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How Are the Smart City Concepts and Technologies Perceived and Utilized? A Systematic Geo-located Twitter Analysis of Smart Cities in Australia

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Highlights

- Innovation, sustainability, and governance are the most popular smart city concepts in Australia
- Internet-of-things, artificial intelligence, and autonomous vehicle technologies are the most popular smart city technologies in Australia
- A balanced concept-technology view exists on perceiving smart cities in Australia
- Sydney, Melbourne, and Brisbane are the leading Australian smart cities
- Systematic geo-located Twitter analytics is an effective analysis technique in urban studies

How Are the Smart City Concepts and Technologies Perceived and Utilized? A Systematic Geo-located Twitter Analysis of Smart Cities in Australia

Abstract: Smart cities is a hot topic in debates about urban policy and practice across the globe. There is, however, limited knowledge and understanding about: Trending smart city concepts and technologies; Relationships between popular smart city concepts and technologies; Policies that influence perception and utilization of smart city concepts and technologies. The aim of this study is to evaluate how smart city concepts and technologies are perceived and utilized in cities. The methodology involves a social media analysis approach—i.e., systematic geo-located Twitter analysis—that contains descriptive, content, policy, and spatial analyses. For the empirical investigation, the Australian context is selected as the testbed. The results reveal that: (a) Innovation, sustainability, and governance are the most popular smart city concepts; (b) Internet-of-things, artificial intelligence, and autonomous vehicle technology are the most popular technologies; (c) A balanced view exists on the importance of both smart city concepts and technologies; (d) Sydney, Melbourne, and Brisbane are the leading Australian smart cities, and; (e) Systematic geo-located Twitter analysis is a useful methodological approach for investigating perceptions and utilization of smart city concepts and technologies. The findings provide a clear snapshot of community perceptions on smart city concepts and technologies, and inform smart city policymaking.

Keywords: smart cities; smart city policy; social media; Twitter; data analytics; big data; Australian cities

1. Introduction

At the dawn of global socioeconomic and environmental crises, the utilization of smart city technologies is seen by many city administrations as a popular avenue to achieve desired urbanization outcomes (Albino et al., 2015; Komninos, 2016). A smart city can be described as an urban locality that employs digital data and technology to create efficiencies for boosting economic development, enhancing quality of life, and improving sustainability of the city (Bibri, 2019). Today, many cities are developing sound smart city strategies, and turning them into official local policies (Townsend, 2013). Successful approaches and practices are emerging in London, San Francisco, Singapore, Stockholm, Toronto, Vienna, and in a few other cities (Yigitcanlar & Kamruzzaman, 2018).

Despite the emergence of good smart city policy practices, our knowledge and understanding about how smart city concepts and technologies are perceived and utilized in cities is very limited (Mah et al., 2012). For instance, the literature does not provide clear answers to the following questions: Which smart city concepts and technologies are currently trending? What are the relationships between popular smart city concepts and technologies? What are the official smart city policies that influence perception and utilization of smart city concepts and technologies? The answers to these questions will inform policymakers and planners in shaping their future policy agendas—e.g., improving the quality and implementation of smart city policies.

In order to address this gap in the literature, the paper evaluates 'how relevant smart city concepts and technologies are perceived and utilized' in cities. This investigation is undertaken through a case study analysis. Australian cities are selected as the testbed—as they are among the early and successful adopters of smart city technologies (Pettit et al., 2018). The study provides a snapshot of community perceptions on smart city concepts and technologies with the objective to inform smart city policymaking.

The methodological approach adopted in this study utilizes a novel approach—instead of traditional survey and interview techniques. Thanks to the proliferation of social media platforms, capturing and evaluating community perceptions has become much easier (Williamson & Ruming, 2019). Social media motivates people to express their thoughts, criticisms, reflections in the form of social media posts (Kankanamge et al., 2020). By commenting, sharing, and responding to such posts, people create trending topics in social media networks—and some go viral (Dufty, 2016). Thus, in this study, trending smart city concepts and technologies are identified and analyzed through the social media analysis of geo-located Twitter messages (tweets).

There are two different types of locations associated with a tweet: (a) Geo-tagged tweets that give the exact longitude and latitude information of the sender; (b) Geo-located tweets that give the area name of the sender's location—e.g., Sydney. In this study, initially geo-tagged tweets are indented to be used, but as there were very limited number of them, instead both geo-tagged and geo-located tweets are used. As the numbers of the geo-tagged tweets were marginal (n=64), in this study we refer the combined set of geo-tagged and geo-located tweets as 'geo-located' (n=3,073). The systematic geo-located Twitter analytics method—containing descriptive, content, policy, and spatial analyses—is used to harvest community perceptions expressed as tweets on smart city-related concepts and technologies.

2. Literature Background

The urbanization rate across the globe has been growing exponentially (Arbolino et al., 2017). Urbanization, when practiced as densification, can have positive consequences in making urban footprint smaller. Nonetheless, when urbanization is coupled with overpopulation, excessive consumerism, and fossil fuel energy dependency, its consequences become catastrophic for the natural systems (Mysterud, 2017; Arbolino et al., 2018). If these issues are not addressed, the challenges of greenhouse gas emissions, climate change, resource scarcity, housing affordability, and food security will become even more acute, threatening our existence on the planet (Zhang et al., 2013; Yigitcanlar et al., 2019b).

Along with sustainability issues, high urbanization levels put heightened pressures on urban infrastructure, amenity and service delivery, and governance of cities (Grossi & Pianezzi, 2017; Mora et al., 2017). Housing large populations in cities—particularly in megacities of over 10 million residents—adds further to the already significant challenges facing urban administrations (Ersoy, 2017). This has led city authorities to search for innovative methods and mechanisms, such as smart and sustainable infrastructures to deliver urban services with increased efficiency (Mora et al., 2019).

In recent years, urban policymakers and technocrats have been adopting technology-centric solutions (such as autonomous vehicles, internet-of-things, artificial intelligence, smart poles, digital twins, blockchain, bigdata, robotics, open data) to urban development and management more than ever (Söderström et al., 2014; Faisal et al., 2019; Yigitcanlar et al., 2019d). Technocentric urban management approaches, which are a part of the 'smart cities' agenda, have become mainstream in many local governments (Caragliu et al., 2011; Praharaj et al., 2018). The digital data and technology utilization aspect of smart cities is widely recognized as their distinctive characteristic in boosting economic growth, enriching living conditions, and maintaining environmental sustainability (Winden & Buuse, 2017; Joss et al., 2019).

The popularity of smart cities has increased rapidly due to their offerings of the digitalization of cities (Yigitcanlar, 2009; Aina, 2017). Paradoxically, the extreme reliance on technology has also created drawbacks. Scholars argue that this dependency on technology solutions could become a threat in the near future. According to Kunzmann (2014, p.9), "there is a darker side of smart city that is not much the access to this technology, but rather the extreme dependency on technology, and on corporations dominating technology and related services".

There are various conceptual smart city frameworks developed so far. For instance, Giffinger & Pichler-Milanović's (2007) put together the following key dimensions in a smart city framework comprising smart environment, people, economy, living, mobility, and governance. This framework was adopted by the European Union. There are few other smart city frameworks. The most notable ones are developed by Errichiello & Marasco (2014), Fernandez-Anez et al. (2017), and Yigitcanlar (2018). These frameworks aimed at providing a clearer view on how the smart city idea can be best operationalized to deliver desired outcomes.

In general, smart city frameworks can be grouped under two categories. The first category is the conceptual frameworks that encompass theories, typologies, features, and strategies for understanding smart cities. They provide the big picture view (De-Jong et al., 2015). The second category is the practical frameworks that contains processes, planning mechanisms, and performance evaluation tools for transforming cities into smart cities. They provide sectoral, specific application area or practical perspectives (Aina, 2017).

There is not any widely accepted generic smart city framework—either conceptual or practical (Deakin & Reid, 2018). Increasing number of local governments have also developed their own smart policy frameworks. To name a few, the following cities have fully-fledged official smart city government policies: Belfast, Brussels, Greenwich, London, Newcastle, Nottingham, Ottawa, San Francisco, San Jose, Singapore, Stockholm, Toronto, Vienna, and Western Sydney (Yigitcanlar et al., 2019c).

Each of these official smart city strategies has their own unique features, and their common elements. Some of them adopted smart city frameworks developed by scholars. For instance, Giffinger & Pichler-Milanović's (2007) framework was adopted in the smart city policy of the City of Newcastle (Australia). Some others formed their own—e.g., Vienna. Despite the popularity of smart cities policy/practice; how relevant concepts and technologies are being perceived and utilized is still an understudied area of research (Alizadeh, 2015; Komninos et al., 2019).

3. Research Design

3.1. Case study

The research selected Australian cities as the case study context. Table 1 shows the 2016 population of Australian states and territories—for the sake of simplification, territories will also be referred to as states in the rest of this paper. The case selection was done due to the following reasons: (a) Australian cities are among the early adopters of smart city technologies (Yigitcanlar, 2018; Yigitcanlar & Kamruzzaman, 2019); (b) Australian cities are listed among the reputable global smart cities (Anthopoulos, 2017); (c) Australian Government introduced a smart city policy in 2016; (d) At present, more than 50 large scale smart city projects across the country are in progress—e.g., Parramatta City Council's smart warning system for flooded roads; Logan City Council's smart urban irrigation system; Cairns Regional Council's smart climate responsive neighborhoods, and; Monash City Council's i-Sense Oakleigh smart connected precinct.

Table 1: Australian state and territory populations

State/Territory	Population
New South Wales (NSW)	7,480,228
Victoria (VIC)	5,926,624
Queensland (QLD)	4,703,193
Western Australia (WA)	2,474,410
South Australia (SA)	1,676,653
Tasmania (TAS)	509,965
Australian Capital Territory (ACT)	397,397
Northern Territory (NT)	228,833

3.2. Data

In recent years, social media channels have been frequently used as key data sources in academic studies. The followings can be given as examples: (a) Determining post-disaster damage levels in smart cities (Kankanamge et al., 2020); (b) Evaluating community perceptions, through opinion mining, on smart city projects (Alizadeh et al., 2019); (c) Calculating home-work travel metrics as smart urban mobility measure (Osorio-Arjona et al., 2019); (d) Assessing the impact of smart tourism policies (Brandt et al., 2017). Despite increasing number of studies, the use of social media content and analytic techniques in relation to smart city concepts and technologies is still an understudied area of research.

This research adopted an analysis framework introduced by Fan & Gordon (2014) to conduct social media data analysis. Social media has altered our modes of work and life, has received attention from multiple fields (Kane, 2017), and there is also an increasing trend toward social media as a source of big data in urban research (Ciuccarelli et al., 2014). The systematic geo-located Twitter analysis framework the study used contains three analysis stages—i.e., 'capture', 'understand', and 'present' (Figure 1).

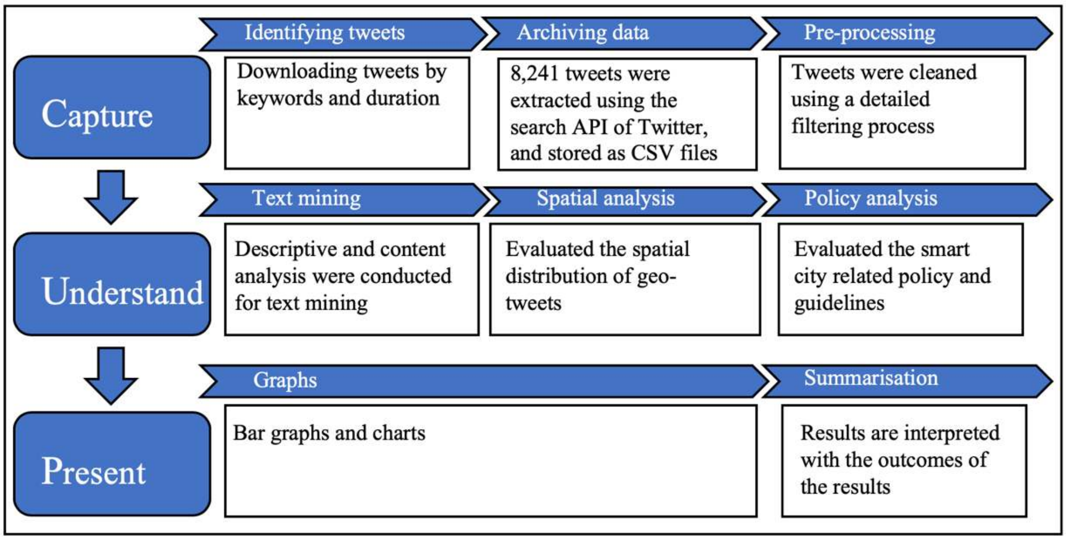

Figure 1: Systematic geo-located Twitter analysis framework (Fan & Gordon, 2014)

The first stage of the framework involves 'capturing' social media information. This study selected Twitter as a potential social media platform. Nonetheless, Twitter has certain merits and limitations. The main merits include: (a) Twitter is the fastest growing social media microblogging service; (b) Researchers and practitioners can use a free Twitter 'application programming interface' (API) to conduct analysis based on their interests; (c) As opposed to Facebook and Instagram, Twitter data is considered as 'open data', which provides succinct real-time data to public (Dufty, 2016); (d) Search and streaming APIs of Twitter allow researchers to write queries and download information under certain keywords and/or hashtags (Guan & Chen, 2014); (e) Analyzing Twitter data is a novel method of harvesting dispersed community knowledge (Kankanamge et al., 2019b).

The main limitation is the restricted API-based data accessibility, where APIs provide access to only 1% of publicly available Twitter data. From this sample, only around 10% is either geo-located or geo-tagged (Cebeillac & Rault, 2016). Even from geo-located and geo-tagged tweets, geo-tagged tweets are becoming further hard to collect. This is due to not sharing personal mobile location information and ethical barriers as such information consist the exact latitude and longitude information of the people.

For instance, from the collected data for this analysis only 64 tweets were consisted with geo-tagged information. Therefore, geo-tagged information is often collected through data providers—i.e., DataSift, with 100% access, which is a costly approach, or geo-tagged tweets become often during crisis periods (Kankanamge et al., 2020). As another limitation, Lin & Cromley (2015) highlighted the bias age group of the Twitter data. Despite these limitations, there is an increasing number of studies use tweets as the main data source (Brandt et al., 2017; Yuan & Liu, 2018).

In this study, Twitter data was collected for the most recent full year—i.e., 2018. The data capturing process started with the identification of keywords. Accordingly, the study downloaded tweets with the keywords of 'smart', 'city', and 'cities' circulated in 2018—between 1 January and 31 December 2018—within Australia. The study did not use the hashtag of #smartcity to download the data as it would limit the retrieved number of tweets. These tweets are already picked up by our abovementioned search keywords. Data was downloaded through APIs obtained from the developers of Twitter. In total, 8,241 tweets were obtained. This dataset was not structured; it included duplicates and incomplete or unusable tweets. The study adopted the four-step data cleaning process, introduced by Arthur et al. (2018) to clean the data.

The four-step data cleaning process consists of time zone, date, bot, and relevance filters. Time zone and date filters removed tweets from the downloaded dataset that are originated from outside of Australia and time period selected. These two filters were applied at the time of downloading data using the Spyder python programming software. Bot and relevance filters were conducted by using Nvivo—a content analysis software. Bot filter removed the repetitions generated through automatic systems. Bots can be easily recognized through the number of repetitions exist—e.g., repeated conference notifications/reminders. Relevance filter was conducted manually by closely inspecting tweets, which are used with a different meaning—e.g., smart people. From the downloaded 8,241 tweets, only 3,073 of them qualified to be used in the study. Figure 2 presents the selection criteria, and types of analyses.

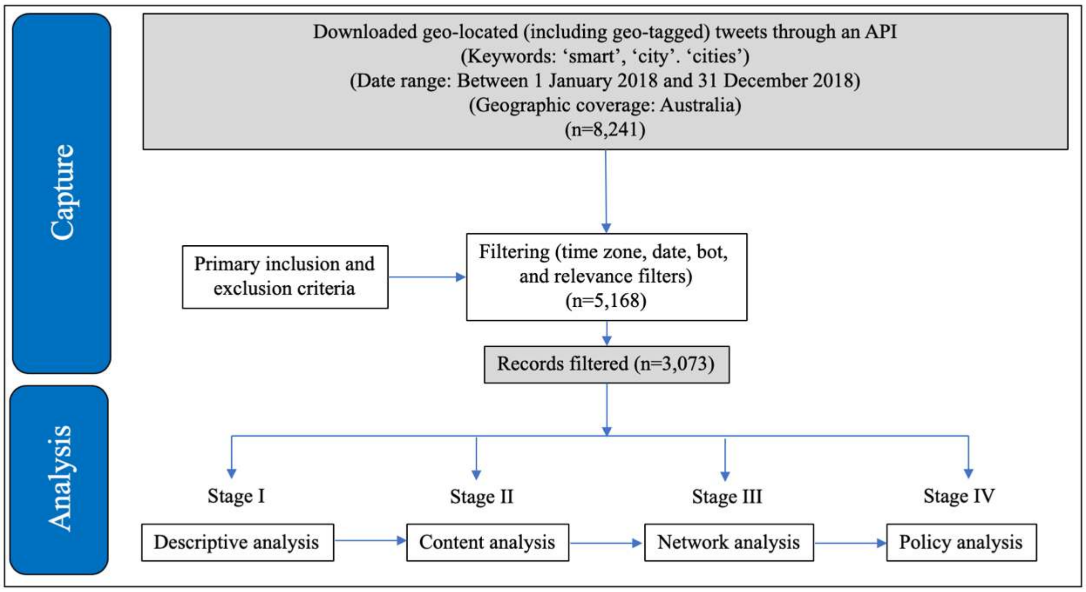

Figure 2: Tweet selection criteria for analysis

The second stage of the framework involved 'understanding' what tweets say/communicate. Four different, but intertwining, analyses were used to understand tweets. They were descriptive, content, network, and policy analyses.

The last stage of the framework involved 'presenting' outcomes of the abovementioned analyses. It adopted appropriate visualizing techniques such as graphs, maps for an easy communication of the results.

3.3. Descriptive analysis

Twitter data contains various information, such as 'created_date', 'user-screen name', 'user-name', 'text', 'photo/video', and 'user-location'. The study used a descriptive analysis (DA) to deliver a broader view about the captured data. This study focused on three descriptive statistics namely Twitter statistics, user analysis, and web-link (URL) analysis. Identifying prominent hashtags are especially useful for urban planners as tweets reflect the emotive and evaluative perceptions of the citizens. Twitter statistics provided information about the number of active users, number of retweets and number of hashtags used. The study considered all 'retweets' as new tweets with the related location of the retweet sender. This information acted as a gateway for many other inline analyses, such as content analysis and spatial analysis.

3.4. Content analysis

Tweets are informal in nature, and consist of lay language, acronyms, URLs, photos, videos, and ideograms. They also contain people's opinions. Analyzing tweets is a sensitive and significant task. Word frequency analysis was the initial point for the content analysis. Word frequency analysis identified the popular concepts and technologies, and then the co-occurrence of words helped in determining the linkages among the concepts and technologies. Popular concepts and technologies reflect both hidden and dispersed community knowledge around smart cities.

The study also conducted a spatial analysis to complement the content analysis. For the analysis, we used the location information collected in tweets to categorize the main themes of the analysis by their locations. We categorized the most popular concepts and technologies into themes based on the origin of tweets (i.e., city and state) using co-occurrence frequencies of words. This presented a snapshot of the most popular concepts and technologies for each state.

3.5. Network analysis

This research used a network analysis to present the association between concepts and technologies and their popularity (centrality). Different metrics can be used in network theory to interpret the strength and topology of a network. We used nodes (concepts and technologies) and edges (relationships between these concepts and technologies) as the key elements of the network. Nodes and edges help in interpreting the network topology. The network topology represents a layout of nodes and edges created based on the co-occurrence of concepts and technologies in tweets and retweets.

Two types of network analysis emerged through the network theory. These analyses were centrality and community-level analyses. First, centrality analysis considered the significance of each node compared to adjacent nodes. Second, community-level analysis explored network-level characteristics such as density. This represents all the possible connections between all the nodes. This study used centrality analysis to identify the association between popular concepts and technologies.

3.6. Policy analysis

Through a policy analysis, the study evaluated prevailing smart city strategies and planning policies. This aimed to understand processes behind the development of planning policies, and the role of strategies in developing the concepts that were identified through descriptive and content analyses. This analysis connects social media data with numerous smart city policies developed and introduced in Australia. It helps in better comprehension of how smart city policies are perceived by the public, and how these policies influenced public perceptions. Exploring both policy and perception dimensions provides policymakers with essential information for consolidating existing policies or developing new effective, efficient, and feasible ones.

4. Results

4.1. What are the trending smart city concepts and technologies?

Of the 3,073 usable tweets, 1,179 (38%) were original, and 1,894 (62%) were retweeted, reflecting the highly interactive nature of users. All Twitter discussions developed in total 28 hashtags. The hashtag analysis identified (excluding #smartcities and #smartcity) 16 key hashtags among them as the most strongly associated ones with the smart city domain. These were: #autonomousvehicle; #transport; #5G; #sustainability; #mobility; #internet-of-things; #energy; #innovation; #governance; #artificialintelligence; #blockchain; #bigdata; #robotics; #opendata; #waste; #startups.

Trending hashtags were: #IoT, #AI, #opendata, #robotics, #bigdata, #autonomous, #automation, #automative, #autonomousvehicle, #driverless, #selfdriving, #5G, #blockchain. Tweets with these hashtags captured views on incorporating novel, innovative, and advance technologies to shape smart cities. Other popular hashtags were: #cybersecurity, #android, #traffic, #software, #digitalbuiltaustralia, #austech, #sustainability, #ausbiz. Tweets with these hashtags concentrated on smart city strategies with an economy and mobility focus. The temporal variation of hashtag usage is significant to the study. For instance, tweet numbers increased substantially between September and October 2018 due to the Smart Cities Week Australia 2018 event in Sydney. The event hashtags such as #SCW and #SCWAus were frequently circulated during this period.

In total, 1,090 users contributed to create the dataset of 3,073 tweets. 69% of the tweets were circulated by individual users, and 31% by institutions. However, 75% of the top-20 most active users were institutional users. These organizations include technology firms, research centers, not-for-profit organizations, and conference organizers. The number of tweets of the most active users ranged between 20 and 150 tweets per year. In terms of followers these organizations had more followers than individuals, meaning they naturally had wider outreach. Yet, it would not be correct to interpret this as their dominance in communicating opinions, as individual user tweets were more than double in quantity than institutional ones.

There were 176 tweets with informative URLs in the dataset. Most of them contained links of blogs, discussion sites, articles, and conference websites that talk about the smart city movement in Australia and overseas. Hot topics discussed include Melbourne's high-tech vision; driverless cars and national autonomous vehicle law; cyber security; smarter irrigation management solutions; and smart waste management systems.

4.2. What are the relationships between smart city concepts and technologies?

Tweets obtained from each state were categorized separately (Figure 3). The states with the highest number of smart city tweets were NSW (1,372), VIC (710), QLD (432), ACT (371), and SA (103). WA (60), and TAS (25) had the lowest number of tweets. The national capital Canberra is located in the Australian Capital Territory (ACT). The city houses almost all of the Federal authorities, and naturally the key national policy issues, including smart cities and technologies, are widely discussed in the city. Interestingly, most of the analyzed tweets consist of scholarly discussions that evaluate the smart city notion under different concepts and technologies. Tweets discussed: Launching robotics roadmaps for automation adoption; Lake Macquarie smart city network project; Tesla's power wall batteries project for smart energy management systems. Twitter provided a user-centric online media/platform to express individual and institutional views on the aforementioned projects. Institutional tweets on policies and projects helped the information circulated widely. This, in return, motivated or provoked individuals to reflect their responses. For instance, 28 individuals have retweeted posts related to Lake Macquarie Smart City Network with their own comments included. This has ultimately developed a thought-provoking discussion thread related to the project by individuals expressing their concerns or endorsements.

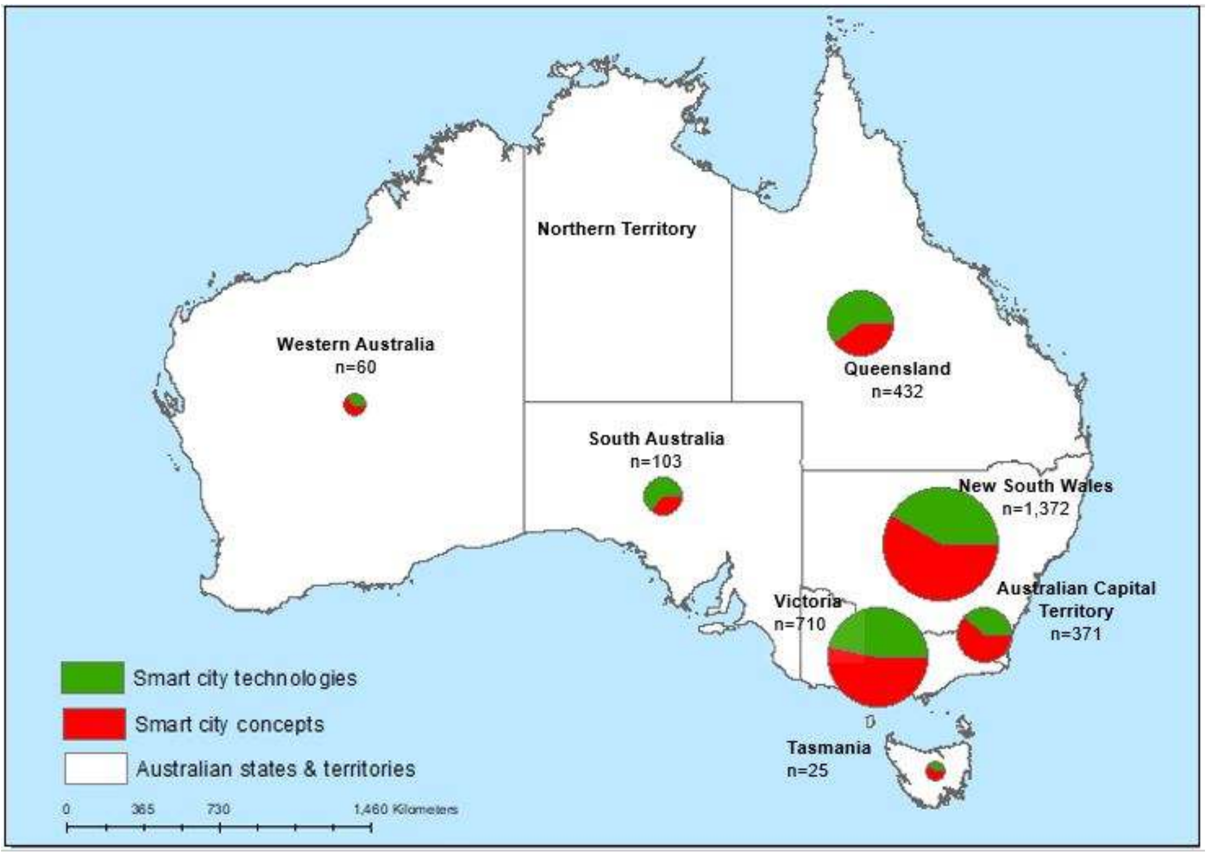

Figure 3: Spatial distribution of tweets

To evaluate the intellectual value of such tweets, the study conducted a word count analysis to identify the frequently used concepts and technologies. When the tweets consisted with more concepts such as innovation and sustainability, they were classified as 'tweets on smart city concepts', and when the tweets discussed about technologies such as AI and IoT, they were classified as 'tweets on smart city technologies'. In a situation, where tweets equally discussed about both concepts and technologies, they were classified under both categories. Further, tweets which generally comment on smart cities without referring to any technology or concept—i.e., Enjoying the life in a smart city of Australia, were ignored.

Finally, the study identified 16 themes that acted as the basis for most of tweets. Across Australia the most referred-to technologies were: Internet-of-Things (IoT) (392); Artificial intelligence (AI) (231); Autonomous vehicle (AV) (220); Big data (152); 5G (126); Robotics (123); Open data (108), and; Blockchain (53). These technologies were discussed in relation to key concepts such as: Innovation (423); Sustainability (413); Start-ups (269); Governance (255); Mobility (97); Waste (82); Energy (19), and; Transport (13). However, as shown in Table 2, the attention paid to each concept and technology varied significantly from state to state.

Australian states have different foci when it comes to adopting novel, innovative and advance technologies for making their cities smart (Table 2). The main exposure technologies of interest in NSW were concentrated around the IoT (162), AI (88), and AV (71); and interest in blockchain was low (0). Conversely, citizens from VIC, QLD, ACT, and SA have a dispersed interest in diversified technologies for smart cities. Although ACT has comparatively lower number of residents, it performs well with a considerable number of tweets. This reflects the extensive interest, knowledge, and awareness of ACT residents on the smart city concepts and technologies. WA and TAS also have a dispersed interest in technologies, but the lower number of tweets made them insignificant/unreliable. The results displayed that motivation and awareness exist among the local communities of each state in making their cities smarter.

Table 2: Smart city technology tweets by states

States \ Technologies	IoT	AI	AV	Big data	5G	Robotics	Open data	Blockchain
ACT	27	15	27	11	9	6	9	6
NSW	162	88	71	54	58	45	32	0
QLD	67	41	39	27	6	21	22	11
SA	21	18	12	12	4	5	8	4
TAS	9	0	1	1	0	0	1	1
VIC	103	66	68	44	47	45	34	30
WA	3	3	2	3	2	1	2	1
AUSTRALIA	392	231	220	152	126	123	108	53

As well as technologies, there were engaging concepts. As given in Table 3, eight popular concepts were identified from tweets scrutinized through a word frequency analysis.

Table 3: Smart city concept tweets by states

States \ Concepts	Innovation	Sustainability	Start-ups	Governance	Mobility	Waste	Energy	Transport
ACT	54	40	14	23	10	12	10	12
NSW	213	140	145	125	44	46	2	4
QLD	30	50	17	31	15	11	2	2
SA	16	6	4	14	5	2	2	0
TAS	5	5	2	7	0	0	0	0
VIC	82	207	88	60	28	19	7	0
WA	11	1	5	6	3	0	1	3
AUSTRALIA	423	413	269	255	97	82	19	13

Innovation (213), start-ups (145), sustainability (140), and governance (e-governance) (125) were the most popular concepts in NSW. However, compared to the number of tweets, sustainability is much popular in VIC (207 tweets) as a concept than in NSW. QLD and ACT were interested in smart city agendas to encourage sustainability in their cities through novel innovations and e-governance practices. Accordingly, Twitter users seem to be extensively interested in making their cities smart in transport, governance, innovative economy (e.g., start-ups), and waste management areas.

Table 4 demonstrates that Twitter users from the capital cities of Australian states were highly active in using social media to discuss concepts and technologies—i.e., Sydney, Melbourne, Brisbane, Canberra, Adelaide, Perth, Hobart. Top-10 Twitter active cities on smart city discussions also include some locations outside the capital cities—i.e., Sunshine Coast, Gold Cost, Ipswich from QLD. Table 4 provides a population weighted rank of the most active locations in terms of smart city discussion. While the top-10 locations do not change, their order do.

Table 4: Most active (top-10) cities in smart city tweets

City	Number of tweets and retweets	Population weighted rank
Sydney (NSW)	1,339	1
Melbourne (VIC)	696	3
Brisbane (QLD)	379	7
Canberra (ACT)	371	4
Adelaide (SA)	103	2
Perth (WA)	52	5
Sunshine Coast (QLD)	29	8
Hobart (TAS)	25	6
Gold Coast (QLD)	14	10
Ipswich (QLD)	10	9

Although Tables 1 and 2 reflect the trending concepts and technologies, they did not reflect the relationships among popular concepts and technologies. Neither did they reflect the popularity of each concept and technology (when all concepts and technologies are considered). Hence, we conducted a network analysis.

Figure 4 presents the layout of network topology, which disclosed the relationships between popular concepts and technologies. Square nodes depict concepts, and circular nodes depict technologies. The widths of the edges show the strength of the relationship exist in between nodes. The strength of the relationships among nodes were calculated through the co-occurrence of concepts and technologies in the tweets and retweets analyzed.

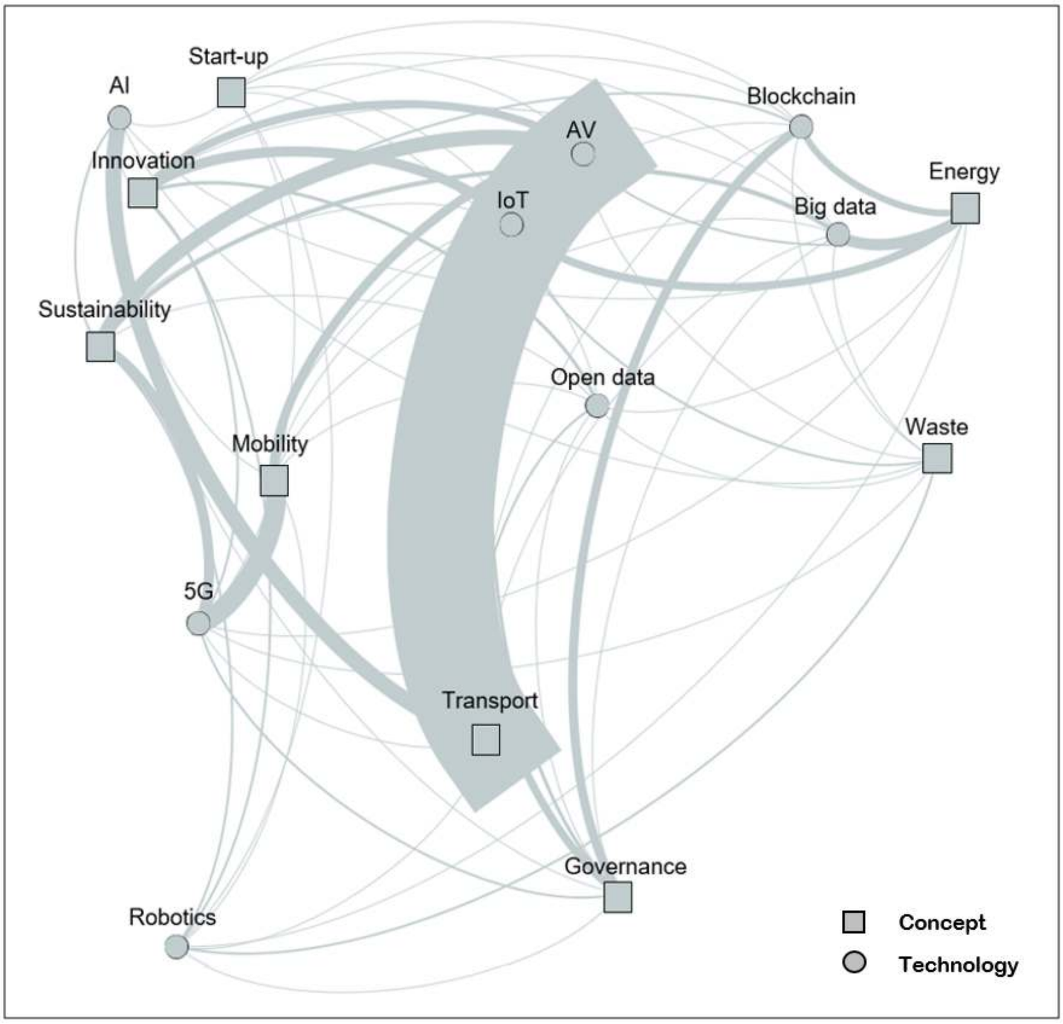

Figure 4: Relationships between popular concepts and technologies

Then, the study calculated the centrality (popularity) level of each node. We used weighted degree centrality—a measure to identify the nodes' connectedness with the other nodes in the network—to quantify the perceived levels/degrees of the aforesaid concepts and technologies. For instance, a node with five links has a higher degree centrality than a node with two links. The number of co-occurrences were used to create/weight the links among the nodes.

As per Table 5, transport (can be merged with mobility) was by far the most central concept. Sustainability was the second most popular concept. Energy, innovation and governance concepts followed. Waste and start-ups (can be merged with innovation) were other concepts gaining popularity.

Table 5: Degree centrality of concepts and technologies

Themes	Concept/technology	Weighted score
AV	Technology	129
Transport	Concept	116
5G	Technology	35
Sustainability	Concept	34
Mobility	Concept	32
IoT	Technology	30
Energy	Concept	29
Innovation	Concept	26
Governance	Concept	24
AI	Technology	22
Block chain	Technology	21
Big data	Technology	20
Robotics	Technology	11
Open data	Technology	11
Waste	Concept	10
Start-ups	Concept	8

Among the technologies, AV was by far the most popular one (by weight) (Table 5), and had a strong relationship first with transport, and then with the other concepts such as sustainability, mobility, energy, and innovation (Figure 4). 5G technology was the next popular technology. IoT, AI, blockchain, and big data were to follow. Robotics and open data were the least popular ones with the lowest centrality.

Within the top-16 themes ranked by weights (Table 5), half of them were concepts, and the other half were technologies. This finding presents a balanced view of concepts and technologies in Australia.

4.3. What are the official smart city policies that influence perception and utilization of smart city concepts and technologies?

In general, Australian states perceived concepts and technologies differently. This is most likely due to the varying degree of externalities of smart city policies on local communities in each state. The more community feel the impacts of such policies (positive or negative), the more they will discuss, appreciate or criticize them. Sound and well communicated policies receive higher support from the public; the opposite is also true.

Australia is rich in urban policy with numerous government policies focusing on smart cities. Prominent national-level authorities that have prepared and launched smart city policies, funds and projects include Smart Cities Council of Australia and New Zealand, Australian Department of Infrastructure, Transport, Cities and Regional Development, and Department of the Prime Minister and Cabinet. NSW, VIC, SA and QLD also have state-level smart city policies. At the local-level, smart city policies are also gaining prominence. Table 6 lists cities with smart city strategy.

Table 6: Local government areas with smart city strategy

State	City	Title	URL
QLD	Brisbane	Smart, Connected Brisbane	https://www.brisbane.qld.gov.au/about-council/governance-and-strategy/vision-and-strategy/smart-connected-brisbane
	Sunshine Coast	Smart City Framework	https://www.sunshinecoast.qld.gov.au/Council/Planning-and-Projects/Major-Regional-Projects/Smart-Cities/Smart-City-Implementation-Program
	Townsville	Smart Townsville	https://www.townsville.qld.gov.au/about-council/news-and-publications/city-update-online/smart-townsville
NSW	Canada Bay	Smart City Draft Plan	https://collaborate.canadabay.nsw.gov.au/smartcity
	Goulburn Mulwaree	Smart City Strategy	https://yoursay.goulburn.nsw.gov.au/smart-city-action-plan
	Lake Macquarie	Smart Council Digital Economy Strategy	https://www.lakemac.com.au/city/smart-city-smart-council
	Newcastle	Draft Smart City Strategy	http://newcastle.nsw.gov.au/Community/Get-Involved/Completed-Consultation-Projects/Community-Planning/Smart-City- Strategy-2017-2021
	Paramatta	Smart City Masterplan	https://www.cityofparramatta.nsw.gov.au/smart-city
	Randwick	Draft Smart City Strategy	https://www.yoursay.randwick.nsw.gov.au/smartcities
	Western Sydney	Smart Cities Plan	https://citydeals.infrastructure.gov.au/western-sydney
NT	Darwin	Smart City Plan	https://citydeals.infrastructure.gov.au/darwin
SA	Adelaide	Smart Cities Plan	https://citydeals.infrastructure.gov.au/adelaide
	Charles Sturt	Smart City Plan	https://www.charlessturt.sa.gov.au/SmartCity
TAS	Hobart	Connected Hobart Smart	https://yoursay.hobartcity.com.au/smart-city

		Cities Action Plan	
	Launceston	Smart Cities Plan	https://www.launceston.tas.gov.au/Launceston-City-Deal/City-Deal-Implementation
VIC	Geelong	Smart Cities Plan	https://citydeals.infrastructure.gov.au/geelong
	Wyndham	Smart City Strategy	https://theloop.wyndham.vic.gov.au/smart-city

Smart city policies are categorized into four themes, transport-, energy-, economy- and governance-related policies. All state capitals except WA and NT have clear policies in these areas. There are also smart city projects in progress across all states. NSW has 13 smart city projects, while VIC, QLD, WA, SA have 10, 9, 7, 6, and 2 projects respectively, and NT has one project.

Transport-related policies are the most prominent. This might be something to do with transport being a major challenge for Australian populations and cities that rely heavily on private motor vehicles. The key smart city strategies in operation that refer to legislative issues for smart cities include: Future Transport Strategy of NSW; Connected and Automated Vehicle Plan; Greater Sydney Service and Infrastructure Plan; National Smart Cities Plan. Policy discussions focusing on new and forthcoming legislation include: AV trial guidelines; New transport rules and regulations; Study lessons learned from the US and Singapore; Changing the sign boards; Changing property and other infrastructure-related guidelines for compliance with automated vehicles; Defining vehicle automation levels, designing trial paths, and; Establishing a standby setting date to end analogue cars; and smart airports. AV projects and policy for smart transport planning under discussion include: Automated traffic management of Fraser Coast, QLD; Driverless shuttle service of Sydney; Semi-automated port operations in port Botany; Australia posts footpath-based delivery through drones.

Energy-related policies of Australia are concerned about balancing energy supply and energy demand reduction through smart energy use (Strengers, 2013). Australian policies on energy have already identified the significance of smart energy usage to cut energy bills and reduce environmental impacts. A number of smart city projects are already in operation. These include: Resilient energy and water systems of Fremantle, WA; Energy efficient housing of South East Perth, WA; Energy data for smart decision-making in Sydney; Smart grid trials in the Greater Newcastle and Sydney CBD. In addition, government policies on increasing infrastructure for electric vehicle users and increasing the awareness about the solar and battery storage technologies have also contributed towards the smart energy movement.

Economy-related policies received considerably less attention across Australia, even though the economy has weakened in recent years. Cities are only starting to consider the economic growth dimensions of smart policies. NSW has embraced investors to help Sydney on its mission to achieve 2021 goals. New start-ups, namely Nomad restaurants, Swill house group, Jolly Swagman Backpackers Sydney, Sydney Science Park, and Smart Innovation Centre are some businesses supporting the Smart Green Business Program of Sydney. It was awarded with the NSW Green Globe Award in 2013. Innovation districts are being developed all across the eastern coast of Australia—Sydney, Melbourne, Brisbane (Esmaeilpoorarabi et al., 2018; Pancholi et al., 2019). However, most of these are not directly linked with the smart city initiatives of their host cities. The national innovation district policy is also divorced from smart cities policy. The only exception is in Queensland. In QLD innovation districts were originally designed as part of the former Smart State Strategy of QLD (Hortz, 2016). However, to address this Australia wide limitation, in late 2018, a national policy released. ‘Principles for Australian Innovation Precincts’ is prepared by the Federal Department of Industry, Innovation and Science emphasizes the connection between innovation district and smart cities.

Governance-related policies are gaining momentum. Australia is a global leader in digitalization of government services. Today, most government services are delivered virtually across many Australian authorities—e.g., tax, development assessment applications. Extensive online services also attract hackers. On cyber security, Australian Strategic Policy Institute (ASPI) develops strategies to protect the privacy of data and information. Introducing a digital identity, to recognize receipt of a digital signature and secure data exchange mechanisms are the foci of the APSI policy.

Our policy analysis reflects the existence of, but limitations in or the inadequacy of the smart city initiatives at the national level. For instance, in 2017, more than 170 local governments applied for a share in AU$50 million smart cities Federal Government funding. This indicates the limitation of the funds for smart city projects in Australia. Some Australian states, such as TAS and NT do not have strong smart city policies. Instead, they have certain relevant projects implemented on demand. Although this is useful, having a sound national- and state-level policy for smart cities will help advance smart urbanism practices in Australia.

5. Discussion and Conclusion

Smart cities have already become a promising approach to create sustainable and livable urban future (Yigitcanlar et al., 2019a). Smart city discussions and awareness are especially high within the Australian professional and business communities. Smart cities are also highly popular in urban policy circles around the globe. Local, regional, and national governments have been working to transform their cities into smart ones through strategies, plans and projects involving the substantial engagement of technology solutions. Still, expectations from smart cities are highly unrealistic as they are full of speculations (Luque-Ayala & Marvin, 2015; Wiig, 2015). There is limited knowledge and understanding about:

Trending concepts and technologies; Relationships between popular concepts and technologies; Policies that influence perception and use of concepts and technologies.

In order to bridge the aforementioned knowledge gap, this study employed systematic geo-located Twitter analysis to scrutinize discourse and policy in Australia. The research particularly focused on addressing the question of: How are the smart city concepts and technologies are perceived and utilized in Australian cities? The study findings provide a clear snapshot of community perceptions, and disclose the following insights that inform smart city policymaking.

First, the results of the analysis showed that innovation, also including start-ups (with 692 of 3,073 tweets—23%), sustainability (413 tweets—13%), and governance (with 255—8%) were the most popular concepts in Twitter discourse across in Australia. When the degree of centrality of concepts is considered, the top-three concepts were transport (includes mobility), sustainability, and energy. This was followed by innovation and governance.

The ranking of the top-three concepts (i.e., innovation, sustainability, governance) in NSW and ACT were same as for Australia. In VIC and QLD, sustainability took the first place (followed by innovation and governance), where in TAS, it moved to the third place (following innovation and governance). In SA and WA, governance moved to the second place (after innovation and before sustainability). The variations between the states are an indication of local contextual differences in policy and planning priorities and conceptualizations of the smart city notion.

Second, the findings revealed that IoT (with 392 of 3,073 tweets—13%), AI (231 tweets—8%), and AV (220 tweets—7%) were the most popular technologies based on Twitter trends. When the degree centrality of concepts is considered the top-three ranking was as follows: AV, 5G, and IoT respectively (followed by AI). No tweets were found from

NSW mentioning the blockchain technology. Though, throughout Australia, blockchain has been widely discussed in relation to energy and governance related issues (Figure 4). The heightened interest in blockchain in VIC is mainly due to the Blockchain Association of Australia being located in Melbourne, VIC. Similarly, in QLD, University of Queensland has a Blockchain Club, and Brisbane, QLD hosts the Blockchain Australia National Meetup Roadshows.

The three technologies (i.e., IoT, AI, AV) were in the top-three in all states besides TAS. Additionally, in some states big data and open data were also shared the top-three position with AV. This finding indicates a degree of consistency across the states. The ranking of the top-three technologies in NSW and QLD were same as for Australia. In VIC, AV moved one step up (following IoT and followed by AI). In ACT and SA, the first position shared by IoT and AV (followed by AI). In WA, the third place was shared by AV and big data (following IoT and AI). In TAS, the second place was shared by AV, big data, and open data (following IoT). Similar to concepts, technologies also showed minor variations across the states. This is an indication of differences in technology adoption and prioritization, and local smart city plans and projects.

Third, the study disclosed that Sydney, Melbourne, and Brisbane as major Australian cities—also their greater city-regions as the leading Australian metropolitan areas—have higher interest in concepts and technologies. Nevertheless, different policy interventions and priorities of cities cause the increase/decrease of the popularity of aforesaid concepts and technologies among the public. For instance, although Brisbane's Smart Connected Brisbane Policy was only released in 2017, Brisbane has been benefiting from the Smart State Strategy legacy of the state government dating back to 1998. Similarly, Melbourne's relatively new smart city strategy is the rebranding of knowledge city (Millar & Ju-Choi, 2010; Yigitcanlar, 2014) policy of the city dating back to early 2000s. In other words, Sydney, Melbourne, and

Brisbane benefits from their path-dependency. Furthermore, these greater city-regions recently received lucrative funds for their smart city endeavors/transformation—as part of the Commonwealth Government's Smart Cities Plan. For instance, Western Sydney City Deal in NSW, Geelong City Deal in VIC, and South East Queensland City Deal in QLD are among them—funding is envisaged to stimulate an increase of the economy by improving the productivity and competitiveness of the region.

Fourth, the network analysis findings pointed out a balanced view on the importance of concepts and technologies to achieve smart urbanism or smart city transformation—perhaps this is the Australian way of realizing the smart city dream. This is a critical finding as only with such a balanced view—seeing technology as a means to a goal rather than fully relying on it as the panacea—, we can address urban developmental problems (Yigitcanlar, 2008). One of the possible reasons for the balanced concept and technology view on smart cities in Australia are the advancing government policy frameworks. Currently more than a dozen sound smart city policy frameworks are available (Table 6) at the local government level, and this number is expected to exponentially increase in the near future.

Fifth, the study proved that systematic geo-located Twitter analysis is a useful methodological approach for investigating perceptions and utilization of concepts and technologies. The social media analytics methodology—the capture-understand-present framework (Fan & Gordon, 2014)—was previously applied to other research areas—e.g., business, and tourism and hospitality (Amadio & Procaccino, 2016). This paper showcases its application in another field—i.e., smart city concepts and technologies.

Next, this study provides a big picture view on the Twitter user perspectives on the smart city concepts and technologies in Australian cities. It also showcases the usefulness of social media analysis as a complementary method to the studies government agencies, not-for-profit organizations and consultancy firms have been undertaking to follow the latest developments in the field and understand the perceptions of authorities, experts and the public at large. The findings are informative and encourage authorities to adopt social media analytics in their routine data collection mechanisms to make more informed decisions.

Lastly, in interpreting the study findings the following limitations should be considered: (a) Twitter is used as a social media channel to capture the views shared in Australia; (b) The study presents a snapshot in time by analyzing tweets from 2018; (c) The study does not involve a time-series analysis; (d) 8,241 tweets were obtained and of these 3,073 qualified for analysis; (e) Different categorizations of smart city concepts and technologies might have an impact of the results; (f) There might be a degree of unconscious bias in the interpretation of the findings. Our prospective studies will concentrate on addressing these limitations.

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