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Artificial Intelligent Technologies for the Construction Industry: How Are They Perceived and Utilized in Australia?

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Abstract: Artificial intelligence (AI) is a powerful technology that can be utilized throughout a construction project lifecycle. Transition to incorporate AI technologies in the construction industry has been delayed due to the lack of know-how and research. There is also a knowledge gap regarding how the public perceives AI technologies, their areas of application, prospects, and constraints in the construction industry. This study aims to explore AI technology adoption prospects and constraints in the Australian construction industry by analyzing social media data. This study adopted social media analytics, along with sentiment and content analyses of Twitter messages (n = 7906), as the methodological approach. The results revealed that: (a) robotics, internet-of-things, and machine learning are the most popular AI technologies in Australia; (b) Australian public sentiments toward AI are mostly positive, whilst some negative perceptions exist; (c) there are distinctive views on the opportunities and constraints of AI among the Australian states/territories; (d) timesaving, innovation, and digitalization are the most common AI prospects; and (e) project risk, security of data, and lack of capabilities are the most common AI constraints. This study is the first to explore AI technology adoption prospects and constraints in the Australian construction industry by analyzing social media data. The findings inform the construction industry on public perceptions and prospects and constraints of AI adoption. In addition, it advocates the search for finding the most efficient means to utilize AI technologies. The study helps public perceptions and prospects and constraints of AI adoption to be factored in construction industry technology adoption.

Keywords: industry 4.0; automation; robotics; digital twin; machine learning; big data; social media analytics

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1. Introduction

Artificial intelligence (AI) technologies have been widely adopted in many industry sectors [1–3]. Among those, the adoption level is significantly lower in the Australian construction industry. The Australian construction industry generates approximately 360 billion in revenue, accounting for 9% of the country's gross domestic product (GDP), and it is expected to grow to 11.5% of the total GDP in the next five years [4]. Nonetheless, its productivity has only increased by 1% over the past two decades. Thus, there are growing concerns regarding efficiency in the industry [5]. The slow growth is a direct result of the fundamental rules and characteristics of the construction market. The cyclical demand is further compounded, leading to low capital investment and limited standardization [6].

In response to the slow growth, the need for investment and research into AI technologies is being explored to streamline the processes and increase productivity [1–3]. The benefits that AI can bring to the construction industry include preventing cost overruns, improving site safety, and managing projects efficiently [7–11]. There has already been substantial growth in the following AI areas of big data and analytics, robotics, automation, data integration, and wearable technology [12,13].

Implementing AI technologies and realizing the benefits it may bring is difficult. Most algorithms require accurate data for training, and collecting data is costly and time-consuming at the beginning [2,14,15]. The implementation of AI in construction remains in the initial stages, even though some larger construction companies have already begun to enjoy the benefits of these technologies. This has resulted in an increased debate on the future of the construction workforce and how AI will impact jobs [16].

Despite the increasing importance of AI for the construction industry, there are only limited studies investigated the AI adoption prospects and constraints in the construction industry [17–19]. Although the industry transforms slowly to digitalize the construction process, firms have an increasing interest when they realize the benefits of AI-powered algorithms and analytics [20,21]. Nonetheless, there are growing but still limited studies reported in the international literature [22–25], and only a few of them look at this issue in the context of Australia [26,27].

A knowledge gap remains regarding how the public perceives the implementation of AI technologies. In addition, how they feel about the extensive application of automated technologies producing sustainable outcomes and making traditional jobs obsolete [7,28–30]. A good understanding of the public perception of AI technologies will inform governing bodies how to respond adequately to public demands and figure out the most efficient ways to implement AI without disrupting traditional work processes [31]. Therefore, it is necessary to study how AI directly interacts with individuals and how different AI technologies can positively or negatively impact individuals or companies in the construction industry.

This study, hence, focuses on the public perception of AI technologies and discusses the prospects and constraints that AI technologies may bring in Australia. We use the social media analytics method and conduct an opinion and content analysis of location-based Twitter messages from Australia. Following this introduction section, Section 2 introduces the methodological approach of the study. Section 3 presents the results of the analysis and observes the data that were collected. Section 4 discusses the study findings, general insights, research limitations, and future research recommendations. Lastly, Section 5 states the final remarks of the paper.

2. Methodology

We investigated the public perception of AI as it becomes more frequently used on construction sites, and project success in the future will be highly dependent on the efficient use of these technologies. The reasons behind this selection include: (a) some of Australia's major construction firms have begun to realize the benefits of AI. These firms successfully adopt AI for their projects to save costs and time; (b) Australia is developing a national AI strategy and roadmap, meaning that AI uptake in cities and industries is planned to avoid solely organic occurrence; (c) the use of social media in Australia is very popular, making it a source of information that can provide a generalized perception of AI in the construction industry. The number of internet users who use social media daily continues to grow in 2021; at present, 79.9% of the Australian population uses social media. This saw an increase of 8.8% in social media usage from 2020. Around 56% of people go online more than 10 times a day, and 26% of people go online more than 20 times a day. Among 79.9% of internet users that use social media, 20% of them have accessed Twitter, and one-third of them tweet daily [32]; (d) Although social media produce an abundance of data regarding AI in Australia, there are not any, to our knowledge, studies investigate the public perception of AI in the construction industry.

Instead of using a traditional data collection method, we employ the social media analysis for this research. As more people use social media to communicate and express their opinions, it has become a source of qualitative data [33]. This data collection method has been used in a wide range of research. Social media allows researchers to engage with a large group of people in an unbiased setting [34]. In addition, researchers can engage with people from a broad geographic area according to user locations, which are tagged in their posts [35].

Twitter was the only social media platform used to obtain data as it's a micro-blogging site. Among the four types of social media services, micro-blogging sites, specifically Twitter, collect information for sentiment analysis [36]. Twitter is one of the ten most visited websites that enable users to post and interact with short messages. The platform allows for opinion and provides very valuable information to scholars. Conducting a sentiment analysis on other social media platforms is not favorable as data are not readily available, unstructured, and often used in short form. This makes the data harder to be analyzed.

A geo-Twitter analysis has proven to be a successful data collection method. The research method is efficient in analyzing public opinions [37]. It offers an insight into new AI technologies that are developing and/or currently being used on construction sites through real-time information [38]. For instance, social media analytics safeguards Australian cities and their residents from the coronavirus outbreak (COVID-19) in 2020 [39].

Initially, sentiment and content analysis were computed for the total number of location-based Twitter messages. To do this, the original dataset was obtained from the QUT Digital Observatory on 5 April 2021 (https://www.qut.edu.au/research/why-qut/infrastructure/digital-observatory). By using five data filtering processes—i.e., frequency analysis, location, date, bot, and relevance filters—11,365 tweets were filtered down to 7906 tweets.

We selected a two-year period from 1 July 2019 to 1 July 2021 for analysis and removed all tweets outside Australia. The reason behind a two-year period was that a one-year period could not provide enough data for analysis or derive objective quantitative results from texts. In addition, a three-year period would not be able to capture the latest trends, as AI in construction is developing fast and public perception changes rapidly. Thus, a two-year period reflected more accurately people's sentiment towards AI in construction. The bot filter is employed to remove tweet repetition.

Secondly, to identify the main themes of tweets about AI applications in the construction industry, NVivo was also used to undertake the content analysis and to analyze word frequency, concepts, and technologies. Next, we conduct a word co-occurrence analysis on tweets that discuss AI technologies and construction-related ideas (or AI application areas).

Fourthly, we conducted a spatial analysis to complement the content analysis. The tweets are classified according to themes, concepts, and technologies based on locations. This allows us to know more about Australia's most popular themes, concepts, and technologies in each state/territory. We used ArcGIS Pro software to visualize the spatial information. The relevance criteria were used to identify tweets related to or discussed AI technologies in construction-related concepts, noting key sentiment words. The scale adopted was as follows: 1 = very positive sentiment, 2 = positive sentiment, 3 = neutral sentiment, 4 = negative sentiment, 5 = very negative sentiment. We then processed these words via Weka software, which created a dataset for further analysis. We showcased the sensitivity of these specific words via Random Tree and Random Forest functions.

Finally, a network analysis was created to present the relationship between AI themes, concepts, and the relationships between AI technologies. In this analysis, we used Gephi software to understand the nodes and edges relationship found in the tweets. Figure 1 shows the research process that was used as the research model.

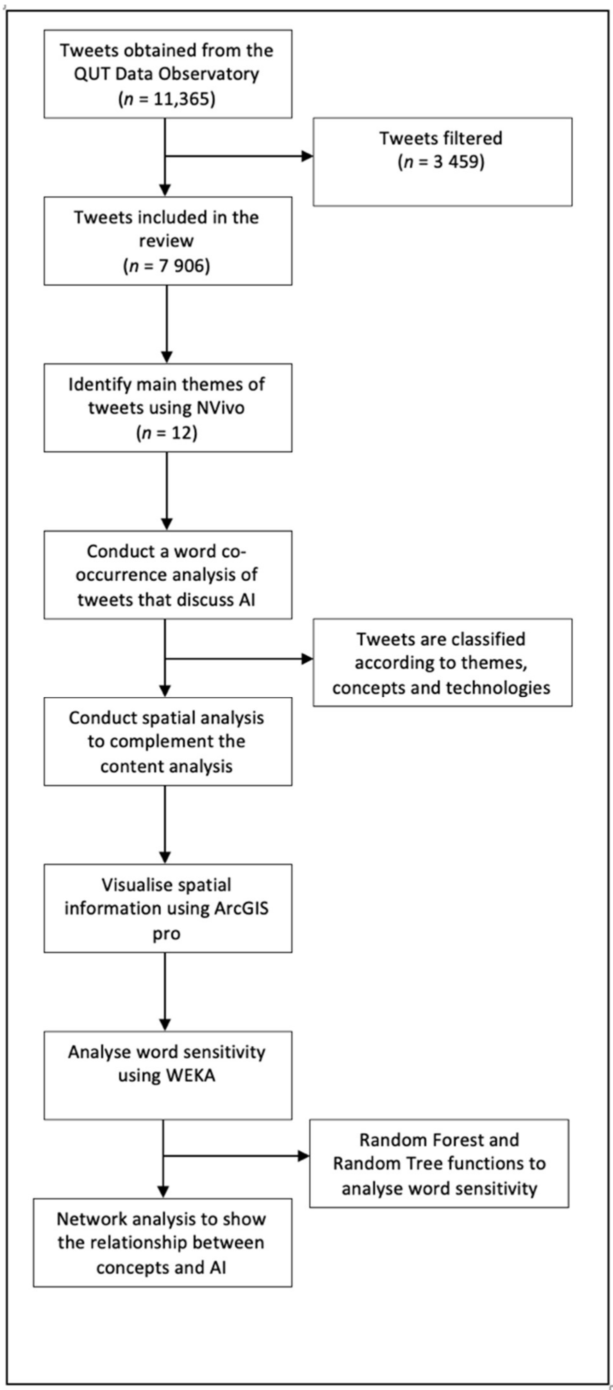


Figure 1. Process of conducting a sentiment analysis.

3. Results

3.1. General Observations

Among 7906 tweets, 39% (n = 2997) were from New South Wales (NSW), followed by 28% (n = 2214) from Victoria (VIC), 19% (n = 1540) from Queensland (QLD), 5% (n = 426) from Western Australia (WA), 5% (n = 364) from South Australia (SA), 3% (n = 258) from Australian Capital Territory (ACT), 1% (n = 55) from Tasmania (TAS), and 1% (n = 52) from Northern Territory (NT) (Figure 2). Compared to other states and territories, ACT and TAS only recorded 55 and 52 tweets, which represented a negligible percentage of 1%. This reveals a low public interest in ACT and TAS community regarding AI-related technologies in the construction industry. A wide range of hashtags was used in the circulated tweets. Among them, tags such as #Industry4.0, #AIconstruction, #IoT, #Predictiveanalytics, #Robotics, #MachineLearning, #Bigdata, #BIM, #Fourththindustryrevolution, #Datamining, and #Automation were the most popular keywords.

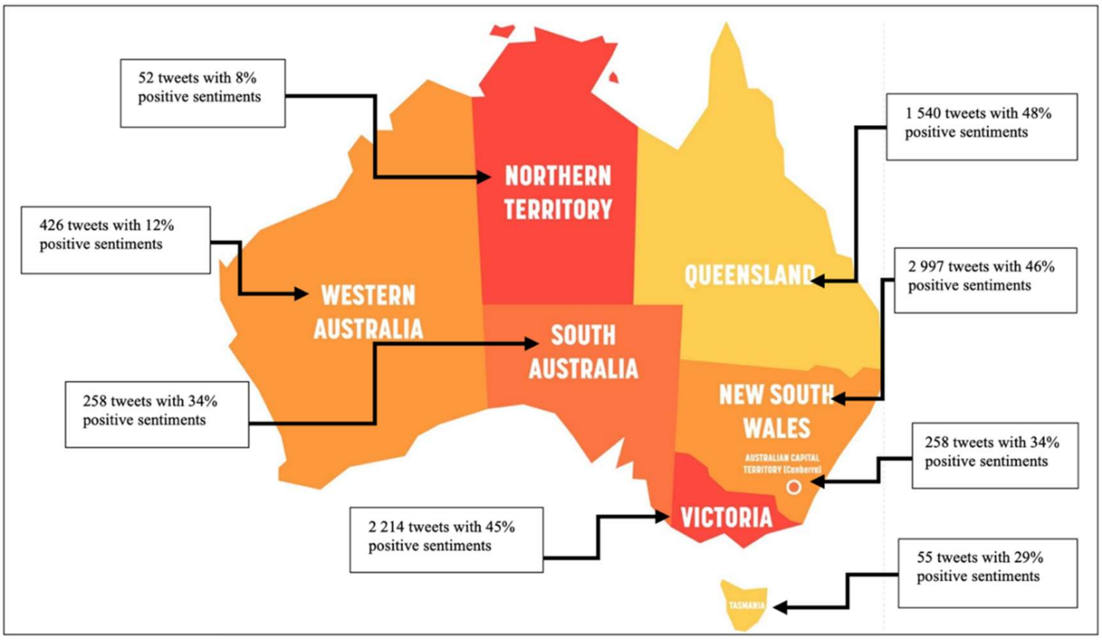


Figure 2. Tweet numbers and positive sentiment percentages by states and territories.

3.2. Community Sentiments

Out of the 7907 tweets, 49% (n = 3396) of them were positive about AI technologies and application within the context of construction. An analysis of positive sentiment in each state and territory is shown in Figure 2.

Around 37% (n = 3085) were negative towards AI in construction. An analysis of negative sentiment in each state and territory is shown in Figure 3.

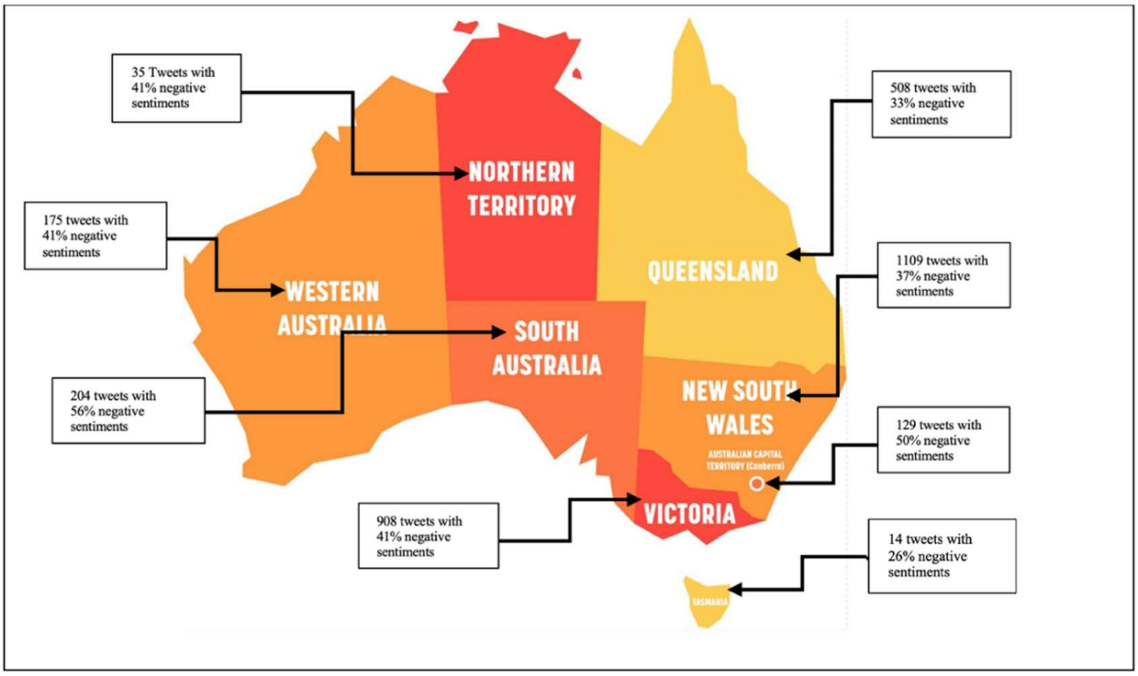


Figure 3. Tweet numbers and negative sentiment percentages by states and territories.

Furthermore, around 14% (n = 1425) of tweets were neutral, where such tweets only used a set of hashtags to express their ideas rather than comments with elaboration. An analysis of neutral sentiment in each state and territory is shown in Figure 4. In addition, Table 1 is an overview of the sentiment analysis of each state and territory, from very positive sentiment to very negative sentiment.

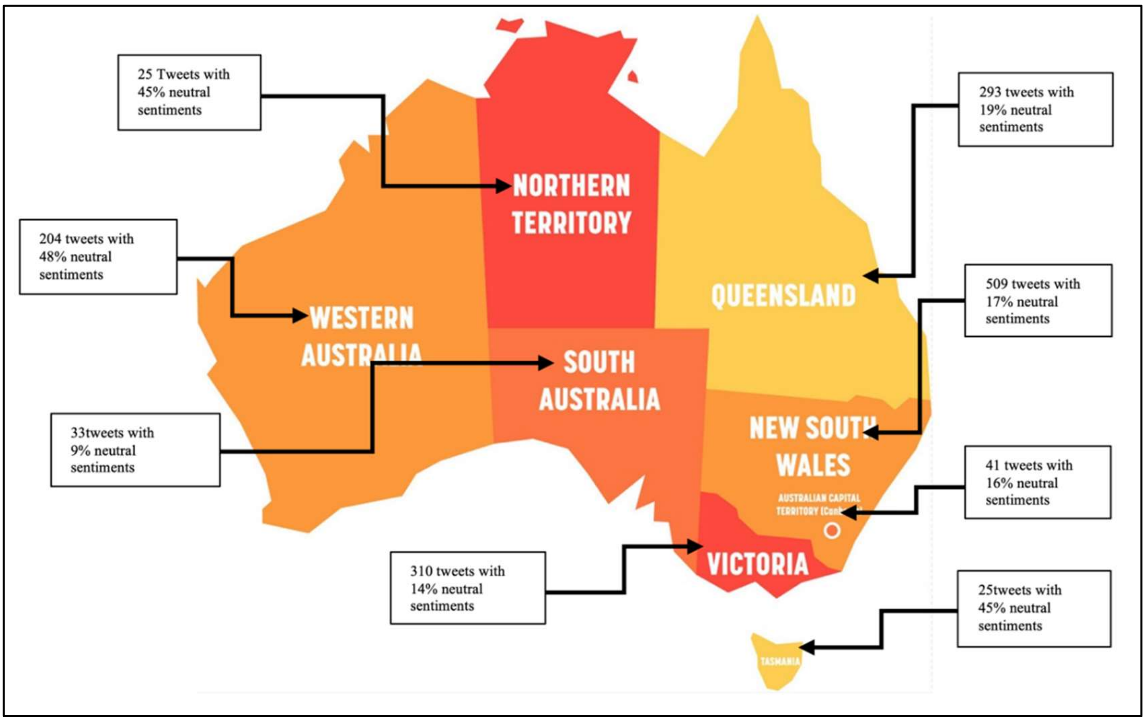


Figure 4. Tweet numbers and neutral sentiment percentages by states and territories.

Table 1. Tweet sentiment in percentages per state/territory.

	QLD	TAS	NSW	SA	ACT	VIC	WA	NT	Australia
Very positive sentiments	12%	8%	7%	7%	6%	6%	3%	0%	6%
Positive sentiments	36%	21%	39%	28%	28%	39%	8%	8%	43%
Neutral sentiments	19%	45%	17%	9%	16%	14%	48%	18%	14%
Negative sentiments	23%	18%	25%	44%	43%	32%	29%	56%	28%
Very negative sentiments	10%	8%	12%	12%	7%	9%	12%	18%	95%
Total	100%	100%	100%	100%	100%	100%	100%	100%	N/A

The tweets from NSW (n = 2997) and QLD (n = 1540) recorded positive sentiment of 46% and 48%, respectively. Both states were the most positive towards AI. VIC had the second-highest number of tweets (n = 2214) with 45% (n = 996) positive and 41% (n = 908) negative, respectively. Out of the 55 tweets from TAS, 45% (n = 25) were neutral. The remaining states perceived AI in construction as negative. From the tweets originating from WA (n = 426) and ACT (n = 258), 41% and 50% were negative, respectively. Out of the 364 tweets from SA, 35% (n = 127) were positive, and 204 (56%) were negative. NT had the lowest number of tweets relating to AI in construction. Among them, 8% (n = 4) were positive, and 74% (n = 38) were negative. NT was the state with the highest percentage of negative sentiment as it was viewed as disruptive to the industry. Example tweets for each sentiment category are given in Table 2.

Table 2. Example tweets from each sentiment category.

Date and time	State/Territory	Tweet	Sentiment
25 April 2020 12:46	NSW	Time is of the essence when dealing with project correspondence and how you can mitigate the risks using platform technology. #AI, #Construction, #Technology	Very positive
22 June 2021 23:19	ACT	Organizations are rethinking their industry framework, improving their manufacturing processes. Looking at a much more holistic supply chain and connected network to drive agility, efficiency, innovation, and sustainability. # Construction #Automation, #Innovation	Positive
12 November 2019 20:32	WA	Automation is standard practice in construction and has been for generations. If you support private enterprise, you also support automation. It will continue, and AI will delete more and more jobs as time goes on. #Future, #MachineLearning	Negative
28 July 2021 13:14	QLD	Do people realize that the Industrial revolution will see massive job losses in construction, let's think about where the income stream will come from? #AI	Very negative
8 August 2021 08:30	VIC	The safety of workers and the profitability of construction projects are paramount concerns for any company. Bosses who put off investing in technology place businesses workers at a significant disadvantage. #Constuction, #Digital, #Technology	Neutral

3.3. Artificial Intelligent Technologies in Construction

By counting word frequency, we identified 12 key AI-related construction technologies (Figure 5 and Table 3), including 'artificial intelligence' (n = 341), 'automation' (n = 475), 'big data' (n = 457), 'blockchain' (n = 147), 'deep learning' (n = 406), 'digital twin' (n = 44), 'IoT' (n = 562), 'machine leaning' (n = 522), 'robotics' (n = 931), 'risk predictive modelling' (n = 55), 'simulation' (n = 13), and 'virtual learning' (n = 75).

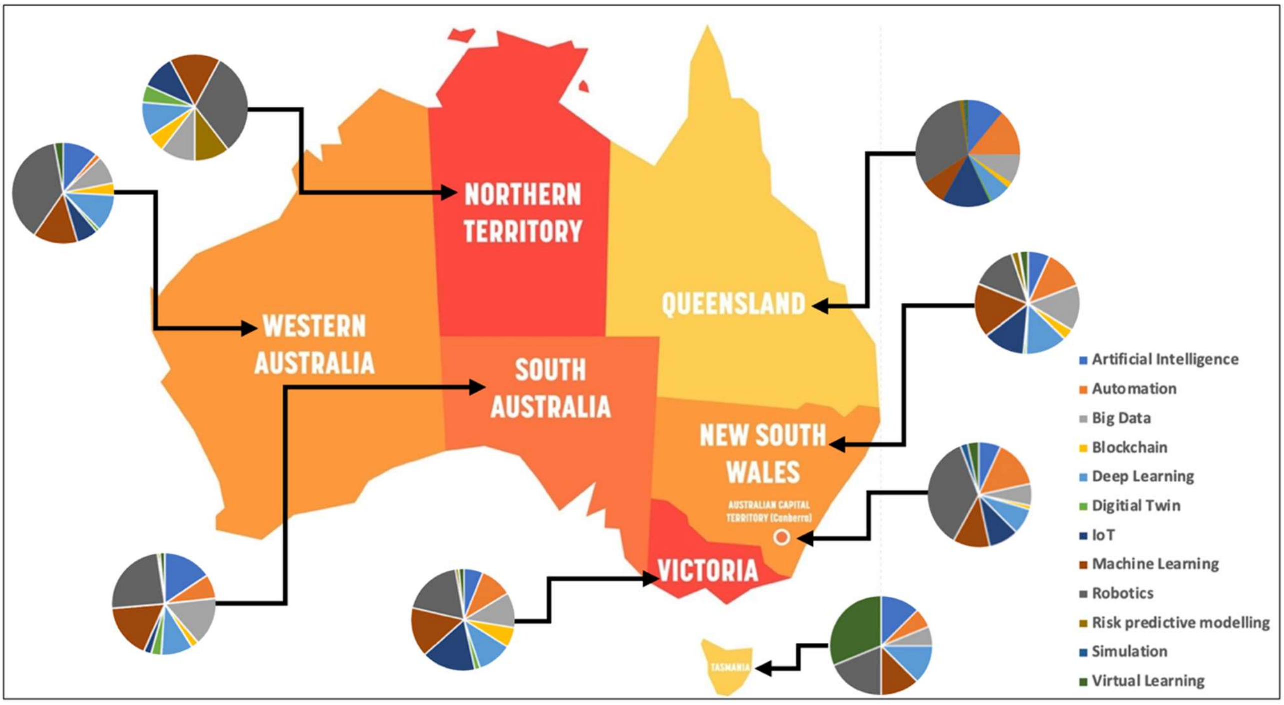


Figure 5. Distribution of tweets about AI technologies in construction per state/territory.

Table 3. Distribution of tweets by AI technologies in construction per state/territory.

	Artificial Intelligence	Automation	Big Data	Blockchain	Deep Learning	Digital Twin	IoT	Machine Learning	Robotics	Risk Prediction Modeling	Simulation	Virtual Learning
NSW	80	147	169	42	159	10	154	194	163	26	4	30
QLD	149	192	123	25	86	9	205	104	431	16	6	12
VIC	64	109	120	68	116	18	178	162	198	10	1	18
WA	20	3	16	7	21	2	12	25	67	0	0	5
SA	20	10	20	3	13	4	3	22	31	1	0	2
TAS	2	1	1	0	2	0	0	2	3	0	0	5
ACT	6	13	6	1	7	0	8	10	32	0	2	3
NT	0	0	2	1	2	1	2	3	6	2	0	0
Total	341	475	457	147	406	44	562	522	931	55	13	75
NSW	23.46%	30.95%	36.98%	28.57%	39.16%	22.73%	27.40%	37.16%	17.51%	47.27%	30.77%	40.00%
QLD	43.70%	40.42%	26.91%	17.01%	21.18%	20.45%	36.48%	19.92%	46.29%	29.09%	46.15%	16.00%
VIC	18.77%	22.95%	26.26%	46.26%	28.57%	40.91%	31.67%	31.03%	21.27%	18.18%	7.69%	24.00%
WA	5.87%	0.63%	3.50%	4.76%	5.17%	4.55%	2.14%	4.79%	7.20%	0.00%	0.00%	6.67%
SA	5.87%	2.11%	4.38%	2.04%	3.20%	9.09%	0.53%	4.21%	3.33%	1.82%	0.00%	2.67%
TAS	0.59%	0.21%	0.22%	0.00%	0.49%	0.00%	0.00%	0.38%	0.32%	0.00%	0.00%	6.67%
ACT	1.76%	2.74%	1.31%	0.68%	1.72%	0.00%	1.42%	1.92%	3.44%	0.00%	15.38%	4.00%
NT	0.00%	0.00%	0.44%	0.68%	0.49%	2.27%	0.36%	0.57%	0.64%	3.64%	0.00%	0.00%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

The popularity of each construction technology is different in each state and territory. For instance, there were more tweets in NSW about 'big data' (n = 169) than QLD (n = 123). Conversely, 'robotics' was around three times more popular (n = 431) in QLD than in VIC (n = 198). Furthermore, different states had different popular topics of AI technologies. For example, 'machine learning' (n = 194) was the most popular tweet related to AI construction technology in NSW. While 'robotics' (n = 198) was the most tweets AI construction technology in VIC, 'robotics' was the most tweeted technology in WA (n = 67), SA (n = 31), ACT (n = 31), and NT (n = 6). 'Virtual Learning' (n = 6) was comparatively high among the tweets circulated in TAS. Table 4 provides examples of tweets that were related to each technology.

Table 4. Example tweets for AI technologies in construction.

Technology	Date and time	State/Territory	Tweet	Sentiment
Artificial intelligence	8 July 2019 11:07	NSW	Artificial intelligence can play a transformative role in improving the efficiency and safety of construction sites by giving developers a transparent overview of their projects.	Positive
Automation	18 January 2021 12:37	QLD	The fourth revolution in the construction industry is characterized by connectivity, advanced analytics, automation, and advanced engineering that made a greater impact after COVID. #Analytics, #Connectivity, #Indsitry4.0, #Technology, #automation	Neutral
Big data	20 May 2020 21:58	QLD	The convergence of automation and intelligence is known as Hyper Automation. Hyper Automation is at the forefront of the industrial revolution as emerging technologies such as natural language processing and big data analytics are now being combined with automation. # Construction #AI	Neutral
Blockchain	25 November 2020 04:02	VIC	We live in a world that's not only powered by technology but also shaped by it. Blockchain and IoT can help improve construction efficiency. #Blockchain, #Technology, #IoT, #AI, #digitaltechnology	Neutral
Deep learning	10 January 2020 08:09	QLD	Aerial imagery company Nearmap has acquired deep learning and analytics technology that extracts data from D models to provide roof geometry for a variety of sectors, including construction.	Neutral
Digital twin	25 May 2019 05:40	VIC	Collaboration is needed to drive construction innovation and industry growth. The technologies include IoT, advanced automation, robotics, 4D printing, machine-to-machine communication, digital twins, and sensor technology.	Positive

Table 4. *Cont.*

Technology	Date and time	State/Territory	Tweet	Sentiment
IoT	10 January 2020 06:00	NSW	Artificial intelligence and IoT will connect construction sites of the future that work faster and more flexibly with minimal downtime. #Iot, #Automation, #AI	Positive
Machine learning	23 February 2019 09:31	VIC	Emerging tech like machine learning and automation is driving massive social change but are these the changes we want? Agree with David Thodey it's time for an informed national conversation on the social implications of the construction revolution.	Negative
Risk prediction modeling	15 March 2019 09:37	NSW	To thrive in the industrial revolution, construction companies are rapidly adopting agile practices. People also need to effectively manage risk.	Neutral
Robotics	19 February 2020 04:46	WA	True focus on founders who bring technology to market that eliminates repetitive manual labor and multiplies human productivity by automating routine tasks. #Construction, #Automation, #Artificialintelligence	Positive
Simulation	12 February 2019 20:42	ACT	Simulations teach humans how to manipulate the arms of the machine rather than having humans teach the machine how to dig for itself. #AI, #Construction	Neutral
Virtual learning	16 April 2021 14:22	NSW	The impact of virtual learning technology is showing a major impact on the transformation of design and planning throughout construction stages. #Virtuallearning, #modeling, #design, #Bim, #Construction, #Technology	Neutral

3.4. Prospects of Artificial Intelligence Technologies in Construction

Based on word frequency, 12 prospects that AI technologies will bring to a construction site were identified from AI related tweets (Figure 6 and Table 5). These include 'accountability' (n = 51), 'accuracy' (n = 66), 'consistency' (n = 37), 'cost reduction' (n = 138), 'digitalization' (n = 767), 'efficiency' (n = 109), 'innovation' (n = 691), 'productivity' (n = 232), 'quality' (n = 73), 'reliability' (n = 35), 'safety' (n = 84), and 'time saving' (n = 294).

Digitalization (n = 767) was the most discussed construction prospect derived from AI-related tweets, but its usability differed from one state/territory to another. While digitalization was the most popular tweets technology concept in NSW (n = 317), QLD (n = 156), VIC (n = 246), and SA (n = 37), TAS's most tweeted technology prospect was 'timesaving' (n = 7). 'Innovation' was the most tweeted concept in ACT (n = 15) and WA (n = 62). Although there were fewer tweets in NT, most were related to the prospect of 'innovation' (n = 5). Table 6 provides examples of tweets related to AI technologies and prospects.

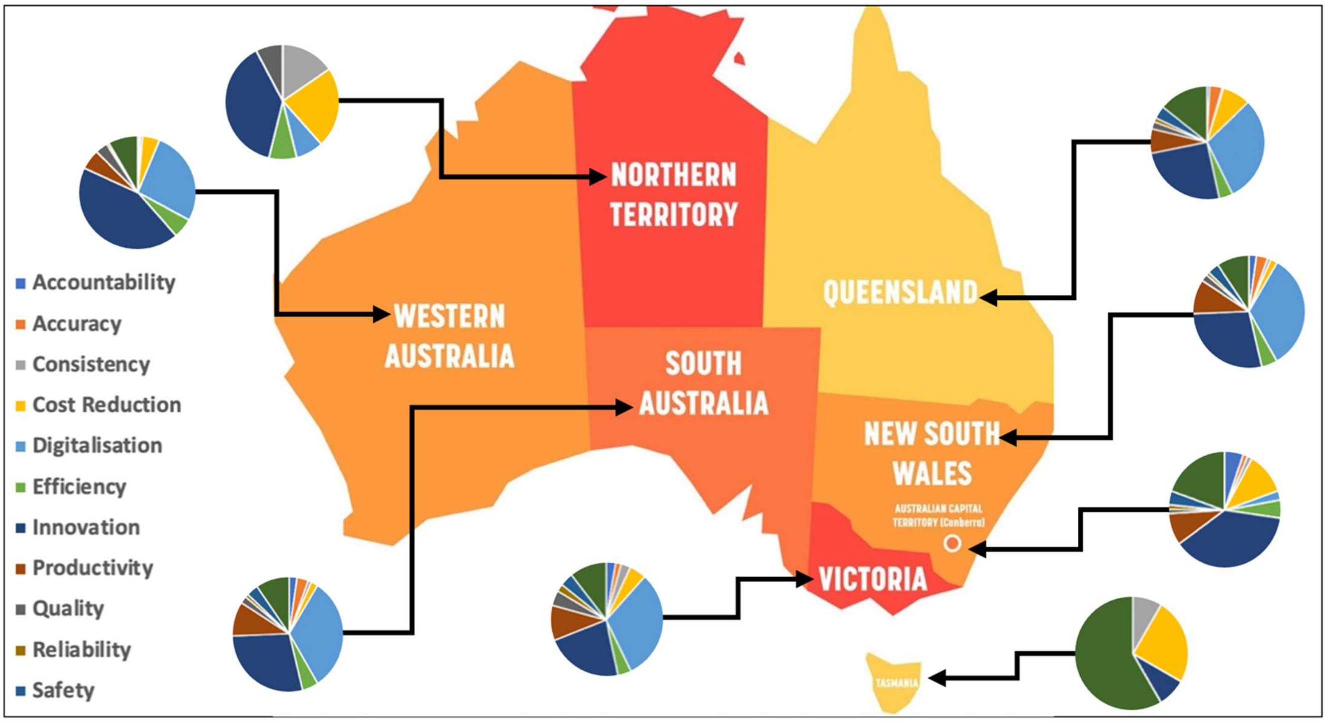


Figure 6. Distribution of tweets by the prospects of AI technologies in construction per state/territory.

3.5. Constraints of Artificial Intelligence Technologies in Construction

A word frequency analysis was also conducted for the 12 constraints that derived from AI related tweets (Figure 7 and Table 7). These included 'complexity' (n = 96), 'disruptiveness' (n = 90), 'higher initial costs' (n = 48), 'higher variability' (n = 53), 'implementation' (n = 76), 'lack of capabilities' (n = 110), 'lack of cohesion' (n = 33, 'project risk' (n = 93), 'resistance' (n = 73), 'security of data' (n = 156), and 'unstructured environment' (n = 95).

Security of data was the most discussed constraint in AI-related tweets, but its usability differed from one state/territory to another. While 'security of data' (n = 156) was the most tweeted AI constraint in NSW (n = 32), VIC (n = 21) and QLD (n = 27), 'unstructured environment' was the most popular constraint concept in WA (n = 9) and ACT (n = 5). Tweets from SA had more discussions related to 'disruptiveness' (n = 5), while 'higher initial costs' were predominately discussed in TAS (n = 3) and NT (n = 9). Table 8 provides examples of tweets related to AI technologies and prospects.

3.6. Prospects and Constraints of AI Technologies in Australian States/Territories

Understanding the public perception of prospects and constraints that AI technologies may bring onto a construction site was at the forefront of this study. A word co-occurrence analysis was conducted, which identified the number of tweets that mentioned an AI technology and prospect or constraint.

Figures 8 and 9 represent the network topography developed based on word co-occurrence analysis. This network typology was initially generated by using Gephi software. Nonetheless, due to the crowdedness of the original figure, a less complex version was recreated by only showing the stronger relationships that occurred between AI technologies and prospect or constraints concepts. As the number of total tweets from prospects was 1319 and constraints was 609, we made two separate connection measurements. We identified a connection between 20 and 29 as more as semi-strong, from 30 to 39 as strong, and 40 or more as very strong. Furthermore, for constraints, we identified between 10 to 15 as semi-strong, from 16 to 20 as strong, and 20 or more as very strong.

Table 5. Distribution of tweets by the prospects of AI technologies in construction per state/territory.

	Accountability	Accuracy	Consistency	Cost Reduction	Digitalization	Efficiency	Innovation	Productivity	Quality	Reliability	Safety	Timesaving
NSW	21	31	9	19	317	43	266	94	19	9	32	90
QLD	4	19	2	42	156	20	132	36	11	6	19	75
VIC	21	12	21	37	246	30	176	81	34	17	30	82
WA	1	0	1	7	38	8	62	8	5	1	0	12
SA	0	3	0	18	37	3	20	6	2	1	0	13
TAS	0	0	1	3	0	0	1	0	0	0	0	7
ACT	4	1	1	9	2	4	29	7	1	1	3	15
NT	0	0	2	3	1	1	5	0	1	0	0	0
Total	51	66	37	138	797	109	691	232	73	35	84	294
NSW	41.18%	46.97%	24.32%	13.77%	39.77%	39.45%	38.49%	40.52%	26.03%	25.71%	38.10%	30.61%
QLD	7.84%	28.79%	5.41%	30.43%	19.57%	18.35%	19.10%	15.52%	15.07%	17.14%	22.62%	25.51%
VIC	41.18%	18.18%	56.76%	26.81%	30.87%	27.52%	25.47%	34.91%	46.58%	48.57%	35.71%	27.89%
WA	1.96%	0.00%	2.70%	5.07%	4.77%	7.34%	8.97%	3.45%	6.85%	2.86%	0.00%	4.08%
SA	0.00%	4.55%	0.00%	13.04%	4.64%	2.75%	2.89%	2.59%	2.74%	2.86%	0.00%	4.42%
TAS	0.00%	0.00%	2.70%	2.17%	0.00%	0.00%	0.14%	0.00%	0.00%	0.00%	0.00%	2.38%
ACT	7.84%	1.52%	2.70%	6.52%	0.25%	3.67%	4.20%	3.02%	1.37%	2.86%	3.57%	5.10%
NT	0.00%	0.00%	5.41%	2.17%	0.13%	0.92%	0.72%	0.00%	1.37%	0.00%	0.00%	0.00%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6. Example tweets of prospects of AI technologies in construction per state/territory.

Prospects of AI Adoption	Date and Time	State/Territory	Tweet
Accountability	30 December 2019 12:42	VIC	We need accountability and a good balance between automation and IoT. #Accountability, #Automation
Accuracy	19 May 2021 08:53	VIC	It's no surprise that there is interest in automation and technologies to lash all aspects of production together. Customers are after more productivity, higher accuracy, and more process driven.
Consistency	10 November 2019 09:15	ACT	The Fourth Industrial Revolution could spell more jobs, not fewer. But people will need different types of skills and need to unlearn and relearn consistency.
Cost reduction	25 December 2020 07:41	NSW	We arrived at the fourth industrial revolution, and it will lead to increased efficiency, new revenue opportunities, and overall cost reductions.
Digitalization	18 August 2019 23:15	NSW	Robots are supposed to destroy most jobs occupied by females, and the immediate social impact on labor is Job Loss of Women. It's safe to say that Australia is perplexed by digitalization.
Efficiency	29 September 2020 16:24	WA	With the help of telematics and fleet management technology, it can help benefit businesses by keeping track of your cranes, helping with compliance, efficiency, and boosting profits. #Construction, #Technology
Innovation	14 February 2019 07:04	QLD	The basic construction of a monetary system must not be confused with innovations in payment technology.
Productivity	23 March 2019 23:00	NSW	Construction has lagged behind other industries in harnessing the benefits of digitalization. But it is now looking to catch up with new technology having enormous potential to make construction greener, safer, and smarter while boosting productivity. #MachineLearning, #AI
Quality	23 January 2020 20:29	NT	The next-generation construction sealant is a high-quality construction sealant based on hybrid technology. It cures under the influence of humidity to form a durable elastic rubber. # Construction
Reliability	24 April 2021 05:39	NSW	Construction is underway on the Victorian NSW Interconnector upgrade. It will allow cheaper generations to be transferred between the states. We're using a new technology called Smart Wires which will improve reliability and avoid the cost of upgrading existing infrastructure.
Safety	13 June 2021 12:24	NSW	Monash University files for privileges of new technology, which identifies safety features of construction machinery on building sites. #Construction
Timesaving	20 January 2020 17:01	QLD	An arm of construction giant BMD has already deployed Octant, and the company expects to reap savings of up to 30% in its turnover in urban development projects.

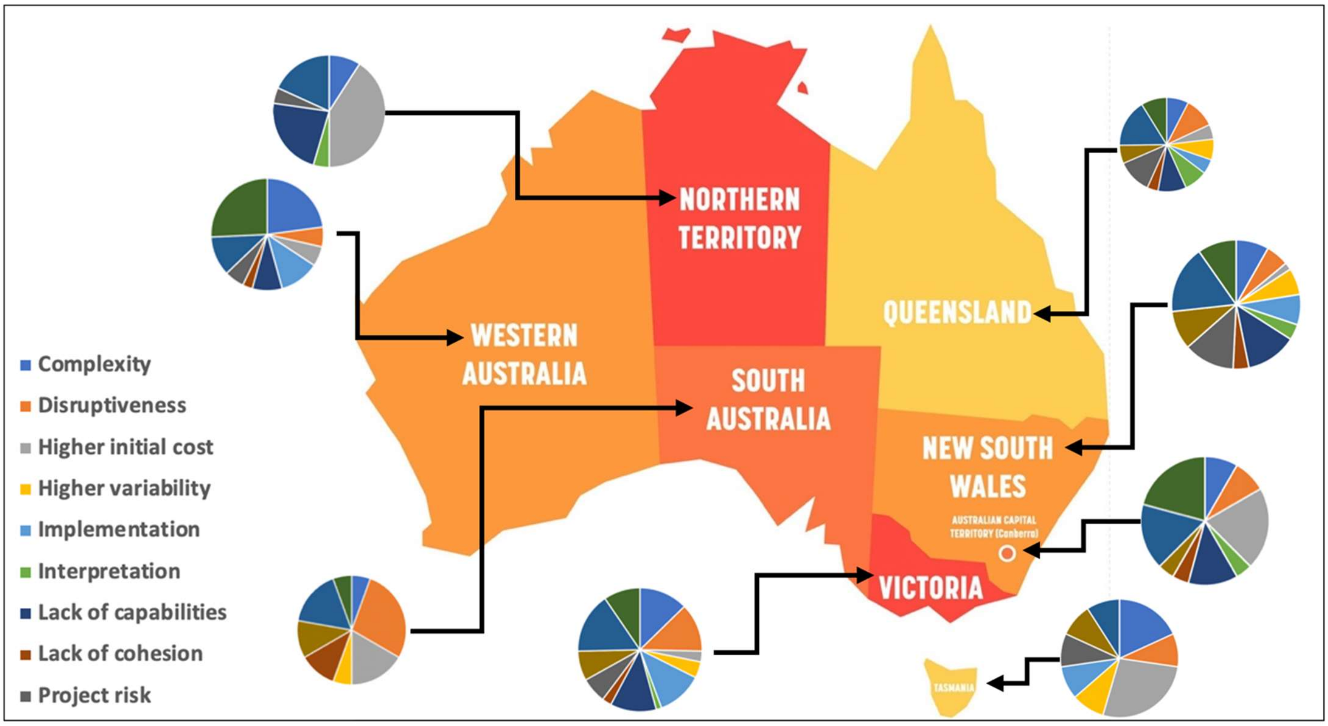


Figure 7. Distribution of tweets by the constraints of AI technologies in construction per state/territory.

3.6.1. Prospects in Relations to AI Technologies

As shown in Table 9, 'robotics' (n = 325) was the AI technology that will have the most positive influence over a construction site. This technology has a close relationship with the following prospects: 'time saving' (n = 62), 'digitalization' (n = 54), 'innovation' (n = 52), and 'efficiency' (n = 42). Secondly, the AI technology that was discussed most was 'automation' (n = 222), which had a close relationship with 'digitalization' (n = 32), 'time saving' (n = 29), innovation (n = 23), and 'quality' (n = 22). The third popular technology was 'machine learning' (n = 162) as it will have a positive impact in construction by increased 'efficiency' (n = 36), 'innovation' (n = 32), 'timesaving' (n = 22), 'digitalization' (n = 21), and 'productivity' (n = 21).

The relationship among the AI-related technologies and prospect—such as 'reliability' (n = 26), 'consistency' (n = 28), 'safety' (n = 40), 'quality' (n = 45), and 'accountability' (n = 46)—were frequently identified in relation to positive attributes that AI technologies can bring to the urban built environment. The tweets related to 'IoT' (n = 160) and the prospects of 'productivity' (n = 38), 'digitalization' (n = 32), 'efficiency' (n = 22), 'time saving' (n = 18), and 'innovation' (n = 17) highlights the positive attributes that IoT will bring to the construction industry in public and private sectors. Nevertheless, AI technology tweets related to the prospects of 'simulation' (n = 9), 'digital twin' (n = 12), 'virtual learning' (n = 20), 'risk predictive modelling' (n = 32), and 'blockchain' (n = 48) were comparatively low.

3.6.2. Constraints in Relations to AI Technologies

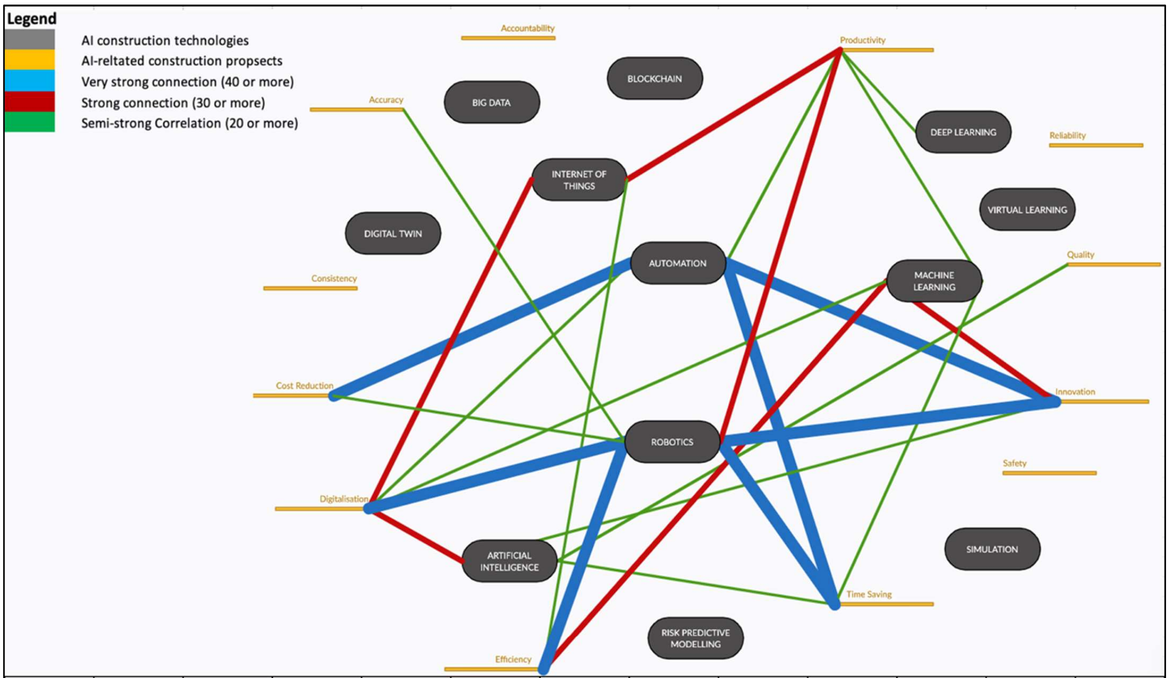
As shown in Table 10, 'robotics' (n = 112) was the AI technology that will have the most negative influence over a construction site. The technology has a close relationship with 'complexity' (n = 19), 'resistance' (n = 18), 'lack of capabilities' (n = 15), and 'project risk' (n = 11). Secondly, 'artificial intelligence' (n = 98) had a close relationship with 'lack of capabilities' (n = 22), 'project risk' (n = 12), 'resistance' (n = 12), 'complexity' (n = 12), and 'disruptiveness' (n = 11). The third popular relationship was 'automation' (n = 71) as it was perceived to have a negative influence over a construction site by being highly 'disruptive' (n = 12), 'project risk' (n = 12), and will be difficult to 'implement' (n = 9).

Table 7. Distribution of tweets by the constraints of AI technologies in construction per state/territory.

	Complexity	Disruptiveness	Higher Initial Cost	Higher Variability	Impleme-ntation	Interpre-tation	Lack of Ca-pabilities	Lack of Cohesion	Project Risk	Resistance	Security of Data	Unstructured Environ-ment
NSW	27	19	6	22	25	13	42	13	42	32	56	32
QLD	18	25	12	17	12	19	23	9	28	15	39	21
VIC	36	36	8	12	34	4	34	7	19	22	45	27
WA	8	2	2	0	4	0	3	1	2	0	4	9
SA	1	5	3	1	0	0	0	2	0	2	3	1
TAS	2	1	3	1	1	0	0	0	1	1	1	0
ACT	2	2	5	0	0	1	3	1	0	1	4	5
NT	2	0	9	0	0	1	5	0	1	0	4	0
Total	96	90	48	53	76	38	110	33	93	73	156	95
NSW	28.13%	21.11%	12.50%	41.51%	32.89%	34.21%	38.18%	39.39%	45.16%	43.84%	35.90%	33.68%
QLD	18.75%	27.78%	25.00%	32.08%	15.79%	50.00%	20.91%	27.27%	30.11%	20.55%	25.00%	22.11%
VIC	37.50%	40.00%	16.67%	22.64%	44.74%	10.53%	30.91%	21.21%	20.43%	30.14%	28.85%	28.42%
WA	8.33%	2.22%	4.17%	0.00%	5.26%	0.00%	2.73%	3.03%	2.15%	0.00%	2.56%	9.47%
SA	1.04%	5.56%	6.25%	1.89%	0.00%	0.00%	0.00%	6.06%	0.00%	2.74%	1.92%	1.05%
TAS	2.08%	1.11%	6.25%	1.89%	1.32%	0.00%	0.00%	0.00%	1.08%	1.37%	0.64%	0.00%
ACT	2.08%	2.22%	10.42%	0.00%	0.00%	2.63%	2.73%	3.03%	0.00%	1.37%	2.56%	5.26%
NT	2.08%	0.00%	18.75%	0.00%	0.00%	2.63%	4.55%	0.00%	1.08%	0.00%	2.56%	0.00%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

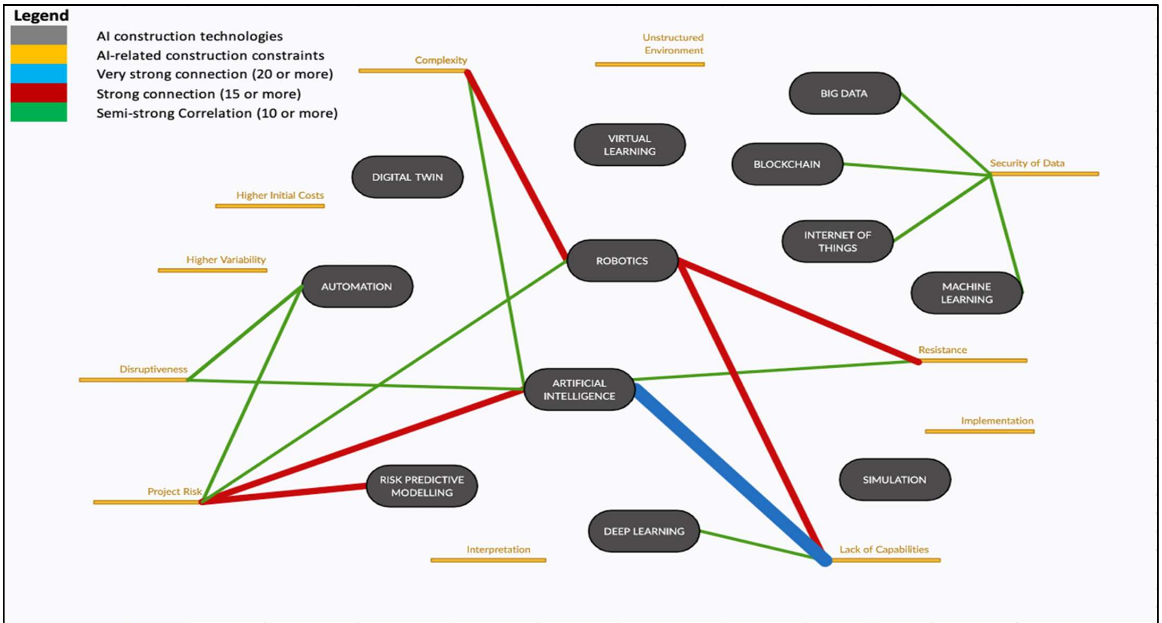
Table 8. Example tweets of constraints of AI technologies in construction per state/territory.

Technology	Date and time	State/Territory	Tweet
Complexity	10 January 2020 23:47	VIC	The Fourth Industrial Revolution is complex as it is unprecedented technologies and characterized by a fusion of advanced robotics, blurring the line between the physical and digital world. #Construction, #Robotics
Disruptiveness	28 April 2021 12.35	NSW	The powerful combination of Artificial intelligence and The Internet of Things will transform entire industries and enable new disruptive services. #AI, #IoT, #Indsutry 4.0
Higher initial costs	14 February 2020 16.58	NSW	While industry trends have been building momentum for some time, McKinsey said that many are now at a point where their greater reliability and higher initial cost are starting to make sense for industrial applications.
High variability	13 July 2020 12.11	WA	Technology is continuing to drive change in the architecture and construction industries, and it is highly variable.
Implementation	6 April 2020 18.21	QLD	Construction technology implementation is only half of the battle. What is just as important is making that technology investment work in a way that extracts maximum value and keeps projects moving.
Interpretation	15 December 2019 18.39	NSW	Virtual reconstruction of a project that cannot be open to interpretation. #Bigdata, #Automation
Lack of capabilities	28 March 2019 01.30	SA	Artificial intelligence is being adopted so fast that its technical capabilities have outpaced the construction of an ethical governance framework. #Artificial Intelligence
Lack of cohesion	25 February 2021 11.44	NSW	Australia's construction industry is committed to a National Strategy to accommodate industry needs that promote technology cohesion.
Project risk	2 February 2021 16.57	TAS	At the advent of the industrial revolution, we must simultaneously be aware of the considerable project risks that are likely to emerge as transformative technologies are assimilated across processes and functions of the industry, government, and broader society. #Construction, #AIconstruction
Resistance	11 May 2020 15.44	VIC	A great article on the Industrial Revolution by the Australian Treasurer. Resistance is futile; embrace the new technologies that will be implemented in projects. Employment will not improve. #Automation, #Bigdata, #Construction
Security of data	18 May 2020 19.52	QLD	Preparing for the industrial revolution requires leadership. Australia needs a construction framework for societal transformation, which includes addressing skills standards and security of data.
Unstructured environment	6 June 2020 03.16	VIC	The construction industry is replacing the traditional working algorithm by providing more intelligent manufacturing equipment and environments #Innovation, #Industry 4.0, #Construction



	Accountability	Accuracy	Consistency	Cost Reduction	Digitalisation	Efficiency	Innovation	Productivity	Quality	Reliability	Safety	Time Saving
Artificial Intelligence					32		23		22			29
Automation				42	22		41	23				42
Deep Learning								22				
IoT					32	22		38				
Machine Learning					21	36	32	21				22
Robotics		23		29	54	42	52	32				62

Figure 8. Relationship between AI technologies and their prospects.



	Complexity	Disruptiveness	Higher initial cost	Higher variability	Implementation	Interpretation	Lack of capabilities	Lack of cohesion	Project risk	Resistance	Security of data	Unstructured environment
Artificial Intelligence	12	11					22		15	12		
Automation		12							12			
Big Data											12	
Blockchain											12	
Deep Learning							12					
IoT											15	
Machine Learning											14	
Robotics	19						15		11	18		
Risk predictive modelling									15			

Figure 9. Relationship between AI technologies and their constraints.

Table 9. Distribution of tweets by the prospects of AI technologies.

	Accountability	Accuracy	Consistency	Cost Reduction	Digitalization	Efficiency	Innovation	Productivity	Quality	Reliability	Safety	Timesaving	Total
Artificial intelligence	8	5	2	12	32	12	23	2	22	3	4	29	154
Automation	7	5	3	42	22	19	41	23	4	2	12	42	222
Big data	3	2	5	3	12	14	14	16	3	4	0	19	95
Blockchain	2	2	2	3	8	12	12	2	0	1	0	4	48
Deep learning	3	1	1	1	8	18	9	22	2	5	2	8	80
Digital twin	1	2	0	2	2	3	0	0	0	0	0	2	12
IoT	4	8	8	3	32	22	17	38	7	2	1	18	160
Machine learning	11	4	2	2	21	36	32	21	3	6	2	22	162
Robotics	4	23	3	29	54	42	52	32	4	2	18	62	325
Risk prediction modeling	2	1	0	5	4	8	5	3	0	0	1	3	32
Simulation	0	1	2	0	3	1	0	1	0	0	0	1	9
Virtual learning	1	1	0	3	8	0	2	0	0	1	0	4	20
Total	46	55	28	105	206	187	207	160	45	26	40	214	1319

Table 10. Distribution of tweets by the constraints of AI technologies.

	Complexity	Disruptiveness	Higher Initial Cost	Higher Variability	Implementation	Interpretation	Lack of Capabilities	Lack of Cohesion	Project Risk	Resistance	Security of Data	Unstructured Environment	Total
Artificial intelligence	12	11	6	2	3	1	22	2	15	12	6	6	98
Automation	4	12	2	3	9	6	2	4	12	8	5	4	71
Big data	2	4	8	2	9	5	2	2	5	2	12	2	55
Blockchain	2	2	0	4	2	0	9	0	9	2	12	1	43
Deep learning	8	8	2	6	1	1	12	7	3	1	2	5	56
Digital twin	2	4	2	1	1	5	2	1	0	0	3	2	23
IoT	7	8	3	6	2	0	4	5	5	3	15	0	58
Machine learning	8	8	4	6	6	2	8	1	3	1	14	1	62
Robotics	19	9	7	7	9	2	15	2	11	18	5	8	112
Risk prediction modeling	1	2	0	1	0	0	0	0	15	0	1	1	21
Simulation	1	0	0	0	0	0	0	1	1	0	0	0	3
Virtual learning	0	1	0	2	0	0	0	1	2	0	1	0	7
Total	66	69	34	40	42	22	76	26	81	47	76	30	609

Although there was also a relationship between AI-related technologies and constraints such as 'interpretation' (n = 22), 'lack of cohesion' (n = 26), 'unstructured environment' (n = 30), and 'higher initial costs' (n = 34) were not as frequently used concerning negative attributes that AI technologies can bring to the urban built environment. Discussions related to AI technologies were 69% less than the prospect that technologies can bring to a construction site. The tweets related to 'machine learning' (n = 62) and the constraints of 'security of data' (n = 14), 'lack of capabilities' (n = 8), 'complexity' (n = 8), and 'disruptiveness' (n = 8) highlight the negative attributes that machine learning will bring to the construction industry in the public and private sectors. Nevertheless, AI technology tweets related to 'simulation' (n = 3), 'virtual learning' (n = 7), 'risk predictive modelling' (n = 21), and 'digital twin' (n = 23) were comparatively low. These four constraints were the same as the four prospects, which shows that they were not discussed frequently on Twitter and can be perceived as a neutral impact that they will bring to the construction industry.

4. Discussion

The last five years have seen major advancements in AI, and it is beginning to gain traction in the construction industry from planning to construction. The potential of AI in the planning and design stages is an increase in the accuracy of cost estimates, accurate milestones, and reduction of onsite risk by using constructive alternative analysis. Furthermore, the benefits of AI in the construction stage are increasing productivity, improving work processes, and reducing the probability of onsite accidents.

Construction firms analyze vast amounts of internal and external unstructured data to provide insights from previous projects. This will allow businesses to generate more accurate estimates, reduce budgets and timeline deviation by an estimated 10–20% and engineering hours by 10–30% [40,41]. AI's potential in construction is to provide real-time insight that will help project managers ensure efficient use of resources, anticipate potential risk, and increase safety. Potential savings from data analytics and related technologies can reduce 10–15% of total construction costs [21,42].

The sentiment towards AI in Australia is becoming more positive, as evident in the findings. The public's opinion has been highly influenced by the Australian government as they have committed $125 million through an 'AI Action Plan' to operate the digital frontier. Furthermore, through this plan, the government has attempted to address the issues identified in this study by investing in the R&D of AI [43]. Additionally, the AI Roadmap also outlines Australia's direction in implementing AI in construction by stating the direction for utilizing AI in Australia to improve the built environment by capturing social, economic, and environmental benefits. This includes improving design, planning, construction, operational, and maintenance of infrastructure and buildings [44]. High construction costs and unplanned cost overruns will be fundamental in AI development, limiting the ability to improve Australian cities and infrastructure.

4.1. Sentiment Analysis

The sentiment analysis found that AI in construction is a growing ecosystem of hardware and software. It has recently gained popularity, and the public perception regarding the use of technology is an understudied area of research [9,10]. AI is a powerful tool that has the power to reshape and disrupt the construction industry. Today, there is limited understanding of the trending construction technologies and their application areas. This is evidenced in the low number of tweets (n = 7907). In addition, there is limited knowledge on the public perception of AI technologies, their application area, and the AI-related policies that businesses need to follow when we incorporate AI. Hence, the study aimed to understand the relationship between AI technologies, their key prospects, and constraints in the construction industry.

Overall, the location-based twitter analysis identifies that 'robotics' (n = 931), 'IoT' (n = 562), 'machine learning' (n = 522), and 'big data' (n = 467) are the most discussed topics of AI technologies for the construction industry across the entire Australia, despite their popularity differs by state and territory. The analysis also revelated that the public perception from the three largest states, NSW, QLD and VIC, were primarily favorable towards AI being implemented in a construction project. While tweets in WA and TA were neutral, and SA, ACT, and NT were mostly negative.

4.1.1. Positive Sentiments

The overall Australian public was positive regarding AI in the construction industry (43% positive sentiment), which is evident in the presented findings. From the identified AI technologies, a prospect analysis was conducted and found that 'timesaving' (n = 214), 'innovation' (n = 207), 'digitalization' (n = 206), and 'efficiency' (n = 187) are the most discussed benefits of AI in construction.

This positive sentiment is driven mainly by the three larger states by population (QLD, VIC, NSW), as they have already invested in the research and development (R&D) of potential AI technologies. In addition, there is a common agreeance between larger construction companies that operate in these states that inadequate project selection is a major challenge. To limit the risk that this challenge may impose, AI technology will need to be implemented into their projects as it will increase efficiency substantially. This has been the key driver that has influenced the construction landscape and increased positive opinion.

4.1.2. Negative Sentiments

Meanwhile, the public also raised concerns about the use of AI in construction, such as data security and a lack of capabilities to incorporate AI technologies. While many AI technologies remain in the R&D phase, they may impose a project risk that has cost implications. Reducing the impact of these three constraints will be necessary for the continuing development of AI in construction. Moreover, a constraint analysis was conducted and found that 'project risk' (n = 81), 'security of data' (n = 76), 'lack of capabilities' (n = 76), and 'disruptiveness (n = 69) were the most discussed disadvantages of AI in the construction industry. It is also noted that both the perceptions on the prospects and constraints were differed by states and territories.

The negative sentiment was driven mainly by the smaller states by population (NT, WA, SA, ACT), as AI technology is still in the initial phase. These states are highly fragmented with smaller construction companies, and there is limited knowledge on the potential technologies may bring. AI is predominately seen as a disruption, as smaller companies cannot compete with larger companies to obtain data to train models. There is a strong focus on the disadvantages that technologies may bring and how they will directly impact the workforce negatively.

4.2. Research Limitations

The study has the following limitations:

- The scope of the research constrains the paper in itself.
- AI in construction is still a broad concept; the relationship between technologies, constraints, and prospects is constantly changing. There is a lack of resemblance between companies.
- The study did not conduct strengths, weaknesses, opportunities, and threats (SWOT).
- The study was only able to analyze 7906 tweets due to data availability limitations.
- The Random Forest and Random Tree software has difficulty detecting positive or negative words when looked at in isolation. For example, it struggles if the general user is sarcastic, ironic, or hyperbolic.

Our prospective research, nevertheless, will focus on addressing these constraints.

4.3. Future Research

In the light of the analysis conducted in this study, the directions for future research are related to the barriers are identified as follows:

- Expanding on the current findings of the research and developing a better understanding of the relationship between AI technologies, prospects, and constraints.
- Using other social media big data. The sentiment analysis only gathered Twitter data from the Australian public. Future studies could obtain Twitter data from various countries to expand on the scope of the paper.
- Expanding on the search parameters and including data obtained from other social media platforms.
- Supplementing the study with mixed methods. Future studies could conduct interviews with construction professionals and gather qualitative data to expand on current literature findings.
- Expanding on the current empirical studies and analysis is needed to further understand public perception towards AI in construction.
- Extending on the current research and assimilating the practical aspect of the technologies to enable guidelines to be produced within the industry for the construction community.

5. Conclusions

There is limited knowledge on the public perception of AI technologies, their application area, and the AI-related policies that businesses need to follow when we incorporate AI [45]. Hence, the study aimed to understand the relationship between AI technologies, their key prospects, and constraints in the construction industry.

Among all states and territories in Australia, QLD (46%), NSW (46%), and VIC (45%) had the highest degree of satisfaction regarding AI in the construction industry. In contrast, given that most states and territories had a positive sentiment, NT (74%), SA (56%), and ACT (50%) had the lowest degree of satisfaction. The states and territories that had the lowest interest in sharing their views on social media channels (i.e., Twitter) showed primarily neutral or negative sentiment. Furthermore, AI 'prospects' (n = 1319) were mentioned twice the amount of 'constraints' (n = 609). We also justified the close relationship between AI technologies and prospects in several analysis procedures, that is, sentiment and content analysis, frequency analysis, content analysis, co-occurrence analysis, and spatial analysis.

This study also highlighted AI as a powerful technology and has the power to reshape and disrupt the construction industry. Today, there is limited understanding of the trending construction technologies and their application areas. This is evidenced in the low number of tweets (n = 7907). AI technologies received less attention on Twitter; additional empirical studies and analysis are needed to further understand public perception towards AI in construction. This will allow construction bodies to ease the transition from traditional management methods to management that incorporates machine and deep learning components to automate various construction stages. We believe the findings of this study inform the construction industry on public perceptions and prospects and constraints of AI adoption and advocate the search for finding the most efficient means to utilize AI technologies. This study captured the general public's perceptions of AI technologies in the construction industry, while our prospective research will concentrate on expanding and consolidating the understanding and relationship between AI technologies and the key actors of the construction industry.

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