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Sentiments about autonomous vehicles

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ABSTRACT

There is a lot of hype about autonomous vehicles (AV) but there are few studies on how people feel about this innovative product. To fill this research gap and to provide richer insights on this subject, this study crawled 10,374 AV-related comments from a microblogging website and used sentiment analysis to evaluate people's feelings and perceptions. The results show that people's sentiments depend not just on the AVs (e.g., their safety and convenience) but also AVs' impact on society, such as unemployment and legislation. The sentiments therefore transcend beyond individual considerations. The paper discusses the implications of the results and the contributions to the AV literature.

1. Introduction

Artificial intelligence (AI) technologies are now applied in many products and services, such as customer service (Adam et al., 2020), face recognition (Lin et al., 2016), and autonomous vehicles (AVs) (Bonnefon et al., 2016). Many countries are now testing AVs in the real-world environment and researchers predicted that AVs would comprise a quarter of private vehicles by 2040 (Yuen et al., 2020). AVs are defined as cars that can move and take driving actions without human drivers or teleoperation control (Frazzoli et al., 2002). They are a form of disruptive technology that can bring about changes to the current transportation system (Milakis et al., 2017). There are many positive user expectations about AVs (Mutz et al., 2016). For example, passengers' accessibility can be enhanced, time and cost of transportation can be reduced, convenience and comfort can be provided for those who do not want or cannot drive, and traffic accidents caused by human drivers can be avoided. There are also negative aspects about AVs, however. These include issues related to their costs and safety (Haboucha et al., 2017).

As AVs are in their development stages, it is useful to gather feedback on how people feel and perceive about this technological product. Understanding people's opinions about AVs can help to inform researchers and practitioners and it can guide developers to build AVs that cater to the needs of prospective users and stakeholders. Among the prior studies about AVs, they are based mostly on quantitative data collected through surveys. There is little research that analyse people's qualitative opinions about AVs (Liu et al., 2019). Using quantitative data from surveys may only reflect prompted concerns and not salient issues (Pettigrew et al., 2019). Thus, to gather more insights on what people think about AVs, this study used a different research approach. This study analyzed the comments gathered from a popular social media website. AVs are new to the market and people can share their comments on social media. Analyzing these comments can help to better understand people's sentiments. If the sentiments are positive, AVs are likely to be well received and their chances of success are high (Payre et al., 2014). On the other hand, AV manufacturers can also learn from the negative comments and improve their upcoming products and offerings. Social media mining can help to extract valuable knowledge,

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patterns, and insights for businesses and researchers (Gundecha and Liu, 2012). It can provide support for inductive work (McAbee et al., 2017) and present researchers the opportunity to generate new theories (Berente et al., 2019). The results of this study can provide suggestions for future development of AVs.

According to a recent report on AV readiness index, the pace of AV development is breath-taking (KPMG, 2018). The report says that "the question is no longer whether but when all road vehicles become fully autonomous". Indeed, AVs are soon to become a reality in China. China has made substantial investments in AV technologies and AVs are among the top priorities for the "Made in China 2025" masterplan (Ren, 2018). Researchers have indicated that AV companies in China will take leading positions in the world (Onag, 2021), given that China has the world's largest automobile market (Chen et al., 2020). However, there may exist psychological roadblocks for users to accept AVs (Shariff et al., 2017). It is useful to know how people feel about AVs because for AVs or technological innovations to be successful, they need to gain acceptance and legitimacy from stakeholders (Hall and Martin, 2005; Bergek et al., 2008; Kaganer et al., 2010). It is important to conduct this research because prior studies on AVs focus mostly on technical aspects (Gandia et al., 2018) and those related to people's perceptions are usually conducted outside China (Wu et al., 2019). Also, unlike many prior studies on this topic, this research is qualitatively oriented. It is exploratory in nature and the purpose is to gain richer insights about people's sentiments. The research questions for this study are: What are the positive and negative sentiments about AVs in China and how can AV practitioners leverage on the sentiments to promote AVs to the market?

This paper is structured as follows: Section 2 presents related work on the technical background about AVs and previous work on perceptions of AVs. Section 3 provides the research method for this study and Section 4 highlights the results. Section 5 discusses the results. Section 6 concludes this study.

2. Related work

2.1. Technical background about AVs

Janai et al. (2017) have summarized the technology requirements for implementing autonomous driving. These include (i) object detection to detect obstacles or other traffic participants, (ii) semantic segmentation to assign pre-defined labels to the images detected on the captured videos, such as cars, roads, and persons, (iii) simultaneous localization and mapping to simultaneously estimate the location of vehicles and continuously build and update the map of the environment, (iv) object tracking to estimate the state of objects over time, and (v) scene understanding to understand the driving environment. To satisfy these requirements and to further build on AV capabilities, developers make use of advanced technologies such as Computer Vision (CV), Artificial Intelligence (AI), and other auxiliary technologies.

The purpose of CV is to acquire, process, and analyze images (Ranft and Stiller, 2016). CV has achieved many breakthroughs in recent years (Liu et al., 2020a) and it is now used in many applications. One common application is to recognize human faces (Ancheta et al., 2018). For example, in the retail industry, Amazon and Alibaba have started operating unmanned stores, which are stores without human cashier (Lee & Kim, 2019). They use CV so that customers can authorize payments with their faces without using mobile devices. Facebook also uses CV to automatically tag friends in photographs. This function reduces the time to tag people in group photographs. In transportation, CV can recognize the number plates of vehicles (Puranic et al., 2016) and help AVs in their navigation. Baidu has used CV for mass production of its fully autonomous buses (Iclodean et al., 2020).

Besides CV, AI technologies such as machine learning (ML) and deep learning (DL) are also used to develop AVs. ML refers to algorithms that detect patterns. It is able to learn how to make predictions by processing data and experiences, rather than receiving explicit programming instructions. DL is a sub-category of ML and it can produce better results than traditional ML because it makes use of what it has learned to make inferences about new data. In its early development, AVs used traditional ML methods such as Support Vector Machine algorithms (Maldonado-Bascon et al., 2007) and pattern matching (Broggi et al., 2007). More recently, AVs used DL such as Convolutional Neural Network (CNN) to improve its capabilities (Ciresan et al., 2012; Jin et al., 2014; Sermanet & Lecun, 2011). Also, new DL algorithms, such as You Only Look Once (YOLO) (Redmon et al., 2016) and Faster-Regional Convolutional Neural Network, which is a regional proposal of CNN (Ren et al., 2017), have been employed to improve the robustness of AV systems.

Other technologies such as Cloud Computing, Internet of Things, and the new generation of mobile network (Jing et al., 2020) are also used to develop AVs. A reliable AV system requires ultra-low latency for data transmission, and so the use of fifth generation (5G) mobile network is necessary for the development of AVs (Li et al., 2017). 5G technologies can provide faster network connection speed that allows thousands of machines and sensors to communicate with each other almost instantly. The telecommunications equipment manufacturer, Huawei, has already started rolling out 5G networks in China (McMorrow & Liu, 2020) and this can help to facilitate the development of AVs in the country. AVs also use the global positioning systems to position driverless cars to obtain more accurate locations. Light detection and ranging (LiDAR) technologies are also used to complement the camera-based perception systems in AVs. A typical LiDAR works by scanning its field of view with one or several laser beams and it is able to make precise measurements of surrounding objects. LiDAR is able to track objects and predict object intention (Li and Ibanez-Guzman, 2020) and it generates data for real-time road lane detection in urban areas (Jung and Bae, 2018).

The car manufacturers are not the only ones that are building AVs. The tech giants, such as Google, Apple, and Baidu, are using advanced technologies to compete in the race to build AVs (Cohen and Hopkins, 2019). There are several levels of AVs. These include no-automation, driver assistance, partial automation, conditional automation, high automation, and full automation (Kyriakidis et al., 2015). Currently, AVs with full automation have been demonstrated.

2.2. Perceptions of AVs

The number of studies related to people's perceptions of AVs is relatively small. Golbabaei et al. (2020) found 80 articles in journals between 2012 and 2019, and about half were published in 2019. The latter result shows that the topic is gathering interest. These articles generally aim to determine people's perceptions, attitudes, or acceptance of AVs and whether they have intentions to adopt AVs. Considering the investments made in developing AVs as well as the potential benefits AVs may provide for society, rejection of AVs can result in heavy losses and it may stifle future innovations (Taeihagh and Lim, 2021).

Researchers have commented that there are great uncertainties regarding people's acceptance and adoption of AVs (Menon et al., 2020). Tennant et al. (2019) pointed out that there are differing results about public attitudes toward AVs. Some studies show respondents have positive attitudes (e.g., Schoettle and Sivak, 2014), whereas others expressed high levels of resistance and negative attitudes (e.g., Haboucha et al., 2017). Most studies show that young people and men are more inclined to accept AVs (Moody et al., 2020; Rice and Winter, 2019). However, some studies also show that age and sex are not related to support for AVs when controlling for psychological and risk perceptions variables (Dixon et al., 2020). Thus, there exist variables beyond the demographic factors that could explain the acceptance of AVs.

Studies have indicated that people are concerned about safety of AVs and the appropriate functioning of the technology (Jing et al., 2020; Kim et al., 2019). Rosell and Allen (2020) showed that safety is a clear determinant of behavioural intention among potential users of driverless vehicles. When riding on AVs, people cede control of vehicles to machines and they are fearful that AVs can cause accidents or are unable to avoid them. There are actual accidents involving AVs (Griggs and Wakabayashi, 2018) and people feel there is a risk when using AVs. On the other hand, studies have also indicated that people are optimistic about AVs. They feel that AVs are beneficial because they can reduce accidents as most accidents are caused by human errors (Dixon et al., 2020).

According to Ward et al. (2017), perceptions of risks and benefits play a central role in people's acceptance of AVs. A number of surveys have asked respondents to rate the benefits and concerns about AVs. For example, Woldeamanuel and Nguyen (2018) asked respondents to rate benefit items such as fewer traffic crashes and increased roadway safety, less stressful driving experience, less traffic congestion, more productive use of travel time, and increased fuel efficiency. Items that rate risks or concerns include safety of vehicle occupants and other road users, systems failure, automated vehicle hacking, performance in unexpected traffic conditions, difficulty in determining who is liable in the event of a crash, privacy risks from data tracking, and decrease in human driving skills over time. A study by Huang and Qian (2021) has shown empirically that people based their adoption intentions on the reasons for and against using AVs.

Researchers have also used technology adoption theories to explain the intentions to adopt AVs. For example, the Technology Acceptance Model (TAM) posits that perceived usefulness and perceived ease of use positively influence adoption intention (Davis, 1989). Perceived usefulness refers to whether the technology is perceived as useful for what people want to do and perceived ease-of-use refers to whether using the technology would be free from effort. The results of prior studies (Choi and Ji, 2015; Koul and Eydgahi, 2018) support TAM and show that TAM can indeed be used to explain the adoption intentions of AVs. Choi and Ji (2015) also used the trust theory (Gefen et al., 2003) to incorporate trust into TAM and showed that trust is positively related to the adoption intention of AVs.

Prior studies have also explored other variables related to AVs. For example, Höltl and Trommer (2013) found that users with more experience in using navigation devices have higher acceptance of AVs than those who are inexperienced. Hegner et al. (2019) found that personal innovativeness is positively related to the adoption of AVs while driving enjoyment is negatively related. That is, people who are willing to try new products are likely to try AVs. Those who enjoy driving, however, have less intention to use AVs. Kaur and Rampersad (2018) also found that AVs' performance expectancy, reliability, security, privacy, and trust are factors related to the acceptance of AVs.

China is developing its AV technology rapidly but there are few studies related to people's perceptions of AVs in China. One recent survey conducted in China show that ninety percent of 2530 respondents are willing to pay for AVs (Wang et al., 2019), indicating that people in China have keen interests in AVs. The study also found that people's acceptance of AVs depends on age, and that their concerns about AVs are related to technical safety as well as legal and liability issues.

As mentioned in the introduction, prior studies about AVs were mostly conducted based on quantitative data collected from surveys. Few used qualitative data in their research. Qualitative data can help to better understand the respondents. When people expressed themselves using qualitative data, they provide additional insights (Jefferson and McDonald, 2019). Pettigrew et al. (2019) collected qualitative data on people's opinions about AVs through a survey. They analysed the opinions by categorizing the data into two dimensions, based on the response valence (positive or negative) and response type (cognitive/concrete or emotional/general). They found five concrete topics in the positive comments. They are related to: "companies", "imminent arrival", "increased safety", "parking" and "electric". There is only one concrete negative topic, which is related to "decreased safety". The results show that AV safety can have positive or negative effects. Also, the positive comments relate to support people gave for AV companies and their excitement about the imminent arrival of AVs. The respondents also believed that AVs would make parking easier and the environment cleaner.

It is noteworthy that there are few studies related to perceptions of AVs across countries. One of these studies found that acceptance of AVs across countries is negatively related to GDP per capita (Nordhoff et al., 2018). That is, people from higher-income countries have lower AV acceptance compared to people from lower-income countries. The study suggested that AVs are appealing to those in lower-income countries because they experience more transport-related problems. However, there could be another reason why AV acceptance is negatively related to income across countries. According to results obtained by Kyriakidis et al. (2015), those in higher-income countries are less comfortable with AVs transmitting data. That is, data privacy is an important consideration for people

in high-income countries, and so this could hinder their acceptance of AVs. Regarding safety of AVs, Schoettle and Sivak (2014) found that people in both low- and high-income countries were equally concerned about safety issues. On the other hand, Moody et al. (2020) found variations in country-level perceptions of current and future AV safety, and attributed them to differences in national road safety conditions. Besides these studies, others have commented that AV acceptance may be affected by cultural characteristics. A recent study by Huang and Qian (2021) showed that in a collectivist country like China, "face consciousness" is related to the reasons for and against adopting AVs. Consumers want to "gain face" by adopting trendy technological products such as AVs and they also want to avoid "losing face" when there is systems failure in AVs.

AVs are the results of technology innovations and studies on technology innovations have indicated that stakeholder analysis is crucial (Hall and Martin, 2005). For innovations to be successful, stakeholders need to legitimise the changes brought about by the innovations (Ferreira et al., 2021). Legitimacy refers to "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995). Ferreira et al. (2022) have pointed out that studies using the legitimacy concept can help to identify causes why stakeholders resist new technology, which is a salient reason why innovative technology failed. If there are inadequate legitimacies, then there is a need to identify a workable solution for the innovation to be accepted. Rao (2000) showed various routes to build constitutive legitimacy with regards to consumers' acceptance of the automobile during the period 1895–1912. Prior to this period, people used horse carriages for transportation. The automobile was then an unfamiliar product to consumers and its reliability was suspect. The results of the study showed that evangelical appeals in the form of reliability contests organized by the auto clubs significantly increased the acceptance of automobile. The significance of the auto clubs and reliability contests declined as advertising by firms grew. After the enactment of automobile legislations, the effect of advertising fell as well.

It is interesting to note that some companies also used celebrity endorsers to promote AVs. For example, Intel featured basketball superstar LeBron James in an Intel-powered driverless car (Jibrell, 2017). It is possible that celebrity endorsement can change audience attitudes toward AVs. A meta-analysis has found that celebrity endorsement routinely evokes positive emotions among audience (Knoll and Matthes, 2017). An experimental study conducted by Myrick et al. (2019) has also shown that celebrity endorsement can alter public perceptions related to risks, benefits, and intentions of AVs.

3. Research method

This study used data gathered from social media to analyse AV-related comments. The research method used in this study is sentiment analysis. Sentiment analysis has been used in a number of recent studies (David et al., 2018). It extracts opinions from massive data sets and determines whether a given corpus has positive, neutral, or negative sentiments (Vinodhini and Chandrasekaran, 2012). Recent progress made in machine learning technologies has enabled vast improvements in the performance and accuracy of sentiment analysis (Dhaoui et al., 2017). Sentiment analysis is useful as it enables researchers to gauge the overall or general sentiments embedded in the data.

In this study, three keywords were used to crawl the "hot posts" in Weibo, which is the most popular Chinese Microblogging site in China (Wang, 2017). The "hot posts" in Weibo are the popular posts defined by the Weibo search system, which is based on the number

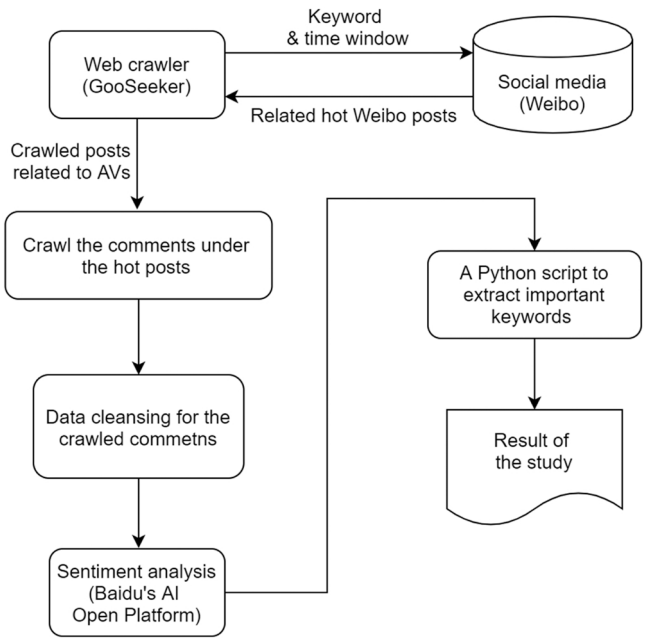

Fig. 1. The workflow of this study.

of views and comments. Posts refer to the original published contents whereas comments are the reply/feedback under the original post. Three keywords were used to search for the "hot posts". They are "unmanned driving" (无人驾驶), "unmanned/autonomous/-driverless vehicle" (无人車) and "autonomous driving" (自动驾驶). The search was based on posts dated January 2017 to May 2020. The starting date of January 2017 was the time when Baidu, one of the leading AV solution providers, commenced mass production of its AVs called "Apollo" (Zhu et al., 2018). The posts extracted from Weibo included some that were related to autonomous delivery robots and drone delivery robots. As the focus of this research is about AVs that transport human passengers, comments related to autonomous delivery robots and drone delivery robots were excluded. Also, some posts were related to celebrities. Given that there is prior research about celebrity endorsement on AVs, this study considered these celebrity-related comments as possible secondary interests. The comments from Weibo were used for analysis after data cleansing. Data cleansing includes removing duplicate comments from the same user. There were 10,374 comments after data cleansing.

This study used Baidu's AI open platform to obtain the sentiment scores and sentiment polarities. The sentiment scores are in the range from 0 to 1. When the scores are close to 0, the sentiments are negative. When they are close to 1, the sentiments are positive. The sentiment polarities are labelled "0", "1", and "2", and they refer to negative, neutral, and positive sentiments respectively. After generating the sentiment scores and polarities, a Python script that embeds a Chinese text segmentation tool called Jieba (Sun, 2015) was executed. The script was used to extract frequently used keywords from comments with negative or positive sentiments. After the keywords were extracted, they were grouped into related topics. The grouping could be done manually or with the help of a computational software such as LDAvis (Sievert & Shirley, 2014). This study used the manual method because the number of keywords is manageable and the keywords are confined to specific domains. The manual process also provides an opportunity to review the comments and the corresponding sentiment polarity related to the keywords. The grouping was conducted by the first author who is familiar with the background of the research. Fig. 1 illustrates the workflow of this study.

4. Results and analysis

4.1. Overview of results

The results on sentiment polarity show that among the 10,374 comments analysed, 5041 (49 %) are negative and 5058 (49 %) are positive. Fig. 2 shows the sentiment polarity over time. The red bars represent the number of comments with negative sentiments and the green bars represent those with positive sentiments. The figure shows that in 2017 and 2018, there are more negative than positive sentiments, while in 2019 and 2020, there are more positive than negative sentiments. Note that data for the distribution of sentiments is presented as descriptive statistics for the study sample. Caution should be exercised in extrapolating the distribution to the general population as the study used a convenience sample.

After performing sentiment analysis, the frequently used keywords were extracted from the comments and they were grouped into related topics. Table 1 presents the topics for each year. There are four topics with negative sentiments and three topics with positive sentiments. The topics with negative sentiments are: (1) safety concerns, (2) unemployment, (3) legalisation, and (4) uncertainties. The topics with positive sentiments are: (1) appreciation of technology, (2) safety benefits, and (3) convenience.

There are a few noteworthy aspects regarding the negative sentiments. First, as shown in Table 1, safety concerns are related to negative sentiments every year. Safety concerns are therefore a main topic for negative sentiments. This result is expected as prior studies have shown that people are concerned about safety of AVs (Xu, et al., 2018, Wang et al., 2019, Rosell and Allen, 2020). Second, the results show that negative sentiments are also related to unemployment, legislation, and uncertainties. These results are significant. They set this study apart from those of prior studies because prior studies drew little or scant attention to these negative aspects of AVs. For example, on unemployment, Kim et al. (2019, p.11) have pointed out that more studies related to job losses due to AVs are needed. With regards to legislation, Chen and Liu (2021, p.1) have commented that research on self-driving car legislation is basically non-existent in China. Regarding uncertainties, many studies (with few exceptions such as Graves (2017)) did not explicitly point out that there are considerable uncertainty surrounding the future of driverless cars that could impact their acceptance.

As for the positive sentiments, the results show that appreciation of technology recurs every year, and so it is a main topic for positive sentiments. For the topic related to safety benefits, we note that while these comments said that AVs are safer than

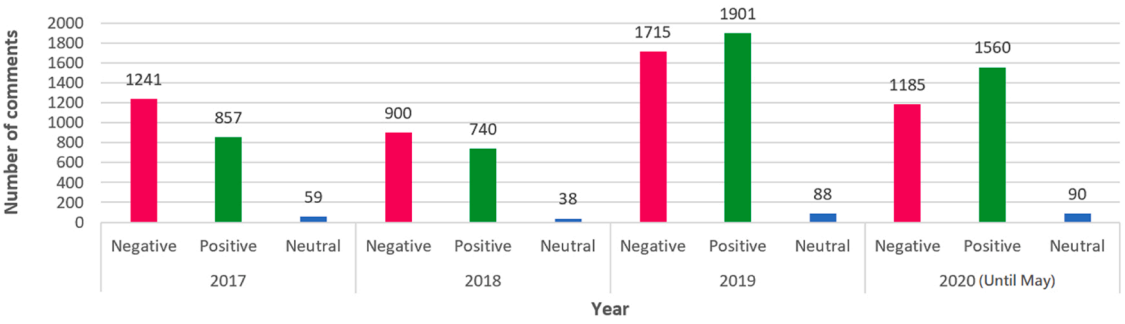

Fig. 2. Distribution of the comments based on sentiment polarity and year.

Table 1
Summary of topics.

Sentiments	Year	Topics
Negative	2017	(1) Safety concerns; (2) Unemployment; (3) Legislation
	2018	(1) Safety concerns; (2) Uncertainties
	2019	(1) Safety concerns; (2) Unemployment; (3) Uncertainties
	2020	(1) Safety concerns; (2) Uncertainties
Positive	2017	(1) Appreciation of technology
	2018	(1) Appreciation of technology
	2019	(1) Appreciation of technology; (2) Safety benefits
	2020	(1) Appreciation of technology; (2) Convenience

conventional vehicles, there are others who said they are concerned about the safety of AVs. These two perspectives of AV safety are consistent with results obtained in prior research (Pettigrew et al., 2019).

4.2. Topics with negative sentiments

4.2.1. Safety concerns

Table 2 shows the detailed results related to safety concerns. The table shows the frequently used keywords for this topic are "safety", "dare not", "accident" and "night". The table also shows there are 369 comments containing the keyword "safety" that have negative sentiments. This is the highest frequency among all the keywords with negative sentiments. Thus, the word "safety" contributes significantly to negative sentiments about AVs.

Reviews of comments show that people think AVs are not as safe as vehicles driven by people. AVs are controlled by computers and people are not confident about abdicating control to AVs. Related comments include: *"No matter how safe it is said, I am still scared"*, *"I still dare not take (AVs) now"* and *"So scary, I dare not take (AVs)"*. To reduce safety concerns, there were suggestions about setting speed limits for AVs: *"Is it safer to limit the speed of the autonomous vehicles?"*.

Other comments about safety concerns show that people are worried whether AVs can react on time: "*Can it brake in an accident? Can it dodge?"* and *"Will it stop if there is a traffic accident?"* Also, people feel that AVs are not safe at night because they seem to be driven by a ghost. For example, some comments said: *"At night, if you take the bus by yourself, it is very terrible if there is no driver"* and *"The car moves by itself, it looks like a ghost is driving"*.

The comments also indicate that safety concerns could be triggered by two causes. One is that people think AVs cannot work like a human driver. AVs are not "smart" enough, and they cannot handle unexpected situations. The second trigger could be caused by people's emotions. They think that AVs are driven by "ghost", especially at night. In summary, the results show that concern over safety is a primary driver of negative sentiments.

4.2.2. Unemployment

Table 3 shows the detailed results related to unemployment. The table shows that three frequently used keywords are related to this topic. They are "driver", "unemployed", and "human being". The comments on this topic indicate that AVs will displace jobs of the drivers, and that AI will also replace jobs that are manned by human beings. People are worried that technologies will replace jobs and so they have negative sentiments. Comments related to unemployment of drivers include: *"Drivers will be unemployed," "Are the bus drivers going to be unemployed?"* and *"Will taxi drivers be unemployed?"* Other related comments include: *"After 10 years, will most of us be unemployed?"* and *"Alas, the unemployment rate in China is getting higher and higher."*

Table 2
Detailed results and examples on negative sentiments related to safety concerns.

Keyword (frequency)	Data exemplar	Sentiment score
safety - 安全 (369)	No one can guarantee absolute safety, what do you think?	0.01
	No matter how safe it is said, I am still scared	0.03
	Is it safer to limit the speed of the autonomous vehicles?	0.16
	I don't know if AI is safe or not, but we cannot rely on AI for everything	0.01
	I always feel autonomous vehicle is unsafe	0.01
	Is it safe? I dare not to take it	0.01
dare not - 不敢 (151)	I still dare not take now	0.11
	So scary, I dare not take	0.01
	Feeling unsafe, dare not take	0.01
accident - 事故 (121)	No human driver? Can it brake in an accident? Can it dodge?	0.01
	Will it stop if there is a traffic accident?	0.01
	Although it is very novel, but what should I do if there is a traffic accident?	0.03
night - 晚上 (79)	At night, if you take the bus by yourself, it is very terrible if there is no driver	0.06
	I am so scared taking an autonomus vehicle at night. The car moves by itself, it looks like a ghost is driving	0.13
	It looks so scary, especially at night	0.04

Table 3
Detailed result and examples related to unemployment.

Keyword (frequency)	Data exemplar	Sentiment score
driver -司机/驾驶员	Drivers will be unemployed	0.01
(357)	Are the bus drivers going to be unemployed?	0.03
	There will be no driver to help with the luggage?	0.13
	How many drivers will lose their jobs?	0.01
unemployed - 失业	After 10 years, will most of us be unemployed?	0.19
(107)	Will taxi drivers be unemployed?	0.10
	Alas, the unemployment rate in China is getting higher and higher	0.01
human being - 人类	Does this mean that somehow the machine has replaced the brains of human beings?	0.01
(62)	Will artificial intelligence replace human beings in the future? That's scary.	0.01
	Human drivers are the cause of traffic accidents	0.02

Some comments compare the capabilities of human beings and machines, such as: *"Does this mean that somehow the machine has replaced the brains of human beings?"* and *"Will artificial intelligence replace human beings in the future? That's scary."* The comments also compare the benefits of AVs versus human drivers. They said that human drivers can provide added services such as helping with passengers' luggage: *"There will be no driver to help with the luggage?"* Others said that AVs are better because they can avoid mistakes caused by human drivers: "*Human drivers are the cause of traffic accidents."*

In summary, the comments on this topic show that people are concerned about unemployment for drivers and those whose jobs will be replaced by technology. The overall sentiments about unemployment are negative.

4.2.3. Legislation

Table 4 shows the detailed results related to legislation. The table shows that three keywords are related to legislation. They are: "law", "illegal", and "traffic police." The comments on legislation arose when Baidu's CEO rode an autonomous car in Beijing in 2017. The car was developed based on Baidu's AI technology. Even though using the autonomous car on the road was novel at that time, people were concerned if it was legal. The news triggered a lot of comments on social media. Some people said they were not sure if AVs should be allowed on the roads. Others asked, *"Do autonomous vehicles apply current laws and regulations?"*, *"If someone is hit, who will be responsible?"* and *"Are you sure AVs are not illegal?"* People feel that traffic police should be responsible for AVs: *"The traffic police are going to catch you"* and *"Does the traffic police stop it?"*.

In summary, the comments on legalisation surfaced when people wondered if it was legal to use AVs on the roads. Examples of legal issues involving AVs include the responsibilities and liabilities of vehicle owners in a traffic accident. People feel that a legal framework is needed for AVs to work smoothly.

4.2.4. Uncertainties

Table 5 shows the detailed results related to uncertainties. The table shows the frequently used keywords associated with uncertainties are "why/how/what if", "if", "technology", "driving licence", and "will it be". The negative sentiments related to uncertainties occurred since 2018. These uncertainties could have arisen because people were anxious to know how AVs would actually work. They realized there were a lot of unresolved issues with AVs. For example, there is a comment about the free-rider problem with AVs: *"I want to ask what if someone gets on the bus without buying ticket"*. Other comments include: *"What if the hacker invades?"*, *"I dare not take, what if the Internet is disconnected?"*, *"If the roadbed collapses, will the car react automatically?"* and *"Will people in the car die if there is a bug?"*.

Some negative sentiments were caused by doubts about AV technologies. The comments said: *"I can only say, the unmanned technology still doesn't work"* and *"It is still easy to have an accident with the current technology"*. In addition, there were a few comments on "driving licence". People thought it would no longer be necessary to take the driving test because the driving licence would be useless if AVs operate by themselves: *"Suddenly I don't want to take the driving test"* and *"The effort I took to get my driving licence had been wasted"*.

In summary, the negative sentiments related to uncertainties show that people were unsure and anxious about AVs. They needed clarifications on matters related to AVs.

Table 4
Detailed results and examples related to legislation.

Keyword (frequency)	Data exemplar	Sentiment score
law - 法律	Do autonomous vehicles apply current laws and regulations?	0.01
(56)	I think autonomous driving is not allowed based on the laws in my country	0.01
	If someone is hit, who will be responsible?	0.01
illegal - 违法	No matter how safe it is, the key is that you broke the law	0.01
(51)	This is illegal	0.01
	Are you sure AVs are not illegal?	0.01
traffic police - 交警	The traffic police are going to catch you	0.04
(37)	What if it is found by the traffic police?	0.01
	Does the traffic police stop it?	0.01

Table 5
Detailed results and examples related to uncertainties.

Keyword (frequency)	Data exemplar	Sentiment score
why/how/what if - 怎么	I want to ask what if someone gets on the bus without buying ticket	0.14
(265)	How to punish unmanned driving violations? It doesn't have driving license.	0.01
	What if the hacker invades?	0.02
	I dare not take, what if the Internet is disconnected?	0.01
if - 如果	If another car clashes behind it, will it stop?	0.12
(167)	If the roadbed collapses, will the car react automatically?	0.01
	If there are people crossing the road, can it brake in time?	0.02
technology - 技术	Obviously, it is technical problem, it cannot judge in such simple scenes.	0.01
(148)	I can only say, the unmanned technology still doesn't work	0.01
	It is still easy to have an accident with the current technology	0.10
driving licence - 驾照	Suddenly I don't want to take the driving test	0.02
(141)	The effort I took to get my driving licence had been wasted	0.01
	Why did I work so hard to get a driving license?	0.01
will it be - 是不是	Will there be more car accidents? Can insurance companies approve them?	0.03
(133)	Will the driving school be affected when autonomous driving goes into production?	0.04
	Will people in the car die if there is a bug?	0.01

4.3. Topics with positive sentiments

4.3.1. Appreciation of technology

Table 6 shows the detailed results related to appreciation of technology. The table shows the keywords on this topic are "technology", "look forward to", "Baidu", "life", "experience", and "5G". This topic constitutes majority of the positive sentiments. The comments on this topic tend to be general and show that people are fascinated by technology. They include comments that show support for AV companies such as Baidu and Tesla. Some comments also said they look forward to experience AVs and the 5G networks.

Examples of comments on this topic include: *"This is the power of technology, so amazing," "Looking forward to better technology,"* and *"This is so cool, extremely looking forward to it."* Other comments specifically mentioned 5G technology: *"The 5G technology revolutionizes our life," "The 5G technology is really powerful,"* and *"The 5G technology and autonomous driving will make something amazing happen."* Also, when people realized that AVs were deployed in specific cities in China, they said they wanted to experience riding an AV: *"This is so cool, I'm going to experience it"* and *"I also want to go to Shanghai to experience it."*

In addition, there are some comments about the posts that contain videos showing celebrities taking AVs. In one of these videos, there was an actress, Ms. Lareina Song, traveling in an autonomous car developed by Baidu. In another video, a popular foreign singer called Dimash was assigned as a tester for Baidu's autonomous bus. There are positive sentiments for the celebrities. By having the

Table 6
Detailed results and examples related to appreciation of technology.

Keyword (frequency)	Data exemplar	Sentiment score
technology - 科技	This is the power of technology, so amazing	0.99
(396)	China's technology is developing better and better	0.99
	Self-driving is safer, I believe in the power of technology	0.99
	Technology is really changing human life	0.97
	With the development of technology, our life becomes more and more intelligent	0.99
	This technology is really more and more advanced	0.90
look forward to - 期待	Looking forward to better technology	0.99
(181)	This is so cool, extremely looking forward to it	0.99
	Wow, I really look forward to it, I want to experience it too.	0.99
Baidu - 百度	Support Baidu	0.99
(180)	Add oil Baidu, I am proud of you	0.99
	Baidu is getting stronger and stronger, great!	0.99
experience - 体验	Great high-tech experience	0.99
(166)	This is so cool, I'm going to experience it	0.99
	I also want to go to Shanghai to experience it	0.99
life - 生活	Technology makes better life	0.99
(144)	The 5G technology revolutionizes our life	0.99
	Technology changes our life. Wow, I want to try it	0.99
5 G	The 5G technology is really powerful	0.99
(142)	The 5G technology will bring us more surprises	0.99
	The 5G technology and autonomous driving will make something amazing happen	0.86
Dimash - 迪玛希	Autonomous driving is very cool. I like Dimash.	0.99
(52)	Dimash is a good match for the autonomous car.	0.99
Lareina Song - 宋祖儿	Lareina is lovely. So is the car.	0.99
(26)		

celebrities appear with the videos, the AV manufacturers were trying to pass the positive sentiments of the celebrities to the AVs. The comments said the celebrities were handsome or lovely, such as "*Lareina is lovely. So is the car"* and *"Dimash is a good match for the autonomous car*."

In summary, the comments pertaining to appreciation of technology are positive. People look forward to using new technology in their daily life. Developers can leverage on people's interests on new technology to help promote AVs on the roads.

4.3.2. Safety benefits

Table 7 shows the detailed results related to safety benefits. The table shows the keyword for this topic is "safer". People believe that AVs are safer when compared to cars that are driven by reckless drivers. There are 132 comments that have positive sentiments on safety, as compared to 369 comments that have negative sentiments for safety. These results show that for the study sample, there are more negative than positive sentiments for safety.

There are several reasons why people think AVs are safer than human drivers. For example, AVs will not drink and drive. They will not get tired and make mistakes. Some comments include: *"Um, it's safer than people. It's impossible to drink and drive"*, *"Autonomous driving is safer, robots will not be fatigued"* and *"I think it is safe. People will make mistakes, but the machine will not"*. In addition, some comments indicate that girls will be safer if they take an autonomous taxi at night because they will not encounter bad taxi drivers.

In summary, the results show that some people feel AVs are safer than vehicles driven by human drivers. Thus, the safety benefits of AVs could motivate people to use AVs.

4.3.3. Convenience

Table 8 shows the detailed results related to convenience. The table shows one keyword on this topic, which is "convenient". The comments for this topic are general in nature and they do not specify why AVs are convenient. They simply expressed convenience in positive light. For example, they mentioned: *"It's so convenient, I like it"* and *"High-tech! It is really more and more convenient"*.

In summary, the comments show that convenience is a factor that is related to people's positive sentiments about AVs. AV developers should therefore consider various aspects of convenience when they design or implement AVs.

5. Discussion

The first research question for this study asks what are the positive and negative sentiments about AVs. The answers are summarized in Table 1 and examples of sentiments expressed in social media are presented in Tables 2 to 8. The results show that sentiments about AVs are not just about AVs per se (whether they are safe and convenient to use), but also about AVs' impact on society, such as unemployment and legislation. The concern is therefore not solely about AVs but the whole AV ecosystem. The stakeholders in the AV ecosystem would involve more people, not just the AV users, but also workers whose jobs will be taken over by technology, as well as other road users who are concerned about their legislative rights. As such, individual and societal acceptance would be necessary for the implementation of AVs. As mentioned earlier, the results of this study are significant because they not only include people's sentiments about AVs, but they also draw attention to people's sentiments about AVs operating in the society. The results show that for a radical innovation like AVs, it is important to identify all the relevant stakeholders and address their concerns (Hall and Martin, 2005). Prior research had paid little attention to the impact of AVs on society. As societal concerns are important considerations, future research should incorporate them into the research context wherever appropriate.

The second research question for this study is about how AV practitioners can leverage on the AV sentiments to promote AVs to the market. There are a number of ways AV promoters can manage people's sentiments to promote AVs. Regarding the negative sentiments, the comments show that safety should not be compromised. People are concerned that if AVs are not safe, they can result in fatal accidents. The numerous comments about safety as well as the explicit nature of the comments suggest that safety is a basic and non-negotiable requirement. Comments that said, "*It is too scary*" and "*I dare not take (AVs)*" show that people will continue to use driver-operated vehicles if they do not feel safe with AVs. As safety risks bear a high cost because a person's life is at stake, people may not want to compromise this risk at all. Safety is therefore a prerequisite for AVs. This means AV developers should focus their attention on safety. They need to ensure that AVs are thoroughly tested before they are allowed on the roads. When AVs are indeed safe, developers should communicate the safety standards to gain trust of prospective users. AV developers should conduct extensive road tests to demonstrate that they address the risks associated with AVs, including system failures and hacking issues. They can organize reliability contests similar to those presented by the auto clubs when the automobile was first introduced in the market in the late 1800s (Rao, 2000). These contests can help to demonstrate how AVs can manage difficult situations. AV developers should present statistics to show that AVs are safer than driver-operated vehicles. When people are convinced about the safety of AVs, it will help to improve their

Table 7
Detailed results and examples on positive sentiments related to safety.

Keyword (frequency)	Data exemplar	Sentiment score
safer -更安全 (132)	Um, it's safer than people. It's impossible to drink and drive	0.67
	Autonomous driving is safer, robots will not be fatigued	0.79
	I think it is safe. People will make mistakes, but the machine will not	0.98
	Very good, I think it's safe to take a taxi at night	0.99
	Oh, now the safety of girls can be guaranteed	0.98

Table 8
Detailed results and examples related to convenience.

Keyword (frequency)	Data exemplar	Sentiment score
convenient -方便 (58)	It's so convenient, I like it	0.99
	High-tech! It is really more and more convenient	0.99
	So convenient	0.95
	So that we can take a taxi at night more conveniently	0.99

legitimacy.

The second way to manage negative sentiments is to assure workers about their jobs. With the development of full automation AVs, the issue about unemployment among drivers will likely gain more prominence (Peters and Jandrić, 2019). The comments about unemployment show concerns not only for the drivers, but also for all those whose jobs will be displaced by technology. Unemployment brings hardship. Businesses must plan and find solutions for employees that will be affected by AVs. If businesses neglect unemployment issues, they will face resistance from various stakeholders and AVs are not likely to succeed. The implication is that businesses must be sensitive when they introduce AVs. To mitigate problems with unemployment, governments and organizations must make plans to enable people to learn new skills to lessen their worries about being replaced by technology. They should introduce AVs in phases to provide more time for people to adapt to changes.

Even though people may have negative sentiments regarding AVs' impact on unemployment, they may still adopt AVs because they are positive about other aspects of AVs. However, other stakeholders like the workers' union can still stall efforts to introduce AVs. Also, if people feel that AVs cause unemployment, they can sabotage AVs. For example, they may bully or create problems for AVs when they are on the roads (Liu et al., 2020b). The radical changes that will be brought about by the AV ecosystem need to be managed to demonstrate their legitimacy so that the innovation can be accepted by the society at large (Millar et al., 2018).

The third way to manage negative sentiments is to ensure that legislation is updated so that there is clear legal responsibilities and liabilities for people that are affected (e.g., AV users, pedestrians, and other road users). The results show that people have negative sentiments if the laws and regulations related to AVs are not updated. Results from prior research have also indicated that people feel they would encounter difficulties in determining who is liable in the event of a crash involving AVs (Menon et al., 2020). As AVs are developing very quickly, the relevant laws and regulations should be updated on a timely basis.

The fourth way to improve sentiments is for automakers to provide clear instructions on how AVs operate and how people can tackle emergent situations involving AVs. This can help to reduce people's anxiety and boost their confidence about AVs. The comments about AVs show that people have negative sentiments because they are uncertain or unsure how AVs will work. Such uncertainties should be addressed, else negative sentiments will persist and prevail. AV promoters can show videos to inform people about AVs or they can provide opportunities for people to ride on AVs. People feel better when they have experience or better understanding about AVs (Penmetsa et al., 2019). The relevant agencies should also address specific concerns raised in the comments and clarify issues to reduce anxieties. For example, regarding the need for a driving licence, the authorities may consider redesigning the driving tests to fit the contexts for AVs.

AVs promoters can also ride on the positive sentiments to boost support for AVs. Many positive comments about AVs show that people are fascinated by advancements in technology. They are amazed by what technology can do. Some are willing to try AVs even though they may be aware of safety risks. According to Roger's five personas for innovation adoption (Rogers, 2003), these people would be classified as innovators or early adopters. They can help to encourage others to use AVs. Similarly, using celebrity endorsers may also help to promote AVs.

Also, to promote AVs, practitioners should gather more feedback about the types of convenience people like about AVs. It is possible that people think AVs are convenient because they do not need to drive, or they do not have to spend much time and effort to park their vehicle. AV developers should determine people's expectations regarding convenience and pay attention to designing AVs that provide convenience. Promoting AVs for their convenience can help to increase sentiments and their acceptance rate.

6. Conclusion

To conclude, this study has contributed to the AV literature by providing a new perspective to study people's perceptions about AVs. This study used sentiment analysis to analyze comments from social media to determine people's feelings for AVs. As people are able to express their comments without inhibitions on social media, their opinions can help to identify salient issues that are deemed truly important. The results of this study show that negative sentiments about AVs relate to safety concerns, unemployment, legislation, and uncertainties, while positive sentiments relate to appreciation of technology, safety benefits, and convenience. The results show that sentiments of AVs depend not just on AVs per se, but also on AVs' impact on society, such as AVs causing unemployment. The results of this study are significant because they provide richer insights on factors related to people's sentiments about AVs. Based on the results obtained, this study has also made recommendations on how to promote AVs to the market.

There are a few limitations regarding the results of this research. First, people who had written comments about AVs in Weibo may not have a common understanding about AVs. Their comments are based on their own interpretation of AVs. Second, people who use social media are likely to be more computer literate. Those who are less computer literate could have been omitted from the study. Future research should include opinions from people who are non-social media users so that their opinions are also represented. Third, this study was conducted in China, while the situation in other countries may be different. As mentioned in our review of related work,

factors such as GDP per capita and cultural characteristics such as collectivism are associated with acceptance of AVs across countries (Nordhoff et al., 2018; Huang and Qian, 2021). As such, results of this study may not be generalizable to countries with relatively high GDP per capita or those with individualistic culture. Fourth, the topics for the positive and negative sentiments were generated manually and therefore the results could be biased. This bias is likely to be minimal as the researcher who performed the grouping of comments is knowledgeable about the subject area. Finally, the software for sentiment analysis may not interpret human language accurately and there could be some margin of error when analyzing the sentiments. However, the accuracy and performance of sentiment analysis software have improved over the years (Dhaoui et al., 2017). Furthermore, the sentiment scores obtained in this study were appraised during the review of comments. The impact of this limitation is therefore likely to be minimal.

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References

Adam, M., Wessel, M., Benlian, A., 2020. AI-based chatbots in customer service and their effects on user compliance. Electron. Mark. 31 (2), 427–445.
Ancheta, R.A., Reyes, F.C., Caliwag, J.A., Castillo, R.E., 2018. Fedsecurity: implementation of computer vision through face and eye detection. Int. J. Mach. Learn. Comput. 8 (6), 619–624.
Berente, N., Seidel, S., Safadi, H., 2019. Research commentary—data-driven computationally intensive theory development. Inf. Syst. Res. 30 (1), 50–64.
Bergek, A., Jacobsson, S., Sandén, B.A., 2008. 'Legitimation' and 'development of positive externalities': two key processes in the formation phase of technological innovation systems. Technol. Anal. Strateg. Manag. 20 (5), 575–592.
Bonnefon, J.F., Shariff, A., Rahwan, I., 2016. The social dilemma of autonomous vehicles. Science 352 (6293), 1573–1576.
Broggi, A., Cerri, P., Medici, P., Porta, P.P., Ghisio, G., 2007. Real time road signs recognition. Intelligent Vehicles Symposium. IEEE.
Chen, Y., Lawell, C.Y., Wang, Y., 2020. The Chinese automobile industry and government policy. Res. Transp. Econ. 84, 100849.
Chen, Z., Liu, S., 2021. China self-driving legislation study. Comput. Law Secur. Rev. 41, 1055555.
Choi, J.K., Ji, Y.G., 2015. Investigating the importance of trust on adopting an autonomous vehicle. Int. J. Hum. -Comput. Interact. 31 (10), 692–702.
Ciresan, D., Meier, U., Masci, J., Schmidhuber, J., 2012. Multi-column deep neural network for traffic sign classification. Neural Netw. 32, 333–338.
Cohen, S.A., Hopkins, D., 2019. Autonomous vehicles and the future of urban tourism. Ann. Tour. Res. 74, 33–42.
David, Z., Ahmed, A., Daniel, Z., Hsinchun, C., 2018. The state-of-the-art in twitter sentiment analysis. ACM Trans. Manag. Inf. Syst. 9 (2), 1–29.
Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of infor-mation technology. MIS Q. 13 (3), 319–340.
Dhaoui, C., Webster, C., Tan, L.P., Norberg, P., Fortin, D., 2017. Social media sentiment analysis: lexicon versus machine learning. J. Consum. Mark. 34 (6), 480–488.
Dixon, G., Hart, P.S., Clarke, C., O'Donnell, N.H., Hmielowski, J., 2020. What drives support for self-driving car technology in the Untied States. J. Risk Res. 23 (3), 275–287.
Ferreira, C., Meadows, M., Azer, E., 2022. Technology legitimation and user resistance: the NHS COVID-19 App. In: Papagiannidis, S., Alamanos, E., Gupta, S., Dwivedi, Y.K., Mäntymäki, M., Pappas, I.O. (Eds.), The Role of Digital Technologies in Shaping the Post-Pandemic World. I3E 2022. *Lecture Notes in Computer Science*. Springer, Cham, p. 13454. https://doi.org/10.1007/978-3-031-15342-6_32.
Ferreira, C., Merendino, A., Meadows, M., 2021. Disruption and legitimacy: big data in society. Inf. Syst. Front. https://doi.org/10.1007/s10796-021-10155-3.
Frazzoli, E., Dahleh, M.A., Feron, E., 2002. Real-time motion planning for agile autonomous vehicles. J. Guid., Control, Dyn. 25 (1), 116–129.
Gandia, R.M., Antonialli, G., Cavazza, B.H., Neto, A.M., Lima, D.A., Sugan, J.Y., Nicolai, I., Zambalde, A.L., 2018. Autonomous vehicles: scientometric and bibliometric review. Transp. Rev. 39 (1), 9–28.
Gefen, D., Karahanna, E., Straub, D.W., 2003. Trust and TAM in online shopping: An integrated model. MIS Q. 27 (1), 51–90.
Golbabaei, F., Yigitcanlar, T., Paz, A., Bunker, J., 2020. Individual predictors of autonomous vehicle public acceptance and intention to use: a systematic review of the literature. J. Open Innov.: Technol., Mark., Complex. 6 (4), 106.
Graves, B., 2017. Considerable uncertainty surrounds the future of driverless vehicles, Gove*rnment Technology* , Sept: ⟨https://www.govtech.com/fs/perspectives/considerable-uncertainty-surrounds-the-future-of-driverless-vehicles.html⟩.
Griggs, T., Wakabayashi, D., 2018. How a self-driving Uber killed a pedestrian in Arizona. *The New York Times*.
Gundecha, P., Liu, H., 2012. Mining social media: a brief introduction. N. Dir. Inform., Optim., Logist., Prod. Tutor. Oper. Res. 1, 17.
Haboucha, C.J., Ishaq, R., Shiftan, Y., 2017. User preferences regarding autonomous vehicles. Transp. Res. Part C: Emerg. Technol. 78, 37–49.
Hall, K.H., Martin, M.J.C., 2005. Disruptive technologies, stakeholders and the innovation value-added chain: a framewok for evaluating radical technology development. RD Manag. 35 (3), 273–284.
Hegner, S.M., Beldad, A.D., Brunswick, G.J., 2019. In automatic we trust: investigating the impact of trust, control, personality characteristics, and extrinsic and intrinsic motivations on the acceptance of autonomous vehicles. Int. J. Hum. Interact. 35 (19), 1769–1780.
Höltl, A., Trommer, S., 2013. Driver assistance systems for transport system efficiency: Influencing factors on user acceptance. J. Intell. Transp. Syst. 17 (3), 245–254.
Huang, Y., Qian, L., 2021. Understanding the potential adoption of autonomous vehicles in China: the perspective of behavioral reasoning theory. Psychol. Mark. 38, 669–690.
Iclodean, C., Cordos, N., Varga, B.O., 2020. Autonomous shuttle bus for public transportation: a review. Energies 13 (11), 2917.
Janai, J., Güney, F., Behl, A., Geiger, A., 2017. Computer vision for autonomous vehicles: Problems, datasets and state-of-the-art. arXiv Prepr. arXiv 1704, *05519*.
Jefferson, J., McDonald, A.D., 2019. The autonomous vehicle social network: Analyzing tweets after a recent Tesla autopilot crash. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications, Sage, Los Angeles, pp. 2071–2075.
Jibrell, A., 2017. Intel, LeBron James team up to build trust in autonomous cars. *Automotive News.*:⟨http://www.autonews.com/article/20171009/MOBILITY/171009772/lebron-james-intel-autonomous-cars⟩.
Jin, J., Fu, K., Zhang, C., 2014. Traffic sign recognition with hinge loss trained convolutional neural networks. IEEE Trans. Intell. Transp. Syst. 15 (5), 1991–2000.
Jing, P., Xu, G., Chen, Y., Shi, Y., Zhan, F., 2020. The determinants behind the acceptance of autonomous vehicles: a systematic review. Sustainability 12 (5), 1719.
Jung, J., Bae, S.-H., 2018. Real-time road lane detection in urban areas using LiDAR data. *Electronics* 2018 7 (11), 276.
Kaganer, E.A., Pawlowski, S.D., Wiley-Patton, S., 2010. Building legitimacy for IT innovations: the case of computerized physician order entry systems. J. Assoc. Inf. Syst. 11 (1).
Kaur, K., Rampersad, G., 2018. Trust in driverless cars: investigating key factors influencing the adoption of driverless cars. J. Eng. Technol. Manag. 48 (1), 87–96.
Kim, M.-K., Park, J.-H., Oh, J., Lee, W.-S., Chung, D., 2019. Identifying and prioritizing the benefits and concerns of connected and autonomous vehicles: a comparison of individual and expert perceptions. Res. Transp. Bus. Manag. *32*. https://doi.org/10.1016/j.rtbm.2020.100438.
Knoll, J., Matthes, J., 2017. The effectiveness of celebrity endorsements: a meta-analysis. J. Acad. Mark. Sci. 45 (1), 55–75.
Koul, S., Eydgahi, A., 2018. Utilizing technology acceptance model (TAM) for driverless car technology adoption. J. Technol. Manag. Innov. 13 (4), 37–46.
KPMG International, (2018). Autonomous vehicles readiness index, available at https://assets.kpmg/content/dam/kpmg/xx/pdf/2018/01/avri.pdf.
Kyriakidis, M., Happee, R., de Winter, J.C., 2015. Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. Transp. Res. Part F: Traffic Psychol. Behav. 32 (1), 127–140.

Lee, E.J., Kim, S.I., 2019. Guideline for improvement of unmanned shopping experience-focusing on seven eleven signature. J. Digit. Converg. 17 (3), 389–394.
Li, X., Samaka, M., Chan, H.A., Bhamare, D., Gupta, L., Guo, C., Jain, R., 2017. Network slicing for 5G: Challenges and opportunities. IEEE Internet Comput. 21 (5), 20–27.
Li, Y., Ibanez-Guzman, J., 2020. Lidar for autonomous driving: the principles, challenges, and trends for automotive lidar and perception systems. IEEE Signal Process. Mag. 37 (4), 50–61.
Lin, W.H., Wang, P., Tsai, C.F., 2016. Face recognition using support vector model classifier for user authentication. Electron. Commer. Res. Appl. 18, 71–82.
Liu, H., Yang, R., Wang, L., Liu, P., 2019. Evaluating initial public acceptance of highly and fully autonomous vehicles. Int. J. Hum. Interact. 35 (11), 919–931.
Liu, L., Ouyang, W., Wang, X., Fieguth, P., Chen, J., Liu, X., Pietikäinen, M., 2020a. Deep learning for generic object detection: a survey. Int. J. Comput. Vis. 128 (2), 261–318.
Liu, P., Du, Y., Wang, L., Ju, D.Y., 2020b. Ready to bully automated vehicles on public roads? Acid. Anal. Prev. 137, 105457.
Maldonado-Bascon, S., Lafuente-Arroyo, S., Gil-Jimenez, P., Gomez-Moreno, H., Lopez-Ferreras, F., 2007. Road-sign detection and recognition based on support vector machines. IEEE Trans. Intell. Transp. Syst. 8 (2), 264–278.
McAbee, S.T., Landis, R.S., Burke, M.I., 2017. Inductive reasoning: the promise of big data. Hum. Resour. Manag. Rev. 27 (2), 277–290.
McMorrow, R., & Liu, N., 2020. China Mobile picks Huawei and ZTE to build its 5G network. Accessed July 22 2020. https://www.ft.com/content/78f172db-7e02–450a-a1c7–8e9c260c2034.
Menon, N., Zhang, Y., Pinjari, A.R., Mannering, F., 2020. A statistical analysis of consumer percceptions towards automated vehicles and their intended adoption. Trans. Plan. Technol. 43 (3), 253–278.
Milakis, D., Van Arem, B., Van Wee, B., 2017. Policy and society related implications of automated driving: a review of literature and directions for future research. J. Intell. Transp. Syst. 21 (4), 324–348.
Millar, C., Lockett, Ladd, T., 2018. Disruption: technology, innovation and society. Technol. Forecast. Soc. Change 129, 254–260.
Moody, J., Bailey, N., Zhao, J., 2020. Public perceptions of autonomous vehicle safety: an international comparison. Saf. Sci. 121, 634–650.
Mutz, F., Veronese, L.P., Oliveira-Santos, T., De Aguiar, E., Cheein, F.A.A., De Souza, A.F., 2016. Large-scale mapping in complex field scenarios using an autonomous car. Expert Syst. Appl. 46, 439–462.
Myrick, J.G., Ahern, L., Shao, R., Conlin, J., 2019. Technology name and celebrity endorsement effects of autonomous vehicle promotional messages: mechanics and moderators. Sci. Commun. 41 (1), 38–65.
Nordhoff, S., Winter, J., Kyriakidis, M., Arem, B., Happee, R., 2018. Acceptance of driverless vehicles: results from a large cross-national questionnaire study. J. Adv. Transp., 5382192
Onag, G., 2021. KPMG: China ranks top 5 in AV partnerships. FutureIOT. ⟨https://futureiot.tech/kpmg-china-ranks-top-5-in-av-partnerships/⟩.
Payre, W., Cestac, J., Delhomme, P., 2014. Intention to use a fully automated car: attitudes and a priori acceptability. Transp. Res. Part F: Traffic Psychol. Behav. 27, 252–263.
Penmetsa, P., Adanu, E.K., Wood, D., Wang, T., Jones, S.L., 2019. Perceptions and expectations of autonomous vehicles – a snapshot of vulnerable road user opinion. Technol. Forecast. Soc. Change 143, 9–13.
Peters, M.A., Jandrić, P., 2019. Education and technological unemployment in the Fourth Industrial Revolution. The Oxford Handbook of Higher Education Systems and University Management. Oxford University Press.
Pettigrew, S., Worrall, C., Talati, Z., Fritschi, L., Norman, R., 2019. Dimensions of attitudes to autonomous vehicles. Urban, Plan. Transp. Res. 7 (1), 19–33.
Puranic, A., Deepak, K.T., Umadevi, V., 2016. Vehicle number plate recognition system: a literature review and implementation using template matching. Int. J. Comput. Appl. 134 (1), 12–16.
Ranft, B., Stiller, C., 2016. The role of machine vision for intelligent vehicles. IEEE Trans. Intell. Veh. 1 (1), 8–19.
Rao, H. , 2000. "'Tests tell': Constitutive legitimacy and consumer acceptance of the automobile: 1895–1912", Ingram, P. and Silverman, B.S. (Ed.) The New Institutionalism in Strategic Management (Advances in Strategic Management, Vol. 19), Emerald Group Publishing Limited, Bingley, pp. 307–335.
Redmon, J., Divvala, S., Girshick, R., & Farhadi, A., 2016. You only look once: unified, real-time object detection. IEEE Conference on Computer Vision and Pattern Recognition (CVPR). IEEE.
Ren, D., 2018. China's drive to become world's most powerful electric car maker. Retrieved July 09, 2020, from https://www.scmp.com/business/china-business/article/2169698/made-china-2025-worlds-biggest-auto-market-wants-be-most.
Ren, S., He, K., Girshick, R., Sun, J., 2017. Faster R-CNN: towards real-time object detection with region proposal networks. IEEE Trans. Pattern Anal. Mach. Intell. 39 (6), 1137–1149.
Rice, S., Winter, S.R., 2019. Do gender and age affect willingness to ride in driverless vehicles: If so, then why? Technol. Soc. 58, 101145.
Rogers, E., 2003. Diffusion of Innovation, 5th Edition, Simon and Schuster.
Rosell, J., Allen, J., 2020. Test-riding the driverless bus: determinants of satisfaction and reuse intention in eight test-track locations. Transp. Res. Part A: Policy Pract. 140, 166–189.
Schoettle, B., Sivak, M. , 2014. Public Opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia, *University of Michigan Transport Research Institute*,⟨http://deepblue.lib.umich.edu/bitstream/handle/2027.42/109433/103139.pdf?sequence=1&isAllowed=y⟩.
Shariff, A., Bonnefon, J., Rahwan, I., 2017. Psychological roadblocks to the adoption of self-driving vehicles. Nat. Hum. Behav. 1, 694–696.
Sermanet, P., Lecun, Y., 2011. Traffic sign recognition with multi-scale Convolutional Networks. Int. Jt. Conf. Neural Netw. 2809–2813.
Suchman, M.C., 1995. Managing legitimacy: strategic and institutional approaches. Acad. Manag. Rev. 20 (3), 571–610.
Sun, J., 2015. Jieba Chinese word segmentation tool, https://github.com/fxsjy/jieba.
Taeihagh, A., Lim, H.S.M., 2021. Towards autonomous vehicles in smart cities: risks and risk governance. In: Hamid, U.Z.A., Al-Turjman, F. (Eds.), Towards Connected and Autonomous Vehicle Highways. EAI/Springer Innovations in Communication and Computing. Springer, Cham. https://doi.org/10.1007/978-3-030-66042-0_7.
Tennant, C., Stares, S., Howard, S., 2019. Public discomfort at the prospect of autonomous vehicles: Building on previous surveys to measure attitudes in 11 countries. Transp. Res. Part F. 64, 98–118.
Vinodhini, G., Chandrasekaran, R.M., 2012. Sentiment analysis and opinion mining: a survey. Int. J. Adv. Res. Comput. Sci. Softw. Eng. 2 (6), 282–292.
Wang, H., You, F., Chu, X., Li, X., Sun, X., 2019. Research on customer marketing acceptance for future automatic driving - A case study in China city. IEEE Access 7, 20938–20949.
Wang, Y., 2017. The rise of Weibo: Lessons Twitter can learn from Chinese upstart. Forbes. https://www.forbes.com/sites/ywang/2017/06/06/the-rise-of-weibo-lessons-twitter-can-learn-from-chinese-upstart/#4bf1d3ba20b0.
Ward, C., Raue, M., Lee, C., D'Ambrosio, L., Coughlin, J.F., 2017. Acceptance of automated driving across generations: the role of risk and benefit perception, knowledge, and trust. Lect. Notes Comput. Sci. 10271, 254–266.
Woldeamanuel, M., Nguyen, D., 2018. Perceived benefits and concerns of autonomous vehicels: an exploratory study of millennials' sentiments of an emerging market. Res. Transp. Econ. 71 (1), 44–53.
Wu, J., Liao, H., Wang, J., Chen, T., 2019. The role of environmental concern in the public acceptance of autonomous electric vehicles: a survey from China. Transp. Res. Part F. 60, 37–46.
Xu, A., Zhang, K., Min, H., Wang, Z., Zhao, X., Liu, P., 2018. What drive people to accept automated vehicles? Findings from a field experiment. Transp. Res. Part C. 95, 320–334.
Yuen, K.F., Wong, Y.D., Ma, F., Wang, X., 2020. The determinants of public acceptance of autonomous vehicles: An innovation diffusion perspective. J. Clean. Prod., 121904
Zhu, F., Ma, L., Xu, X., Guo, D., Cui, X., & Kong, Q., 2018. Baidu Apollo auto-calibration system - An industry-level data-driven and learning based vehicle longitude dynamic calibrating algorithm. Retrieved July 28, 2020, from the arXiv database.