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Understanding Autonomous Road Public Transport Acceptance: A Study of Singapore

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Abstract: This study examines the perceptions of concerns and benefits surrounding autonomous road vehicles deployed for public transport, their relationships with public acceptance, and what the public prefers during its implementation. Surveying 210 participants in Singapore, we found a general acceptance of the deployment of autonomous road public transport in Singapore with agreement that introducing them would be beneficial, particularly in improving public transport reliability and accessibility. However, they reported concerns in the areas of technical-related issues and legal liability. Participants who perceived greater benefits were also likely to report greater acceptance, even after taking into account their concerns and sociodemographic backgrounds. Participants also reported preferences for human operators to continue playing an active role, the government to test the autonomous vehicles extensively before making them available for public use and greater clarity on the legal liability when accidents involving autonomous vehicles occur when autonomous road public transport is eventually implemented.

Keywords: autonomous vehicles; public transportation; technology adoption; public acceptance

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1. Introduction

Public transport is an essential service in society, particularly for cities and urban areas where population density is highest, space is a premium, and mass commutes and vehicle congestion are daily affairs. With rapid development, prototyping and on-road trials of automated vehicles (AV) underway, the progress in this area suggests that deploying AVs for public transport could be realised within the next few years. Examples of AV road trials include the GATEway Project in Greenwich, UK and the Automated Road Transport System in La Rochelle in France. When this happens, it is likely that the transport systems that we are familiar with today will undergo fundamental changes, modifying how we will travel, access and use public transport in the future.

Several studies and reports have explored the potential applications of AVs in many areas of urban transport (e.g., [1–5]). In addition, there are studies focusing on understanding the perceptions and acceptance of AVs (e.g., [6–12]). These studies suggest that there is general acceptance regarding AVs but there are challenges such as speed, efficiency and safety raised by potential users that have to be addressed [6–12]. While useful, these studies largely focused on specific applications of AVs as private vehicles or short distance shuttles. These findings may not necessarily capture the acceptance or perceptions of the overall concept of introducing AVs into public transportation, particularly in the context of a dense public transport-centric city. Hence, this paper focuses on the potential expanded application of AVs in public transportation.

1.1. Autonomous Road Public Transport

AVs in public transport are not entirely new as many cities and countries have deployed them in varying forms (e.g., driverless trains in subway and metro systems). However, deploying AVs as road public transport will be different as they share public roads and spaces with other vehicles and will come in close interactions with the public, as opposed to being in confined, predetermined spaces.

Hence, autonomous road public transport has been envisioned to have the ability to transform public transport systems by bringing in new forms of shared mobility that is also safer and more efficient [13]. This potentially increases the appeal and use of public transport which will ease traffic congestions in cities, and coupled with improved fuel economy and reduction in emissions, will reduce the environmental impact of transportation [2]. Public transport might also be made more accessible, by providing on-demand public transport to low demand or underserved areas reliably and safely as the automation also addresses manpower constraints and reduces human errors [4]. The nature of AVs also means that manpower is freed up for jobs and services that require greater manpower. Lastly, it is also envisioned that autonomous road public transport will contribute towards keeping public transport affordable.

While AVs may hold many promises of improvements for public transport, there remain challenges that have yet to be adequately addressed, including issues surrounding safety, system security, vehicle control, ethics, legal liability and even integration with other transport modes [11,12,14]. These issues have a direct influence on the public's perception of AVs and ultimately, their acceptance and adoption of AVs that are deployed for public transport [9,15].

1.2. Autonomous Road Public Transport in Singapore

In Singapore, different forms and applications of AVs are currently being developed and prototyped for service as autonomous road public transport. These undertakings are part of Singapore's Smart Nation strategy for transportation to address the growing demand for transportation underscored by a growing and ageing population housed within a land-scare Singapore. The Committee on Autonomous Road Transport for Singapore charts the strategic direction for AV-enabled land mobility concepts in Singapore, and the Singapore Autonomous Vehicle Initiative explores the technological possibilities that AVs can create for Singapore [16].

Development of AVs in Singapore started in 2010, and public trials have been conducted since 2014 [17]. The world's first commercial autonomous mobility-on-demand service was also tested in 2016 by nuTonomy [18]. In 2018, driverless shuttles serving a predefined were also tested on public roads [19]. Currently, the Land Transport Authority (LTA) is developing an autonomous bus that can seat 40 passengers with ST Kinetics [20] and has announced that three towns (Punggol, Tengah and the Jurong Innovation District) will have autonomous buses and shuttles plying their roads from 2022, with autonomous buses being deployed during off-peak periods and autonomous shuttles providing first-last-mile connections in these districts [21].

1.3. The Current Research

Here, a survey-based pilot study conducted in Singapore is reported to explore how the public perceives autonomous road public transport, focusing on the perceived benefits and concerns and implementation preferences. While previous studies (e.g., [9,11,12,22]) have focused on specific types of AVs (mainly shuttles), the application of AV in public transportation is framed more broadly in this study. This was done deliberately for two reasons. First, the study aimed to understand perceptions of plans to introduce AVs in public transport in Singapore. Second, the specifics of how AVs will be implemented in public transport is yet to be decided. In the context of an upcoming deployment of autonomous road public transport in Singapore, the findings here will identify further strands of investigations to develop effective implementation strategy for autonomous road public transport in Singapore and provide insights for similar cities. Four questions are answered here:

(1) What is the level of acceptance of autonomous road public transport in Singapore?
(2) What are the concerns surrounding the implementation of autonomous road public transport in Singapore?
(3) What are some of the benefits thought to arise from the implementation of autonomous road public transport in Singapore?
(4) What would the Singapore public like to see implemented when autonomous road public transport is first introduced?

2. Method

2.1. Procedure

Informed by a prior literature review on the emerging transport technologies and developments pertinent for Singapore, a 49-item self-report online survey was created to explore the concerns, benefits and implementation preferences around autonomous road public transport implementation in Singapore and its future adoption intention (acceptance). To start, participants were asked two questions to self-report i) their level of knowledge of AVs in general (measured on a 5-point Likert scale ranging from 1 [I have never heard of AVs prior to this study] to 5 [I have a good understanding about AVs]), and ii) whether they have had prior experience riding on an AV (with the response options of 'yes', 'no' and 'unsure'). Following which, we shared information about the current state of implementation of AVs in public transport in Singapore with respondents using a short one-page writeup with pictures of ongoing trials to ensure respondents had the same level of basic understanding as it was still a concept at the time of the study (see Appendix A).

Participants were recruited via an open call for research participation on the university's website and through snowball sampling. The study was conducted between July and August 2018 and participants did not receive any incentives for participation. A quality check of the responses was then conducted (e.g., for straightlining of responses and speeding through the survey).

2.2. Participants

210 participants completed the survey, of which 46.6% were female and their ages ranged from 18 to 79 years. Our sample comprised of relatively younger and higher educated participants, in part due an overrepresentation of university students (23.6%). Nevertheless, 73.8% of participants were daily public transport users. This is slightly higher than the 67% public transport mode share during peak hours [23] but is close to the ambition of achieving 75% public transport mode share set by the LTA. Thus, we conducted further analyses without weighting the responses. Detailed demographics are provided in Table 1.

Table 1. Sample Demographics.

Variable	% of Sample	% of Adult Population
Age		
19–29	50.9	12.4
30–39	11.2	13.2
40–49	19.3	13.8
50–59	10.6	13.9
60–69	6.2	11.0
70–79	1.9	35.7
Marital status		
Married	39.8	60.0
Separated/Divorced	2.5	8.9
Single	57.8	31.2
Labour status		

Table 1. *Cont.*

Variable	% of Sample	% of Adult Population
Employed	65.9	96.1
Unemployed	6.3	3.9
Retired	4.3	-
Student	23.6	-
Education status		
Masters and above	23.0	-
Undergraduate degree	41.0	-
A level/Diploma	21.7	-
O level/Nitec/Higher Nitec and below	9.3	-
Other qualifications	5.0	-
Physical disability		
Yes	13.0	-
No	87.0	-

N = 210. Percentages are rounded off to one decimal place and may not necessarily add to 100%. '-' indicates unavailable population data.

2.3. Measures

We developed the questionnaire exploring the concerns, benefits and implementation preferences around autonomous road public transport implementation based on past studies (e.g., [7,22,24]) with contextualisation to Singapore when necessary, informed by our prior review of future transportation technologies in Singapore [25]. We explored 8 items for 'concerns', 7 items for 'benefits' and 11 items for 'implementation preferences'. Participants responded on 5-point Likert scales, ranging from 'strongly agree' to 'strongly disagree'. The individual items in each aspect are presented in Tables 2–4. Exploratory factor analyses found that the items in each aspect clearly loaded on a single factor.

Table 2. Perceived concerns about autonomous road public transport.

Concern	Mean (SD)
Autonomous vehicles in public transport may not drive as well as human drivers do.	3.41 (1.02)
Introducing autonomous vehicles in public transport could lead to job loss.	4.00 (0.99)
Introducing autonomous vehicles in public transport could be dangerous while there are also human-operated cars on the streets.	4.00 (0.99)
Introducing autonomous vehicles in public transport could cause accidents triggered by technical error.	4.17 (0.76)
Autonomous vehicles in public transport may not be secure from hackers.	4.07 (0.74)
Autonomous vehicles in public transport could be confused in unexpected/unprecedented situations.	4.17 (0.81)
Introducing autonomous vehicles in public transport could lead to legal liability issues when a crash is caused by the vehicle.	4.15 (0.84)
Public transport fares would increase when autonomous vehicles are introduced in public transport.	3.42 (1.04)

Responses were on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

To measure intention to adopt autonomous road public transport when available, measuring acceptance, we used a 3-item measure with a 5-point Likert scale informed by the UTAUT2 model [26] that demonstrated excellent internal reliability in this study, Cronbach's alpha = 0.94. The final items and measures developed for the study are shown in Tables 2–4.

Table 3. Perceived benefits of autonomous road public transport.

Benefit	Mean (SD)
Introducing autonomous vehicles in public transport would lead to shorter travel times.	3.36 (1.02)
Introducing autonomous vehicles in public transport would improve public transport reliability.	3.53 (1.01)
Introducing autonomous vehicles in public transport would improve travel comfort.	3.34 (1.02)
Autonomous vehicles in public transport are safer than having manual driving.	3.22 (1.07)
Introducing autonomous vehicles in public transport would reduce traffic jams.	3.23 (1.11)
Introducing autonomous vehicles in public transport could solve the transport problems of older or disabled people.	3.22 (1.17)
Introducing autonomous vehicles in public transport could solve the transport problems of people without a driving licence.	3.78 (1.03)

Responses were on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

Table 4. Implementation preferences when introducing autonomous road public transport.

Implementation Preference	Mean (SD)
Free test rides should be offered in order to experience personally what riding an autonomous vehicle is like.	4.26 (0.90)
Clearer clarification of liability when an autonomous vehicle causes an accident.	4.50 (0.79)
Comprehensive public education campaign to ensure better understanding of how the autonomous technology works and what are the possibilities and limitations.	4.46 (0.79)
Knowing that users were involved in the design of autonomous vehicles for public transport use.	4.13 (0.94)
While there are human-operated vehicles and autonomous vehicles, special lanes for autonomous vehicles should be created (similar to existing bus lanes).	4.09 (1.02)
For autonomous vehicles in public transport, human operators should continue to play an active role. For example, monitoring the system.	4.55 (0.70)
The government should provide incentives such as lower fares when riding on autonomous vehicles in public transport.	4.10 (1.04)
I would wait until others have already used autonomous vehicles on public transport before considering using it myself.	3.27 (1.21)
There should be human operators on board to have the possibility of taking over control whenever needed.	3.88 (1.08)
I would like to have a button inside the autonomous vehicle which I can press to stop it.	4.02 (1.07)
I would like to have autonomous vehicles tested on the roads extensively by the authorities first before opening it to the public.	4.69 (0.65)

Responses were on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

3. Results

Prior to the survey, participants self-reported their level of knowledge of AVs in general. Out of all participants, 13% responded that they have not heard of AVs prior to this study and 11.5% responded that they had a good understanding of AVs. The remaining 75.5% responded between these two options. The mean response on a 5-point Likert scale was 2.98 (sd = 1.19).

To the question on prior experiences AVs, 23% of participants reported having ridden on one, with 71% reporting not having so and 6% reporting being unsure if they have done so.

3.1. Acceptance of Autonomous Road Public Transport

Overall, the participants were positive in their acceptance of autonomous road transport with an average score of 3.87 (SD = 0.93) on a scale from 1 (very unlikely) to 5 (very likely). There were no significant differences observed in the acceptance scores across sex, age, marital status, labour status and physical disability status, $p = 0.20$ to 0.97.

3.2. Perceived Concerns

Table 2 summarises the eight concerns about implementing autonomous road public transport we explored. The average scores in all eight concerns indicate that these are present concerns, but technical-related issues (i.e., accidents triggered by technical error and confusion during unexpected/unprecedented situations) and legal liability saw the highest average levels of concern. Meanwhile, the performance of the vehicle and the transport cost were less of a concern for our participants. In addition, one-sample t tests revealed that the mean scores for all concerns were significantly different from the mean of the scale, all $p < 0.001$. No significant differences were observed in the level of all eight concerns across sex, age, marital status, educational level, labour status and physical disability status, $p = 0.19$ to 0.82.

3.3. Perceived Benefits

Table 3 summarises the seven benefits of the implementation of autonomous road public transport that we explored. Generally, the average scores for all seven benefits indicate that the participants perceive that there will be benefits from the introduction of autonomous road public transport. Nevertheless, the magnitude of the mean scores observed here are relatively close to 3, the 'neutral' option in this questionnaire. One-sample t tests revealed that the mean scores for all benefits were significantly different from the mean of the scale, all $p < 0.05$. No significant differences were observed in the responses across sex, age, marital status, education level, labour status and physical disability status, $p = 0.07$ to 0.86, except for the following: 1) male participants reported a greater perception that autonomous road public transport are safer than manual driving (mean (SD) = 3.40 (1.20)) compared to their female counterparts, mean (SD) = 2.96 (0.88), $p = 0.01$; and 2) participants with educational qualifications of masters and above reported lower perception of improvement of travel comfort by the potential introduction AVs in public transport (mean (SD) = 3.05 (0.97)) compared to the rest of the participants, with means ranging from 3.38 to 3.73, $p = 0.014$.

3.4. Implementation Preferences

Table 4 summarises the 11 implementation preferences that we explored. All implementation preferences explored here were supported by the participants, with all but two (waiting until others have tried before using it, and having human operators on board) reporting means scores above 4 (the 'agree' option on a 5-point Likert scale), suggesting strong preferences for them to be introduced when implementing autonomous road public transport. Nevertheless, one-sample t tests revealed that the mean preference scores for all implementation options were significantly different from the mean of the scale, all $p < 0.05$ No significant differences were observed across sex, age, marital status, labour status and physical disability status, $p = 0.07$ to 0.86, only across education levels. Participants with educational qualifications of masters reported lower preference for waiting for others to use autonomous road public transport before trying it themselves (mean (SD) = 2.59 (1.21)), compared to the rest of the participants, means ranging from 3.29 to 3.74, $p = 0.001$.

3.5. Relationships Between Perception and Acceptance

Correlation and linear regression analyses investigated how perceptions of concerns and benefits related with acceptance of autonomous road public transport. Here, we used the mean score across the eight items exploring concerns (mean (SD) = 3.93 (0.80)) and seven items exploring benefits (mean (SD) = 3.39 (0.80)) as a proxy of overall perceptions of concerns and benefits.

As would be expected, the perception of concerns was significantly negatively related with the acceptance of autonomous road public transport ($r = -0.19$, $p < 0.05$) while the perception of benefits was significantly positively related with acceptance ($r = 0.62$, $p < 0.001$). Following which, we conducted linear regressions, first separately for perception of concerns (Model 1) and perception of benefits (Model 2), next with both perceptions (Model 3), and finally with the sociodemographic variables (gender, sex, and marital, labour, education and disability statuses; Model 4).

Individually, both the perceptions of concerns (Model 1) and benefits (Model 2) significantly predicted the acceptance of autonomous road public transport though the perception of benefits provided greater explanatory power of acceptance. When both perceptions were modelled together (Model 3), the perception of benefits emerged as the only significant predictor of acceptance, indicating that the perception of benefits explained some of the perception of concerns surrounding autonomous road public transport. Nonetheless, the total variance in acceptance explained when both perceptions are modelled increased only marginally to 0.40 from 0.38 when only the perception of benefits was modelled. Finally, there was no significant changes to the above model even after accounting for the effects of sociodemographics on acceptance (Model 4). The results of the regressions are summarised in Table 5.

Table 5. Linear regression model of the relationships between perceptions of concerns and benefits with acceptance of autonomous road public transport.

Variables	β			
	Model 1 [a]	Model 2 [b]	Model 3 [c]	Model 4 [d]
Perception of concerns	−0.19 *		−0.06	−0.05
Perception of benefits		0.62 **	0.62 **	0.57 **
Gender				
Male				Ref
Female				−0.02
Age				
19–29				Ref
30–39				−0.11
40–49				−0.09
50–59				0.02
60–79				−0.03
Marital status				
Married				Ref
Separated/Divorced				−0.13
Single				−0.17
Labour status				
Employed				Ref
Unemployed				−0.08
Retired				−0.09
Student				0.09
Education status				
O level/Nitec/Higher Nitec and below				Ref
Other qualifications				−0.16
A level/Diploma				−0.02
Undergraduate degree				0.06
Masters and above				0.20
Physical disability				
No				Ref
Yes				0.10
R Square	0.04	0.38	0.40	0.44

* = $p < 0.05$; ** = $p < 0.001$; [a] with concerns as the sole independent variable; [b] with benefits as the sole independent variable; [c] with both concerns and benefits as independent variables; [d] with both concerns and benefits as independent variables and gender, age, marital, labour, education and disability statuses as covariates; ref = reference category.

Following the results of the linear regressions, we conducted a mediator analysis to explore if the relationship between the perception of concerns and acceptance of autonomous road public transport was mediated by the perception of benefits. Conditional process modelling [27] was used for this analysis, with bootstrapping of 5000 iterations to estimate 95% confidence intervals for all regression coefficients. Figure 1 presents the results of the analysis. As can be seen, the relationship between the perception of concerns and acceptance of autonomous road public transport was partially mediated by the perception of benefits. A Sobel test was conducted and the results supported the conclusion of a partial mediation in the model tested ($z = 1.85$, $p = 0.06$).

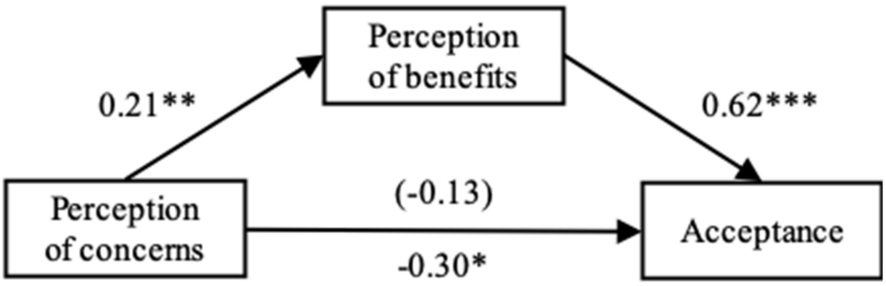

Figure 1. Relationship between perception of concerns and acceptance of autonomous road public transport partially mediated by perception of benefits. Standard regression coefficients are reported; value in brackets represents the indirect effect of the perception of benefits. * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

4. Discussion

Various studies have explored the perception of AVs but most of these studies focused on the use of AVs in an individual and private manner (e.g., [7–10]). Here, we focused on how the public accepts the concept of AVs as road public transport, their perceptions of concerns and benefits, and implementation preferences in Singapore.

Our results suggest there is an overall acceptance of the deployment of autonomous road public transport in Singapore, consistent with previous studies in other cities (e.g., [9,11,12]). This observed acceptance was higher as the perception of concerns surrounding its implementation reduces and the perceptions of its benefits increased. Further analysis suggests that an individual's perception of benefits partially mediates the relationship between the perception of concerns and acceptance. This reflects moral-normative system evaluation between the perception of potential benefits and risk (concerns) in the cognitive process preceding AV acceptance proposed in the recently published Multi-Level Model on Autonomous Vehicle Acceptance, and further suggests the existence of a partial mediation [28]. Individuals who perceive greater levels of benefits arising from the implementation of autonomous road public transport report a correspondingly greater acceptance even after considering their concerns. This was observed across sociodemographic here despite previous studies suggesting that there might be differences in the level of acceptance of AVs across gender [10,24,29–31] and age [31,32], although it should be noted that our sample was relatively younger than the general population. However, previous work in Singapore found similar observations where the receptiveness and adoption of technology was homogeneously high in the population, regardless of age [33–35].

Among the concerns that our participants responded to most strongly were technical-related issues (i.e., accidents on the AVs triggered by technical error and uncertainty in reaction by the AVs when encountering unexpected/unprecedented situations) and the uncertainty over legal liability when accidents involving AVs occur, in line with previous findings (e.g., [11,31,36]). Particularly, for the Singapore context where there is relatively higher trust in the government to set standards for the industry [37], there was a strong preference for the government to test AVs extensively prior to implementation. These implementation preferences are important considerations for transport operators and authorities when implementing autonomous road public transport in Singapore.

As noted earlier, the perception of benefits was the strongest predictor of acceptance of autonomous road public transport and we observed that the two benefits that our participants perceived will be realised were that autonomous road public transport will improve the reliability and accessibility of public transport. Of particular interest for Singapore is the perception that autonomous public transport will improve the accessibility to transportation, especially for those without driving licences. This supports the LTA's vision to transform Singapore into a car-lite and public transport-centric city with first and last mile conducted by walking and cycling, and by AVs in future [38]. This suggests that increased accessibility and reliability of public transport enabled by AVs in future might encourage a mode shift towards public transport.

On affordability, a possible increase in the cost of public transport after introducing AVs was among the least of our participants' concerns. Interpreted together with the expectation of governmental provision of financial incentives to ride on AVs in public transport, it is likely that participants expect fares to remain largely the same. Thus, we need further understanding of how the public valuates AVs in public transport for Singapore.

A limitation of our study is that the sample may be prone to selection bias as it was comprised of a larger proportion of students and younger individuals than found in the general population. However, this younger population will, in time, come to be the key user group when AVs are eventually introduced in Singapore's public transport in the next decade. Notwithstanding, the findings provide useful early insights into perceptions of autonomous road public transport and acceptance among a Singaporean public transport user sample, and highlight potential focus areas for public transport operators and authorities when planning for implementing AVs. Nevertheless, there remains a need to understand how these perceptions form, the underlying mechanisms with acceptance and eventual adoption, and potential intervention levers for encouraging acceptance and adoption during implementation. A useful guiding framework is the Multi-Level Model on Autonomous Vehicle Acceptance [28]. Future work should also consider conducting similar studies using this framework and include population segments with specific transport requirements (e.g., children, the elderly and people with disability) as their perceptions and acceptance of AVs may differ. In addition, it will be useful to conduct such study in cities that are planning to implement AVs in public transport as a way to inform implementation strategy.

5. Conclusions

Our findings contribute towards a better understanding of public perception and acceptance of AV implementation in public transport in Singapore. Both the perceptions of concerns and benefits are related to acceptance of autonomous road public transport. However, the relationship between the perception of concerns and acceptance is partially mediated by the perception of benefits. We also observed stronger preferences for comprehensive AV testing, and assurance of safety and liability prior to implementation.

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Appendix A

Autonomous or self-driving road vehicles are those that operate without a human driver. Real-time information is obtained by scanning the surrounding, communicating with other cars and infrastructure to enable it to make automatic decisions while operating.

Autonomous vehicles have the potential to radically transform our transport system and improve our living environment. Singapore is currently exploring how they can be applied to public transport.

Driverless trains have been in operation in Singapore since 1999 and are now found on the North East, Circle and Downtown MRT Lines, and the Bukit Panjang, Punggol and Sengkang LRT lines.

In addition, a project is underway to develop and trial autonomous buses to serve fixed and scheduled services in the future. Trials are scheduled to begin in 2022 in Punggol, Tengah and the Jurong Innovation District.

Figure A1. Information presented to participants at the start of the survey.

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