prepare the infrastructure and social awareness to adopt AV technologies for the better. This study reviews the current AV related strategies and policies in Australian states/territories to evaluate their preparedness for the advent of AVs. Our review shows that New South Wales and South Australia have initiated plans and policies to adopt AV technologies, however, have different approaches and objectives. Victoria has developed some policies and strategies to prepare for common use of AVs, and Queensland has initiated trials and strategies. Other states and territories are yet to follow the developments and lessons learned from these states.

1. Introduction

Autonomous vehicles (AVs) have been gaining attention from policy makers, planners and researchers (Fraedrich et al., 2019, Saghir and Sands, 2020, González-González et al., 2019). Although not currently available for public use, AVs are predicted to be occupying a high proportion of roads over the next few decades (Shatu and Kamruzzaman, 2022, Cohen and Cavoli, 2019, Stead and Vaddadi, 2019). AVs are vehicles that operate through using various technological capabilities including machine learning, network analysis, and recognition algorithms to partially or completely take over the role of the human driver (Botello et al., 2019).

Scholars have identified a wide range of benefits for AVs, from lower travel costs, safe navigations and efficiency in road use to increased convenience and social equality (Freemark et al., 2019, Saghir and Sands, 2020). However, AVs can be associated with negative impacts such as increased road congestion, reduced use of public transport, higher environmental pollution and reduced accessibility for low-income groups (Freemark et al., 2019, Faisal et al., 2019). AV could also impact urban landscape and land uses, for example, by providing easy commute to distant destinations, which could encourage urban sprawl (Freemark et al., 2019, Legacy et al., 2019, Faisal et al., 2019, Staricco et al., 2019, Saghir and Sands, 2020, Stead and Vaddadi, 2019). Impacts of AVs on individuals, such as accessibility, are still to be studied as AVs are not yet publicly available for use and many of those impacts are not known (Botello et al., 2019). While some characteristics of AVs, such as self-parking and street space occupancy, have been widely studied and discussed, there is limited investigation around their impacts on land use, built environment and active transport (Fraedrich et al., 2019, Botello et

al., 2019). This lack of awareness of the potential impacts and consequences of using AVs have prevented the development of relevant policies and strategies.

AVs are described as disruptive technologies (Legacy et al., 2019, Faisal et al., 2019) and hence, require sufficient preparation and planning for their arrival into cities. These preparations provide opportunities for them to be advancing city mobility rather than disrupting it (Freemark et al., 2019, Staricco et al., 2019, Saghir and Sands, 2020, González-González et al., 2019). Urban policies and plans can shape the introduction and use of AVs in cities instead of adapting to and accommodating the emerging AV trends in cities (Stead and Vaddadi, 2019, Staricco et al., 2019, González-González et al., 2019). However, lack of evidence, social and environmental uncertainties, nature and magnitude of AV effects, and lack of comprehensive knowledge of AV impacts have resulted in limited development of plans and policies in this area (Staricco et al., 2019, Cohen and Cavoli, 2019, Faisal et al., 2021, González-González et al., 2019). Some governments such as the United States have introduced AV related policies (Freemark et al., 2019). Others, such as the Australian government, have just started to provide direction and guidelines for future policies and plans (Shatu and Kamruzzaman, 2022, Legacy et al., 2019). Examples of Australian initiatives are: the Federal Government's commitment to change driving laws to facilitate the operation of AVs (National Transport Commission, 2018), Automated Driving System permit scheme in Victoria (VicRoads, 2018), The Cooperative and Automated Vehicle Initiative (CAVI) in Queensland (Queensland Government, 2021), Motor Vehicles (Trials of Automotive Technologies) Amendment Act 2016 in South Australia (The Parliament of South Australia, 2016), and planning to build infrastructure capabilities to support partially and/or highly automated vehicles on motorways and major roads in New South Wales (Transport for New South Wales, 2020b). However, these efforts are towards supporting the operation of AVs and not on directing their introduction and use of them in the urban system.

This study reviews the current AV related strategies and policies in Australian states and territories to identify any planning gaps that need to be addressed in future policy making. The main research question of the study is 'how are Australian states and territories preparing for the arrival of AVs into their cities?'

Following this introduction, Section 2 outlines the 'Method' employed to address the research question. Section 3 'Results' presents the findings of the review process. Section 4 discusses the implications of the findings; and Section 5 summarises the main findings and provides conclusions.

2. Method

To address the research question, we collected and reviewed documents from state and territory governments in Australia that set guidelines, strategies and policies for city transport. The collection of documents started with a Google search directed at each of the Australian capital cities separately with the following search terms and their variants using the following script: ["city plan*" OR "strategic plan*" OR "transport strateg*" OR "land use plan*" OR "transport plan*" OR "regional plan*" OR "urban plan*" AND "[City Name]"] where city name was replaced by Australian capital cities in separate search intervals.

In the next step, we reviewed official websites of respective city governments and municipality websites for related documents containing keywords ["autonomous" OR "automated" or "driverless" OR "active transport*"]. This search process yielded 53 documents.

2.1 Document selection

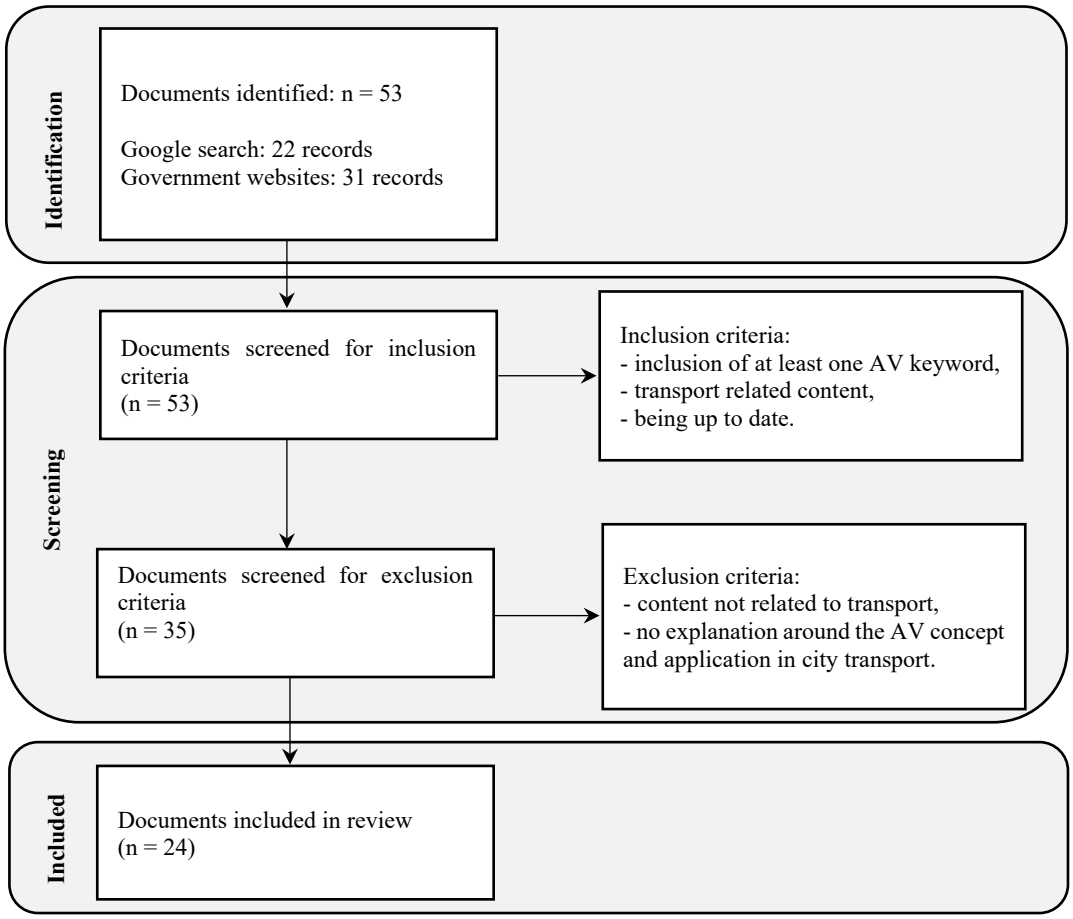
A set of inclusion and exclusion criteria were designed to identify related documents. The inclusion criteria included 'inclusion of at least one AV keyword', 'transport related content' and 'be up to date (e.g. published after 2010 or being the latest development of a series of related documents)'. Exclusion criteria included 'content not related to city transport', and 'no explanation around the AV concept and application in city transport'. The selection process yielded 24 documents for review.

2.3 Review approach

Following the selection process was the review of the documents to obtain important information for an overview of the recognition of AVs in current strategies and policies. The 24 eligible documents were reviewed, and their key information collected. The collected information was organised according to pre-defined variables (Table 1).

Figure 1 summarises the methodological approach for identifying relevant documents.

Figure 1. Identification of the documents for the review



2.4 Analysis approach

There is limited research about the place of AV in future transport plans and policies in the Australian context. Shatu and Kamruzzaman (2022) developed a conceptual framework to analyse the ways private AVs and shared autonomous vehicles (SAVs) could influence active transport. Their framework shows that AVs and SAVs could impact active transport through

35 different pathways/variables. The variables of the framework developed in this study are summarized in Table 1.

Table 1. AV variables affecting city transport

AV		**SAV**
Type of multitasking capabilities in AV	AV mode share	Separated SAV infrastructure
Efficiency in road space use	Separated AV lanes	SAV mode share
Cost of AV	Active transport related road rules	Attractiveness of SAVs
Human machine interaction technology	Current level of active transport use	Value of travel time saving
		Walking time
AV in shared road space	Land use Policy	Transfer + Wait time
Value of travel time saving	Accessibility	Coverage
Travel time	Sprawl	Fare
Ownership of AV	Congestion level	Type of multitasking capabilities in AV
Safety perception on AVs	AV speed	Stop location
AV related road rules	Active transport infrastructure	Integration with other modes
Attractiveness of AVs	Socio-demographics	Ownership of SAV

While variables listed in Table 1 are derived to analyse the impact of AVs and SAVs on active transport, it provides a distinct baseline to study AVs and SAVs in the absence of a comprehensive policy framework for Australian cities. Furthermore, as discussed by Sohrabi et al. (2020), increased awareness of AVs' impact on public health and sustainable transport can open the pathway for development of AV regulations and adaptation. We adopt the variables from Table 1 as AV attributes in city transport that need to be addressed in policies, strategies and guidelines. The information collected through our review (Section 2.3) were compared against the variables in Table 1 for analysis and discussion.

3. Results

The 24 documents included in the review can be grouped into 5 types as policies, plans and guidelines, strategies, legislations, and projects. Most of the documents belong to governments of New South Wales (NSW), South Australia (SA), and Victoria (VIC) by 25%, 20.8% and 20.8% respectively. Governments of Queensland (QLD) have produced 3 documents (12.5%), Western Australia (WA) two documents (8.3%), and Tasmania (TAS), Australian Capitan Territory (ACT) and Northern Territory (NT) each produced 1 document (4.2%). Table 2 shows the typology of the reviewed documents. The detailed document attributes are available in Appendix 1.

Table 2. Document typology

Document type	Frequency	Published by
Plans and guidelines	11	ACT, NSW, NT, SA, TAS, VIC, WA
Strategies	7	NSW, QLD, VIC, WA
Policies	2	SA
Legislation	3	NSW, QLD, SA
Project	1	QLD

Figure 2 shows the variations in the documents published by each state and territory. SA, NSW and QLD have published more diverse document types compared to VIC and WA. TAS, NT and ACT have only published plans and guidelines in relation to AV.

Figure 2. Documents typology in each state/territory

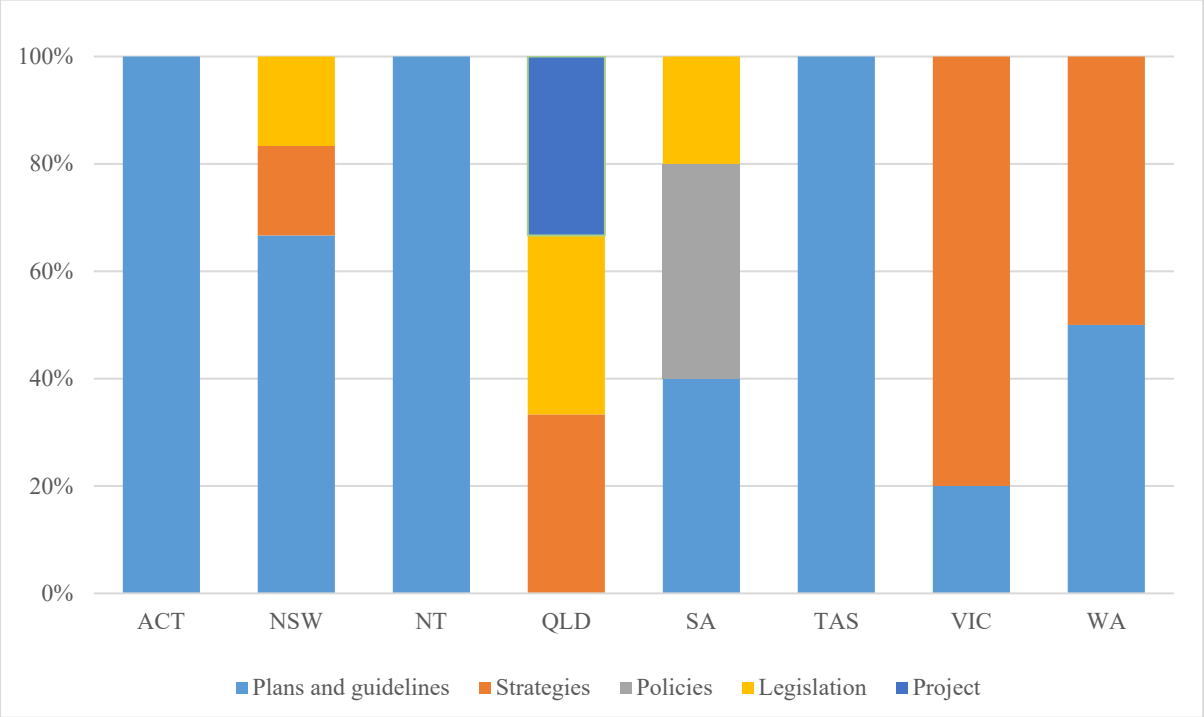
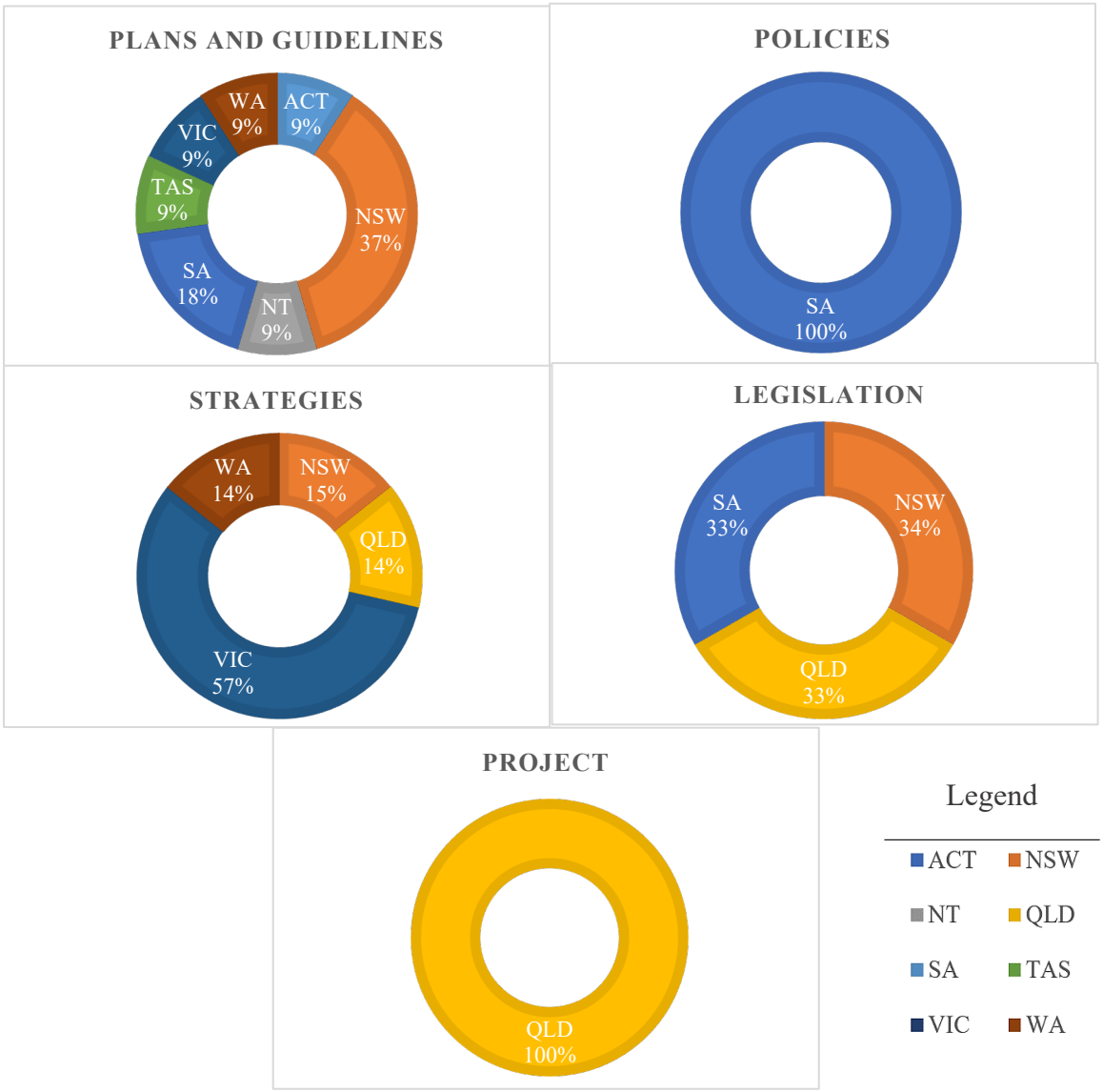


Figure 3 demonstrates the contribution of states and territories to each document type. Plans and guideline are commonly published documents containing AV related content. Policies and project types are only published in SA and QLD respectively.

Figure 3. State and territory contribution to document typology



3.1 AV variables in the document typology

Some AV variables are frequently addressed in the reviewed documents such AV related road rules, Safety perception on AVs, and AV in shared road space. Similarly, some variables related to active transport have been addressed in the review like Active transport infrastructure and Accessibility. On the contrary, variable such as Type of multitasking capabilities in AV and AV speed did not appear in the documents reviewed. Comparing variables in the AV group with those in the SAV group shows that SAV has attracted less attention in the policies and strategies.

Table 3 shows variable addressing information in the reviewed documents.

Table 3. AV variable requirements citations in document typology

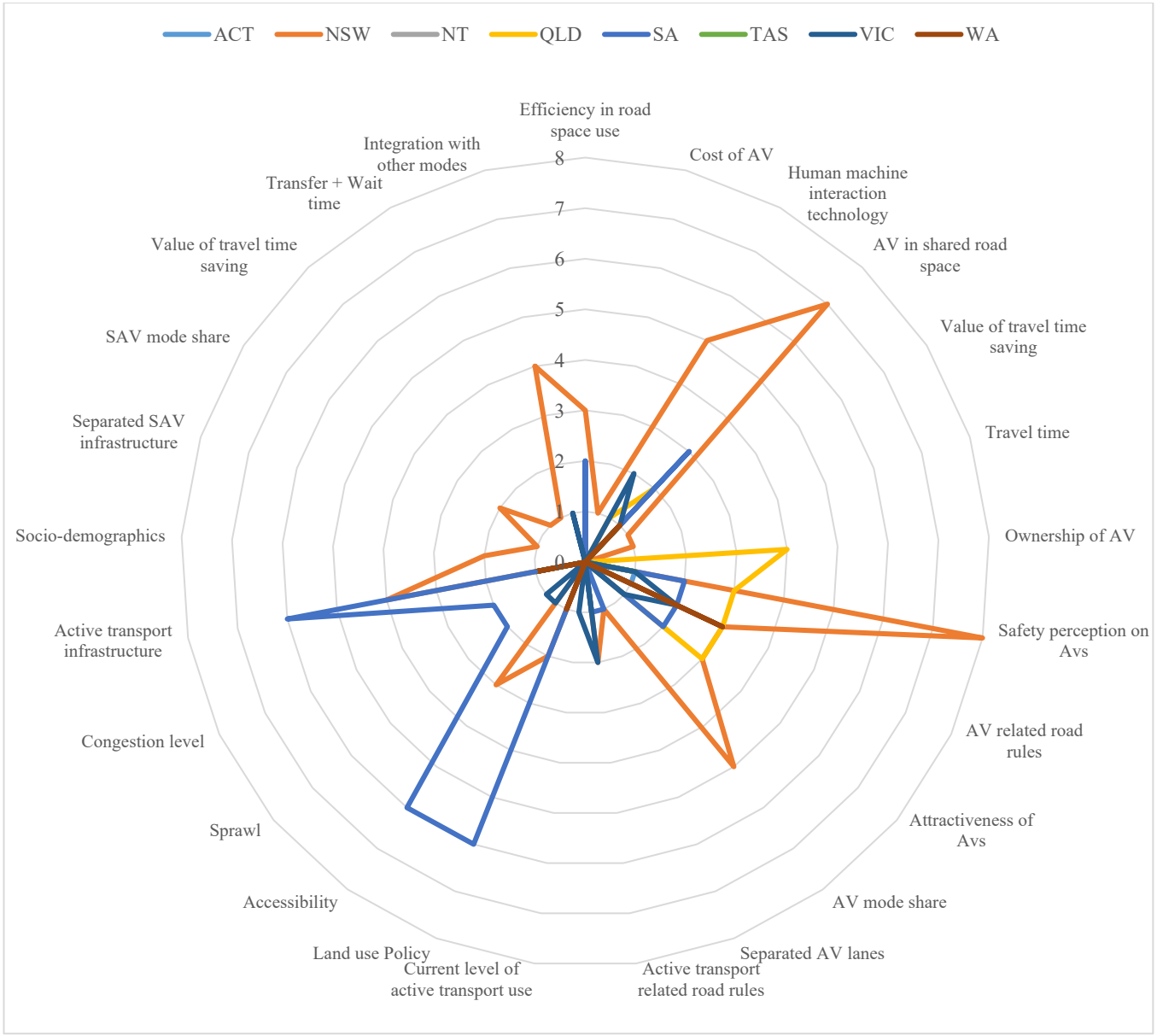
Variable group	Variables	Publishing state/territory	Number of citations	Document typology	Citations
AV	Type of multitasking capabilities in AV	-	-	-	-
	Efficiency in road space use	NSW, SA, QLD, VIC	6	Plans and guidelines; Policies; Project; Strategies	Greater Sydney Commision (2017), Transport for New South Wales (2020b), Transport for New South Wales (2020a), Government of South Australia (2017), The State Planning Commission (2019), Queensland Government (2021)
	Cost of AV	NSW	1	Strategies	Transport for New South Wales (2020b)
	Human machine interaction technology	NSW, QLD, VIC	8	Plans and guidelines; Project; Strategies	Transport for New South Wales (2020a), Queensland Government (2021), Victoria State Government (2021), Victoria State Government (2020)
	AV in shared road space	NSW, SA, QLD, VIC, TAS, WA	15	Plans and guidelines; Legislation; Policies; Project; Strategies;	Transport for New South Wales (2020b), Transport for New South Wales (2021b), Transport for New South Wales (2020a), The Parliament of South Australia (2016), Government of South Australia (2017), The State Planning Commission (2019), Queensland Government (2021), Department of Transport and Main Roads (2020), Victoria State Government (2020), Venkataraman (2021), The Government of Western Australia (2020)
	Value of travel time saving	NSW	2	Plans and guidelines	Greater Sydney Commision (2017)
	Travel time	NSW	1	Plans and guidelines	Greater Sydney Commision (2017)
	Ownership of AV	QLD	4	Project; Strategies	Queensland Government (2021), Department of Transport and Main Roads (2020)
	Safety perception on Avs	ACT; NSW; SA; QLD	16	Plans and guidelines; Legislation; Project; Strategies	Australian Capital Territory (2020), Transport for New South Wales (2020b), Transport for New South Wales (2021a), Transport for New South Wales (2020a), Parliament of New South Wales (2017), Government of South Australia (2019), State Planning Commission (, Queensland Government (2021), Motor Accident Insurance Commission (2021), Department of Transport and Main Roads (2020), City of Melbourne (2020), Venkataraman (2021)
	AV related road rules	ACT, NSW, SA, QLD, VIC, WA	14	Plans and guidelines; Strategies; Legislation	Australian Capital Territory (2020), Transport for New South Wales (2021b), Transport for New South Wales (2020a), The Parliament of South Australia (2016), Government of South Australia (2017), State Planning Commission (, Motor Accident Insurance Commission (2021), Department of Transport and Main Roads (2020), City of Melbourne (2020), VicRoads (2018), The Government of Western Australia (2020), Department of Transport et al. (2020)
	Attractiveness of Avs	NSW, SA, QLD, VIC	9	Plans and guidelines; Policies; Project; Strategies;	Transport for New South Wales (2020a), The State Planning Commission (2019), Queensland Government (2021), Victoria State Government (2019)
	AV mode share	NSW	5	Plans and guidelines	Transport for New South Wales (2021b), Greater Sydney Commision (2017), Transport for New South Wales (2020a)
	Separated AV lanes	NSW, SA	2	Plans and guidelines	Transport for New South Wales (2020a), Government of South Australia (2017)

Variable group	Variables	Publishing state/territory	Number of citations	Document typology	Citations
	Active transport related road rules	ACT, NSW, SA, VIC	6	Plans and guidelines; Policies; Strategies	Australian Capital Territory (2020), Transport for New South Wales (2021b), The State Planning Commission (2019), Victoria State Government (2021), Victoria State Government (2020)
	Current level of active transport use	VIC	1	Strategies	Victoria State Government (2019)
	Land use Policy	NSW, SA, WA	9	Plans and guidelines; Policies; Strategies	Transport for New South Wales (2020a), (Government of South Australia, 2017), The State Planning Commission (2019), The Government of Western Australia (2020)
	Accessibility	NSW, SA, VIC	10	Plans and guidelines; Policies; Strategies	Greater Sydney Commision (2017), Transport for New South Wales (2020a), Government of South Australia (2017), The State Planning Commission (2019), City of Melbourne (2020)
	Sprawl	SA, VIC	3	Strategies; Policies	The State Planning Commission (2019), City of Melbourne (2020)
	Congestion level	SA	2	Policies; Plans and guidelines	The State Planning Commission (2019), Government of South Australia (2017)
	AV speed	-	-	-	-
	Active transport infrastructure	ACT, NSW, SA, VIC, TAS, WA	14	Plans and guidelines; Policies; Strategies	Australian Capital Territory (2020), Transport for New South Wales (2021b), Transport for New South Wales (2021a), Government of South Australia (2017), The State Planning Commission (2019), Victoria State Government (2019), Venkataraman (2021), Department of Transport et al. (2020)
	Socio-demographics	NSW	2	Plans and guidelines	Transport for New South Wales (2020a)
SAV	Separated SAV infrastructure	NSW	1	Plans and guidelines	Transport for New South Wales (2021b)
	SAV mode share	NSW	2	Plans and guidelines	Transport for New South Wales (2021b)
	Attractiveness of SAVs	-	-	-	-
	Value of travel time saving	NSW	2	Plans and guidelines	Greater Sydney Commision (2017)
	Walking time	-	-	-	-
	Transfer + Wait time	NSW	1	Plans and guidelines	Greater Sydney Commision (2017)
	Coverage	-	-	-	-
	Fare	-	-	-	-
	Type of multitasking capabilities in AV	-	-	-	-
	Stop location	-	-	-	-
	Integration with other modes	NSW, VIC	5	Plans and guidelines; Strategies	Greater Sydney Commision (2017), Transport for New South Wales (2021b), Victoria State Government (2019)
	Ownership of SAV	-	-	-	-

Interesting to note that NT has developed one document (plans and guidelines) in relation to AV, however, it has not addressed any of our targeted variables from Table 1.

A comparison of the states and territories in addressing the AV variables is shown in Figure 4. Table 3 and Figure 4 illustrate that NSW and SA have been more proactive in developing plans and policies for AV preparation of the cities. VIC and QLD have same level of activity in developing documentation. However, VIC's publications are mostly strategies and QLD's publications are around their Cooperative and Automated Vehicle Initiative (CAVI). TAS, NT and ACT have similar approach in their guidelines and plans with specific focus on observing the general trends in Australia and following the advancements by other states.

Figure 4. Comparison of the states and territories in addressing AV variables[1]



[1] The variables with no citation are excluded from Figure 4 to improve readability

4. Discussion

The most cited variable in the document review is **Safety perception on AVs**. Although AVs are not available to the public yet, Australian policy makers are concerned with any potential safety implications. The **Safety perceptions of AVs** is twofold. One perception considers AV an opportunity to improve mobility through provision of road safety benefits (Australian Capital Territory, 2020, Department of Transport and Main Roads, 2020). The other perception is concerned with the reliability of AV performance (Transport for New South Wales, 2021a, Government of South Australia, 2019, City of Melbourne, 2020), provision of compatible infrastructure (Transport for New South Wales, 2021a), and need for them to comply with regulations (Transport for New South Wales, 2020a). The latter perspective has received more attention from states and territories. The legislative documents from SA (The Parliament of South Australia, 2016) and NSW (Parliament of New South Wales, 2017) are also concerned with the safety of AVs. In this regard, QLD has made third party insurance for all AVs compulsory (Motor Accident Insurance Commission, 2021).

AV in shared road space has also been frequently addressed in our document review. While some states such as NSW (Transport for New South Wales, 2020b, Transport for New South Wales, 2020a), VIC (Victoria State Government, 2020) and QLD (Department of Transport and Main Roads, 2020) are more concerned with the required infrastructure (e.g. sensors and data collection), other states like SA (Government of South Australia, 2017, The State Planning Commission, 2019) and WA (The Government of Western Australia, 2020) consider the long term impact of AVs on urbans forms, and liveability and sustainability of the cities.

Unlike **AV in shared road space**, the two variables **Separated AV lanes** and **Separated SAV infrastructure** have minimal considerations in the documents. This difference indicates that the policy makers are inclined towards making adjustment to the available infrastructure and accommodating AVs and SAVs into shared roads rather than developing separate facilities for them.

AV mode share, **SAV mode share**, and **Integration with other modes** have appeared several times in the NSW documents, emphasizing on their role in delivering mobility as a service (Transport for New South Wales, 2021b, Transport for New South Wales, 2020a, Greater Sydney Commision, 2017). Victoria also supports the integration of AVs and SAVs as potential new rideshare options (Victoria State Government, 2019).

AV related road rules are frequently addressed in the reviewed documents. The legislative documents from NSW, GLD and SA have already considered regulative measure for AV compliance with road rules and responsible parties in the event of accidents. NSW and WA have priorities the implementation of nationally consistent regulations and policies and VIC's policies include protection of urban amenities. VIC also developed Automated Driving System permit scheme in preparation for the relevant road regulations.

Variables such as **Travel time**, **Value of travel time saving**, and **Transfer + Wait time** have only been noted in NSW (Greater Sydney Commision, 2017) as part of their net-zero emissions pathway towards sustainability. AVs are expected to contribute to this objective by potentially connecting residents to nearby strategic or metropolitan centres in a 30-minute timeframe.

QLD has reviewed **Ownership of AV** in their strategies and the CAVI project through raising awareness of the benefits of the technology, understand user perceptions and building partnerships to increase AV capabilities (Queensland Government, 2021, Department of Transport and Main Roads, 2020).

Similar to the **Ownership of AV**, states such as NSW and QLD reviewed the **Attractiveness of AVs** through their role in mobility services by raising public awareness of AV benefits, increase user acceptance through communication, demonstrations etc. SA on the other hand, sees **Attractiveness of AVs** in their capacity to increase liveability and sustainability of cities (The State Planning Commission, 2019).

NSW reviewed the **Socio-demographics** and **Land use policy** variables in their plans by and supporting optimal us e of AVs. SA is preparing policy frameworks to address AV in future **Land use policy** planning by investigating the impact of AV on future urban form and considering mix-used developments, supporting both AV technology and active transport. SA follows the same mix-used approach in the policies to prevent **Sprawl** and monitor **Congestion level**.

The variables related to active transport have appeared frequently in the document review however, not many have been addressed in line with AV related policies. Specifically, **Active transport infrastructure** and **Active transport related road rules** have been mentioned in the documents from all states. While SA have been focused on improving the infrastructure to promote, enhance and encourage active transport, NSW and TAS emphasized on the safety measures for current active transport facilities. VIC aims to expand the facilities and infrastructure and improve the safety for active transport users. WA and VIC plan to investigate Current level of active transport use to plan for promotion and encouragement of active transport. **Accessibility**, another active transport variable, is addressed in NSW in line with **Attractiveness of AVs** and their advantages. In SA, **Accessibility** is part of their mix-used development plans to create walkable, carbon-efficient environments in cities.

5. Conclusion

Our review showed that Australian states and territories have started their preparation for the arrivals of AVs to their cities. While SA and NSW have plans and policies in place, QLD and VIC developed strategies and projects to evaluate the needs and prepare for future developments. WA, TAS, ACT and NT have indicated the need for future policy developments and regulations, but their current activities involve following and monitoring other states and the federal government's actions.

The states' policies are also diverse in their directions and approaches. SA is mainly concerned with sustainability and creating liveable, walkable, and accessible city centers. NSW has directed their efforts towards provision of infrastructure for AVs and take advantage of their benefits. QLD is invested in their CAVI project but also developed strategy and legislation as preventative measures. VIC follows a mixed approach, through enhancing sustainability and preparing facilities and infrastructure for AVs in cities. Future research could analyse the implications of the variables across the documents identified in this research and evaluate their effectiveness for future transport planning in Australia.

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Appendix 1. Documents included in the review

State/territory	Document title	Document type
Australian Capital Territory (ACT)	ACT Road Safety Action Plan 2020-2023	Plans and guidelines
New South Wales (NSW)	Future Transport Strategy 2056	Strategies
	Future Transport Technology Roadmap 2021-2024	Plans and guidelines
	A Metropolis of Three Cities	Plans and guidelines
	2026 Road Safety Action Plan	Plans and guidelines
	Future Transport 2056 - Connected and Automated Vehicles Plan	Plans and guidelines
	The Transport Legislation Amendment (Automated Vehicle Trials and Innovation) Act	Legislation
Northern Territory (NT)	Working with other states and jurisdictions to develop a national automated vehicle regulatory framework	Plans and guidelines
Queensland (QLD)	The Cooperative and Automated Vehicle Initiative (CAVI)	Project
	MAIC - Motor accident Insurance Commission	Legislation
	Queensland Transport Strategy	Strategies
South Australia (SA)	Motor Vehicles (Trials of Automotive Technologies) Amendment Act 2016	Legislation
	Automated Vehicle Trials Safety Assurance Framework	Plans and guidelines
	The 30-Year Plan for Greater Adelaide - 2017	Plans and guidelines
	State Planning Policies for South Australia - 2019	Policies
	State Planning Policies Engagement Report - Section 73 (7) of the Planning, Development and Infrastructure Act 2016	Policies
Tasmania (TAS)	Inquiry into Road Safety in Tasmania	Plans and guidelines
Victoria	City of Melbourne transport strategy 2030	Strategies

(VIC)	Department of Transport Strategic Plan 2021-2025	Strategies
	Victorian Road Safety Strategy 2021–2030	Strategies
	Department of Transport Strategic Plan 2021-2025	Strategies
	VIC roads	Plans and guidelines
Western Australia (WA)	Department of Transport Strategic Plan 2020-22	Strategies
	Connecting People and Places Transport Portfolio 2019-20	Plans and guidelines