Last-Mile Delivery Drone Acceptance: Increased knowledge does not imply increased acceptance

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Figure 1. "Titan Drone in-game". Zephyr Drone Flight Simulator, 2022. Author's screenshot.

Driven by emerging technologies and increasing clarity in regulations, unmanned aerial vehicles (UAVs), or 'drones', are expected to take on a major role in smart cities of the future. Their applications are ever-growing and vary from agriculture to surveillance to logistics. However, studies that document public acceptance towards drone use in the last mile parcel delivery sector are still in their infancy, more less so such that also point to effective methods on how to influence and subsequently raise it. This paper's contribution consists of first constructing a conceptual model to measure technology acceptance of delivery drones, and then assessing it by applying it in one specific scenario: providing people with first-hand Drone Simulator experience as means to increase this delivery drone acceptance, wherein the novelty of this study lies.

Additional Key Words and Phrases: Smart cities, unmanned aerial vehicles (UAVs), delivery drones, technology acceptance, last-mile delivery, simulator

1. INTRODUCTION

Unmanned aerial vehicles (UAVs), or drones, are commonly defined as "devices used or intended to be used for flight in the air that have no onboard pilot" [1]. While they initially found application mainly in the military sector [2], commercialization of this technology has led to their current widespread use in the domains of, amongst many others, medicine, agriculture, security, surveillance, and logistics [3]. The opportunities for wide civil applications and their collaborative character and connectivity have earned UAVs a vital role in supporting smart cities in becoming "smarter". Drone adoption has been proven to greatly benefit smart city development when deployed effectively and efficiently, as early in its commercial use spread as 2014 [4]. Yet one issue smart cities of the future face is the tremendous increase in parcel deliveries that affects logistics companies and consumers alike [5]. Successful adoption of last-mile delivery drones thus offers to handle this increase in demand while at the same time promises to expand sales as it allows for a faster and cheaper delivery process, and amongst other benefits, has the potential to better the traffic congestion situation and to reduce CO_2 emissions [6]. There are, however, several bottlenecks identified to hamper drone deployment in the logistics sector, as transformation in customer behavior is inevitable with any new technology. One such issue is technology acceptance levels of delivery UAVs. Trends so far show that citizens are reluctant to adopt this logistics innovation and their acceptance levels fall within the range of neutral to negative. Researchers in the Netherlands [7][8], Germany [9], and Europe-wide [10] are consistent in their findings that people do recognize advantages in drones being utilized for the 'common good'. Services like medical deliveries, firefighting, inspection of buildings and rescue missions find wider acceptance and support. However, with regards to commercial and private use, public attitudes point to an as low as only 42% support for parcel delivery drones [11]. To improve this, research efforts have been made to determine critical factors and methods that influence this [12], [13]. While this shows that the social factor in drone adoption is accounted for, the movement of research in the field of delivery UAVs acceptance is still in its infancy and cannot keep up with their growing market share and there-accompanying innovations. This technology's market viability reveals that already in 2019, the delivery drone market was able to reach around 7.5% of the European Union's population. With an increase in investments in hardware this number could soon enough lie at 27% [14] And it is the increase of customers' knowledge of the technology that would increase acceptance and bridge this gap. This calls for active effort in this field as conclusively effective ways to address public reactions, perceptions, and desire to use the technology in the delivery

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sector are yet to be identified and tested. This paper's contribution thus lies in examining the effects of one such method – the use of Drone Simulators – as a means to give people first-hand experience with drones, increase their knowledge about the underlying technology, and subsequently raise their acceptance. Community concerns pose a threat to restrict delivery UAVs' dissemination equally so as cultivating positive attitudes towards them popularizes use and eases adoption. These challenges reinforce the argument for the relevance of the present research, which is outlined in Section 2.

2. RESEARCH OUTLINE

As mentioned, this paper will examine the effectiveness of using Drone Simulators as a method to increase public acceptance of delivery UAVs. This method choice is based on previous findings that show that giving participants greater knowledge and understanding of the concept would allow them to make a more informed view, make them more open to the technology, and increase their levels of self-declared drone familiarity [15]. Demonstrations through drone simulators are also said to be able to serve as a tool to engage and "involve people in the decision-making process about the future of drones" [16]. Even though no studies so far reported on the potential effects of drone simulators on acceptance, in previous work 89% of interviewed First-Person View drone pilots do recommend using drone simulators to achieve the learnability effect itself [17]. Studies making use of simulators for improving learnability and acceptance do exist for other innovative means of transport and logistics such as self-driving cars [18][19], but none so far concern drones, wherein the novelty of this work lies.

In order to investigate whether such a tool can help increase the acceptance of last-mile delivery drones, however, the first step is being able to measure this acceptance. To that end, the first part of this research consists of conducting a Systematic Literature Review, and then building a conceptual model that defines the acceptance factors for last-mile delivery drones. The review itself and its findings are described in Section 3. The second part of this research applies the conceptual model in practice and investigates what implications providing potential users with drone simulator experience has for drone acceptance. To do so, an empirical study was run with 31 participants. It followed a "repeated-measure design" [20]. The study, its analysis, and results are described in Sections 4 - 7. The conclusion, Limitations and Future Work are discussed in Section 8.

The study will have several contributions for both UAV developers, and for commercial businesses that plan to make use of the technology. It will propose a conceptual model that can be used to stakeholders' benefit as it validates which factors are the most influential to acceptance based on a thorough literature review of previous work in the field. It will also add to the list of tested methods that serve to affect and possibly raise technology acceptance. These together will serve as a useful basis for understanding and targeting users' perception of last-mile delivery drones, with a focus on the efficacy of simulator usage within the bounds of the Netherlands, which, to the author's knowledge, has not been researched to the date of writing this paper. To fulfill its purpose in bridging the identified knowledge gap, the study aims to answer the main research question (RQ):

Can public acceptance of delivery drones be improved by increasing people's knowledge of how drones work using a drone simulator?

To answer this, the study sets two goals for itself. The first goal is to identify the factors that influence public acceptance of last-mile delivery drones and to construct a conceptual model with them that is able to explain societal acceptance levels of delivery UAVs. Once constructed, a survey questionnaire with items that measure each identified construct is put together to ease testing. This poses the following research sub-question (SQ1):

SQ1. *What are the factors that influence the public acceptance of last-mile delivery drones?*

In order to test the proposed model, it was applied in one specific scenario intended to improve acceptance of last-mile delivery drones: the use of simulators to train potential future clients. The goal is to capture whether a drone simulator experience can change one's perception on delivery drones, for which acceptance factors, and what significance do these changes, if any, carry. This leads to the second sub-question (SQ2):

SQ2. *What is the effect of training potential users with drone simulators on the acceptance of last-mile delivery drones?*

3. RESEARCH METHODOLOGY

To answer SQ1, this study first performs a Systematic Literature Review following the PRISMA protocol [21], and then a selection procedure of the factors identified across research to be influential on delivery drone acceptance. The methodology used for developing the conceptual model is inspired by the work of N. Jasim et al. [13], and loosely follows their variable identification method. This procedure is divided into three stages: compiling all identified variables, combining overlapping variables, and mapping similar in meaning variables from other models to UTAUT2 or TAM. Based on the results, a conceptual model for the factors affecting last-mile delivery drones' acceptance is constructed. It serves to capture the participant's stance on the identified acceptance factors pre- and post- the simulation phase.

To answer SQ2, a Drone Simulator Software is chosen that resembles a real-life experience of a drone package delivery scenario. A task list is constructed that exhaustively covers the functionalities that can be demonstrated within the environment. This task list is assigned to each participant for execution within the environment. The process is closely monitored by the researcher as participants are invited to University of Twente grounds, get provided with the enlisted means, and are briefed and debriefed on this phase's aim and on instructions necessary to use the controller and operate the drone. Post the simulator experience, participants are asked to fill out the questionnaire again by using the same name or pseudonym as they initially did. The pre- and post-simulator data is then matched and analyzed by performing inferential tests on it so differences between initial and post-simulator measurements can be established, if any.

4. LITERATURE REVIEW

Multiple different models have been proposed to predict and explain how users come to accept delivery UAVs. Amongst those, the studies examined within this literature review make use of the following models, in their full or partially adapted form: Technology Acceptance Model (TAM) [22]–[25], Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)[13], Theory of Planned Behavior (TBP)[6], Diffusion of Innovation Theory (DOI)[26], Motivational Consumer Innovativeness Scale (MCIS)[27], and the Model of Goal-directed Behavior (MGB) [28].

So far, TAM seems to be the most deployed theory in the field yet, not only for UAVs, but also for a wide range of other autonomous delivery technologies and services[29], [30], followed by UTAUT2 [31], [32]. However, for this study's conceptual model, variables from the remaining enlisted frameworks are also included as TAM and UTAUT2 have both been found to not account for perceived risk that, as pointed by [33], has a major impact on societal acceptance as "TAM combined with risk theory leads to a better model". Many studies considered here share the same findings [7], [23], [24], [26], [27]. This shows perceived risk is often used in conjunction with both TAM and DOI theories. Therefore, in this study, the perceived risk element and its subdimensions in the context of drone deliveries (privacy, performance, financial, physical) will be treated as part of the extended TAM to ease variable mapping to existing models. Multiple other extensions similar in nature that have been proven to have significant effects on acceptance are examined in the studies considered in this work. It was therefore decided that, since no one unified theory exists that explains delivery UAV acceptance fully, and factors seem to have different influence based on context (rural vs urban population [23]), a combination of multiple models deployed in practice can best explain civil acceptance of last-mile delivery drones and its variance. This study makes use of the most recent relevant to the topic works that reflect this.

Search Strategy. For this literature review, the scientific databases Scopus and Google Scholar were used. The search terms were based on the three constructs. Each one entailed multiple keywords to ensure a comprehensive overview of already conducted and assessed interventions in this area. These can be seen in Table 2. After applying the search terms, 153 results (n=153) were found.

Construct 1: Delivery Drones
'delivery drone*' OR 'delivery UAV*'

AND

Construct 3: Technology Acceptance Models
'TAM' OR 'UTAUT*'

AND

Construct 2: Technology Acceptance
'accept*' OR 'attitude*' OR 'adopt*' OR 'factor*' OR 'determinant*' OR ("technology acceptance" OR "public acceptance")

Figure 2. Construct Search Terms

Thereafter, multiple rounds of exclusion took place. Papers have only been included if they are written in the English language, relate to delivery UAV acceptance, they were published in the last 5 years (2017 – 2022) (the decision about this period lies in the fact that from 2016 on drone industry growth soared as the American Federal Aviation Administration (FAA) released a new act to allow for broader drone flying exemptions [34]), they develop their own conceptual model or draw on an existing one ((extended) TAM, UTAUT2, DOI or similar) by expanding it to fit the context of delivery drones, the sample size used is significant for the population tested, and they are peer-reviewed. The exclusion criteria (EC) are formally defined in Appendix B. After applying said criteria to the initial set of results and cross-matching Google Scholar and Scopus works, 22 papers (n=22) were pinpointed to be of relevance. The papers were read thoroughly, papers not written in English were excluded; the models they made use of were cross-matched, and studies that made used replicated models and factors were excluded. In the end, 9 studies were identified to match the criteria (n=9). To the knowledge of the author, the collection of these studies exhausts the existing work in the field that fits the enlisted requirements. Table 1 has been prepared to summarize these, by displaying author(s), year of publication, country, methodology use and sample size tested, model it was based on, and consumer acceptance factors proven to be significant (with the level of significance expressed as a $\boldsymbol{p}$-Value, $\boldsymbol{p}$-Value < 0.05).

Table 1. Studies Summary

Author	Year	Country	Significant Factors	Methodology	Model
C. Chen et al. [22]	2018	USA	Personal innovativeness; Perceived usefulness	Survey questionnaire (157)	TAM
W. Yoo et al. [23]	2018	USA	Perceived usefulness; Perceived risk (Performance, Privacy); Individual characteristics (Personal innovativeness)	Survey questionnaire (296)	TAM
M. Knobloch et al.[24]	2020	Germany	Perceived usefulness; Perceived risk (Financial, Physical); Social interaction	Survey questionnaire (211)	TAM
N. I. Jasim et al. [13]	2022	Malaysia	Perceived usefulness; Perceived ease of use; Social influence; Facilitating conditions; Trust; Hedonic motivation; Price sensitivity; Individual characteristics (Personal innovativeness)	Survey questionnaire (209)	UTAUT2
J. Hwang et al. [35]	2020	Korea	Consumer innovativeness (Novelty seeking, quality experience seeking, hedonic experience seeking, social distinctiveness)	Survey questionnaire (321)	TBP

J. A. Frazier [26]	2021	USA	Perceived usefulness, Perceived risk (Performance), Individual characteristics (Drone familiarity)	Survey questionnaire (1062), Interviews(10)	DOI
A. O. Mathew et al. [27]	2021	India	Consumer innovativeness (Functional, Cognitive), Perceived risk (Privacy), Green image	Survey questionnaire (310)	MCIS
C. N. Osakwe et al. [28]	2021	Czech Republic	Outcome expectancy; Lifestyle compatibility; Self-efficacy	Survey questionnaire (549)	MGB
K. Bogatzki et al. [25]	2017	Germany	Price sensitivity; Perceived usefulness; Hedonic motivation; Perceived ease of use	Survey questionnaire (556)	TAM

5. CONCEPTUAL MODEL

After conducting a systematic literature review and identifying all significant variables, the variable identification procedure is divided into the following stages:

Stage 1. Compile all identified variables: At Stage 1, all significant variables are combined. Result: 39 significant factors.
Stage 2. Combine overlapping variables: At Stage 2, all variables that are duplicates are combined. Result: 23 significant factors.
Stage 3. Combine similar variables in UTAUT 2 or TAM: At Stage 3, variables that result from other models but share the same or similar constructs in TAM or UTAUT 2 are combined in meaning. Result: 16 identified factors; Combinations displayed in Table 2.

Table 2. Variable Mapping

Variable	Study Reference	UTAUT2/TAM Constructs
Functional personal innovativeness	A. Mathew et al. [27]	Perceived usefulness
Quality experience seeking	J. Hwang et al. [35]	
Perceived usefulness	[13], [22]–[25]	
Cognitive personal innovativeness	A. Mathew et al. [27]	Perceived ease of use
Perceived ease of use	[13], [25]	
Complexity	J. A. Frazier [26]	
Outcome expectancy	K. Bogatzki et al. [25]	
Compatibility	C. Osakwe et al. [28]	Facilitating conditions
Price sensitivity	[13], [25]	Price value

The factors identified to influence the public acceptance of last-mile delivery drones are as follows: Perceived ease of use, Perceived usefulness, Perceived risk (multidimensional: financial, performance, physical, privacy), Hedonic motivation, Social influence, Price value, Facilitating conditions, Green image, Trust, Personal innovativeness, Drone familiarity, Social contact, Self-efficacy. Based on the results, a conceptual model for the factors affecting last-mile delivery drones' acceptance has been constructed and displayed in Appendix A. The variables have been color-coded to display their conceptual model of origin, grouped under TAM, extended TAM, UTAUT2 and Others.

6. SURVEY QUESTIONNAIRE

A survey questionnaire is constructed based on the conceptual model and is displayed in Appendix C. It serves to capture the participant's stance on the afore-identified acceptance factors. It is used twice – first pre-, and then post- the Drone Simulator experience provided to participants. Thus, here it is a matter of a repeated measure design wherein data is collected about the same variables with the same items for a matched subject pre- and post- the simulator intervention [20]. The process and materials have been approved by the Ethics Committee Computer & Information Science. For participants' convenience, it is held online using XM Qualtrics. Participant recruitment took place as to assure a sufficient sample size would partake in all three parts of the study including the physical drone simulation experience. For the first part of the questionnaire - demographic data collection, participants are asked to provide the following information: gender, age group, area of residence (urban, rural) (based on findings that delivery drone attitude factors differ based on area of residence [23]). To ensure accurate matching between pre- and post-simulator data, participants are also asked to enter a pseudonym of choice that they would then use in both survey phases so that progression in construct opinion can be tracked. The second part the survey consists of 34 questionnaire items in the form of statements. These are grouped under each construct as this format has been pointed out to best explain user acceptance while minimizing user confusion and annoyance [36]. This also allows for participants to follow a logical train of thought. In comparison to the conceptual model (16 constructs), the statements concern only 10 constructs (Perceived ease of use, perceived usefulness, perceived risk (financial, performance, physical, privacy), hedonic motivation, social influence, price value, facilitating conditions, green image, trust, opinion passing). Drone familiarity here is considered a personal characteristic, thus this data is collected only in the pre-intervention questionnaire and treated as a moderating factor. Furthermore, personal Innovativeness also classifies as a personal characteristic [35], and has thus been excluded from the pre- and post-questionnaire as it is beyond the scope of what this study measures. As self-efficacy's interpretation in the context of drone deliveries is 'the perceived ability to accomplish', the question items overlap with these of perceived Ease of Use and have been omitted, making it the third excluded construct. Perceived risk is treated as a single multidimensional construct.

Participants make use of a 5-Point Likert Scale (1 = "Strongly disagree" to 5 = "Strongly agree") to rate these statements as due to its simplicity, this scale has been shown to increase response rates and response quality, and to decrease frustration [37].

6.1 Participant Recruitment

For the first phase of the research – collecting people's (initial) stance on delivery drones with regards to the 10 identified constructs – the online survey instrument XM Qualtrics was used to distribute the survey questionnaire and collect responses. The survey instrument was first tested with three participants to ensure that the survey completion time communicated to respondents was accurate, and to identify any errors or points that lack clarity. Upon initial testing phase, information about the approximate survey completion time was shortened, and a field for a pseudonym of choice collection was added to allow for data matching with the post-simulator questionnaire responses. An info brochure and a consent form were included, both displayed and available for download. Participants were recruited using Social Media platforms (Facebook, Instagram, WhatsApp), word of mouth, and random selection and approaching.

Inclusion Criteria. English proficiency; from the age of 18 and above; from the area of or around Enschede or such that are willing to commit to travelling to the simulator experience location; not experienced with delivery drones and Zephyr Drone Flight simulator.

Participants. A total of 50 participants filled out the survey questionnaire; out of these, 37 agreed to continue their participation in the second and third phase of the research. After excluding incomplete questionnaires, or ones deemed unusable (through a 'Dummy question' exclusion), 31 participants were recruited to campus grounds to participate in the simulation phase (n=31). This is the complete number of participants used in this scientific research. One week had been allocated to the recruitment phase, as per planning. Out of 31 respondents, the majority (n=29) falls within the age group of 18 – 24. 26 participants (n=26) have indicated they reside in an urban area. There are 20 participants that identify as male, 10 female ones, and one 'Prefer not to say'. Among these, there were 3 respondents not familiar at all with drones, 18 slightly familiar, 8 moderately familiar, and 2 extremely familiar ones. Most of them (n=19) have had some contact with drones in the past 6 months. None of them had ever experienced the Drone Simulator of choice, nor had encountered delivery drones, which deemed them suitable for the next study phase.

7. DRONE SIMULATOR EXPERIENCE

After having collected participants' initial stance on delivery UAVs, approved candidates were recruited to Campus Grounds to participate in the Drone Simulator Experience phase of this research wherein they were asked to execute a set of tasks within the chosen simulator environment. After doing so, they had to fill out the questionnaire again using the same pseudonym as initially so the data could be matched with the first data collection point, and conclusions could be derived about the effects of drone simulators on consumer acceptance of drones. The process in detail is described in the following subsections. In-game screenshots of the simulator, and of the set-up can be found in Appendix D.

7.1 Instrumentation and Setting

Instrumentation. The simulator used was picked based on the following requirements: correct physics, progress tracking tool, Windows compatibility, compatibility with game console controllers (as a drone controller was not a resource available for this research), multiple modes of flying, regulation violation warnings (according FAA standards), customizable weather conditions, multiple scenarios, real-time feedback system, various drone models; After using independent reviews to compare 9 available simulators [38][39], Zephyr Drone Flight Simulator was chosen for this research. The controller used was a PlayStation 5 DualSense wireless controller (as the placement of the sticks best resembled this of the original controller). The scenario picked was 'Yard' as it offered a real-time feedback point system, and the setting and task list resembled a delivery scenario the closest (compared to other available maps: The Hill, Parking Lot). The map 'Yard' features a middle-sized home and other common obstacles such as a shed, a parked car, electricity cords, yard decorations, a fence and similar. The tasks to execute within the map are part of Zephyr's drone pilot education training program and offer built-in classroom management. They consist of the following objectives: hover over the house; hover over the hot tub for 5 seconds; fly counterclockwise around the property passing through all of the 4 objectives; make a quick loop in front of the house passing through all of the 3 objectives; look at the car; land The pre-defined task list was chosen as it eases tracking and provides in-game instructions, along with visuals that clearly indicate what the participant should do, making it very beginner-friendly. The drone simulator used is a 'Titan', an industrial-purposed drone developed by Motion Robotics, that has a payload delivery ability of up to 5 kg, and a tolerant mounting mechanism for a safe and secure package mounting [40]. Participants' performance is logged by tracking task completion time, crashes, resets, speed, altitude, and altitude- and line-of-sight violations. Metrics are displayed to the participant in a report post mission completion.

Setting. Participants were sat down, the simulator was started for them on the researcher's device (laptop), they were given a controller, received instructions, and positioned the controller sticks in a way that they could lift off. After exploring the map freely, they were requested to execute the tasks displayed in-game. The participants had the opportunity to rest, follow the task list in an arbitrary order, or choose to not complete the full task list so feelings of drowsiness, frustration, and of boredom could be reduced/avoided. At the end of the simulator phase (when completing the task list, or upon request of the participant), they were asked to fill out the questionnaire again.

7.2 Post-simulator Data Analysis

Post-completion of all three phases of the study, the survey questionnaire results were captured and analyzed. The survey made use of a 5-Likert scale whose labels range from "Strongly disagree" to "Strongly agree". To each such category, a number was assigned ranging from -2 (Strongly Disagree) to +2 (Strongly Agree). The answers were collected and analyzed with non-parametric inferential statistics. The choice of a non-parametric test is because of the use of a Likert scale for collecting data, as "the initial analysis of Likert scalar data should not involve parametric statistics but should rely on the ordinal nature of the data" [41]. Because Likert scales are considered ordinal (and not interval), the mean average and other parameters required for a parametric test cannot be calculated. Among the non-parametric tests, the most indicated ones are the Wilcoxon Signed-rank test and the Kolmogorov-Smirnov Z test. While the former test checks for significant differences in the centrality (based on ranks and median), the latter checks for significant differences in the shape of the distribution of the ranks on both samples being compared. The latter – the Kolmogorov-Smirnov test – was chosen because it is sensitive to any change in the shape and the polarity the research checks for does not need to be specified (although a two-tailed Wilcoxon signed-rank test could also be used here). Furthermore, the Kolmogorov-Smirnov test “is distribution-free because the procedure does not depend upon which distribution is completely specified under H0” [42].

The goal of the analysis is to show for each acceptance construct whether a significant change is to be observed in the shape of the histograms when comparing answers given before and after the simulation (level of significance expressed as a ***p***-Value, ***p***-Value < 0.05). Based on convention, the alpha value **α** was determined to be 5% (0.05), meaning the alternative hypothesis (The drone simulator experience has a significant influence on participants’ acceptance) will be rejected if the p-value is not lesser than 0.05. The results of all the inferential tests are listed in Table 3.

Perceived Ease of Use. Perceived Ease of Use (PEOU) is defined as a person’s subjective belief about the “degree to which they can use a particular system free of effort” [43], one of the central constructs of TAM. Here it is reasonable to expect that, after training participants with the simulator, their perception of this construct will change as experience has been pointed out to be a top predictor of PEOU [44]. Most respondents (n=29) did not have any prior drone experience, thus their stance on PEOU changed significantly. The level of clarity on how to interact with delivery drones increased for all participants (48.39% somewhat agree). However, for most of them the perception of how easy it is to receive packages, and how intuitive it is to use the service, sunk (-25%). This is because with an increase in knowledge of how drones operate, users also get a better grasp of how complex the technology behind them is, making their post-simulator stance more accurate than before.

Perceived Usefulness. A central construct of TAM, Perceived Usefulness (PU) is a user’s subjective belief about the “ability to use particular technology to enhance their job performance” [43], and is considered a main driver for intention to adopt. Participants were asked to what extent they agree with delivery UAVs’ effectiveness and efficiency. By making use of the drone simulator, users could only judge the drone’s speed, yet it did not provide any grounds for comparison with other delivery services in terms of effectiveness. Significant changes in stance were thus not expected. As results show, this is indeed the case as users’ pre-simulator opinion remained stable. A slight non-significant positive change was observed regarding “Delivery drone services are likely to shorten delivery time.” (+16%).

Hedonic Motivation. Hedonic Motivation is defined as “the fun or pleasure derived from using a technology”[45]. This work assumes that, because participants that recognize the pleasure in using delivery drone services would be more open-minded towards UAVs [46] using the simulator as a form of a gamified learning experience would prove to be beneficial. However, as observed during the simulation experience itself, users often got frustrated with fulfilling the given tasks and preliminary gave up on completing them, even though elaborate guidance was provided to them. This made the experience less enjoyable and caused annoyance. The simulator did not influence their stance significantly, with slight negative changes observed on “Using delivery drone services is likely to give me a sense of personal enjoyment.” This confirms other findings that “frustration may occur if the participant is unfamiliar with the technology, negatively impacting performance while using VR” [47], which makes this method not suitable for targeting this construct.

Social Influence. Social Influence means that the consumer gets a feeling that they are projecting a specific image when using technology. In this context, past findings point to people interpreting the meaning of a delivery drone and drawing conclusions about the people using them [48]. This study assumes people would feel that using delivery drone services, a novice technology would enhance their social status, increasing acceptance. However, a drone simulator would not have a significant impact on this aspect as it does not put the user in a social setting. Indeed, only the sense of being distinguished when using the service had increased slightly (+13%), the rest remains stable at “Somewhat agree”.

Price Value. The price value construct relates to the monetary aspects of the technology. However, delivery UAVs are in their development stage and are yet to demonstrate their benefits and how those relate to their price [49], this construct therefore more so tests price sensitivity. It is not yet clear what the price of such a service would be, and how it would compare to other methods. This work assumes that some changes in opinion might occur, yet they will not be significant as participants do not receive price information, and a simulator merely demonstrates the benefits a delivery UAV brings, thus cannot justify the future price. This was indeed the case, as both pre- and post the simulator, participants remained largely negative (50% completely disagree with paying a higher price to use the

Table 3. Post-Simulator Results

Ease of Use			Usefulness			Hedonic motivation			Social influence			Price value			Facilitating conditions		
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
0,00004	0,04231	0,04536	0,98681	0,13811	0,96636	0,57218	0,68323	0,80959	0,92321	0,95483	0,45972	0,96550	0,23485	0,90043	0,98761	1,00000	0,57358
Relevant			Not relevant			Not relevant			Not relevant			Not relevant			Not relevant		

Green image			Opinion passing			Trust		Financial		Performance		Physical		Privacy		Construct
Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Question Item
0,97617	0,77628	0,39136	0,62979	0,22484	0,85330	0,42658	0,67110	0,82967	0,81925	0,36071	0,08679	0,46352	0,64552	0,81339	0,97657	p-value
Not relevant			Not relevant			Not relevant		Not relevant		Not relevant		Not relevant		Not relevant		Relevance

service). This might also be due to the age group and status of participants as they are mostly students of the age 25 or younger.

Facilitating Conditions. Facilitating conditions stands for “consumers' perceptions of the resources and support available to perform a behavior” [50]. This entails available technology, peer/societal support, prior knowledge, access to knowledge, acquired skills. The study assumes some changes in users’ perception as the simulator and the training modules it offers demonstrate available community support participants might not have been aware of before. Although observed changes are not significant, users do now feel like it is more likely that they could get help from others in using the service (+10%).

Green Image. Under Green Image is “consumers’ perceptions of a brand that is solely linked to environmental commitment and environmental concerns”[51]. As concerns about the environment grow, so does the likeliness of consumers opting for using a product or service known for its environmental friendliness. As the technology is not yet deployed, study results display users as uncertain about their stance on delivery UAVs’ green image. Post-simulator no changes in opinion are observed as the simulator itself is not capable of demonstrating how it could mitigate environmental concerns, only how it functions.

Opinion Passing. Opinion Passing means sharing content with others after having experienced and identified benefits for oneself post using a certain product. As previous research shows, it is related to the personal characteristic Personal Innovativeness, and plays a role of an important social influence aspect when innovative users influence less innovative ones to try out a new product or service [52]. Participants’ opinion remains stable on this aspect, with most respondents being unsure whether they would pass this information down to peers and colleagues. As this work does not capture whether participants carry this innovative character trait, and the sample surveyed is relatively small, it cannot be concluded whether not wanting to recommend the service to others is due to personal characteristics, or for other reasons related to the service itself.

Trust. Under Trust, it is understood “the degree to which consumers generally trust a particular technology system”[53]. This study asks whether participants have concerns about the delivery UAV technology and whether they find it frightening. Responses, although not fully unified, show that people do lack trust in the service for the most part (48%). Post-simulator the study assumed that opinions would be somewhat influenced as the demonstration could potentially increase knowledge and decrease some concerns. Contrary to that, opinions stayed negative, with fear of the technology increasing slightly (+5%). Studies show that perceived trust directly correlates to levels of familiarity with the technology [54] and this work supports this claim as participants were largely unfamiliar with drones. A mix of interventions, information provision and demonstrations would most likely result in a more dramatic increase in familiarity than what the current simulator provides.

Perceived Risk. Perceived Risk is defined as the “potential for loss in the pursuit of a desired outcome of using an service” [55], and for the purpose of this study is viewed as a multidimensional construct consisting of Financial, Performance, Physical, Privacy risk. As delivery UAVs are a novice technology, higher levels of uncertainty about existing risks are possible. This work assumes changes in opinion will occur as the simulator will better demonstrate what drones are capable of. This will either confirm existing opinions, or mitigate risks as previous work points that some knowledge may raise risk awareness, but with an increase in knowledge and experience, these risks may dissipate [56]. High levels of uncertainty were observed about all enlisted risks.

Financial. This entails a fear that an investment in the service might not pay off. Participants agree with that, as 55% support the related statements (+15%). Although the change is not significant, the simulator demonstration has helped confirm people’s stance, moving it from ‘Neither agree nor disagree’ to ‘Somewhat agree’. This originates from the high level of uncertainty about the future price of this service, and the work predicts such perceived risk will remain until actual deployment.

Performance. This risk aspect reflects the concern of the drone performing lesser than other delivery alternatives and losing the delivered parcel or damaging it. Pre-simulator most respondents were uncertain. After getting a better feel of the scanning mechanisms drones use to locate the end-delivery point, a +40% increase was observed in the amount of users that found drones to be just as likely, or even more reliable, to deliver the package to the right address. However, a non-significant change (+17%) in the likeliness of the drone damaging the package also appeared. This might be due to some users experiencing difficulties with landing the drone simulator properly, making them biased towards safety.

Physical. This aspect relates to concerns about consumer health or the health of other human beings or animals [57]. As this fear stems mainly from the possibility of the drone crashing and causing substantial damage to its surroundings, and the simulator did provide real-time crashing demonstrations when users got too close to objects and buildings, this has resulted in a slight increase (+10%) in their perception of damage likeliness.

Privacy. This stems from users fearing a drone might enter their private property, or that excessive data might be collected for the drone to fulfill the delivery. Post-simulator, a slight increase (+10%) is to be observed in people that felt their privacy may be threatened (42%). The fear of needing to share more data to receive the package has slightly been mitigated (-5%). Overall, respondents do have privacy concerns, inconsistent with previous work that shows privacy to be an issue mostly to rural residents [23], which is seemingly not the case with Enschede.

8. CONCLUSION AND FUTURE WORK

This research was conducted to address the both theoretically and managerially important knowledge gap with regards to quantifying definitive methods to evaluate and ensure civil drone acceptance. The aim was to build a better understanding of how last-mile delivery drone acceptance can be assessed, and to measure the effectiveness of one means to raise this acceptance – training potential users with a drone simulator.

For the time-being, the research showed that the most important difference post the simulator experience was in Perceived Ease of Use. While the simulator experience increased participants’ perceived knowledge about the technology, with this increase in knowledge their perception of the actual ease of use dropped notably. Performance risk in terms of delivery precision was mitigated as, after experiencing the simulator, users felt delivery drones to be more reliable than other means of transport in finding the right address of delivery. On the other hand, the simulator had slightly negative effects on the remaining risks, also confirming to users that delivery drone services do not seem to be a worthwhile investment in their current state of drone technology development, and they would certainly not be willing to pay more for it. This is inconsistent with findings of other studies that show customers are willing to pay more to use the new technology [13], but does find support in multiple works where experienced drone users were a little more concerned than non-drone users [15] (as respondents gained experience, their concerns increased). Further than that, the simulation did not render significant changes on participants' acceptance beyond the Perceived Ease of Use construct, rather only helped respondents that were unsure in their opinion beforehand ('Somewhat agree', 'Somewhat disagree', 'Neither agree nor disagree') to reaffirm their pre-existing beliefs and resulted in them having a stronger opinion in the same direction.

In light of these results, it seems that training potential users with drone simulators does increase their familiarity with the technology along with their self-reported knowledge on the topic but, as a stand-alone method, does not suffice to increase public acceptance of delivery drones. This is supported by other studies that show knowledge self-assessments to be superficial as even though such methods do increase familiarity, this does not necessarily give potential users the technical knowledge necessary to offer a grounded opinion on the risks and benefits drones offer [58]. As building drone knowledge and subsequently acceptance is a non-linear process [56], "a combination of statistical data and emotional persuasions" is the best engagement tactic to channel positive attitudes towards UAVs [59]. Therefore, this study suggests that using only a drone simulator to achieve a significant increase in acceptance seems to only affect a limited number of constructs. To address the issue at scale, a broader range of innovative approaches needs to be deployed (information campaigns, demonstrations, media attention, and field studies), as increased knowledge does not per se imply increased acceptance.

Future work may include an extended effort to develop a comprehensive list of mitigation methods that, in combination with each other, can ease drone adoption. While the use of a simulator offers a chance for users to experience delivery drone functionalities, it comes with the limitations that a virtual environment poses, e.g., the lack of harm or consequences when crashing the drone, or the pre-set weather conditions. Simulators can enhance training and adoption, but the way the technology is introduced to potential users may impact their attitude towards it. For more precise results, users should first be familiarized with the simulation software so their level of confidence when using it can be higher, and they can explore the environment and the drone's capabilities more freely.

Another limitation of this work is the small and homogenous sample size, i.e., consisting only of university students of the age of 25 or under. A bigger more diverse group can support some claims made in this work, and undermine others.

Nevertheless, the methodology described here allows for replication, and other researchers can validate the model and survey instrument used and extend and/or adapt their use to multiple other use-case scenarios, virtual environment variations, and to the adoption process of (less) immersive technologies. This is a foundation upon which future work can build and pave the way to successful drone deployment in the logistics sector. The process requires not only an understanding of acceptance factors, and an increase in end-users' awareness, but should also involve potential end-users in the decision process in an engaging manner so that delivery UAVs can be put in the service of community empowerment in smart cities of the future.

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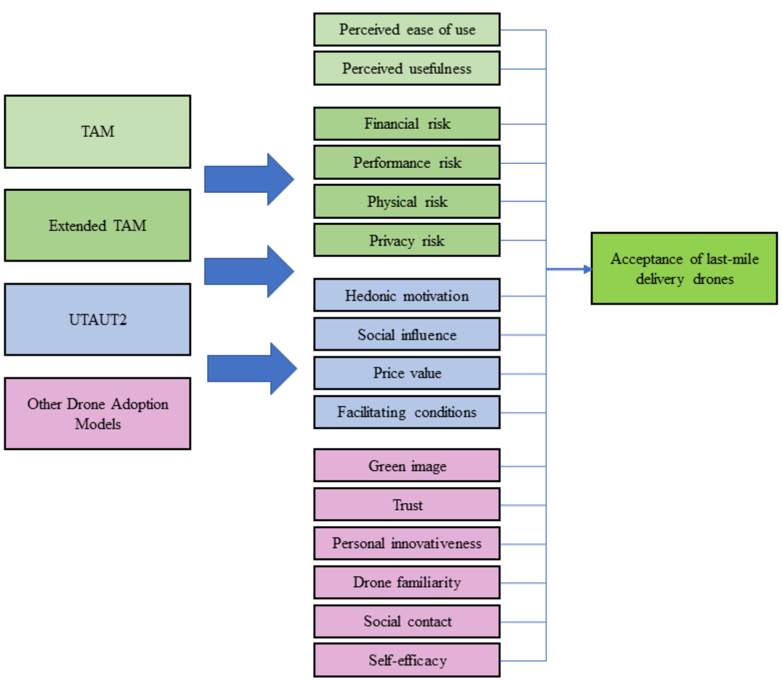
APPENDIX A

Figure 3. Conceptual Model



APPENDIX B

Figure 4. Paper Exclusion Criteria

Research Paper Exclusion Criteria
EC1 The paper is a duplicate
EC2 The paper is not available for free access/access through educational institution University of Twente/requested access
EC3 The paper is not peer-reviewed
EC4 The paper is not offered in the English language
EC5 The paper is not focused on delivery UAVs
EC6 The paper is not based on a verified Technology Acceptance Model or does not develop their own model and then verifies it
EC7 The paper does not include experimental research
EC8 The sample size used is not significant in proportion to the population it draws conclusions about
EC9 The paper is older than 5 years

APPENDIX C

QUESTIONNAIREB ITEMS AND SOURCES

Perceived Ease of Use [26]**:**
It is clear to me how to interact with delivery drones.
I believe receiving packages via drone delivery would be easy.
Overall, I believe that a drone delivery service would be easy to use.

Perceived usefulness [25]
Using delivery drone services to receive parcels would increase my productivity.
Delivery drone services are likely to shorten delivery time.
Delivery drones would deliver parcels more effectively.

Hedonic Motivation [25]
Using delivery drone services would be fun.
Using delivery drone services is likely to give me a sense of personal enjoyment.
Using delivery drone services would be entertaining.

Social Influence [27]
Showing that I use delivery drone services could impress others.
Using delivery drone services would show that I am an early adopter.
Using delivery drone services could distinguish me from others.

Price Value [25]
If drone delivery was likely to be more expensive than conventional delivery options, that would not matter to me.
I would not mind spending a lot of money for getting my orders delivered by drones.
I am likely to spend extra to try out drones as a delivery option.

Facilitating conditions [23]
I feel receiving my parcel via drone delivery services would fit into my lifestyle.
Delivery drones are compatible with other technologies I use.
I could get help from others when I have difficulties using delivery drone services.

Green Image [27]
By using drone delivery services, I can demonstrate that I care about environmental conservation.
Drone delivery services are likely to be successful in environmental protection.
Drone delivery services are likely to become well-established in environmental concerns.

Opinion Passing [29]
I am likely to have positive things to say about drone delivery services.
I am likely to recommend drone delivery services to others.
I am likely to encourage others to use drone delivery services.

Trust [29]
I generally have concerns about using delivery drones.
Delivery drones are somewhat frightening to me.

Perceived risk [24]
Financial Risk
I am concerned that an investment in drone delivery services would not pay off.
I am concerned that potential extra costs for drone delivery services are not worth it.
Performance Risk
Delivery drones may be more likely to delivery my package to the wrong address when compared to other delivery methods.
Delivery drones are likely to malfunction and damage the package they are carrying.
Physical Risk
I am concerned that my delivery drone services usage could injure my neighbors, housemates, or pets physically.
I am concerned that a drone could injure me during the unloading process.
Privacy Risk
I am concerned that delivery drones could threaten my privacy.
I am concerned that I have to share more data to use drone delivery services.

APPENDIX D

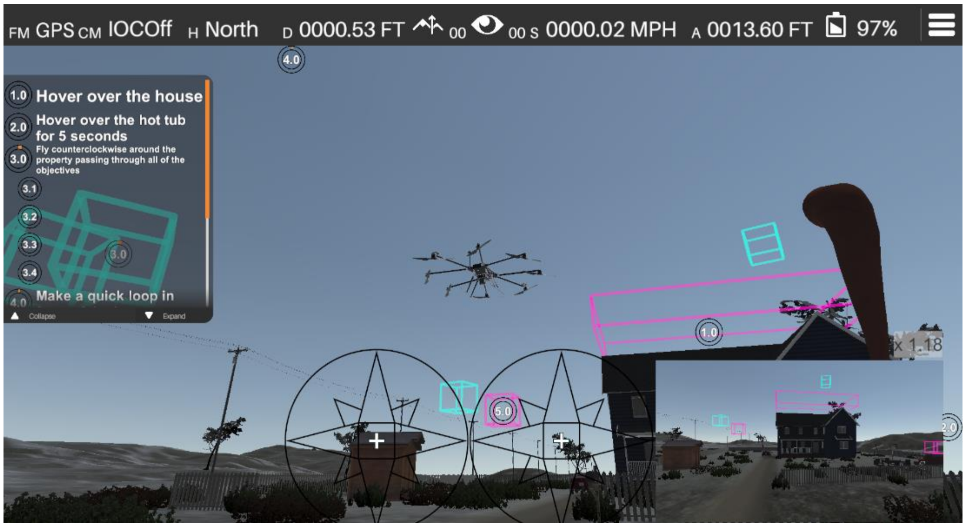


Figure 5. “Titan Drone in 'Yard' map”. Zephyr Drone Flight Simulator, 2022. Author’s screenshot.

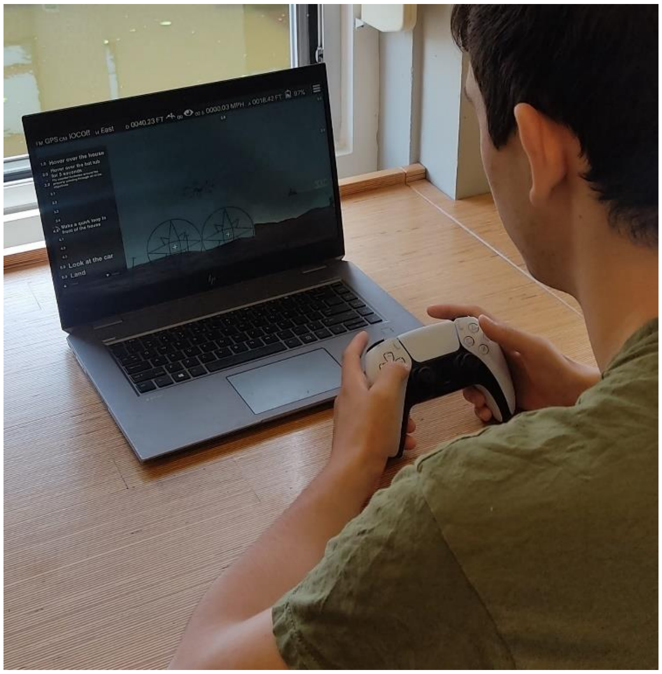


Figure 6. "Participant trying out the simulator". Zephyr Drone Flight Simulator, 2022. Author's picture.