Acceptance of Autonomous Vehicles in Last-Mile Delivery

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***Abstract*—The COVID-19 pandemic has accelerated the contactless adoption of contactless ordering, payment, and delivery for both businesses and consumers. In a technology-savvy era, contactless delivery has emerged as an alternative and complementary to conventional delivery options. However, it is critical to identify the acceptance of these autonomous vehicle technologies for last-mile delivery. To explore the factors influencing consumer acceptance, seven proposed hypotheses were formulated and tested with a quantitative approach based on a stated preference survey. The survey instrument was created according to existing scales of the Technology Acceptance Model (TAM) along with customer concerns. Analytical results reveal that potential consumers in Singapore have a positive attitude toward the use of last-mile autonomous deliveries, where perceived usefulness, perceived ease of use and perception acted as the strongest predictor of intention to accept the last-mile delivery served by autonomous vehicles.**

Keywords— autonomous vehicle, last-mile delivery, stated preference survey, Technology Acceptance Model (TAM)

I. Introduction

Considering the rapid spread of COVID-19 regardless of borders, it has permanently altered the retail landscape with businesses shifting their focus onto e-commerce platforms to support contactless transactions to reduce the spread of the virus transmission [1]. With e-commerce on the rise, the demand for home deliveries will increase rapidly. However, how contactless delivery contributes to reducing human interactions in last-mile logistics amidst Covid-19 in the technology-savvy era becomes a major concern. Presently in Singapore, several contactless delivery options are available for recipients to collect their items without coming into contact with couriers, such as smart lockers or home delivery communicated by Apps without contact between deliverers and consignees. Even so, these collection methods nevertheless encompass potential health risks since either recipient would have to be physically there at the smart lockers for collection or couriers would have to be physically present at the recipient's front door to drop off the parcels.

With the current COVID-19 pandemic making social distancing the new normal, autonomous vehicles seem to be a resolution as they could essentially lessen the physical contact points in last-mile logistics by allowing couriers and recipients to complete deliveries without human interactions. Autonomous vehicles are capable of navigating around public spaces without human intervention during the delivery process. At the distribution centre, parcels, food and grocery orders can be stored inside the automated retrieval units of these delivery vehicles and granted access only to the correct recipients. This prioritises cargo security along with the safety of both the courier and recipient by eliminating the need for human contact from front door deliveries. Starship has completed two million last-mile deliveries by the end of 2021, using its autonomous robots [2].

Autonomous last-mile logistics has attracted interest from numerous researchers with some having strong growth projections of the autonomous last-mile service and foreseeing it to be the leading technology near future. Autonomous vehicles are likely to populate over 25% of the global market by 2040 [3]. The ultimate success of new technologies entering the market strongly relies on the acceptance of consumers [4]. Accordingly, this study uses the technology acceptance model (TAM) to preliminarily explore the factors antecedent to the acceptance of consumers in Singapore when using autonomous vehicles in last-mile delivery. Factor and correlation analyses are employed to evaluate the validity and reliability of the proposed TAM. The remainder of this paper is organised as follows: Section 2 reviews recent research on applications and research of autonomous deliveries, followed by the antecedents of acceptance in adopting new technologies. Section 3 presents the data collection and the proposed TAM framework. The results and discussions are expressed in Section 4, while Section 5 shows the conclusions.

II. Literature Review

A. Applications of Autonomous Vehicles in Singapore

Autonomous vehicles refer to driverless vehicles which are proficient in route navigation, parking, environment positioning and autonomously planning routes without human intervention [5]. The Society of Automotive Engineers categorised vehicle automation into six distinct levels. Level 0 to 2 vehicles require the driver's supervision to monitor the driving environment with driver support features, whereas Level 3 to 5 vehicles possess automated driving features and take over the driving task. While Level 3 and 4 vehicles will only operate if all required conditions are met, Level 5 vehicles offer complete driving automation under all conditions [6].

The Singapore government mounted the city-state as a real-world laboratory and global testing bed for autonomous vehicles since 2010 [7], for attracting software developers, research scientists and promising autonomous vehicle start-ups to develop and integrate autonomous vehicle technologies in the city-state. Moreover, authorities in Singapore have applied self-driving technology to public transport to overcome land and manpower constraints [8]. The country has been largely focusing on developing a Singapore Smart

Mobility 2030 program on venturing into autonomous transport plans with autonomous taxis, buses, and shuttles [9].

Driverless technology had been widely engaged within Singapore's hospitality sector, where driverless robots calibrated to move autonomously were employed to assist in daily housekeeping duties by delivering room amenities and in-room meals to guests [10]. Moreover, a significant productivity savings of 19.3 man-hours daily when two autonomous linen cart robots were deployed for housekeeping functions in smart hotels [11].

B. *Antecedents of Acceptance of Last-mile Autonomous Deliveries*

It is always important to examine the factors influencing consumer intention to use the new services during the introduction of new forms of technologies [12]. Consequently, the question raises whether consumers accept last-mile autonomous deliveries as a new means of option to get their orders delivered. The expectation of consumers toward technology usage influences their acceptance level [13]. In terms of technology usage, the needed infrastructure to use the new technology can be said to be interrelated to the facilitating conditions. Facilitating conditions refer to a determinant of both behavioural intention and technology use [14], possessing a direct effect on actual technology usage considering the availability of the resources.

Exploring antecedent fractures of acceptance is one of the most important issues when analysing the social behaviour of people. Some behavioural studies further comprise a perceived construct, which is widely used to model the acceptance of a variety of new information technology products and also to predict levels of usage [15]. Sheu [16] investigated the influences of quality, sacrifice, value, and satisfaction on favourable behavioural intentions and unfavourable behavioural intentions. There are two main constructs developed in TAM, namely, perceived usefulness and perceived ease of use. Research suggests that both are of major importance in determining which variables could influence user intentions toward adopting new technology. For example, perceived usefulness was a direct determinant of intention to use [17], and individuals are more likely to adopt new technology once they perceive it to be easy to use [18].

Kim and Kankanhalli [19] developed a model to explain resistance before a new system implementation by leveraging literature on the technology acceptance and resistance models. In addition to usefulness and ease of use, perceived value, indicating the perceived benefits an individual will enjoy from implementing new technology, and switching costs, referring to the adverse effects an individual would experience when switching from the status quo to new technology, were considered. The importance of risk as a key predictor of human behaviour can't be ignored, as the effects of risk and uncertainty can't be mitigated in supply chain management and information technologies [20].

Moreover, a financial outlay is crucial to implementing new technologies [21], as there is a strong association between price value and behavioural intention to use [14]. Delivery fees have a significant impact on consumer decisions in online retailing [22]. Analytical results revealed important delivery attributes affecting consumer preferences in online retailing, such as price, delivery speed and tracking capabilities [23].

The major concern of respondents with autonomous deliveries, for example, robots in its study, represents the perceived security in terms of theft or damage to the robot's contents [24]. The survey findings revealed that among the pre-listed scenarios, including malfunctioning, navigation and safety issues posed by the delivery robots being raised, consumers were most concerned about their cargo being stolen during the autonomous delivery process. Half of the survey participants were not convinced of the safety of their products when delivered with autonomous vehicles [25].

Similar to parcel security, consumers are concerned about the threats to data security or privacy since personally identifiable information such as names, home addresses or contact numbers are transmitted between the control centre and autonomous delivery vehicles when delivering orders [25]. Couriers hold the necessary identifiable private information of the recipient and thus, both traditional and autonomous last-mile delivery face threats of misuse or abuse of information. Internet users are concerned about the appropriate use of their personal information as a data security breach would allow unauthorised access and use of consumers' confidential information [26-27]. American International Group [28] sampled 400 Singaporeans and found that the security of computer systems plays a critical role in resisting their adoption of driverless vehicles.

III. Research Approaches

Technology acceptance means the choice of an individual to voluntarily accept new technologies. For successful implementation and utilisation of the new technology, the willingness of users plays a crucial role [29]. Due to the rapid development of new technologies in past decades, researchers have developed several models to explore users' attributes for technology acceptance. In particular, TAMs have been verified multiple times to determine their effectiveness for many information technology-based applications. TAM originated from the fields of sociology and psychology, as well as the most frequently used model in various practical studies [20]. TAM is utilised to forecast the adoption of new technology among users and to highlight the potential problems of designing information systems before implementation. For example, scholars adopted the TAM framework to evaluate the acceptance of using artificial intelligence in customer services [30-31].

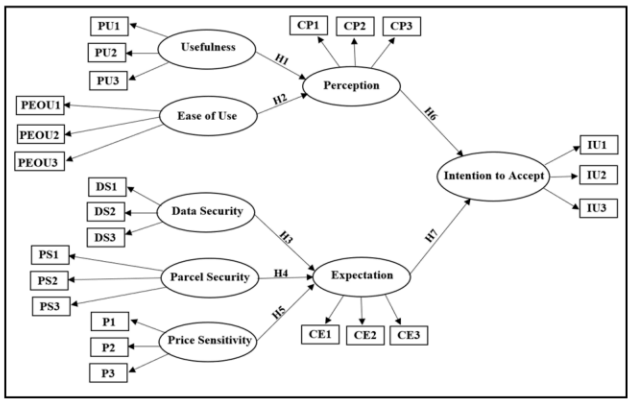

Fig. 1. The research framework

In addition to the perception of introducing last-mile autonomous deliveries, a stated preference survey was developed to measure customer expectations in security and

price concerns for the new technology which is not adopted in Singapore's last-mile delivery. Constructs and indicators were developed based on literature to preliminarily discuss the acceptance of implementing last-mile autonomous deliveries in Singapore. Figure 1 illustrates the proposed constructs and hypotheses in this study.

Table 1 lists the constructs and measurement items used in this study. The measurement items of these constructs are adopted and modified according to previous studies, and all of them use a Likert 5-point scales rating from "strongly disagree = 1" to "strongly agree = 5"

TABLE I. DETAILS OF MEASUREMENT ITEMS

Construct	Measurement item	References
Perception	CP1: I have a generally favourable attitude towards using last-mile autonomous deliveries	[32]
	CP2: I like the idea of using last-mile autonomous deliveries	
	CP3: I find that an autonomous vehicle is more advantageous than delivery by a courier	
Usefulness	PU1: Autonomous vehicles would be a useful means of delivery for my online purchases	[33-34]
	PU2: Using an autonomous vehicle would allow me to receive parcels faster	
	PU3: Using an autonomous vehicle to receive parcels would be much better than the delivery by a courier	
Ease of Use	PEOU1: I think learning to use the autonomous vehicle would be easy for me	[33]
	PEOU2: I believe autonomous vehicles are easy to use	
	PEOU3: Interaction with an autonomous vehicle should be easy	
Expectation	CE1: I expect difficulty in using the resources necessary to manage autonomous vehicles as it will be complex	[14, 21]
	CE2: I expect the lack of knowledge necessary to use autonomous vehicles will hinder my acceptance of that	
	CE3: The availability of support provided is unimportant to me	
Data Security	DS1: Using autonomous vehicles would not lead to a loss of privacy for me as my personal information would be kept secured and treated confidentially	[5]
	DS2: Using autonomous vehicles would not increase the chances that my personal information will be used for other purposes	
	DS3: I believe that autonomous deliveries protect my privacy	
Parcel Security	PS1: I feel secure using autonomous vehicles in last-mile delivery	[35]
	PS2: I feel that the autonomous vehicles have the safety measures in place to protect my parcels	
	PS3: I feel confident that my parcels are safe with autonomous deliveries	
Price Sensitivity	P1: The cost of delivery for my online purchases is important to me	[21, 36]
	P2: I would less likely to use autonomous vehicles in last-mile if it costs more than conventional delivery options	
	P3: I would be less willing to pay more to use autonomous vehicles as a delivery option if it will likely cost more than conventional delivery options	
Intention to Accept	IU1: I am willing to accept autonomous vehicles in last-mile delivery	[36]
	IU2: I intend to use autonomous vehicles when available in the future	
	IU3: I would use autonomous vehicles when available in the future.	

This study employs a combination of voluntary response sampling and snowball sampling due to the current measures on minimising social contact. The survey invitation link was distributed mainly via WhatsApp, Facebook, and Instagram. The use of voluntary response sampling can help reduce the time spent searching for participants that meet the sample criteria. With the geographical project focus on Singapore, data filtering would be conducted to remove respondents not staying in Singapore to ensure the accuracy and relevance of the survey outcome. For the final survey, a total of 107 effective responses were collected.

IV. RESULTS AND DISCUSSIONS

Confirmatory factor analysis and structural equation modelling were conducted by using SPSS 25. Table 2 demonstrates all relevant estimates for the eight constructs, where the analytic results indicated that all of the standardised factor loadings possess a statistical significance of $p<0.05$.

TABLE II. RELIABILITY ANALYSIS OF CONSTRUCTS

Construct	Cronbach's Alpha
Perception	0.80
Usefulness	0.80
Ease of Use	0.69
Expectation	0.73
Data Security	0.85
Parcel Security	0.85
Price Sensitivity	0.67
Intention to Accept	0.89

A Cronbach's Alpha value of 0.70 is a commonly acceptable reliability coefficient, even though the value of 0.60 – 0.70 is still acceptable [37]. According to Table 2, Cronbach's Alpha value for most of the items ranges from 0.67 – 0.89. The values further explain that these construct variables are valid as they were mostly above the 0.70 level, indicating strong scale reliability.

Pearson's Correlation Analysis was used to explore the strength of the relationship between the above-stated independent variables and consumer perception/intention to use. The results of Pearson's correlation analysis have been illustrated in Figure 2.

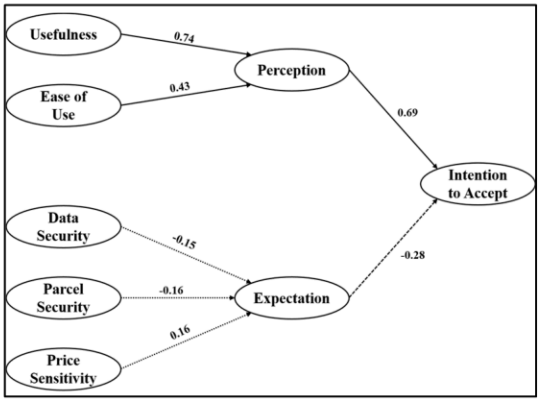

Fig. 2. Results of Pearson's correlation analysis

Akoglu [38] reviewed some literature and summarised reporting correlation coefficients along with associated strength. A coefficient greater than 0.7 refers to a strong-very strong correlation, while a coefficient ranging between 0.4 and 0.7 means a moderate-strong correlation. It is a weak-moderate correlation when the coefficient stands around 0.3, whereas a coefficient lower than 0.2 indicates a weak or negligible correlation.

In dealing with the direct effects of consumer perceptions on intention to accept, the three relationships considered in H1, H2, and H6 are verified. From the results of Pearson's Correlation Analysis, both the constructs of perceived usefulness (r=0.74) and perceived ease of use (r=0.43) have a significant positive relationship with consumer perception of autonomous vehicles in last-mile delivery. These results imply that consumer perception of last-mile autonomous deliveries will positively improve with greater effects of usefulness and ease of use perceived by the consumers. In addition, the consumer perception construct also has a statistically significant relationship (r=0.69) with consumer intention of acceptance for last-mile autonomous deliveries, thus supporting H6. The result indicated that consumer perception has a direct impact on consumer intention to accept autonomous vehicles, suggesting that TAM applies well in exploring the acceptance of last-mile autonomous deliveries.

Regarding other customer concerns in the last-mile autonomous deliveries, only the construct expectation are moderately correlated to the intention to accept (H7) with a coefficient r=-0.28. Notably, the measurements proposed in this construct are all negative questions indicating difficulty, lack and unimportance, leading to the negative correlation between expectation and the intention to accept autonomous vehicles in last-mile delivery. It means users expect simpler and easier learning to adopt last-mile autonomous deliveries with available and appropriate support to facilitate their intention to accept the use of autonomous vehicles.

However, the correlations between the expectation and data security, parcel security and price sensitivity (H3, H4 and H5) are weak, i.e., the concerns on data security, parcel security and price are not critical factors affecting the level of expectation. In fact, consignees might not put much attention to how their cargo is delivered if the risks in security are similar between last-mile deliveries conducted by autonomous vehicles and human couriers.

V. Conclusions

This is the age of empowered customers who demand more efficient and secure last-mile delivery by leveraging technologies. In particular, the COVID-19 pandemic makes social distancing the new normal where couriers try to complete deliveries with minimal human interactions with recipients. Using autonomous vehicles in last-mile delivery contains the possibility of addressing these requirements, providing more efficiently and securely contactless to-door deliveries. The development and implementation of a novel technology do not guarantee that it will be used and otherwise succeed. This study provides evidence that usefulness, ease of use and perception are antecedents to the behavioural intention of last-mile autonomous deliveries implementation. However, neither the correlated relationships between expectation and security nor the correlation between expectation and price sensitivity was observed to be significant during autonomous vehicle technology implementation.

These conclusions offer some managerial implications. First, usefulness and ease of use are critical factors having indirectly positive correlations to the behavioural intention with an intermediate construct perception. This implies that the level of perception is likely to contribute to the specification and improvements of the intention to accept if firms improve the values of last-mile autonomous delivery systems perceived by users. Managers thus must make the learning of new technologies easier and clearer. Well-developed instructions are helpful in ways that facilitate barriers and resistance to accepting autonomous systems. Secondly, companies that would like to improve the perception must pay attention to improving the usefulness of autonomous vehicles by making them more effective and complying with the last-mile delivery operations. Last-mile autonomous deliveries have the potential benefits to improve flows of physical goods, information and capital. However, to achieve the ubiquity of autonomous vehicles, which is essential for these benefits to be fully realised, increased awareness of the technology and interoperability across different networks.

This study is helpful for a logistics organisation to efficiently understand how its users evaluate autonomous vehicle technologies in last-mile delivery and accordingly prioritise strategies to ensure smooth implementation of autonomous vehicle technology. However, there were some limitations. First, it has to be mentioned that autonomous vehicles are not yet reached marketability in the last-mile delivery market of Singapore, and a stated preference survey was employed. Consumers' ability to justify autonomous vehicles' benefits and challenges in last-mile delivery is limited and unclear. Second, due to the current pandemic and measures on social distancing, it was not possible to distribute the survey via other methods apart from through the Internet. Voluntary sampling brings a certain degree of the drawback of self-selection bias since not all volunteered participants might be relevant to the study. Moreover, the collection of survey responses was only able to reach out mainly to young and middle-aged adults. Notably, there were no participants aged 65 and above. All these elements played a part in affecting the distribution of the sample size. A larger sample size, with a relatively even distribution of different age groups, will likely contribute to a more meaningful and reliable survey result, as well as strengthen future research on consumer acceptance of autonomous delivery technology in Singapore.

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