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Article

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Article

Artificial Intelligence Technologies and Related Urban Planning and Development Concepts: How Are They Perceived and Utilized in Australia?

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Abstract: Artificial intelligence (AI) is a powerful technology with an increasing popularity and applications in areas ranging from marketing to banking and finance, from agriculture to healthcare and security, from space exploration to robotics and transport, and from chatbots to artificial creativity and manufacturing. Although many of these areas closely relate to the urban context, there is limited understanding of the trending AI technologies and their application areas—or concepts—in the urban planning and development fields. Similarly, there is a knowledge gap in how the public perceives AI technologies, their application areas, and the AI-related policies and practices of our cities. This study aims to advance our understanding of the relationship between the key AI technologies ($n = 15$) and their key application areas ($n = 16$) in urban planning and development. To this end, this study examines public perceptions of how AI technologies and their application areas in urban planning and development are perceived and utilized in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method, and conducts sentiment and content analyses of location-based Twitter messages ($n = 11,236$) from Australia. The results disclose that: (a) digital transformation, innovation, and sustainability are the most popular AI application areas in urban planning and development; (b) drones, automation, robotics, and big data are the most popular AI technologies utilized in urban planning and development, and; (c) achieving the digital transformation and sustainability of cities through the use of AI technologies—such as big data, automation and robotics—is the central community discussion topic.

Keywords: artificial intelligence (AI); urban planning and development; public perception; big data; automation; robotics; digital transformation; innovation; sustainability; Australia

1. Introduction

Cities provide tangible and intangible infrastructures and platforms from which individuals are able to self-actualize, and consequently create goods and services that further enhance the standards of living of the broader population [1]. The city, therefore, has an overarching responsibility for the impact that its hard and soft attributes have on its inhabitants, rendering it an institution that must guarantee the efficiency and reliability of its urban matrix [2]. As part of the constant necessity to boost development and economic growth, cities are leveraging the benefits of technological advancements and implementing the latest artificial intelligence (AI) technologies; the aim is to exponentially increase sustainability through the efficient use of energy and resources [3–5].

Technologies that leverage AI are currently being utilized in many cities across the globe, for example in Amsterdam, London, San Francisco, Stockholm, Singapore, Hong Kong, Vienna, and Toronto, to optimize their urban functionality and service efficiency [6,7]. For instance, the smart grid initiative acts as one of the foundations for the utilization of AI in cities; it facilitates spatial navigation in the form of interactive and automated systems that use data processing technology to reveal the dynamics of the urban grid. In this way, digitalization has enabled cities to identify specific needs, leading to increased productivity and economic performance [2]. Subsequently, AI offers an opportunity for enhanced city governance [8]; AI concepts and technologies can influence and improve the manner in which the city serves its citizens and provide everyone with the desired and responsible urban futures [9,10].

One of the most outstanding factors that have led cities to becoming smart is an inherent necessity to adapt to environmentally friendly initiatives [11]. The unprecedented reality of global warming has made it necessary to restructure the use of resources, where smart technologies are required to assist in the homogenous distribution of resources, resulting in the reduction in the carbon footprint of cities [12,13]. Accordingly, smart environment technologies are applied in cities—they are generally AI-driven systems, which come in the form of smart traffic lights, noise prediction, air quality prediction, and foot traffic as well as car traffic prediction faculties. All this is made possible thanks to the big data technology, which facilitates data capture [2]. This results in hyper-accurate urban data, which permits for highly productive interventions, enabling cities to use their resources sustainably [14].

It is evident that cities, so far, have been reaping significant benefits from utilizing AI to design and implement city management strategies [15]. Nevertheless, it is estimated that a knowledge gap remains, specifically in the manner in which the public perceives the implementation of those technologies, and how they feel about the extensive application of AI in their cities [16]. A solid understanding of the public's perceptions about AI concepts and technologies in their cities would inform policymakers of the general public sentiment regarding the different aspects of AI [17,18]. Consequently, governing bodies would be better prepared to respond to the public's demands and to adopt urban AI technology and applications [19]. It is, hence, necessary to explore the ways in which AI directly interacts with individuals and to dissect the manner in which the different AI instruments can potentially benefit or impair an individual or community.

The discourse on AI has become prevalent in Australia in recent times [20–23]. In particular, the arrival of autonomous vehicles (AV), robotics, machine learning (ML), internet-of-things (IoT), block chain, augmented reality (AR) and virtual reality (VR) technologies has resulted in a widespread debate on the future of AI in Australian cities; citizens have begun to contemplate how big data, 5G, surveillance and cybersecurity will impact their daily life. This paper thus focuses on the public's perception of AI concepts and technologies in urban planning and development, in the context of Australian cities. The methodological approach of this study employs the social media analytics method, and conducts sentiment and content analyses of location-based Twitter messages from Australia.

Following this introduction, Section 2 of the paper provides a literature background on the topic of investigation. Then, Section 3 introduces the methodological approach of the study. Next, Section 4 presents the results of the analysis. Afterwards, Section 5 discusses the study findings and generated

insights. Lastly, Section 6 concludes the paper with the study highlights, final remarks and future research directions.

2. Literature Background

2.1. Artificial Intelligence

AI is one of the most disruptive technologies of our time [24]. AI can be defined as machines or computers that mimic cognitive functions that humans associate with the human mind, such as learning and problem solving [25]. AI is a branch of computer science that perceives its environment and acts to maximize its chances of success. Furthermore, AI is capable of learning from past experiences, of making reasoned decisions, and of responding rapidly [26]. The scientific goal of AI researchers, hence, is to understand intelligence by building computer programs that exhibit symbolic inference or reasoning. For instance, according to [27], the four main components of AI are:

- *Expert system*: Handles the situation under examination as an expert and yields the desired or expected performance.
- *Heuristic problem solving*: Consists of evaluating a small range of solutions and may involve some guesswork to find near-optimal solutions.
- *Natural language processing*: Enables communication between human and machine in natural language.
- *Computer vision*: Generates the ability to recognize shapes and features automatically.

AI is already being used in today’s society in numerous areas, including but not limited to marketing, finance, agriculture, healthcare, security, robotics, transport, and artificial creativity and manufacturing [28,29]. In recent years, AI has become an integral part of urban services, as it offers efficient and effective platforms and smart governance opportunities [30,31]. There are several types of AI hardware (e.g., machines/robots) and software (e.g., algorithms) that each have different capabilities at different levels of development [32]. These levels are illustrated in Figure 1 and described below.

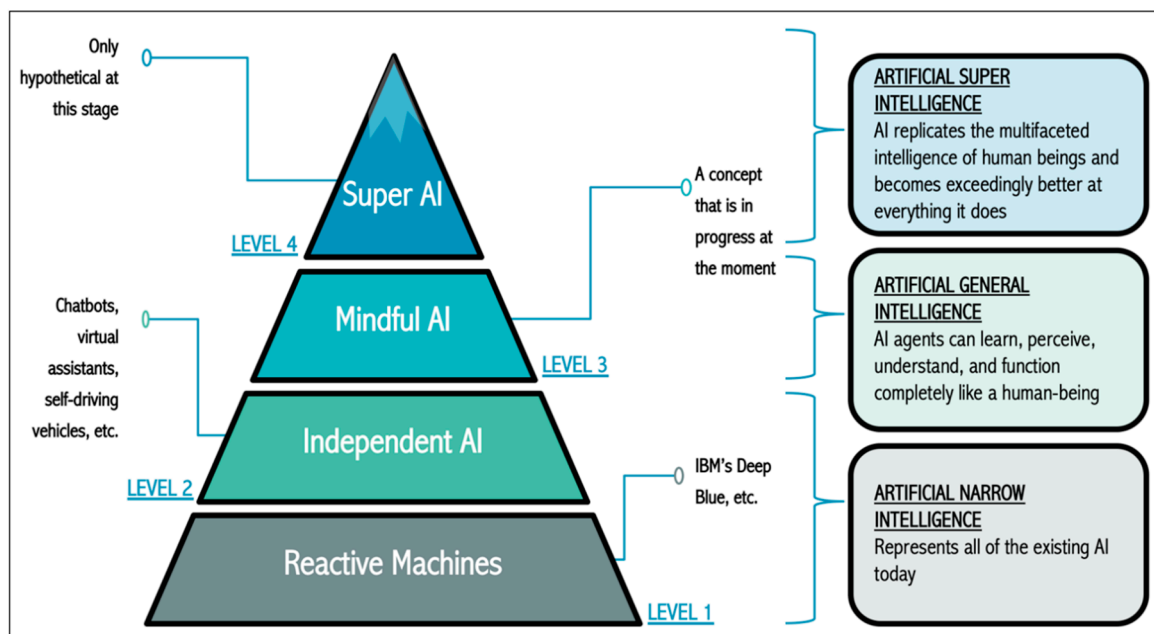


Figure 1. Levels of artificial intelligence, derived from [33].

Level 1 refers to ‘Reactive machines’, which are programmed to undertake a single task and carry it out perfectly. However, this type of machine cannot learn further as it reacts to human input, rather than planning and pursuing its own original agenda [34]. Level 2 is the ‘Independent AI’,

as human actions do not dictate all of the software actions; after some human lead, AI learns and improves its own ability to perform a given task. AI levels 1 and 2 are referred to as 'artificially narrow intelligence', and they are currently being used in practice and are commonly applied in urban planning and development. Level 3 AI is called 'Mindful AI' and is capable of thinking thanks to a consciousness of its own and multiple domains of knowledge. This level of AI is currently at the stage of conceptual progress. Lastly, Level 4 is called 'Super AI', as it does anything and everything better than humans do [35]. This level of AI is currently at the hypothetical stage.

2.2. Artificial Intelligence Technologies

The market for AI technologies is growing as large corporations are beginning to increase their investment in AI solutions. According to IDC [36], the AI market is expected to grow from USD 8 billion in 2016 to USD 57.6 billion by 2021. A study conducted by Cearley et al. [37] identified the AI technologies with the most growth so far:

- *Augmented reality*: Designers enhance parts of a user's physical world with computer generated input that ranges from sound, video, and graphics to GPS overlay.
- *Automation*: Software that follows the instructions or workflows established by individuals for simple and repetitive tasks.
- *Big data*: Structured and unstructured data that are collected by an organization and can be mined for information extraction and used in machine learning projects, predictive modelling and other advanced analytical applications.
- *Biometrics*: This enables natural interactions between humans and machines through image, touch recognition, speech and body language.
- *Block chain*: This is a public electronic ledger that can openly share information with many disparate users to create an unalterable record of transactions.
- *Deep learning platforms*: These are machine learning systems that consist of artificial networks with multiple layers; deep learning is capable of recognizing and classifying patterns.
- *Digital twins*: These are digital representations that simulate a real-life object through the law of physics, material properties, virtualized sensors and causality.
- *Machine learning platforms*: These provide algorithms, application programming interfaces (APIs), development and training toolkits.
- *Natural language generation*: This produces text from computer data, and it is currently being used in customer service, report generation, and summarizing business intelligence insights.
- *Robotics*: This refers to the use of machines to perform tasks that are traditionally completed by humans.
- *Virtual agents*: These are advanced systems that can network with humans.

Thanks to the extensive research and advances in the field of AI, it is expected that by the end of 2035, our society and cities will transition from the current AI with complex machine language towards AI that will likely be fully understood by humans [38].

2.3. Artificial Intelligence Application Areas in Urban Planning and Development

The urban planning environment is increasingly turning to specialized technologies to address uses related to sustainability, society, security, transportation, infrastructure and governance [39]. The term urban artificial intelligence refers to AI that is embodied in urban spaces and infrastructure. These technologies are turning cities into autonomous entities that operate in an unsupervised manner [40]. The emerging concept of smart cities has promoted the development of IoT and through it the incorporation of sensors and big data [41,42]. The surge in data brings new possibilities to design, management, and the economy. Furthermore, IoT supports increased connectivity that leads to the generation of data and its subsequent capture, analysis, and distribution, contributing to better smart city development [43,44].

AI can significantly contribute to planning by binding frameworks that encompass key dimensions, such as culture, metabolism, and governance, ensuring their achievement. Data can now be sourced from numerous neighborhoods to gain a more holistic understanding of the urban fabric. This allows planners and policymakers to shift from closed systems (interlinked urban elements) to an open, fragmented, peri-urban fabric that has tangible impacts on density fragmentation, cohesion, and compactness [43].

AI-based data processing can help offer better prevision of livability, through the creation of a clean, healthy, and conducive environment for people to live and work in, overcoming the urban challenges of pollution and congestion [45]. Additionally, urban areas that leverage AI are enabling infrastructures that attract higher economic returns by offering connectivity, energy and computing capabilities that support globally competitive jobs, as well as talented and knowledgeable workers [46].

3. Research Design

3.1. Case Study

This research paper follows a case study approach. The conducted case study focused on the current status of AI and on the identification of AI applications in urban planning and development activities in Australian cities. The reasons behind this selection include: (a) some of Australia's major cities are considered to be among the leading smart cities in the world. These cities are successfully adopting smart urban technologies that also include AI-related technologies and applications [47]; (b) Australia is among the countries that developed a national AI strategy and roadmap, meaning that AI uptake in cities is planned rather than done on an ad hoc basis [48], and; (c) social media use is highly popular in the country, making it a source of firsthand information regarding the Australian society, including its perception of urban technologies. About 66% of Australian Internet users use social media daily and around 34% use social media more than five times a day [49]. Among the 66%, 19% of them have accessed Twitter and one-third of them tweet daily [50]; (d) although large amounts of social media data are available regarding AI in Australia, very few studies have been conducted to draw conclusions from these big data. For instance, Yigitcanlar et al. [47] performed social media analytics on Twitter data to evaluate smart city concepts and technologies across Australia, such as AI, big data, 5G, IoT, AVs, and robotics. However, further investigations are required to capture and evaluate the public's perception of AI and its urban and social implications in Australia.

3.2. Methodology

Instead of using a traditional data collection method, the methodological approach applied in this study employs a contemporary method—i.e., social media analysis. As social media are ever-evolving platforms, where people can share thoughts and opinions, they have become a new source of qualitative data [51]. This data collection method has started to be used as the main data source in a large number of studies. Social media have offered an opportunity to engage with larger groups of people, in an unbiased setting [52]. In addition, researchers are able to engage with people from broader geographic areas with the help of the location of social media users, which is tagged in their posts [53].

A geo-Twitter analysis has proven to be a very successful data collection method [54]; hence, this method was used in this study. A geo-Twitter analysis increases efficiency in analyzing a large amount of shared thoughts and opinions [55], and real-time information on ongoing social issues [56]. For instance, social media analytics has contributed to safeguarding Australian cities and their residents from the coronavirus outbreak (COVID-19) in 2020 [57].

Initially, sentiment and content analyses were completed for the total number of location-based Twitter messages—a.k.a. tweets. To do this, the original dataset obtained (from the QUT Digital Observatory—<https://www.qut.edu.au/institute-for-future-environments/facilities/digital-observatory/digital-observatory-databank>) with 98,534 tweets was filtered down to 11,236 tweets. This was done using five data filtering processes, which included frequency analysis, location, date, bot, and relevance filters.

Firstly, we selected the most recent one-year period for the analysis—hence, all tweets outside of Australia and not within the 10 June 2019 to 10 June 2020-time period were removed from this dataset. The reason for only selecting one-year period was two-fold. The first one is to capture the latest trends, as in the technology domain, the development is fast and public perceptions change rather rapidly. The second is easing the analysis tasks, as there have been around 50,000 to 100,000 tweets on AI shared annually in Australia during the last five years. The bot filter removed tweet repetitions with the program 'NVivo'—a content analysis automatic software system. In regard to identifying the tweets on themes associated with AI applications in urban planning and development, NVivo was also used.

Secondly, word frequency analysis was conducted using NVivo, with the aim of identifying popular themes, concepts, and technologies.

Next, a word co-occurrence analysis identified the tweets that discussed both AI technologies and urban planning and development-related concepts (or AI application areas) in a single Twitter message. For this analysis, Nvivo software was employed.

Fourthly, a spatial analysis was conducted to complement the content analysis, which included the tweets being separated by location and collected to help categorize themes, concepts, and technologies based on these locations. This created an overview of the most popular themes, concepts, and technologies for each state/territory in Australia. ArcGIS Pro software was used for visualizing the spatial information.

Then, the relevance filter was completed manually and was used to identify tweets that were related to or discussed AI technologies and urban planning and development related concepts, noting key sentiment words. These words were then classified on a scale of one to three, to measure the sensitivity. This scale was read as: 1 = positive sentiment, 2 = negative sentiment, and 3 = neutral sentiment. These words were then pre-processed in the program 'Weka', which created a dataset that further analyzed the word content. The sensitivity of these specific words was showcased in a 'Random tree' classification type.

Finally, a network analysis has been created to present the relationships between AI themes, concepts, and technologies, presenting the most popular relationships more centrally. In this analysis, nodes (themes, concepts, and technologies) and edges (relationships between these themes, concepts, and technologies) were used as the key elements of the network. These assist in understanding the network typology, which represents the arrangement of nodes and edges on the basis of the co-occurrence of the themes, concepts, and technologies found in the tweets. For this analysis Gephi software was employed.

4. Results

4.1. General Observations

From the final dataset of 11,262 tweets, 52% ($n = 5850$) were from NSW, 15% ($n = 1704$) were from VIC, 12% ($n = 1349$) were from SA, 10% ($n = 1124$) were from WA, 7% ($n = 787$) were from QLD, 2% ($n = 260$) were from TAS, and 1% ($n = 133$) were from ACT (Figure 2). Compared to the other states and territories, the number of tweets received from NT was recorded as 55, which represented a negligible percentage of 0%. This reveals the low interests among the NT community regarding AI-related applications. A wide range of hashtags were used in the circulated tweets. Among them, hashtags such as #AI, #IoT, #digital, #robotics, #future, #technology, #automation, #bigdata, #VR, #AR, #crypto, #bitcoin, #machine learning, and #ML were the most popular ones.

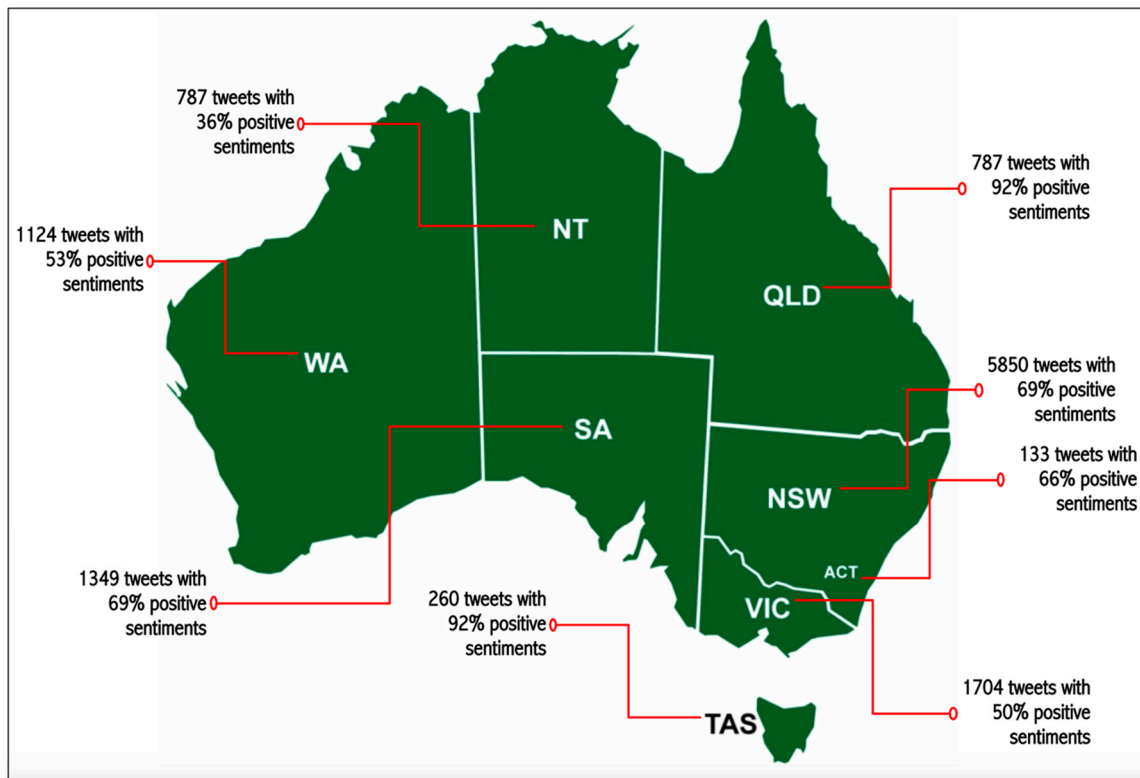


Figure 2. Tweet numbers and positive sentiment percentages by states and territories.

4.2. Community Sentiments

Out of analyzed 11,262 tweets, 66% ($n = 7475$) of them carried positive sentiments related to AI technologies and applications within the context of urban planning and development. About 17% ($n = 1935$) had negative sentiments towards AI technologies. Around 16% ($n = 1852$) of the tweets had neutral sentiments, where such tweets used only a set of hashtags to express their ideas rather than elaborative comments (Table 1).

From the tweets originating from NSW and SA, $n = 5850$ and 1349 , respectively, 69% of them contained positive sentiments—4022 and 932 tweets from NSW and SA were positive in nature, respectively. While 14% of tweets were negative in NSW, this figure was only 4% in SA. Out of 133 tweets originating from ACT, 66% ($n = 88$) were positive and 17% ($n = 22$) were negative. VIC had the second highest number of tweets ($n = 1704$), and among them 50% ($n = 854$) were positive and 42% ($n = 715$) were negative. From the 1124 tweets originating from WA, 53% ($n = 599$) were positive and 22% ($n = 251$) were negative in nature. NT had the lower number of tweets related to AI; among them, 36% ($n = 20$) were positive and only 11% ($n = 6$) were negative. Significantly, 53% ($n = 29$) of tweets from NT were neutral. Example tweets for each sentiment category are given in Table 2.

4.3. Artificial Intelligence Technologies

Using a word frequency analysis technique, 15 key AI-related technologies were derived from the collected tweets (Figure 3 and Table 3). These technologies are ‘robotics’ ($n = 3055$), ‘drones’ ($n = 1943$), ‘automation’ ($n = 717$), ‘digital twins’ ($n = 337$), ‘block chain’ ($n = 263$), ‘machine learning’ ($n = 236$), ‘digital networks’ ($n = 207$), ‘digital currency’ ($n = 192$), ‘5G technology’ ($n = 178$), ‘big data’ ($n = 154$), ‘augmented reality’ ($n = 124$), ‘3D printing’ ($n = 101$), ‘virtual reality’ ($n = 86$), ‘telephony’ ($n = 13$), and ‘chatbots’ ($n = 11$).

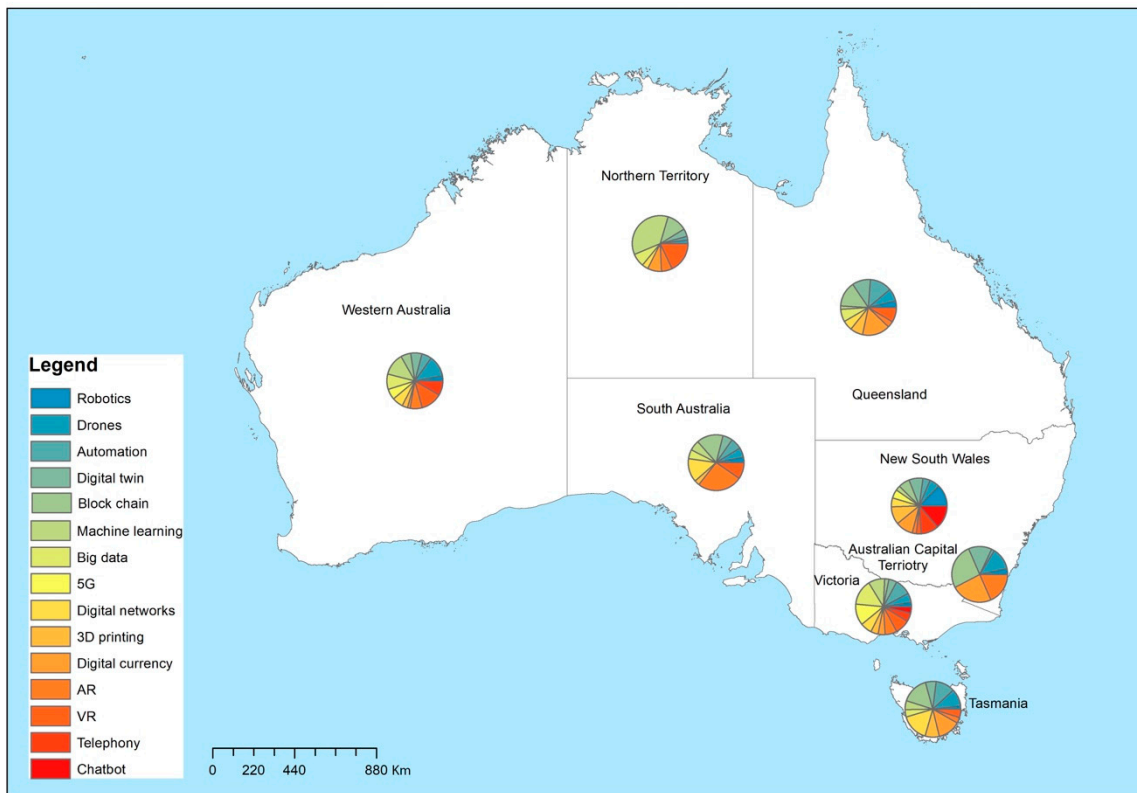


Figure 3. Distribution of tweets by artificial intelligence (AI)-related technologies per state/territory.

Nonetheless, the popularity of each technology differs from one state or territory to another. For instance, in VIC, there are more tweets about ‘automation’ ($n = 317$) compared to in NSW ($n = 180$). Conversely, ‘robotics’ is around seven times more popular ($n = 2328$) in NSW than in VIC ($n = 340$). Likewise, tweets from different states and territories had more tweets related to different AI-related technologies. ‘Robotics’ ($n = 2348$) was the most tweeted about AI technology in NSW. In contrast, ‘drones’ were the most tweeted technology in VIC ($n = 499$), WA ($n = 433$), SA ($n = 146$), QLD ($n = 96$), TAS ($n = 48$) and ACT ($n = 22$). ‘Machine learning’ ($n = 11$) was comparatively high among the tweets circulated in NT. Table 4 provides exemplar tweets related to each technology.

4.4. Artificial Intelligence Related Urban Planning and Development Concepts

On the basis of a word frequency analysis, 16 key urban planning and development related concepts were derived from the AI-related tweets (Figure 4 and Table 5). These concepts are ‘sustainability’ ($n = 774$), ‘cybersecurity’ ($n = 741$), ‘innovation’ ($n = 734$), ‘construction’ ($n = 644$), ‘governance’ ($n = 585$), ‘transportation’ ($n = 275$), ‘health’ ($n = 263$), ‘communication’ ($n = 241$), ‘digital transformation’ ($n = 203$), ‘mobility’ ($n = 190$), ‘energy’ ($n = 184$), ‘infrastructure’ ($n = 156$), ‘waste’ ($n = 144$), ‘economy’ ($n = 124$), ‘environment’ ($n = 118$), and ‘tourism’ ($n = 20$).

Sustainability was the most commonly discussed urban planning and development concept, but its usability differed from one state/territory to another. While ‘sustainability’ ($n = 418$) was the most commonly tweeted urban planning and development concept in NSW, ‘innovation’ was most popular in VIC ($n = 182$), WA ($n = 122$) and SA ($n = 110$). The use of AI-related technologies in ‘governance’ was the most popular concept in QLD ($n = 29$) and ACT ($n = 10$). Tweets from TAS had more discussions related to use of AI in ‘construction’ ($n = 20$). Although there was a lower number of tweets in NT, most of them were related to use of AI for ‘sustainability’ ($n = 9$).

Table 4. Example tweets for AI-related technologies.

Technology	Data and Time	State	Tweet	Sentiment
Robotics	18/06/2020 2:14 p.m.	NSW	Boston Dynamics starts selling its Spot robot your own pet robot dog for \$74,500 #Robotics #ArtificialIntelligence #robotpetdog #exciting	Positive
Drones	10/01/2020 7:22 p.m.	QLD	These drones plant thousands of trees ðŸŒ³ every day. Shooting the seeds into the ground. Huge opportunity for massive global tree planting!	Positive
Automation	18/12/2019 9:18 p.m.	VIC	As automation technology becomes more ingrained into the workplace, employee training becomes critical to direct employees' time toward higher-value work. The results of this survey are fascinating #SkillsGap #DigitalSkills	Positive
Digital twins	5/02/2020 1:38 p.m.	VIC	See my virtual replica. Experience the difference and the excitements #digitaltwin	Positive
Block chain	16/07/2019 8:35 p.m.	TAS	A place with abundant renewable generation such as wind, pumped hydro and cool climate would be perfect. #TAS and @HydroTasmania has all three, combined with a blockchain based electricity marketplace and we can use the exist #futuristic #sustainableworld	Positive
Machine learning	5/02/2020 11:03 a.m.	ACT	Really excited for this one—our contribution to the discussion on predicting performances based on training load. Plus, an extra section using machine learning to combine the data from multiple athletes to predict outcomes for one. All done using #rstats h	Positive
Network	22/01/2019 5:34 a.m.	SA	A Hacker-Proof Quantum Network Is Hiding In This City Tunnel. We all are at a big risk	Negative
Digital currency	9/01/2020 11:49 a.m.	NSW	The latest The Bitcoin Profits Daily! https://t.co/qTJJaBkGEO Thanks to @EllenDibble @linasantlinijos #cryptocurrency #cryptocurrency #enjoytheprofit	Positive
5G technology	9/12/2019 2:27 a.m.	TAS	What has #5G got to do with helping reduce road traffic accidents? #EmergingTech #AI #ML #IoT #SelfDrivingCars #SmartCities #SelfDriving #Driverless #AutonomousVehicles #SelfDrivingCars #autonomousdriving #Automotive #selfDrivingCar #4IR #safercities	Positive
Big data	2/04/2019 11:09 a.m.	WA	Training doctors while using #AugmentedReality via @futurism #AR #VR #Healthcare #InternetofThings #IoT #SmartCity #SmartPhones #ArtificialIntelligence #AI #BigData #DataAnalytics #Data #Video	Positive
Augmented reality	17/01/2019 10:08 a.m.	WA	The AR market today is similar to where the IoT market was in 2010. AR's capacity to visualize, instruct, and interact can transform the way we work with data #success #newtech	Positive
3D printing	17/01/2019 12:33 a.m.	WA	Did my first 3D printing? It's amazing super-duper excited to share it with you	Positive
Virtual reality	29/03/2019 8:34 a.m.	SA	How exciting to see what is possible when AI meets virtual reality in the treatment of mental health conditions	Positive
Telephony	29/08/2019 5:12 p.m.	NT	Telephony technology has evolved rapidly keeping people distant emotionally and physically	Negative
Chatbots	19/06/2020 3:26 a.m.	NSW	How can I find screenshots or scripts from the CyberLover chatbot (the bot used to flirt with people in order to steal their data)? I would like to see some of the conversations it held. #wrongexamples	Negative

As shown in Table 5, the use of AI technologies in relation to transportation, health, communication and digital transformation were also some of the frequently used concepts (or AI application areas). Furthermore, concepts such as ‘mobility’, ‘energy’, ‘waste’, ‘economy’, ‘environment’ and ‘tourism’ did not receive much attention, and thus they can be identified as emerging topics within the research contexts of novel AI applications. Table 6 provides exemplar tweets related to each urban planning and development concept.

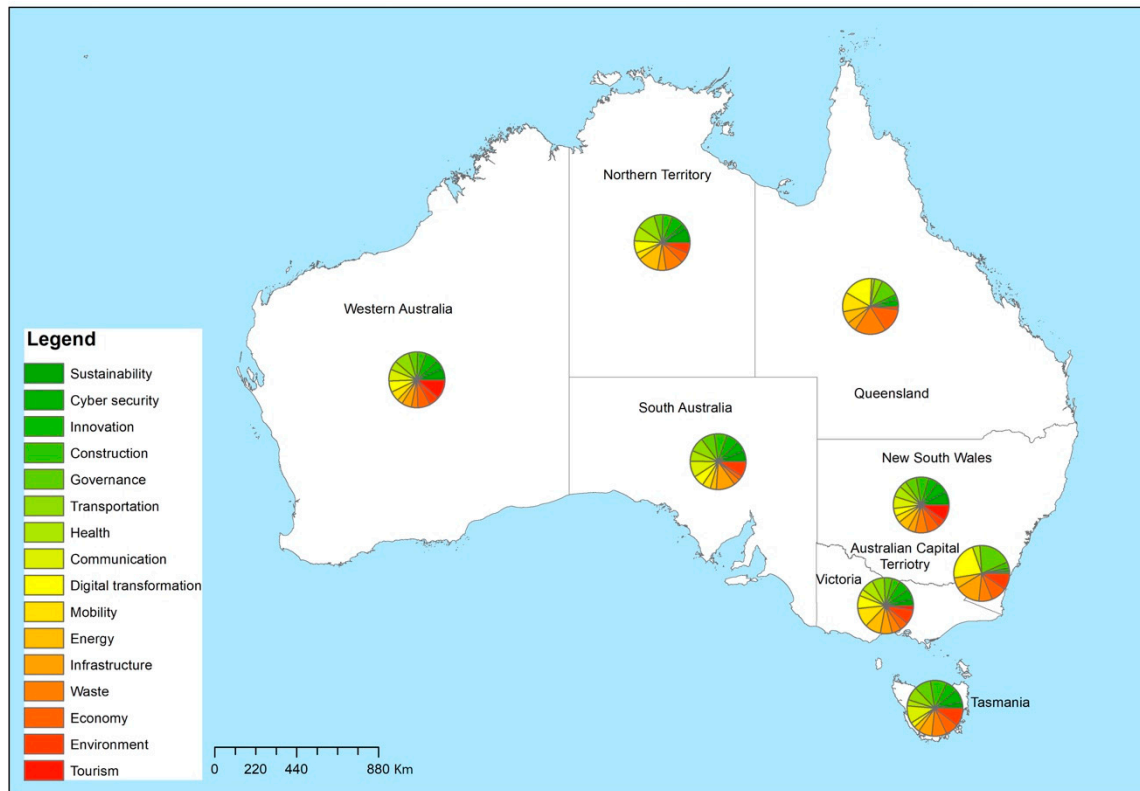


Figure 4. Distribution of tweets by urban planning and development concepts per state/territory.

4.5. Relationships between Artificial Intelligence Technologies and Urban Planning and Development Concepts

The objective has been to understand AI-related technologies and the public perception of their application in the urban context. To this end, this study conducted a word co-occurrence analysis, which identified the number of tweets that mentioned both technology and the urban planning and development concepts (Table 7).

Figure 5 represents the network topology, developed on the basis of the word co-occurrence analysis. This network typology was initially generated by using the Gephi software. Nonetheless, due to the crowdedness of the original figure—shown in the lower left side of Figure 5—a less complex version was recreated by only showing the stronger relationships occurred between AI technologies and urban planning and development concepts. For that, we identified connections less than 50 as weak or mid-strength, and removed them from the figure. Connection counts between 50 and 99 are determined as semi-strong, connections between 100 and 199 are categorized as strong, and connections over 200 are labeled as very strong. Figure 5 illustrates these connections, where only the prominent connections are shown in the main part of the figure, and the full connections are given at the lower left side of the figure.

Table 5. Distribution of tweets by urban planning and development concepts per state/territory.

	Sustainability	Cybersecurity	Innovation	Construction	Governance	Transportation	Health	Communication	Digital Transformation	Mobility	Energy	Infrastructure	Waste	Economy	Environment	Tourism
NSW	418	358	285	324	264	78	115	116	63	54	79	48	72	61	37	13
VIC	119	173	182	123	101	78	76	35	61	82	67	42	30	24	38	2
WA	115	86	122	72	66	55	30	36	29	24	13	20	12	20	15	5
SA	101	89	110	97	93	47	33	46	26	19	13	35	11	6	21	0
QLD	3	13	11	1	29	6	2	0	16	10	6	4	12	8	1	0
TAS	9	18	16	20	18	7	3	8	2	0	2	4	4	3	4	0
ACT	0	1	1	2	10	0	1	0	4	0	1	2	1	1	1	0
NT	9	3	7	5	4	4	3	0	2	1	3	1	2	1	1	0
Total	774	741	734	644	585	275	263	241	203	190	184	156	144	124	118	20
NSW	54.01	48.31	38.83	50.31	45.13	28.36	43.73	48.13	31.03	28.42	42.93	30.77	50.01	49.19	31.36	65
VIC	15.37	23.35	24.79	19.09	17.26	28.36	28.89	14.52	30.05	43.16	36.41	26.92	20.83	19.35	32.19	10
WA	14.86	11.61	16.62	11.18	11.28	20.01	11.41	14.94	14.29	12.63	7.07	12.82	8.33	16.13	12.71	25
SA	13.05	12.01	14.99	15.06	15.9	17.09	12.55	19.09	12.81	10	7.07	22.44	7.64	4.84	17.8	0
QLD	0.39	1.75	1.5	0.16	4.96	2.18	0.76	0	7.88	5.26	3.26	2.56	8.33	6.45	0.85	0
TAS	1.16	2.43	2.18	3.11	3.08	2.55	1.14	3.32	0.99	0	1.09	2.56	2.78	2.42	3.39	0
ACT	0	0.13	0.14	0.31	1.71	0	0.38	0	1.97	0	0.54	1.28	0.69	0.81	0.85	0
NT	1.16	0.41	0.95	0.78	0.68	1.45	1.14	0	0.98	0.53	1.63	0.65	1.39	0.81	0.85	0
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6. Example tweets for urban planning and development concepts.

Concepts	Data and Time	State	Tweet	Sentiment
Sustainability	17/06/2020 5:26 a.m.	NSW	3Ai Director @feraldata and @anucecs Dean @profElanor join the world-first Global Partnership on Artificial Intelligence. An exciting opportunity for Australia to contribute to global work on AI and to shape a safe, responsible and sustainable future.	Positive
Cybersecurity	18/06/2020 10:07 a.m.	NSW	Digital human rights issues such as data privacy, cybersecurity and social impacts of AI can pose risks to companies, and protection of digital human rights take on new considerations in the post-COVID-19 era, according to @Robeco https://t.co/9zvXiVIDdJ	Negative
Innovation	9/01/2020 10:29 p.m.	QLD	We are thrilled to be featured in an @AllianceQQ Mag Dec/Jan issue article focusing on new #technology impacting #mining. "The industry is now seeing a second wave of technological #innovation based on #digitisation and #IoT"	Positive
Construction	4/02/2020 2:17 p.m.	SA	I'm working on some amazing #hightech projects with the awesome team. #IOT #industrialiot #meshnetworks #smartmine #miningsolutions #miningtechnology #agriculture #agritech #agribusiness #construction #smartcity	Positive
Governance	29/10/2019 2:14 p.m.	ACT	How can governments earn trust in the next generation of AI; bot powered digital services? @piawaugh introduces our new fave term Citizen's Ledger in this A+ read on trust infrastructure for the future of democratic government #fake&fraud	Negative

Table 6. Cont.

Concepts	Data and Time	State	Tweet	Sentiment
Transportation	29/05/2019 10:13 a.m.		One of my favorite PBLs that my Ts do is #smartreynoldsburg. Based on what Ss learn about our city’s past; the future of transportation; energy, Ss create a 3D model of what Reynoldsburg will look like in 50 years, complete with an autonomous car. #teachingland	Positive
Health	16/06/2020 5:56 p.m.	NSW	Big day today—I have now performed more than 300 transoral robotic surgeries on the da Vinci platform. Thank you to my surgical team and @SVHSydney for the cake! #TORS #HNC #HeadandNeckCancer #roboticsurgery @device_robotics https://t.co/KNhGv1YF4n	Positive
Communication	3/09/2019 11:50 a.m.	SA	We are excited to announce the new research initiative: Information, Communication the Data Society. ICDS is an interdisciplinary research initiative on the way AI and algorithms affect the role, impact and regulation of information	Positive
Digital transformation	1/04/2019 5:29 a.m.	NSW	What is the #InternetOfThings? Why is it so important? #IoT #DigitalTransformation #Automation #SmartCity #AutonomousVehicles #Driverless #SmartCars #SmartHome #CyberSecurity #SmartTech	Neutral
Mobility	31/03/2019 4:51 p.m.	SA	Should the AIUS SA focus on the Future of Mobility such as driverless shuttles and other autonomous vehicles? Let us know by completing our 5 min survey!	Neutral
Energy	20/08/2019 6:27 a.m.	WA	Australian @PowerLedger_io successfully trialled its blockchain platform’s use in P2P trading of renewable electricity in Japan	Positive
Infrastructure	16/04/2020 1:38 p.m.	QLD	#Virtual presence for physical one could have taken at least a generation #Coronavirus #Covid19 did it in months To #sustain it with #reliability #security & #capacity strong #Telecom infrastructure like #5G is important than ever #ICT #VR #AR #AI #Cloud #Data #IoT #CyberSecurity #safercities	Positive
Waste	17/06/2020 5:43 a.m.	NSW	As part of a new partnership with @Microsoft, we’re using artificial intelligence (AI) and other digital technologies to boost farming and tackle global challenges including illegal fishing and plastic waste	Positive
Economy	1/05/2020 2:08 a.m.	TAS	Excited to introduce the AI Economist: Extends ideas from Reinforcement Learning for tackling inequality through learned tax policy design. The framework optimizes productivity and equality.	Positive
Environment	10/09/2019 6:57 p.m.	TAS	Going digital will save the environment. Go digital!!!	Positive
Tourism	25/06/2019 7:00 a.m.	QLD	Autonomous regions, have been well prepared for the peak #tourism season #easytravel #easyapps	Positive

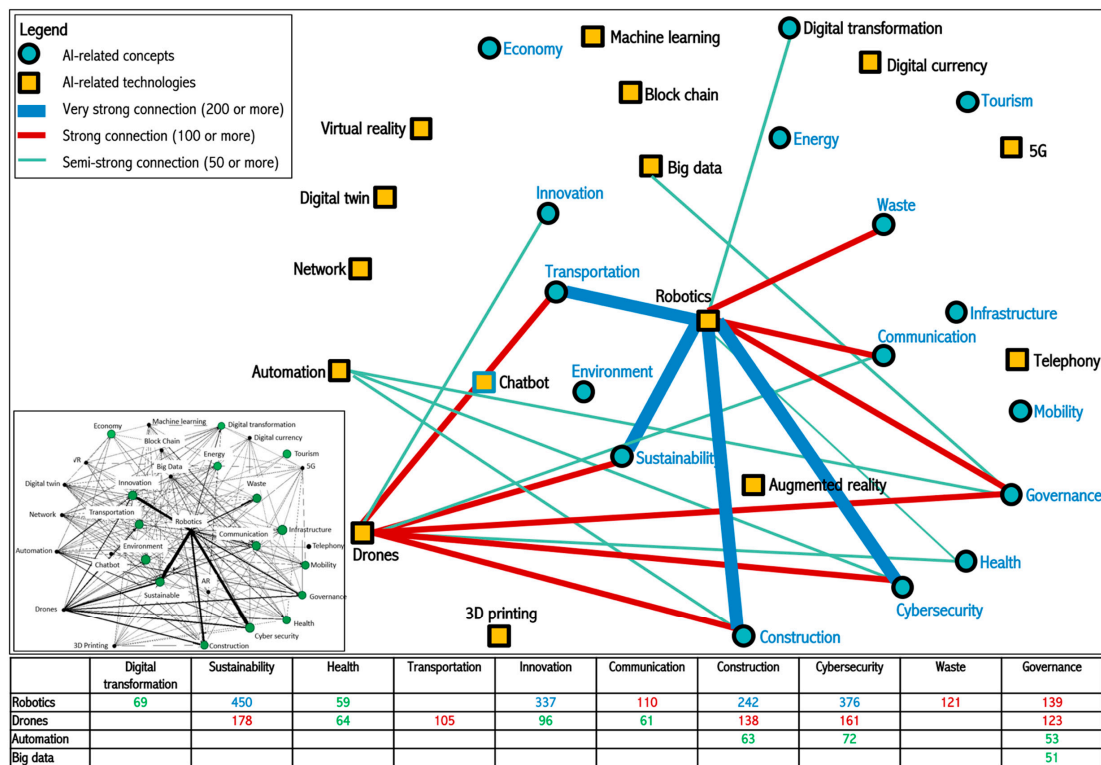


Figure 5. Relationships between AI technologies and urban planning and development concepts.

As shown in Figure 5, robotics has a close relationship with urban planning and development concepts such as ‘innovation’ ($n = 337$), ‘sustainability’ ($n = 450$), ‘cybersecurity’ ($n = 376$), ‘construction’ ($n = 242$), ‘governance’ ($n = 139$) and ‘waste management’ ($n = 121$). Secondly, the relationships between ‘drone’ technology and ‘sustainability’ ($n = 178$), ‘cybersecurity’ ($n = 161$) and ‘construction’ ($n = 138$) were very pronounced. The third popular relationship was the use of ‘autonomation’ in ‘cybersecurity’ ($n = 72$), ‘construction’ ($n = 63$), ‘innovation’ ($n = 61$), and ‘transportation’ ($n = 48$). Fourthly, the relationship between ‘big data’ and ‘governance’ ($n = 51$), and ‘cybersecurity’ ($n = 42$) was visible.

Although the relationships among the AI-related technologies such as ‘digital twin’, ‘digital networking’, ‘machine learning’, ‘3D printing’ and ‘5G’ were not as frequently used in relation to the derived urban planning and development concepts, they can be identified as emerging discussions within the Twitter hemisphere. The existence of tweets related to the ‘digital twin’ and ‘governance’ ($n = 28$), ‘digital transformation’ ($n = 28$) and ‘innovation’ ($n = 26$) highlighted the increasing importance of ‘digital twin’ technology in our society—both the public and private sectors. Nevertheless, tweets related to technologies such as ‘block chain’, ‘AR’, ‘VR’, ‘digital currency’, ‘chatbot’ and ‘telephony’ were comparatively low. Table 8 shows the example tweets which discuss AI technologies in the derived urban planning and development concepts (or, in other words, AI application areas).

Table 7. Technology-concept relationship word co-occurrence analysis.

	Digital Transformation	Sustainability	Health	Environment	Economy	Transportation	Innovation	Communication	Construction	Tourism	Infrastructure	Energy	Cybersecurity	Mobility	Waste	Governance	Total
Robotics	69	450	59	13	22	40	337	110	242	2	14	16	376	44	121	139	2054
Drones	10	178	64	37	17	105	96	61	138	2	29	16	161	13	26	123	1076
Automation	28	48	8	0	18	16	61	26	63	2	4	12	72	8	9	53	428
Big data	11	2	13	12	6	12	25	19	33	0	10	14	42	6	2	51	258
Digital twin	28	23	12	2	8	6	26	4	20	0	12	9	15	6	6	28	205
Network	28	23	12	2	0	8	16	10	23	0	11	20	22	4	2	17	198
Machine learning	4	12	2	2	2	4	16	41	2	0	0	6	6	0	0	8	105
3D printing	2	19	4	0	0	2	13	0	14	0	8	6	6	2	2	6	84
5G	5	14	4	0	2	4	15	2	13	0	2	2	2	8	0	4	77
Block chain	4	10	5	2	0	2	10	6	0	0	0	0	11	2	4	2	58
AR	10	10	2	2	2	2	10	0	7	0	2	2	3	6	0	0	58
VR	11	9	0	0	4	2	13	0	4	0	0	4	0	4	0	4	55
Digital currency	2	10	2	0	0	5	9	0	2	0	0	3	5	0	0	8	46
Chatbot	0	0	0	0	0	0	0	4	6	0	0	0	1	0	0	2	13
Telephony	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	6
Total	212	808	187	72	81	208	647	289	567	6	92	110	722	103	172	445	4721

Table 8. Example tweets showing the relationship between AI technologies and urban planning and development concepts.

Data and Time	State	Tweet	AI Technology	Urban Planning and Development Concept	Sentiment
14/11/2019 5:57 p.m.	VIC	Great to see @cserAdelaide Lending Library #sphero kit in action with classes designing and building a Sustainable City and then coding robots through the streets of the city.	Robotics	Sustainability	Positive
3/01/2019 7:26 a.m.	NSW	Building #Sustainable #transport platforms will provide a more efficient #smartcity and cheaper than autonomous and electric vehicles	Automation	Transportation	Positive
17/06/2019 10:36 a.m.	QLD	City Loses \$500,000 to Phishing Attack #CyberSecurity #Databreach #Ransomware #Hackers #infosec @reach2ratan #AI #bots #malware #DDoS #Digitaltransformation #Fintech #Blockchain #Chatbots #Bigdata #datascience #Digital	Chatbot, Big data	Cybersecurity, Digital transformation	Negative
8/08/2019 11:35 a.m.	TAS	@UTAS_@DeformedEarth @CityByrne @homehillwines Drone video of @homehillwines landslide and @UTAS_#UTAS_GSS student at work collecting 3D spatial data. Thanks @homehillwines for your fantastic hospitality!	Drone	Environment	Positive
5/08/2019 4:24 p.m.	NSW	Humanity must now accept that a digital economy implemented by global governance w/AI world systems for ppl and planet is the way forward from 2020 #bitcoins	Digital currency	Economy, Governance	Positive
29/03/2019 8:34 a.m.	SA	How exciting to see what is possible when AI meets virtual reality in the treatment of mental health conditions	VR	Health	Positive

5. Discussion

AI is a widely used technology in Australia across many urban planning and development areas, including, but not limited to, health, safety, environment, energy, infrastructure, transport, education and urban services [58]. Nonetheless, public perceptions regarding the use of AI are an understudied line of research [59]. The study at hand focused on addressing this limitation. Accordingly, the community's positive perceptions regarding the use of AI are evident in the presented findings. This is to say, overall, the Australian public has a positive perception of AI and its use to make cities more sustainable, innovative, accessible, healthy, and livable [60,61].

Nonetheless, in the analyzed tweets, the public has also raised concerns about the use of AI, particularly in terms of cybersecurity breaches. Especially during the pandemic, a large part of Australian society was intending to move towards digital transformation. Due to the cyber-attack boom in 2020 in Australia, the discussions on cybersecurity and the ethical concerns associated with using AI technologies become highly prominent [62,63]. Australian researchers have also highlighted the importance of understanding the loopholes in the present AI systems [64]. Furthermore, the digital transformation has had a negative impact on the elderly population, as they need more assistance to use the technology [65,66].

The Australian government has already drafted an 'AI Action Plan' for all Australians, and is currently seeking feedback from the wider community [67]. Through this plan, the Australian government has attempted to address the issue of cybersecurity by preparing and publishing an 'AI Ethics Framework'. This framework addresses the following issues: (a) human, social and environmental wellbeing; (b) human-centered values; (c) fairness; (d) privacy protection and security; (e) reliability and safety; (f) transparency and explainability; (g) contestability; and (h) accountability [68]. Moreover, the Australian government has identified the importance of using AI in the aging and disability sector to reduce costs while making quality care accessible to adult Australians [48]. Nevertheless, it is important to pay attention to the user-friendliness and affordability of AI technologies, particularly concerning the disadvantaged populations [69].

In 2019, the Australian government released an AI roadmap that recognizes the current global shift towards smart cities and smart urban infrastructure [48]. The roadmap suggests that government institutions should work with private organizations to develop, advance, and deploy AI solutions that will improve the urban environment and will help shape sustainable urban futures.

The roadmap has pointed to the potential benefits of AI, such as economic growth (Australia could become a key player on the global AI market in 2030, reaching a value of AUD 22.17 trillion), improved quality of life, environmental sustainability, and solution of the problems experienced by the aging society [48]. The roadmap involves the use of AI to decrease the costs and improve the effectiveness of built infrastructure planning, design, construction, operation and maintenance. This is significant in the built environment as there is a shortcoming of built infrastructure, as it is already impacting the operations of towns and cities around Australia [48]. The following are urban planning and development concepts that were mentioned in the roadmap:

- *Improve the digital infrastructure* (for data transmission storage, analysis and acquisition) so that AI can safely and effectively be used across Australian cities.
- *Develop AI for better towns, cities, and infrastructure*, to improve the safety, efficiency, cost-effectiveness, and quality of the built environment.
- *Improve design, planning, construction, operation, and maintenance* of infrastructure and building with AI.
- *Utilize AI to improve the efficiency and safety* of transportation, electricity, and water services throughout the urban environment.
- *Improve AI technology* that reduces high construction costs and unplanned cost overruns as it is limiting the ability to improve cities and infrastructure.

Since 2010, The Australian Research Council (ARC) has awarded over AUD 243 million to research regarding AI and data processing. Significant investment went towards block chain, AR/VR, robotic process automation (RPA), natural language processing (NLP), and computer vision. These technologies represent the functionality of a digital co-worker, as it encompasses both rule-based activities and judgement-based activities [70]. The following are the key concepts that were developed in the funded research and have influenced the perception of AI-related urban planning and development:

- *Data analytics*: Real-time or historical data that can provide insights into an urban environment. A key example are intelligent traffic lights that use data analytics to coordinate and make time-based changes in the traffic lights.
- *Machine learning*: Computer vision techniques to collect and annotate datasets. The model can be applied to predict the roads that will undergo more 'Wear and Tear', allowing maintenance crews to focus their energy on repairing potholes, instead of looking for them.
- *Deep learning*: Complex algorithm that analyses large datasets to give planners a predictive insight into data. This provides urban planners with an insight into the nature of traffic, management of traffic flows, and the design of new public transportation.

Perhaps the most important digital infrastructure in the future would be to provide distributed AI services to support the development and operations of ubiquitous urban, rural, industrial, and other applications [71]. The 5G networks that promise us unprecedented mobile internet speed have started to appear around the world. However, AI infrastructure requires more than mere fast networks. The work on the sixth generation (6G) networks has begun. The 6G networks are expected to support extreme-scale ubiquitous AI services through next-generation softwarization, platformization, heterogeneity, and configurability of networks [71]. This is a technology that will likely have unimaginable impacts on urban planning and development [72].

6. Conclusions

AI is undoubtedly a powerful technology and has already started to reshape and disrupt our economy, society, cities, and urban management systems [73,74]. Today, there is limited understanding of the trending AI technologies and their application areas—or concepts—in the urban planning and development fields [75]. Moreover, there is a knowledge gap in how the public perceives AI technologies, their application areas, and the AI-related policies and practices of our cities [76,77]. Hence, the study at hand aimed at advancing our understanding of the relationship between the key AI technologies and their key application areas in urban planning and development.

The social media analytics undertaken in this study has important findings. Overall, the location-based twitter analysis throughout this study has identified that: (a) 'Sustainability' ($n = 774$ tweets); (b) 'Cybersecurity' ($n = 741$); (c) 'Innovation' ($n = 734$), and; (d) 'Construction' ($n = 644$) are generally the mostly discussed urban planning and development concepts across the entirety of Australia, although the popularity differs by states and territories. To accomplish the listed concepts, the following AI-related technologies are the most popularly discussed ones: (a) 'Robotics' ($n = 3055$ out of 11,262, 27%); (b) 'Drones' ($n = 1943$, 17%), and; (c) 'Automation' ($n = 717$, 23%). The sentiment analysis has also defined that the degree of satisfaction across Australian communities is relatively high. It has been demonstrated that 'robotics', 'drones' and 'automation' are the AI fields that have a close relationship with the urban planning and development concepts of 'sustainability', 'cybersecurity', 'innovation' and 'construction'.

This study has also disclosed that QLD and TAS have the highest degree of satisfaction (92% of positive sentiments) among the other states and territories. In contrast, given that most states and territories gained dominant positive sentiments, NT has had the lowest degree of satisfaction, as demonstrated by a higher level of neutral sentiments (53%), as well as low interests in sharing their views on social media channels (i.e., Twitter), comprising slightly over 0% of the tweets studied. Meanwhile, NSW and VIC, to which the highest percentage of the total tweets belonged, had a lower

degree of satisfaction than QLD and TAS. However, their degrees of satisfaction are also relatively high. The close relationship between popular technologies and concepts was also justified in a number of analysis procedures—i.e., sentiment and content analyses, frequency analysis, content analysis, co-occurrence analysis, and spatial analysis.

In addition, concepts and technologies that have received less attention on Twitter are considered to be emerging topics and thus are deemed important to keep track of. This study also addressed the significance of improving all of the identified AI-related technologies for their safety, effectiveness, efficiency, and affordances throughout the Australian AI Roadmap. Further empirical studies and analyses are needed to make concerted consolidations of AI across Australia to better understand the public perceptions with improved ethics, regulation, design, planning, construction, operation, and maintenance toward better Australian towns, cities, infrastructure, and buildings. In this prospective research, a particular attention should also be paid to further consolidate the understanding and relation between AI and responsible urban innovation [78–80].

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