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Public acceptance of drone applications in a highly urbanized environment

Lynn Kai Lin Tan [a,1], Beng Chong Lim [b], Guihyun Park [c], Kin Huat Low [d,*], Victor Chuan Seng Yeo [b]

[a] Air Traffic Management Research Institute, Nanyang Technological University, 637460, Singapore
[b] Nanyang Business School, Nanyang Technological University, 639798, Singapore
[c] Research School of Management, The Australia National University, 2601, Australia
[d] School of Mechanical and Aerospace Engineering, Nanyang Technological University, 639798, Singapore

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ABSTRACT

Human societies are constantly affected by advancement in technologies. Could drone application be the next game changer? Building on the Knowledge, Attitude and Practice (KAP) model, we conducted a study to examine public perceptions of drone application in a South East Asian city state. While there are a number of common findings with past research, we were able to extend the understanding of drone application in urban areas with the following findings. First, using two knowledge tests, we were able to confirm that the majority of the public seems to have a good understanding of what a drone is. Second, acceptance levels towards drones did significantly differ depending on the context of use. Industrial areas had the highest acceptance level, followed by recreational areas and commercial areas while residential areas had the lowest acceptance level. Finally, different factors may be responsible for the varying levels of acceptance across the different contexts. We provided preliminary evidence that two factors – fears and concerns, and perceived potential benefits – affected the public acceptance levels differently depending on the contexts of drone applications. We concluded with implications for future research and policy makers.

1. Introduction

Human societies are constantly affected by advancement in technologies. Think about the difference the invention of electricity has made to modern societies and human lives. Again, no one will disagree on the huge impact brought about by the advancements of automobile technologies on human lives - Model T built by the Ford Motor Company was a practical, affordable car for the masses. Fast forward to the twenty first century, many of us probably cannot imagine not having our smartphone by our side for a day. Indeed, technologies have transformed the way we live, commute, communicate and socialize with our loved ones, colleagues, friends or even strangers.

While drone technologies are not new, it has not permeated our daily lives until a few years ago. These days, news of emerging applications of drone technologies are ubiquitous. Be it for routine building inspection, constant security surveillance, or last mile commercial delivery, drone technologies have been touted as a cost-effective solution. With the rapid advancement in drone technologies, there is a growing interest among business leaders, policymakers and regulators, and the general public to apply the technology in a myriad of areas such as aerial photography, infrastructure inspection, search and rescue, commercial delivery, and surveillance for law enforcement [1]. Increasingly, there is no doubt that this technology will find its way into more areas of application for state, industrial, commercial, and recreational purposes in the foreseeable future [2]. Indeed, drone technologies if adopted widely could have the potential like those technologies mentioned earlier to impact how our society functions as a system. Imagine a drone carrying a pizza delivery zooming past your windows on the 20th floor of your apartment block or a drone flying overhead on a surveillance operation while you are doing your weekend shopping along your favorite shopping belt. Many of us may enjoy watching sci-fi movies with drones of varying shapes and sizes flying in between and sometimes in and out of buildings, landings and taking offs in proximity of each other, but are we ready for these drones to be an integral part of our daily lives? We agree with Aydin [3] that "public acceptance of any technology is necessary for realizing their benefits fully" (pg. 2). Drone application in

* Corresponding author.
E-mail address: mkhlow@ntu.edu.sg (K.H. Low).
[1] PhD candidate, School of Social Sciences, Singapore Management University, Singapore 178,903.

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public areas is more than a technological issue. To ensure successful implementation, social and psychological dimensions of drone operations in urban environment must be fully understood in order to enhance public acceptance of the technology. Is the public ready for the sci-fi scenario where a system of drones flies overhead conducting different types of operations from surveillance to delivery to search and rescue? How much does the public know about drone technology? Do they see potential benefits of drone technology in their daily lives? What would be their fears and concerns? How receptive are they to drone technology?

While the potential applications and associated benefits of drone technologies are unlimited, the level of public support and acceptance will have a direct impact on the scope and pace of adoption of the emerging technology in general [4]. Hence the purpose of our research is twofold. First, we aim to build on existing research findings by using a sample from a South East Asian country, Singapore. Second, we believe that the level of public acceptance is context specific. To our best knowledge, existing research have mainly been conducted in Western countries such as Australia [1], United States of America (e.g. Ref. [5,6], Switzerland [7], Germany [8] and Canada [9].NNn No research study, based on our literature search, has been conducted in an Asian country. In addition, we also believe that a highly urbanized Singapore presents a more appropriate context for the investigation of public perceptions with regards to drone applications, which we will elaborate further in the subsequent section. As for the suggestion of context-specific public acceptance in our study, we found that existing research has conceptualized public acceptance as context free. In other words, participants were often asked to respond to survey items such as "To what extent do you think the risks (of drones) are acceptable?" [1]. The assumption here is these participants would either accept or reject the idea of drone applications. Klauser and Pedrozo [7] found support that public acceptance of drones vary across various types of contexts. They found that social support for rural spaces for both hobby drones and commercial drones were higher than private and urban spaces. Hence, we postulate that whether one is open to the idea of drone application is affected not only by its function (for e.g., building inspection, commercial delivery, and security surveillance), but also by the contexts in which the technology is being used (for e.g., residential areas, commercial areas, industrial areas and recreational areas). For instance, people may be more accepting of using drones for building inspection in industrial areas compared to residential areas. Similarly, people may be more receptive toward security surveillance in commercial and industrial areas compared to residential and recreational areas. Hence, our research seeks to investigate public acceptance in four different contexts – residential, recreational, industrial and commercial areas – in order to understand the nuances of public perceptions with regards to drone applications in urban environment. With the four contexts as the basis for comparison, we aim to build on existing findings by exploring the factors that are associated with public acceptance. Hopefully, by understanding the specific factors that are associated with public acceptance, policymakers, government regulators and business leaders could be more targeted in their effort to enhance public acceptance of drone applications. We hope that our research will be able to contribute toward this effort. In the next few sections, we first provide an overview of current literature on drone application, followed by our research questions and hypotheses before concluding with some practical and research implications.

1.1. *A brief history of drone technology*

Technically known as an unmanned aerial vehicle (UAV), a drone is an aircraft without a human pilot on board [10]. In many cases, the pilots could be nearby, while in other cases, the pilots could be far away in a control room. In our paper, we chose to use the term "drone" to depict the technology for two reasons. First, this is a commonly used term in the mass media hence, the public would likely have heard of "drone" rather than "UAV" or any other technical terms. Second, Clothier et al. [1] did not find any significant difference in the ratings of safety risk perception when different terminologies such as drone, unmanned aircraft, autonomous aircraft, and remotely piloted aircraft, were used. In addition, PytlikZillig et al. [6] also reported no change in public support due to the terminology used (e.g., UAS, UAV, aerial robot, or drone) in their research. For decades, drones were used extensively by the military as part of their operations. Therefore, it was not surprising that a text analysis of 1948 articles on drones in Australia and New Zealand found that 82% of the articles associated the concept of "drone" with "military strikes" [1]. Readers who are interested in the origins of drone technology in the military can refer to Aydin [3] for a detailed review. For the purpose of our paper, it is sufficient to say that while drone technology has its roots in the military, its application has evolved over the last decade, and a number of commercial, industrial and recreational applications have emerged. More applications are emerging as we speak. Indeed, Aydin [3] has compiled a list of 40 current and future applications of the drone technology.

1.2. *Understanding public perceptions of drones*

In this study, we follow the Knowledge, Attitudes and Practice model (KAP), which proposes a framework for understanding important psychological constructs that the public hold towards drone technology. This framework has been widely used by many other researchers who sought to investigate the reactions of the public towards existing or emerging technologies, to better integrate these technologies into society. Some work following the KAP model includes studying public factors pertaining to innovative financing infrastructural systems [11], climate change reporting [12], personal protective equipment for farmers [13] and safety equipment for engineers [14]. Some recent work investigating public perception towards drone technology had also adopted the KAP model but these studies focused only on participants from the United States [3,15]. In this study, we use the KAP model as a guiding framework to include various factors that are potentially associated with the Singaporean public's level of acceptance towards drones.

According to the KAP model, crucial societal factors that can impact the acceptance and integration of new technologies into society can be assessed by surveying the public on several types of questions. Firstly, knowledge levels of the public should be assessed. Another important category of information to survey the public on is their attitudes towards drones, and finally, the level to which the public practice using drones. In the following section, we discuss the variables measured in this study and categorised them according to the KAP model.

1.2.1. *Knowledge*

1.2.1.1. Knowledge tests. To assess the Singaporean public's knowledge towards drones, this study included 2 knowledge tests to assess the public's visual and semantic understanding of drones; these tests were a picture knowledge test with 6 images of either drones or non-drones, and a worded knowledge test with 7 items that either fit or does not fit into the definition of a "drone". Both tests are created by the authors.

A number of studies have been conducted to examine public understanding and perceptions of drone applications. In terms of public understanding of drones, Reddy and DeLaurentis [15] found that 93% of their 400 survey respondents have heard about drones. More recently, a study by Aydin [3] found that almost 80% of the 153 survey participants listed mainstream news media and movies or television series as their main sources of information regarding drones. In addition, this study also found that drone users have greater knowledge about drones compared to non-users (general public). However, Tam [16] found that only 39% of the 158 survey participants were somewhat familiar with Unmanned Aerial Vehicles (note that "drone" was not used). Similarly, Eyerman et al. [17] also reported that just slightly more than 56% of the public knew about UAV applications. Overall, past work suggests that the public in general are somewhat aware of drone technology as it has been proliferated in the mass media in recent years.

1.2.2. Attitudes

The main attitude this study seeks to investigate is the Singaporean public's level of acceptance towards drone technology operating in the urban spaces of Singapore. To investigate this, this study included several measures assessing participant's acceptance level towards drones and how it varies based on other important factors.

1.2.2.1. The use of the drone and who the drone user is. A recent study conducted by Klauser and Pedrozo [7] in Switzerland found that the public supported drone use by the military, police and for scientific research but not for commercial and hobby applications (e.g. delivery). Together with studies such as Boucher [18]; Jenkins-Smith, Gupta, Silva, Herron, & Ripberger [19] and Eyerman et al. [17]; it does appear that public perceptions of drones and their acceptance of its applications are greatly dependent on what the drone technologies are being used for (i.e., the purpose of the drone application) and by whom. In this study, we also seek to investigate how public acceptance towards drones vary based on who the user is and what the drone is being used for.

1.2.3. Practice

1.2.3.1. Prior experience with drones. This study included a measure of the public's level of practice with drone operations. We postulate that an individual's prior experience with drone technology may also affect the level of public acceptance. People with experience with drones were found to have different concerns about drone operations than lay people with less experience with drones [8] – specifically, experienced drone operators reported drone accidents as their primary concern while lay people reported privacy. As such, we believe that the public's level of experience with drones is important to investigate.

1.2.4. Demographics

Finally, demographic information was measured, including gender, age, socioeconomic status (SES), occupation, annual income, industry, nature of work, and their highest educational qualification. Past work has found that some demographic factors are associated with public acceptance of drone. To begin with, people of younger ages reported higher willingness to use emerging technologies, such as driverless cars [20], compared to older people. In Switzerland, older age groups have higher resistance towards drones [7]. Further, females were found to have higher fear towards autonomous robots and artificial intelligence [21]. Other work has found associations between age, gender, and socioeconomic status (SES) with public acceptance of emerging technologies (e.g. Refs. [22–25]).

1.3. Building on the KAP model

To contribute to the literature on understanding public perceptions of drones, we sought to build on the KAP model. Specifically, we propose that the factors included in our KAP model would be associated with the public's heuristic evaluations of drone technology, which in turn is associated with their acceptance towards drone technology (see Fig. 1 for our proposed framework).

1.3.1. Value perceptions

Value perceptions refer to a type of heuristic cue that people rely on to evaluate their attitudes on various targets, such as emerging technologies. In this investigation, value perceptions are measured by surveying participants on their fears and concerns, as well as their perceived benefits towards drones. A recent study by Aydin [3] concluded that drone technologies were generally not accepted by the public except when used for public safety and scientific research purposes; the main concern identified was privacy. Other studies also found that privacy played a critical role in the public's perception of the drone technologies [18,26]. Other top concerns include physical safety, specifically regarding the idea that drone parts may fall and injure pedestrians below, and misuse by unauthorized personnel (see Refs. [10,27,28]. In addition, drone applications that could potentially benefit others were more acceptable to the survey participants compared to those drone use that only benefited the user. Not surprisingly, the public also wanted more monitoring and regulations for the latter.

Past work has found that value perceptions are key to predicting public acceptance of emerging technologies [20,29]. However, this past work did not relate value perceptions to the widely used KAP model. Hence, we propose in this paper that the framework in Fig. 1 explains how the KAP model can be integrated with other factors that ultimately predict public acceptance levels.

1.3.2. Public acceptance based on the context of drone operation

As mentioned earlier in section 1, public support for drones varied based on the type of area the drone is operating in Ref. [7]. In our paper, we included 4 common types of urban spaces in Singapore – residential areas, commercial areas, industrial areas and recreational areas – and sought to investigate how public acceptance varied according to the type of area the drone operates in.

In light of the thexisting findings, Lidynia et al. [8] has aptly called for more research to examine the conditions in which the public would have a more receptive attitude towards drone use. According to past work, perceptions of risks and benefits of technology can serve as important heuristic cues in determining one's attitude toward the

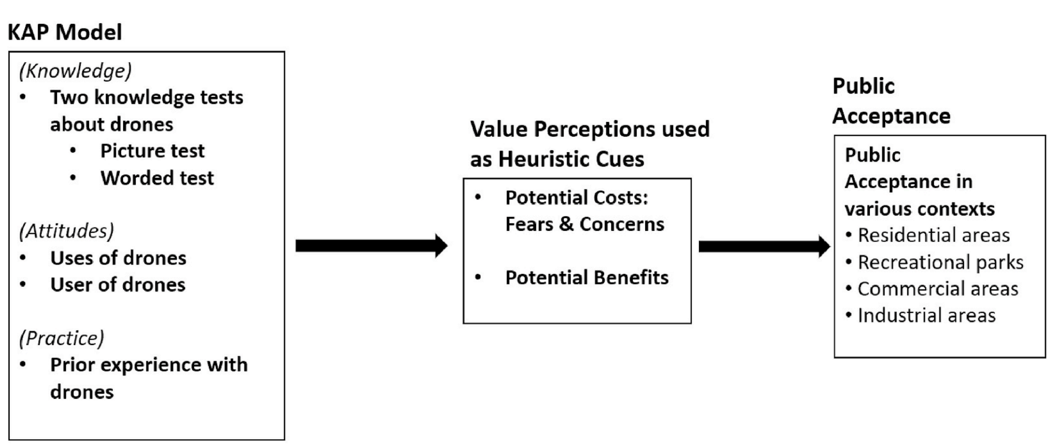


Fig. 1. Proposed framework for understanding public acceptance levels towards drones operating in various contexts.

technology [20,29,30]. Hence, in this study, we sought to use Structural Equation Modelling (SEM) to examine how fears, concerns and perceived benefits of drone technology is related to the acceptance of drones in various contexts.

1.4. Objectives of the study

As mentioned earlier, the objective of our study is twofold.

First, we aim to build on the findings of Reddy and DeLaurentis [15] and Aydin [3] with our Singapore sample. Singapore is a highly urbanized city state where its population is extensively exposed to mass media and emerging technologies. Already, there is an ongoing effort by the government to explore drone applications in the city state for different purposes, such as industrial pipeline inspection (The Straits Times, November 6, 2018) and drone delivery services (The Straits Times, [31]. While many of the previous studies were conducted in well developed countries such as the USA, Australia and Canada, it was not entirely clear whether the participants were residing in the cities of these countries or in the suburban or even rural regions of these countries. We agree with Klauser and Pedrozo [7] that there may be a difference in public perceptions between city dwellers and rural residents as the environmental contexts are different. Cities are often more built up and hence more congested compared to the vast spaces afforded to the residents of rural regions. In addition, the perception of risks and benefits may also be different, for example rural residents may perceive less risks associated with drone applications because of the availability of open spaces compared to urban residents. Hence, as this is the first study in a highly urbanized environment where drone application can have a direct impact on the daily lives of its residents, both positively (e.g., provision of cost-effective services) and negatively (e.g., privacy issues and sound pollution), we are confident that the findings from this study will be able to contribute to the existing literature.

Second, we hope to answer Lidynia et al.'s [8] call for more research into the understanding of the conditions in which drone use could potentially be more acceptable to the public. Hence, besides examining *how* drones are being used or potentially can be used, we hope to extend current knowledge of public perceptions of drone application by examining *where* drones are being used or potentially can be used for. While we agree that *how* and *where* drones are used may be somewhat related, we believe that separating the two aspects will provide more conceptual clarity and more insights into potential drone applications especially in public spaces. For instance, as highlighted earlier, people may be more accepting of using drones for building inspection in industrial areas compared to residential areas. Similarly, people may be more receptive toward security surveillance in commercial and industrial areas compared to residential and recreational areas. Therefore, while we investigate public support for the different drone applications, we also examine how public support varies across environmental contexts in which the drones can be used. Specifically, we examined four environmental contexts – residential, recreational, commercial, and industrial. In a highly urbanized environment, these contexts are clearly demarcated and easily recognized by the residents compared to rural areas. We believe separating how and where is fundamentally important as it may allow the policy makers and the regulators to better finetune their policies and regulation for drone applications. Furthermore, we separate *how* a drone is used from *who* is the user. Past research (such as [6,7] has focused primarily on the purpose of drone use but do not clearly distinguish between purpose of use and who the user of the drone is (e.g. government, commercial, hobbyist etc.). Based on the variables we included according to the KAP model and our framework in Fig. 1, we have the following research questions.

1. How accurate is the Singaporean public's knowledge of drones?
2. Are drone users more knowledgeable than non-users?
3. Which drone applications are most supported in general?
4. What are the fears and concerns associated with drone applications in general?
5. What are the perceived potential benefits of drone use?
6. Does public acceptance for drone applications vary across the four contexts – residential, recreational, commercial, and industrial?
7. How does two heuristic factors – potential costs and potential benefits - account for the different levels of public acceptance for drone applications across the four contexts?

2. Method

2.1. Participants

A sample size of N = 1050 Singaporean residents and permanent residents (PRs) was obtained. (Note: To obtain the long-term views and meaningful feedback, the survey excluded short-term work-pass and visiting groups.) The research was administered online using the software from Qualtrics. The data collection occurred in the middle of 2019 (from April 17, 2019 to June 4, 2019). The collection process was done in collaboration with the vendor, Qualtrics. The gender distribution of the sample was 41.8% females, 57.7% males, and 0.5% others. The age distribution is 33.3% from 21 to 30 years old, 23.4% from 31 to 40 years old, 9.9% 41–50 years old, 22.8% 51–60 years old, 9.0% 61–70 years old, 1.5% 71–80 years old. The sample comprised of 77.0% Chinese, 11.8% Malay, 6.7% Indian, 1.5% Eurasian, and 3.1% Others. Among 'others', the respondents had indicated that they were Filipino, Caucasian, Javanese, Arab or Bangladeshi. This demographic distribution is reflective of the general Singaporean population.

2.2. Procedure

The online questionnaire comprised of 126 items in total and took an average of 20 min to complete. First, basic demographic questions were asked, including gender, age, race, occupation, income level, and educational level. For participants that had indicated their occupation as working adults (N = 836, which made up 79.6% of the sample), they were directed to the questions about their income, industry, and nature of their work. Those who identified as "student" (8.95%), and "non-working adult" (11.43%) skipped these 3 items.

The next section was a picture and a worded knowledge test to assess the participants' level of understanding the public has towards drones (Appendices A and B). After the knowledge tests, the participants were provided with the accurate definition of drones from the field of engineering to ensure that everyone is on the same page when interpreting the term 'drone' before proceeding to the next section of the survey (Appendix C). In the following sections, participants reported their prior experience with drones and their levels of support for drones used for purposes such as rescue, photograph, and delivery by various users such as government, commercial and public (Appendix D). Upon completing the support questionnaire, the participants reported their level of fears and concerns towards drones while presented with visual examples of drones (Appendix E). They also identified specific fears or concerns they held towards drones. In their last section of the survey, the participants were presented with four images of drone flying in different areas (i.e., residential, recreational, commercial, and industrial) and reported their acceptance of drone flying in the four different areas (Appendix F). Specifically, participants were asked to take a look at each of the images and visualize the drone in the depicted locations. This visualization procedure prompted the participants to contextualize the use of drones in each area. The entire survey used in this study are available in the supplemental website.

2.3. Measures

2.3.1. Demographics

Participants were asked single-itemed demographic questions pertaining to their gender, age, level of residence, occupation, annual income, industry, nature of work, and their highest educational qualification based on the Singapore education system.

2.3.2. Knowledge tests

Two knowledge tests were developed by the authors and given to participants. The first was a picture test where 6 pictures of drones or non-drones were depicted (Appendix A). Participants had to correctly identify whether each image is a drone or non-drone. This test was intended to assess participants' understanding towards the visual components of a drone. The second test was a worded test where participants were given 7 phrases that describe or do not describe a "drone" (Appendix B). Participants had to correctly identify whether each phrase describes drones or not. This second worded test was intended to measure more precisely the semantic understanding participants held towards drones. The two types of knowledge tests correlate significantly with each other with $r = 0.25$, $p < .01$.

2.3.3. Experience with drones

Participants' prior experiences with drones was measured with 3 items on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). A sample item is "I operate drones often." This scale was self-created by the authors and demonstrated good internal reliability ($\alpha = 0.83$).

2.3.4. Support for drone use and users

Participants were presented with a list of potential drone uses (e.g., search and rescue, combat/military) by different users (e.g., government, commercial, and public) and rated their level of support for each case on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*) (Refer to Appendix D). We created this list of uses based on existing literature and news reports about current or possible functions of drones (e.g., Refs. [6,7,10].

2.3.5. Fears and concerns towards drones

Participants were presented with 4 different images of drones (Appendix E) and rated their fears and concerns based on a three-item scale adapted from Lidynia et al. [8] ($\alpha = 0.62$). Sample items are "I am comfortable seeing drones flying around" and "I have concerns about drone usage in my surroundings (Reverse)". All 3 items were measured on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*).

2.3.6. Potential benefits of drones

This scale was developed by the authors to reflect four areas of potential benefits drones can bring about – consumer benefits, economic benefits, workplace safety improvements and improved safety of neighborhoods due to better law enforcement. Participants' perceived benefits of drone was measured with 4 items on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). A sample item is "Drone technology will increase productivity in the Singapore economy" ($\alpha = 0.89$).

2.3.7. Public acceptance of drones by area

Participants' acceptance of drone in four different urban areas (i.e., residential, recreational, commercial, and industrial) was measured with 12 items (3 items for each area) on a 6-point scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). A sample item is "I can accept the use of drones in recreational parks". Composite scales were created per area: residential ($\alpha = 0.90$), recreational ($\alpha = 0.91$), commercial ($\alpha = 0.92$), and industrial ($\alpha = 0.93$). Further, to improve the quality of response, we had attached 2 pictures per area with a drone superimposed into the sky of the picture (Refer to Appendix F). Before answering the 3 items per area, participants were given instructions to visualize the scenario in the images vividly. The instruction given was "Please take a moment to look at the following images and visualize the drone in the depicted locations." This was to help participants contextualize the use of drones in each area, rather than simply asking them to rate their acceptance levels through only worded descriptions.

3. Results

3.1. How accurate is the Singaporean public's knowledge of drones?

Based on the results of both the picture and word knowledge test (picture: $M = 4.79/6.00$, $SD = 0.84$; word: $M = 5.55/7.00$, $SD = 1.24$), the majority of the public seem to have a good understanding of what a drone is. 75.8% of participants scored at least 4 out of 6 on the picture-based test and 92.1% of participants scored at least 4 out of 7 on the word-based test.

However, closer analysis of their responses on individual test items reveals that the public appear somewhat confused with two features of a drone. The first is whether drones are manned or unmanned aerial vehicles. On item 4 (refer to Appendix A), only 46% of respondents correctly indicated that the picture (of a hovering vehicle with a man onboard) does not depict a drone. The second is whether drones can be large aerial vehicles. Specifically, only 58% and 46% of the respondents got the answers right for the third and fourth items respectively on the picture knowledge test. Item 3 depicted a large drone while item 4 depicted a pilot on an aerial vehicle. Additionally, the items that has the lowest correct responses is item 8 (i.e., drones can be as large as a commercial aircraft) in the word knowledge test (Refer to Appendix B). Only 52.3% of participants responded correctly. The next two lowest percentages of correct responses were for items 1 (71.7%) and 2 (74.7%) on the word knowledge test which were both related to "manned" vs "unmanned" feature of a drone.

If we consider the other end of the size spectrum, 79.1% of participants correctly responded that drones can be as small as an insect. Hence, it appears that the misconception the public has about the possible sizes of drones only hold for large-sized drones, but less so for small-sized drones. It is plausible that this is the result of Singapore's relative lack of media portrayal of drones associated with military uses, especially military functions that need large drones (e.g. missile-carrying drones).

3.1.1. Gender

An independent *t*-test between males and females revealed that the gender effect on the picture-based test ($t(1042) = 3.51$, $p < .001$) where males were found to perform significantly better than females (male: $M = 4.87/6.00$, $SD = 0.76$, female: $M = 4.68/6.00$, $SD = 0.92$). However, there was no significant difference between males and females on the word-based test ($t(1043) = 1.27$, $p = .20$).

3.1.2. Age

Based on a one-way ANOVA, there are no significant age effects on both test scores (picture-based: $F(6, 1043) = 0.54$, $p = .77$; word-based: $F(6, 1043) = 0.54$, $p = .39$).

3.1.3. Educational level

There are significant differences between the various education levels of respondents on their scores on the picture-based test ($F(6, 977) = 3.51$, $p < .01$). There are also significant differences between the various education levels of respondents on the word-based test ($F(6, 977) = 6.33$, $p < .000$). For both tests, those who received a higher education were more likely to score high on the tests.

Post-hoc comparisons were conducted using the Tukey HSD test. For the picture knowledge test scores, those who had GCE Normal level as their highest educational level ($M = 4.51$, $SD = 1.01$) scored significantly lower ($p < .05$) from those who have diplomas ($M = 4.89$, $SD = 0.68$) and from those with a Bachelor's degree ($M = 4.87$, $SD = 0.76$).

Similarly, for the word knowledge test, several pairs of groups, based on education level, differed in test scores. Specifically, those with GCE Normal level certificates ($M = 5.08$, $SD = 1.38$) scored significantly lower from those with a Bachelor's degree ($M = 5.80$, $SD = 1.14$) ($p < .001$) and from those with a Post-graduate degree ($M = 5.68$, $SD = 1.23$) on the word knowledge test ($p < .05$). In addition, those with GCE O level certificates ($M = 5.22$, $SD = 1.14$) scored significantly lower ($p < .001$) from those with a bachelor's degree ($M = 5.80$, $SD = 1.14$) on the word knowledge test.

In summary, it does appear that higher educational levels were positively associated with better performance on both knowledge tests.

3.1.4. Current occupation

A one-way ANOVA test revealed non-significant effects of occupation (3 categorical options of student, working adult, or non-working adult) (picture: $F(2, 1047) = 0.25$, $p = .78$; word: $F(2, 1047) = 1.44$, $p = .24$).

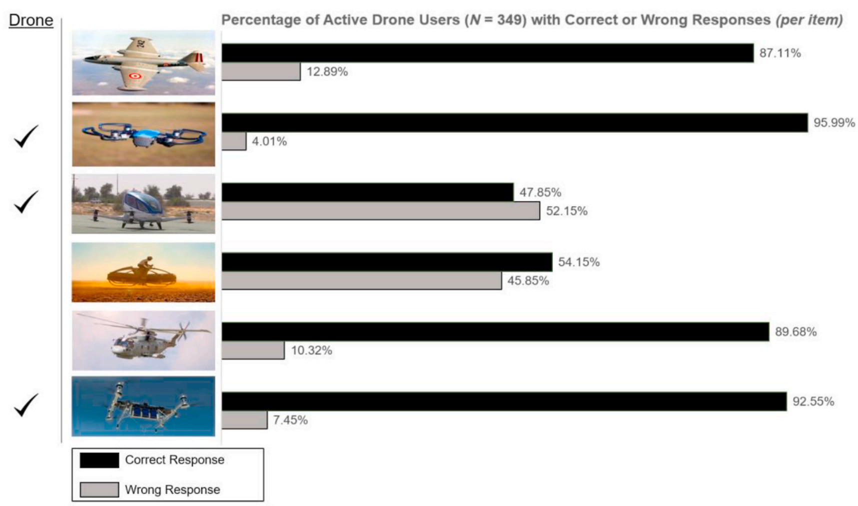
3.1.5. Types of industries

Considering only the industries with a substantial sample size, we included industries represented by at least 40 participants (which is 4.78% of the 836 working adults). Based on the 7 industries with substantial representation, a one-way ANOVA revealed significant differences between the 7 industries for the picture-based test score ($F(6, 495) = 2.30$, $p = .03$), but not for the word-based test score ($F(6, 495) = 0.40$, $p = .88$). Specifically, the mean picture knowledge test scores of those who indicated their industry as engineering ($M = 5.01$, $SD = 0.69$) was significantly higher ($p < .05$) from those who indicated their industry as manufacturing ($M = 4.61$, $SD = 1.20$).

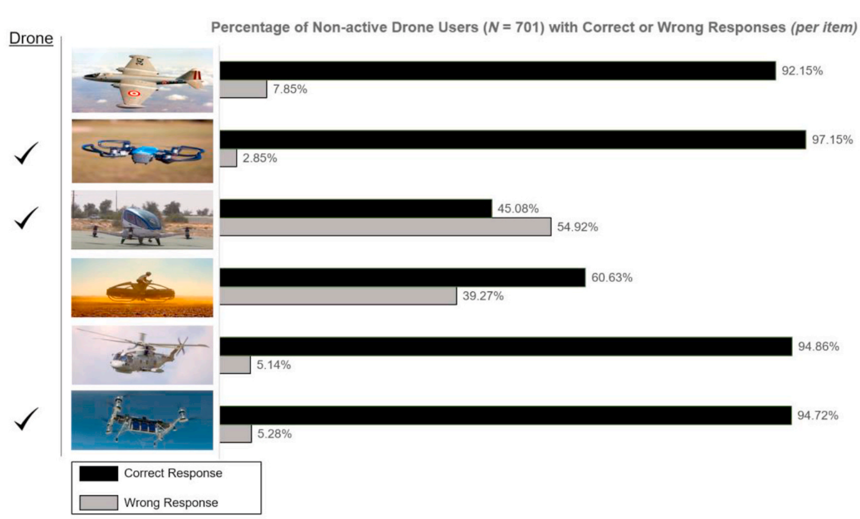
3.2. Are drone users more knowledgeable than non-users?

Those who responded that they have active drone experience, those with active experience scored significantly lower (Levene's test $F = 6.14$, $p < .05$, $t(667) = 3.10$, $p < .01$) on the picture-based test than those without active experience with drones (active: $M = 4.67$, $SD = 0.86$; non-active: $M = 4.85$, $SD = 0.82$).

Upon further analysis, specifically, people with active drone experience scored significantly poorer on picture item 1 (Levene's test $F = 27.14$, $p < .000$, $t(577) = 2.45$, $p < .05$), item 4 (Levene's test $F = 10.96$,



(a)



(b)

Fig. 2. a & 2b. Percentage of active versus non active drone users who responded correctly on each item on the picture knowledge test.

$p = .001$, $t(683) = 1.99$, $p < .05$) and item 5 (Levene's test $F = 39.16$, $p = .000$, $t(536) = 2.83$, $p < .01$) (refer to Fig. 2a and 2b). The other items did not yield significant differences in scores between those with and without active drone experience. Apparently, those active drone users mistake images of non-drones as drones.

On the word knowledge test, equal variances were not assumed (Levene's test $F = 5.40$, $p < .05$), $t(645) = 1.26$, $p = .208$). The mean word knowledge test scores between those with active experience and those without active experience with drones (active: $M = 5.48$, $SD = 1.31$; non-active: $M = 5.59$, $SD = 1.20$) are not significantly different on the word-based test.

3.3. Which drone applications are most supported in general?

Respondents were asked to indicate their level of support for 3 types of drone users, namely government, commercial and industrial, and public operators, on a list of drone uses that are applicable to each type of operator. Responses are on a 6-point Likert scale where 1 = strongly disagree, 6 = strongly agree. The following diagram depicts the percentage of respondents who answered 4, "somewhat agree" and above, for each drone use and user/operator.

There are several noteworthy findings from Figs. 3–5, and Table 1. Firstly, the proportion of the 1050 respondents who favored the drone uses never falls below 62.0%. This suggests that the majority of the respondents were generally accepting of wider drone applications. The highest proportion of support from the sample is 92.1%, for the drone use of search and rescue by government users. The drone use with the lowest proportion of support from the sample is transporting people by commercial and industrial users (62.0%). Also, in comparison to the previous studies conducted in U.S. and Swtizerland [5–7], our Singaporean sample is more open to adoption of drone technologies. The final point worth noting pertains to the uses that are applicable to all 3 types of drone users – support for public use generally is low compared to most other uses or users (entertainment/performances in airspace: 67.41%, photography/videography: 64.48%) (see Figs. 3-5).

Based on the finding that support for drones used by the public is lowest, and the ranked support levels for various drone uses in Table 1, it appears that generally the drone uses that serve to benefit society at large (e.g. search and rescue, and disaster management) have higher public support than drone uses that only benefit individuals (e.g. photography/videography), or impact individuals negatively (e.g. issuing speeding and parking tickets).

3.3.1. Cross-cultural comparison

There are several cross-cultural comparisons that can be made between our study and other countries where similar studies for public support regarding various drone uses are investigated (Refer to Fig. 6 below; United States: [5,6,17]; Switzerland: [7]. Some notable comparisons are as follows.

Empirical evidence across countries (Singapore, several studies in the United States, and Switzerland), revealed that the use of drones for "search and rescue" consistently has high public support. In Singapore and US, environmental uses seem to have high support [6] and the drone function of issuing speeding ticket consistently has relatively lower public support (see Ref. [5]. In Singapore and Switzerland, scientific research has high support, and photography has low support [7]. Another commonality between Singapore and Switzerland is that drones used for research has higher support than postal delivery. However, a key difference is that for drone delivery, the proportion of the sample who support this drone use is still relatively high compared to Switzerland (Singapore: 82.9% vs Switzerland: 18.0%).

Zooming out to see the big picture, it should be noted that despite the rank orders, as mentioned earlier, the majority of the 1050 respondents from Singapore sample supported drones for all the various uses – the percentage of participants who accept drones used for various functions by various users did not fall below 60%, while all other studies have proportions of the public accepting drone uses falling below 60%. For Singaporean sample, the drone use with the lowest support is transporting people (62%). This suggests that Singaporeans are relatively open to wider adoption of drone technologies, compared to other western countries.

Apart from making cross-cultural comparisons in terms of the level of support for various drone uses, there also appear to be cross-cultural differences in the public's acceptance level of various drone users (refer to Fig. 7).

Based on the Singaporean sample from this study (N = 1050), we ranked the acceptability the public has towards various users by taking the mean percentage of acceptance levels the sample rated for the specific users based on 2 drone functions that is common to all types of drone users – namely, photography/videography, and entertainment. By only considering the public acceptance ratings for these 2 drone functions, we are standardising the drone functions such that the acceptance rate is reflective of the varying type of user and not due to differences in drone functions by each user. By using the term 'acceptance' here, we refer to the mean rating of acceptability towards photography/videography or entertainment by each user exceeding 3.5 (which is the midpoint of the 6 point Likert scale from 1 = strongly disagree to 6 = strongly agree). Based on this method, the sample demonstrated highest acceptability for government users (80.8% had a mean rating of at least 3.5 across both functions of photography/videography and

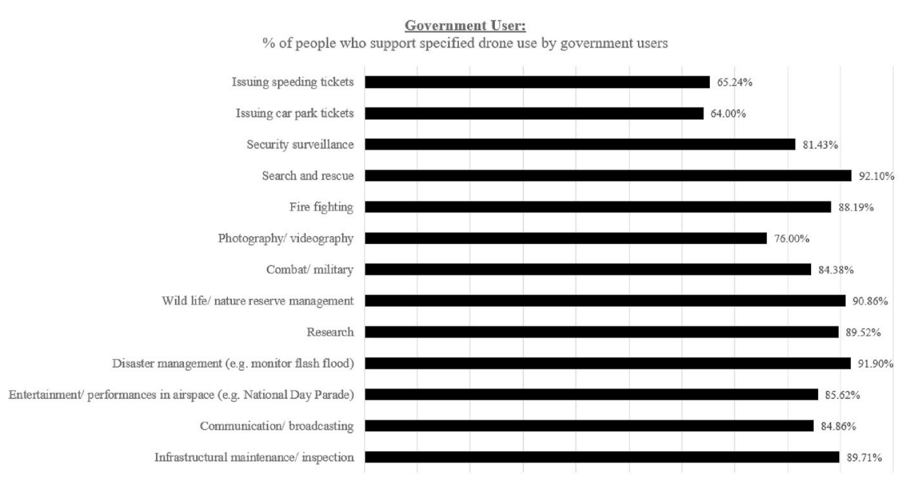


Fig. 3. Percentage of people who support each specific drone use by government users.

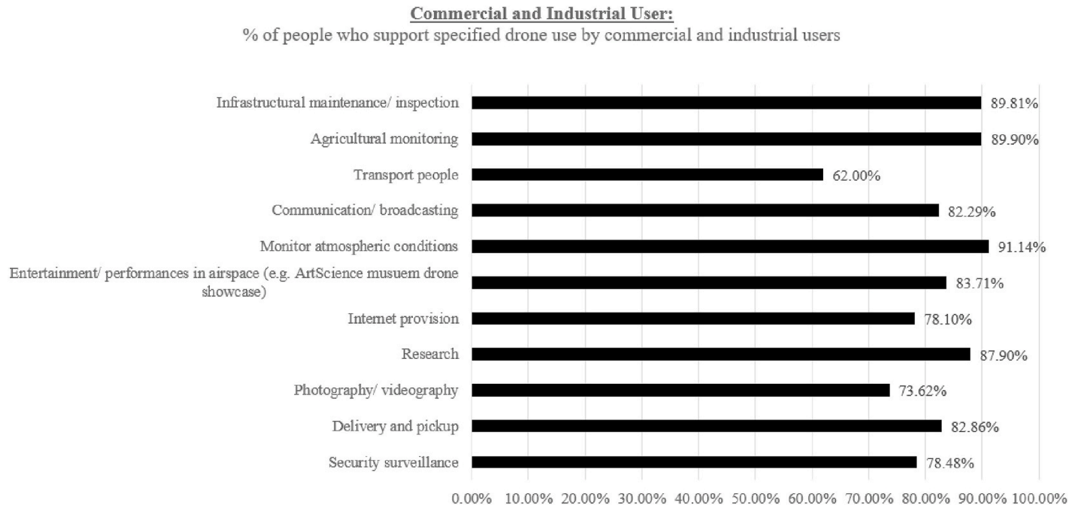


Fig. 4. Percentage of people who support each specific drone use by commercial and industrial users.

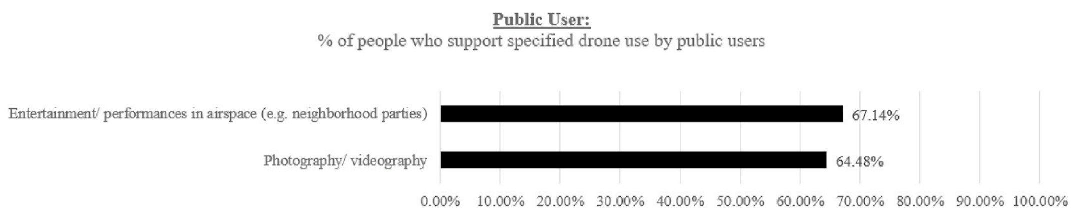


Fig. 5. Percentage of people who support each specific drone use by public users.

entertainment), followed by commercial and industrial users (73.6%), and finally public users (65.8%).

Klauser and Pedrozo [7] had conducted a study on how user of drone affects public acceptability levels among Swiss nationals (N = 604). Generally, the ranked order of support for each drone user is in this order: police (72.0%), military (unarmed functions) (65.0%), hobby (32.0%), and finally commercial (23.0%). This is somewhat consistent with our findings in the sense that government-affiliated drone users have the highest public acceptance. The difference is that the Swiss sample accepted hobby drone use more than commercial drone use, while the Singaporean sample seem to accept commercial drone use more than public (hobbyist) drone use. It should also be noted that the acceptability rates of the Singaporean sample is 65.8% at worst (for public users), but the Swiss sample's acceptability rates for hobby (32.0%) and commercial drone (23.0%) users comprise a minority. Finally, another study by PytlikZilig et al. [6] was conducted in the United States where an online MTurk survey revealed that the 301 respondents rated that they would accept government users of drones more than commercial users.

An important common observation is that across the 3 studies conducted in Singapore, Switzerland and United States, the public seems to accept government-affliated drone users more than commercial drone users.

3.4. *What are the fears and concerns associated with drone applications in general?*

Participants in general reported a low level of fears and concerns (M = 3.53; SD = 0.96). For those participants reported a medium to a high level of fears and concerns (579 participants who scored 4 and below), additional questions were provided to further identify the specific nature of their fears and concerns. The top 4 fears and concerns indicated by the Singaporean public is misuse of drones by unauthorized personnel, inability to identify whether drones are filming or not, drones being a threat to one's physical safety if parts of it falls, and loss of privacy. This is consistent with other research that also indicate similar concerns expressed by the public (e.g., Refs. [3,18,27,32,33].

3.5. *What are the perceived potential benefits of drone use?*

The level of perceived benefits of drone use was generally high ($M = 4.38$ out of 6.00, $SD = 0.97$). Specifically, participants perceived the extent to which they perceive drones to be beneficial in 4 ways – to consumers ($M = 4.40$, $SD = 1.09$), to the economy ($M = 4.40$, $SD = 1.11$), to safety levels in the workplace ($M = 4.46$, $SD = 1.14$), and to safety levels in neighbourhoods ($M = 4.25$, $SD = 1.19$). A repeated measures ANOVA was conducted to investigate whether the perceived level of benefits from drones differed based on the domain of benefit. There was a significant difference found ($F(1, 1049) = 21194.94$, $p < .000$). Post-hoc Bonferroni tests revealed that perceived benefits accrued in the first three domains – namely consumers, economy, workplace safety – significantly higher than domain of neighbourhood safety ($p < .05$). In sum, generally, the public appear to have the idea that drones are beneficial to society, but more so in terms of benefitting consumers, the economy and improving workplace safety, compared to improving neighbourhood safety.

3.6. *Does public acceptance for drone applications vary across the four contexts – residential, recreational, commercial, and industrial?*

A repeated measures ANOVA was conducted to analyse whether the acceptance levels towards drones differed significantly based on the location of drone operation. The results revealed that the mean difference between acceptance levels did indeed differ significantly from each other ($F(1, 1049) = 21840.82$, $p < .000$; Residential: $M = 3.87$, $SD = 1.24$, Recreational: $M = 4.40$, $SD = 1.12$, Commercial: $M = 4.30$, $SD = 1.12$, Industrial: $M = 4.58$, $SD = 1.16$). Post-hoc pairwise comparisons revealed that all the mean acceptance levels towards drones of the 4

Table 1
Level of public support for each type of drone use and by each type of user in rank-order.

Drone User	Drone Use	% of sample who favours drone use by specified user
Government	Search and rescue	92.10%
Government	Disaster management (e.g. monitor flash flood)	91.90%
Commercial and industrial	Monitor atmospheric conditions	91.14%
Government	Wild life/nature reserve management	90.86%
Commercial and industrial	Agricultural monitoring	89.90%
Commercial and industrial	Infrastructural maintenance/ inspection	89.81%
Government	Infrastructural maintenance/ inspection	89.71%
Government	Research	89.52%
Government	Fire fighting	88.19%
Commercial and industrial	Research	87.90%
Government	Entertainment/performances in airspace (e.g. National Day Parade)	85.62%
Government	Communication/broadcasting	84.86%
Government	Combat/military	84.38%
Commercial and industrial	Entertainment/performances in airspace (e.g. ArtScience museum drone showcase)	83.71%
Commercial and industrial	Delivery and pickup	82.86%
Commercial and industrial	Communication/broadcasting	82.29%
Government	Security surveillance	81.43%
Commercial and industrial	Security surveillance	78.48%
Commercial and industrial	Internet provision	78.10%
Government	Photography/videography	76.00%
Commercial and industrial	Photography/videography	73.62%
Public	Entertainment/performances in airspace (e.g. neighbourhood parties)	67.14%
Government	Issuing speeding tickets	65.24%
Public	Photography/videography	64.48%
Government	Issuing car park tickets	64.00%
Commercial and industrial	Transport people	62.00%

areas differed significantly from each other (all $p < .001$). Overall, this means that the levels of acceptance towards drones are significantly different based on the context or location of drone operation.

3.7. How does two heuristic factors – potential costs and potential benefits - account for the different levels of public acceptance for drone applications across the four contexts?

Research has suggested that people use value predispositions, such as perceptions of benefits and risks, as heuristics to determine their support for an emerging technology [20,29,30]. We used Structural Equation Modeling (SEM) to examine the relationships between these two factors (i.e., fears and concerns, and perceived potential benefits) that could potentially affect public's level of acceptance in terms drone use in the 4 different contexts.

SEM is a statistical method that involves testing a network of relationships among measured (observed) variables, and latent (unobserved) variables. Observed and latent variables are represented by rectangles and circles, respectively. In SEM, the relationships among the variables are estimated using linear regression. Fig. 8 captures the network of relationships among the observed and latent variables; each arrow represents a linear regression, with the respective regression coefficient.

Apart from testing the linear relationships among the variables, we also assessed the fit of our hypothesized model (Fig. 8) based on the collected data; this means investigating the extent to which our proposed model corresponds with the network of relationships that the data supports. The correlations among variables included in the SEM model is reflected in Table 2. While we did not make specific hypotheses regarding their relationships, we do believe that the two factors, fears and concerns, and perceived potential benefits, would affect the acceptance level differently depending on the specific context. All parameters, standard errors, significant tests, and fit indices are based on Full Information Maximum Likelihood estimation using Mplus 7 [34]. To assess model fit, apart from examining the fit with the chi square test, we also used the recommended fit indices: root mean square error of approximation (RMSEA), comparative fit index (CFI), standardized root mean square residual (SRMR). RMSEA values less than 0.05 indicate a good fit while values between 0.05 and 0.08 indicate moderate fit [35, 36]. We also adopted CFI values greater than 0.95 to indicate good fit, based on the recommendations of Hu and Bentler [36]. Finally, SRMR values less than 0.08 also indicate good fit [36]. The proposed model (Fig. 8) demonstrated good fit (RMSEA = 0.052; CFI = 0.978; SRMR =

	Singapore (present study)						United States						Switzerland	
	Government Singapore/ PR (N=1050)	**Percentage of participants who rated 4 and above**	**Commercial & Industrial** Singapore/ PR (N=1050)	**Percentage of participants who rated 4 and above**	**Public** Singapore/ PR (N=1050)	**Percentage of participants who rated 4 and above**	**U.S, Amazon Mturk Workers (N=301)**	**Percentage of participants who support this drone use**	**Nationally representative sample in the United States (N=2119)**	**Percentage of participants who support this drone use**	**National sample of (N=1708)**	**Percentage of participants who support this drone use**	**Swiss Nationals from 4 Municipalities (N= approx. 600)**	**Percentage of participants who rated 'favourable'**
1	Search and rescue	92.1%	Monitor atmospheric conditions	91.1%	Entertainment/ performances in airspace (e.g. parties)	67.1%	Environment	71%	Search and rescue	88%	Search and rescue	80%	Scientific research	81%
2	Disaster management (e.g. flashfloods)	91.9%	Agricultural monitoring	89.9%	Photography/ Videography	64.5%	Economic	54%	Homeland security	67%	Track runaway criminals	67%	Police mandates	63%
3	Wild life/ nature reserve management	90.9%	Infrastructural maintenance/ Inspection	89.8%			Security	39%	Fight crime	63%	Control illegal immigration	64%	Aerial photography	49%
4	Infrastructural maintenance / inspection	89.7%	Research	87.9%					Commercial	61%	Issue speeding tickets	23%	Postal deliveries	18%
5	Research	89.5%	Entertainment/ performances in airspace (e.g. ArtScience Musuem)	83.7%					General use in U.S.	57%				
6	Fire fighting	88.2%	Delivery and Pickup	82.9%										
7	Entertainment/ performance in airspace (e.g. NDP)	85.6%	Communication/ Broadcasting	82.3%										
8	Communication/ broadcasting	84.9%	Security Surveillance	78.5%										
9	Combat/ Military	84.4%	Internet provision	78.1%										
10	Security Surveillance	81.4%	Photography/ Videography	73.6%										
11	Photography/ Videography	76.0%	Transporting people	62.0%										
12	Issuing speeding tickets	65.2%												
13	Issuing carpark tickets	64.0%												

Fig. 6. Public support for various uses of drones across countries.

	Present study		(Klauser & Pedrozo, 2017)		(PytlikZillig, Duncan, et. al., 2018)	
	Singapore Singapore/ PR (N=1050)	Average percentage who accept this user for common functions (photography & entertainment)	**Switzerland** Swiss Nationals from 4 Municipalities (N= approx. 600)	Percentage of participants that rated that they support drones used by this user	**United States** MTurk Workers (N=301)	-
1	Government	80.80%	Police	72.0%	Government	-
2	Commercial & Industrial	73.6%	Military (unarmed functions)	65.0%	Businesses	-
3	Public	65.8%	Hobby	32.0%		
4			Commercial	23.0%		

Fig. 7. Ranked acceptance level of drone users across countries.

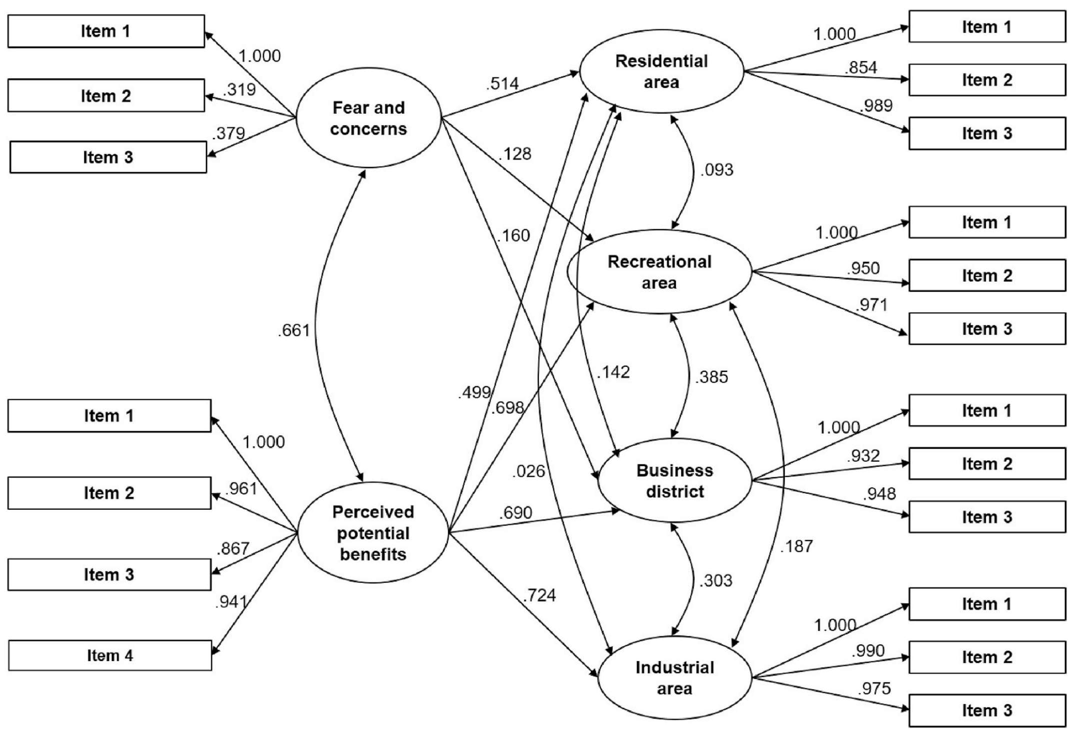


Fig. 8. Relationships between public's fears and concerns, perceived potential benefits, and their acceptance towards drones for various locations.

0.038). In general, as expected, fears and concerns and perceived potential benefits affected the levels of acceptance differently depending on the specific context. Fears and concerns were the main factor that affected one's level of acceptance for drone use in residential area while it has no effect on drone use in industrial areas. On the other hand, perceived potential benefits affected their levels of acceptance for drone use for all contexts, although to a lesser extent for residential areas. This implies that if public acceptance of drones were to be improved, several factors have to be considered – the level of fears and concerns towards drones, the perceived potential benefits of drones and the contexts in which drones will be used. Specifically, alleviating fears and concerns levels can improve acceptance levels in residential areas, recreational areas and commercial areas, but not in industrial areas. Improving perceived potential benefits would be more effective in increasing acceptance levels when the context of drone operation is recreational areas, commercial areas, and industrial areas, but less effective for residential areas.

4. Discussion

Is the public ready for extensive drone applications to be an integral part of their daily lives? As mentioned earlier, public acceptance of any technology is necessary for realizing their benefits fully. This research has two objectives. First, we believe that the sample we have chosen – Singapore as a highly urbanized city state – is an ideal candidate to examine the level of public acceptance on drone applications. While similar studies have been conducted in other countries, most of the studies did not specify whether the respondents were from urban, suburban, or rural areas of these countries. As their experiences and frame of reference differed, it would be challenging to interpret their levels of acceptance for drone applications. Second, we hope to answer Lidynia et al.'s [8] call for more research into the understanding of the conditions in which drone use could potentially be more acceptable to the public. Specifically, with the use of the KAP model, we investigated the perceptions toward different applications of drones across different users as well as different areas, which provided a more comprehensive understanding of the public's general sense of acceptance in different conditions. Hence, this paper sought to contribute to existing literature and hopefully also help policymakers better understand the nature of public perceptions towards drones.

4.1. *Summary and interpretation of results*

4.1.1. *How accurate is the Singaporean public's knowledge of drones?*

Generally, a majority of the public seem to have a good understanding of what a drone is. However, the study also revealed two features of drones that the public seemed unsure about, namely whether drones have an on-board pilot or not, and whether drones can be as large

Table 2
Correlation table for the items included in the structural equation modelling.

	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
"1."rowhead	Fear & Concern (Item 1)	1.00																		
"2."rowhead	Fear & Concern (Item 2)	.512**	1.00																	
"3."rowhead	Fear & Concern (Item 3)	.252**	.284**	1.00																
"4."rowhead	Perceived Benefit (Item 1, Consumers)	.149**	.113**	.474**	1.00															
"5."rowhead	Perceived Benefit (Item 2, Economy)	.150**	.135**	.481**	.747**	1.00														
"6."rowhead	Perceived Benefit (Item 3, Workplace Safety)	.111**	.075*	.355**	.620**	.637**	1.00													
"7."rowhead	Perceived Benefit (Item 4, Neighbourhood Safety)	.115**	.150**	.462**	.621**	.665**	.653**	1.00												
"8."rowhead	Acceptance in Residential Areas (Item 1)	.142**	.199**	.502**	.551**	.538**	.446**	.588**	1.00											
"9."rowhead	Acceptance in Residential Areas (Item 2)	.133**	.252**	.565**	.509**	.519**	.394**	.544**	.781**	1.00										
"10."rowhead	Acceptance in Residential Areas (Item 3)	.183**	.335**	.542**	.425**	.396**	.319**	.489**	.692**	.783**	1.00									
"11."rowhead	Acceptance in Recreational Areas (Item 1)	.124**	.083**	.420**	.560**	.537**	.512**	.491**	.513**	.475**	.400**	1.00								
"12."rowhead	Acceptance in Recreational Areas (Item 2)	.159**	.088**	.407**	.532**	.537**	.481**	.471**	.484**	.479**	.388**	.845**	1.00							
"13."rowhead	Acceptance in Recreational Areas (Item 3)	.194**	.155**	.386**	.456**	.431**	.407**	.408**	.397**	.387**	.452**	.723**	.757**	1.00						
"14."rowhead	Acceptance in Commercial Areas (Item 1)	.154**	.116**	.436**	.581**	.548**	.502**	.516**	.565**	.531**	.434**	.680**	.657**	.573**	1.00					
"15."rowhead	Acceptance in Commercial Areas (Item 2)	.172**	.117**	.434**	.551**	.548**	.472**	.501**	.502**	.532**	.434**	.653**	.698**	.620**	.858**	1.00				
"16."rowhead	Acceptance in Commercial Areas (Item 3)	.216**	.154**	.387**	.449**	.426**	.407**	.429**	.428**	.426**	.463**	.570**	.588**	.686**	.746**	.784**	1.00			
"17."rowhead	Acceptance in Industrial Areas (Item 1)	.147**	.061*	.250**	.439**	.456**	.464**	.398**	.404**	.313**	.236**	.463**	.464**	.372**	.554**	.557**	.463**	1.00		
"18."rowhead	Acceptance in Industrial Areas (Item 2)	.149**	.062*	.261**	.430**	.439**	.453**	.374**	.376**	.312**	.233**	.444**	.463**	.376**	.534**	.542**	.444**	.880**	1.00	
"19."rowhead	Acceptance in Industrial Areas (Item 3)	.145**	.067*	.212**	.376**	.376**	.415**	.368**	.310**	.259**	.286**	.389**	.403**	.458**	.426**	.464**	.544**	.775**	.770**	1.00

*p ≤ .05, **p ≤ .01.

as commercial planes. Further analysis also reveals that those who are male, working in engineering industry, or more educated were more knowledgeable about drone than females, working in non-engineering industry, or less educated. This is consistent with previous work [3,21,37].

4.1.2. Are active drone users more knowledgeable than non-users?

This study operationalised active drone users as people who reported having a good amount of experience operating drones first-hand. Surprisingly, these active drone users were slightly poorer at identifying drones from pictures than those without active experience. Specifically, active drone users had identified pictures 1 and 5 (a manned military aircraft and a typical manned helicopter) wrongly as drones than non-active drone users. Unfortunately, our data does not allow further analysis to understand the reasons why this was the case. However, we speculate that active drone users may have read too much into the pictures. For example, for picture items 1 and 5 (See Appendix A) the active drone users might have mistaken them as potential developments in drone technologies where military aircrafts and helicopters are piloted remotely. Therefore, the active drone users could have made assumptions that were not true while non-active users responded based on what they saw in the pictures.

4.1.3. Which drone applications are most supported in general?

As mentioned, in general, majority of the public supported all drone applications, however the support differed depending on the functions and users. Drone applications by government users received higher support compared to commercial and public users. Drone applications with higher levels of support include search and rescue, disaster management, monitoring or preserving environments. Drone applications with the lowest levels of support were transporting people and photography. Compared to the previous studies on the same topic that were conducted in the other countries, we found similar patterns where the public generally support the applications of drone for search and rescue purposes; where they were more conservative toward photography or videography that impose a more serious concern of privacy [6,7,17].

4.1.4. What are the fears and concerns associated with drone applications in general?

The top 4 fears and concerns were misuse of drones by unauthorized personnel, inability to identify whether drones are filming or not, drones being a threat to one's physical safety, and loss of privacy. These findings are also consistent with the previous studies conducted in the other countries, where their top concerns of drone application include privacy, bodily harm, and property damages (e.g., Refs. [1,17,38]. These findings are also consistent with the previous section about government users having the most public support, compared to commercial and public users. These fears and concerns also corroborate with the finding that the public has lower support for drones used for photography or videography.

4.1.5. What are the perceived potential benefits of drone use?

The Singaporean public appears to have a decent perception of the potential benefits drones can bring about. More specifically, our findings identified that these perceived potential benefits lie in the domains of benefiting consumers, the economy and improving workplace safety, but to a lower extent for improving neighbourhood safety.

4.1.6. Does public acceptance for drone applications vary across the contexts?

We found that acceptance levels towards drones did significantly differ depending on the contexts of use – industrial areas had the highest acceptance level while residential areas had the lowest acceptance level among the four contexts. To our best knowledge, this is the first study that identified the effects of different urban contexts on public acceptance of drone use.

4.1.7. How does two heuristic factors – potential costs and potential benefits - account for the different levels of public acceptance for drone applications across the four contexts?

We found that fears and concerns significantly predict acceptance levels of drones in residential areas, but not significantly related to acceptance levels of drones operating in industrial parks. This implies that people's acceptance of drone use in industrial parks are not affected by their concerns and fears. On the other hand, perceived potential benefits appear to be less critical in predicting acceptance levels in residential areas but are an important predictor of acceptance levels in the other three locations (i.e., industrial, commercial, and recreational). Therefore, when it comes to the residential area, highlighting the potential benefits of using drones may not be as effective to enhance the public sentiment on drone acceptance.

Being the first of such studies in Asia, this study has broadened our understanding on public perceptions of drone applications. While replicating past research using an Asian sample, by itself, is a contribution, we felt that we have also contributed further to the extant literature in three ways. First, we measured respondents' actual knowledge rather than their perceived knowledge on drones. Second, we examined four different contexts in our study to better understand the nuances of public perceptions. Specifically, we have shown that public perceptions did differ depending on the contexts of drone operation. Finally, we have provided preliminary evidence that the factors affecting public acceptance of or support for drone application might be different depending on the contexts of use. In this case, fears and concerns appeared to be a more salient factor for drone use in residential areas while perceived potential benefits could be a more critical consideration for non-residential areas such as industrial parks. We hope that our findings have provided some useful considerations for further research endeavours.

4.2. Practical implications

Not surprisingly, the media industry appears to have a huge impact on public perceptions and their understanding of drones. For example, in Australia and New Zealand, Clothier et al. [1] found that 82% of media portrayal of drones associate drones with 'military strikes. In another study, Reddy and DeLaurentis [15] found that 93% of survey respondents from the general public of the United States have heard of drones, and most of these people indicated that they know of drones through movies and news media. Hence, it is critical that policy makers might want to utilize various media platforms to educate the public on drone technologies and its potential applications, focusing on both potential benefits to individuals, communities and society and on the privacy and safety issues. As highlighted by our study, it does appear that the public did differentiate where and how drones were being used. Their level of acceptance varied with the contexts of application. More critically, the factors that influence their perceptions were also different. For residential areas, fears and concerns were the paramount factor while for other non-residential areas, perceived potential benefits matter more. Hence, policy makers, when taking the educational approach to drone application for the public, would need to nuance the information provided to the public depending on the contexts of drone application.

It is worth mentioning that past work has found that after personally riding an autonomous minibus in Germany, the 942 participants appeared to have higher acceptance towards the autonomous vehicle [39]. Furthermore, in this study, having a pleasant first experience was also an important determinant of acceptance towards the technology. Apart from promoting public acceptance through educational means such as distributing semantic information, policy makers can also consider giving the public a pleasant hands-on experience with drones to improve their acceptance level.

In summary, while we agree that provision of educational information on the benefits and safety of drone use [40], and a pleasant first-hand experience [39] can increase public acceptance, we would recommend weighing the information provided differently depending on the contexts of use.

4.3. Limitations and future directions

As with all research, we want to acknowledge the following limitations. Hopefully, future research can also take these limitations into account when designing their studies. First, as this was an online survey, despite our best effort, the sample is certainly not as representative as we wanted. For one, we were not able to recruit participants who are non-internet users. Furthermore, the pool of participants recruited by Qualtrics to participate in this survey might differ systematically from others who are not in this subject pool. Pertaining to sample characteristics, it should also be noted that our study includes residents of Singapore, a highly urbanized city-state. The psychology behind the public acceptance towards drones likely will differ for residents of rural areas – rural residents feel less positively about autonomous vehicles (like cars or buses) than urban residents [41]. Moreover, ethnic composition of neighbourhoods are found to affect support for drones [26]; Singapore's neighbourhoods are relatively ethnically homogenous but this may not be the case in other nations.

Secondly, these findings may not be generalisable to other Asian countries because Singapore is relatively more developed and urbanized compared to its neighbouring countries; Singapore has a 100% urbanized population, while its neighbouring countries have lower proportions of urbanized populations – Indonesia (55.3%), Malaysia, (76.0%), Philippines (46.9%), Thailand (49.9%) (The World Bank, 2018). Further, Singapore has had made more advances in technology and hence, Singaporeans may be more open or ready for the new advances drone technology. These differences in the level of urbanisation and societal exposure to technological advances might render our findings non-applicable to other Asian countries.

Thirdly, the knowledge tests that we used were based on existing definitions of what comprises a drone. This test has not been validated to be a comprehensive test that reflects all important aspects of drones. For instance, it does not test knowledge about the history of the drones, nor did it test for knowledge about existing drone regulations (for items measuring these aspects of drone knowledge, refer to Ref. [3]; and [15]. Future research could work on developing a more comprehensive knowledge test for drones.

Fourthly, the list of drone uses and functions are not exhaustive as the advancement of the technology will allow for endless possibilities of drone applications. Aydin [3] has provided a list of 40 current and future drone functions, some of which are not included in this study, such as drone racing, herding cattle, and monitoring nuclear plants for nuclear spills, as these were not relevant for our sample. Perhaps, future research can explore these additional uses of drones.

The fifth limitation of this investigation is that it did not capture whether physical factors of drones could potentially affect public acceptance towards drones. For instance, Chang, Chundury and Chetty [32] allowed 20 participants in the United States to interact with a real or model drone, and found that participants reported darker drone colours as more threatening. Larger drones were perceived to have something hidden inside and raised concerns about safety for pedestrians below the flying drone. The buzzing sound made from the drone while reported to be "uninviting" and "scary", were preferred to silent drones because of their detectability. Having bumpers around the drone also improved the participant's reported safety concerns. Thus, future work could also further investigate whether and how various physical dimensions of drones can affect public acceptance towards drones.

Finally, while our study attempted to capture some fears and concerns people might have towards drones operating in urban spaces, it should be noted that since the technology has not been widely introduced into society, the existing fears and concerns may be limited to the researchers' and participants' imagination, but not based on real experiences. Some fears and concerns may arise only when drones are already integrated into an urban society. Firstly, research has found that small drones operating near roads do serve as a distraction to drivers [42] – in a driving simulation, drivers shift their attention to look continuously at the drone (and the operator) for 2 or more seconds, which is sufficient to drastically increase the chances of a traffic accident [43]. Next, members of the public have indicated that they felt safer if there is a minimum separation distance between drones [32]. This means that another potential sources of concern could be if drones appear to fly to close to each other. From a concept-of-operations perspective, the required separation distance between drones also appear to be negatively related to the number of flight-path conflicts between concurrently operating drones in the same airspace [44]. Hence, a larger separation distance required between drones will potential ail public concerns and also reduce flight-path conflicts among the drones. Future work can consider investigating how such potential problems, such as drones distracting drivers, and close proximity of operating drones, can affect public acceptance towards drones.

5. Conclusion

Is the public ready for extensive drone application? Based on our research and others, we believe the answer is a "tentative yes" although more work must be done to educate the public on the potential benefits and at the same time, allay their fears and concerns especially for drone applications in residential areas.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2020.101462.

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Beng Chong Lim: Prof Lim is a faculty at Nanyang Business School, Nanyang Technological University Singapore. He taught academic courses such as Research Methods, Leadership and Organisational Behaviour to Team Development at the Master and Ph.D. levels and Managing Organizational Change and Talent Sourcing and Acquisition at the Undergrad level. He has published in numerous international journals such as Journal of Applied Psychology, Organisational Behaviour and Human Decision Processes, Journal of Organisational Behaviour, Organisation Research Methods, Academy of Management Journal, Academy of Management Discoveries, Organisational Dynamics, Personnel Psychology, Human Resource Management Review, and in Science, the world's leading journal of original scientific research.

Guihyun Grace Park: Guihyun Park is a senior lecturer of Management at Australian National University. She received a PhD in organizational psychology from Michigan State University. Her research examines information processing, emotion, and creativity.

Kin Huat Low: Kin Huat Low is currently a professor in the School of Mechanical and Aerospace Engineering, Nanyang Technological University in Singapore. Dr. Low obtained his BSc degree from the National Cheng Kung University in Taiwan, his MSc and Ph.D. degrees in Mechanical Engineering from the University of Waterloo, Canada. He is an author or co-author of about 400 journal and conference papers in the areas of robotics, biomimetics and rehabilitation robotics, unmanned aerial vehicles, air traffic management, impacts, power transmission systems, structural dynamics and vibrations. Kin Huat is also an Honorary Member of the Global UTM Association (GUTMA).

Lynn K. L. Tan: Lynn Tan was a full-time research assistant at the Air Traffic Management Research Institute in 2018 and 2019. She is now a first year PhD student under the supervision of Associate Professor Norman Li, in the School of Social Sciences at Singapore Management University. Her research interests include the impact of evolutionary mismatch in the modern societies, mating strategies and life history theory.

Victor Chuan Seng Yeo: Victor C. S. Yeo is currently Associate Professor Nanyang Business School, Nanyang Technological University. His areas of expertise are in corporate law and governance and legal risk management. His publications include the co-authoring of several books and publications in both academic and professional journals in these fields. Professor Yeo continues to be actively involved in corporate advisory work and has designed and conducted numerous training programmes for directors and corporate executives of various private as well as publicly listed companies, members of professional bodies and officers of governmental institutions.