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The User Acceptance of Autonomous Shuttles in Pretoria

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***Abstract*—**Autonomous vehicles look set to drastically alter the way we move people and goods, in urban as well as rural areas. However, little has been written about Africa with this regard. Moreover, in order for this new technology to be adopted, user acceptance is vital. The current research examines the user acceptance of autonomous minibus shuttles, as a solution for first/last mile public transport in Pretoria, South Africa. Of the respondents surveyed, only 2.31% perceived them as not useful. Respondents showed more interest in using these shuttles in combination with the bus rapid transit system (75.4%) as opposed to other modes of public transportation (40%). The significance of these findings is that they can help ensure that the implementation of autonomous public transport in South Africa is adapted to the local user. Furthermore, these findings could be adapted for other South African cities and other cities across the continent.

***Keywords*—**Autonomous buses and shuttles, autonomous public transport, urban mobility, user acceptance.

I. Introduction

AUTONOMOUS vehicles (AVs) look set to drastically alter the way we move people and goods, in urban as well as rural areas [1]. Current trends predict that AVs will account for up to 40% of distances covered in Europe by 2030 [2]. Interestingly, the trajectory these developments will take in Africa, the world's third largest continent, has received limited coverage. Having said this, AVs cannot operate in a silo. A primary prerequisite for their success will be their acceptance by end-users [3]. As such, it is important to not only investigate user acceptance (UA), but to do so at an early stage, preferably before they are rolled out [4].

Many studies have been performed on the potential of automated shuttles (ABs) as public transportation in European countries notably in Germany [5], Norway [6], Switzerland [7] and France [7]. Despite its importance, little research is available on UA and the implementation of these shuttles in public transportation in the context of African countries. As Africa's most industrialized economy, it is plausible that the roll out of automated shuttles in Africa will start in South Africa, before moving on towards the rest of the continent. As such, it is vital to understand UA and the factors that influence it in South African cities.

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II. User Acceptance

UA is founded on the use of socio-psychological models, in particular the Theory of Reasoned Action (TRA) to predict human behavior [8]. The TRA also laid the foundations for subsequent models such as the Technology Acceptance Model (TAM) [9], [10] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [11]. Previous research has shown that in the context of ABs, UA depends on factors including the performance expectancy (perceived usefulness) [7], [12] and effort expectancy (perceived ease of use) [7], [12], with perceived usefulness being of most significance [12] and both factors accounted for in the TAM and UTAUT. Moreover, UA has been shown to be nationality as well as culture dependent [13], [14], with residents of lower income countries being more open and accepting to AVs than their higher income counterparts [4]. The UA for ABs reported in previous studies in Germany and Norway (all considered high-income countries) can be seen in Table I. To this end, the current research aims at determining Pretoria users' evaluation or perception ABs.

TABLE I
UA of Autonomous Buses Reported in Previous Studies

Country	Research Question
Germany	UA of AB is influenced by previous experience of AVs [5]. 77.6% of respondents can imagine using ABs.
Norway	71.8% of respondents from the Norwegian Automotive Association surveyed (to evaluate the probability of respondents switching over to public transport due to ABs) did not evaluate ABs as useful [6].
Germany	85% behavioral intention of respondents with a high willingness to use the shuttles in public transport [12].

III. Methodology

A. Approach

The main objective of this study is to determine the UA of autonomous shuttles in Pretoria, and determine whether the provision of these shuttles can improve the usage behavior of available formal public transport and the BRT system. A summary of the research questions can be seen in Table II. These research questions will be addressed using a survey. The proposed survey is an adaptation of a survey obtained from literature in [6]. This approach ensures that:

1) All items in the survey have been successfully applied to similar research on UA to avoid issues related to validity (how well the collected data covers the actual area of

investigation [15]) and reliability (repeatability [15]), and
2) The process enables direct comparison with other studies conducted in the literature.

TABLE II
RESEARCH QUESTIONS

Reference	Research Question
RQ1	What is the current level of UA to autonomous buses in Pretoria? How does this acceptance compare to other countries e.g., Germany or Norway and can this comparison be used to predict user behavior during future implementation?
RQ2	Can the current ongoing roll out of BRT buses in Pretoria be combined with automated shuttles? What level of UA will this receive? Can automated shuttles be used to solve the current interconnectivity issues i.e., driving users from home or work to public transport nodes?
RQ3	Will the use of autonomous buses encourage current private car users to start using public transport?
RQ4	Would users anticipate that they would feel safe (especially against crime) in an automated shuttle? Do users perceive this solution as safe?

B. Adaptation of Items

To ensure the appropriateness of the proposed questionnaire, items have been adapted in the following way:
1) Questions relating to public transport modes have been adapted to correspond to the public transport modes available in Pretoria and South Africa. An example of this is question 17, where tram station and subway station have been replaced by minibus taxi collection point, BRT stop and Gautrain station.
2) The demographic measures have been adapted to the South African 2011 census questionnaire format [16]. As an example, income classification in question 27 corresponds to the income classification from the South African national census of 2011. Another example is the population group classification data in question 32, which was included due to the importance of demographic statistics in South Africa.

A summary of how the research questions and items in [6] have been adapted to answer the research questions from this study can be seen in Table III.

TABLE III
ANALYSIS OF THE QUESTIONS ADDRESSED BY THE SURVEY

Initial Research Questions from [6]	Survey Question Number	Current Research Question
Do respondents perceive the shuttles as useful?	Q5 – Q7 & Q14 – Q22	RQ1
Do individuals intend to use the BRT system and other public transport modes more often if shuttles provide better access to it? **	Q5 – Q8 & Q14 – Q22	RQ1, RQ2, RQ3
What kind of benefits do individuals expect from driverless shuttles?	Q5, Q6, Q10	For comparison
Are individuals willing to see more automation in the future?	Q11	For comparison
Do individuals perceive the shuttles as a safe and secure transport mode?	Q10, Q11, Q12	RQ4
Do the individuals trust the ability of the authorities to reduce the accident risks with driverless shuttles?	Q10, Q11, Q13	RQ4

** adapted to incorporate the different public transport modes in this study

C. Additions Based on South African Context

The impact of protest action in South Africa is substantial. Protest action by operators of public transport often causes great disruptions to the economy because users do not have many alternative transport modes. Moreover, previous experience from the implementation of e-hailing services in South Africa shows that there is often a great deal of resistance including threats of violence (from established role-players) against new players entering the public transport market [17]. However, as was the case with Uber, users in South Africa have shown interest in using new transport services in spite of this resistance. Question 6 of the survey aims to address the context-specific questions of:
1) Users' intention to use autonomous minibuses during protest action by the operators of other public transport modes, and
2) Whether the objection of other role-players (for example owners of other modes of public transport, other commuter) will have any impact on the users' intention of usage.

Furthermore, users may also feel that automated shuttles may serve as an alternative to existing public transport modes due to inherent existing inefficiencies. Where the perceived usefulness of ABs is ascertained in Q7, users are also given the option of ABs as an alternative to existing public transport.

D. Survey Set-Up and Procedure

The questionnaire consisted of three parts as was the case in [5]. The first part contained an introductory text as well as a question that checked if the potential participant was a resident or had resided in Pretoria in the past (only participants who live or had lived in Pretoria were allowed to participate). This was followed by the section on autonomous shuttles. A small description of driverless shuttles together with a short video of their application, which helped the respondents visualize these shuttles as was proposed in [18] and implemented in [19]. Part 2 looked to ascertain the respondents' perceived usefulness of the driverless shuttles together with their intention of usage (and acceptance). In part 3, questions related to transport modes and the respondent's current proximity to public transport in residential areas and places of work/study were posed. At the end of the survey, the respondents were required to enter their demographic data.

The survey was made available online to respondents via [20] between 9 June 2020 and 5 July 2020. Respondents could access the survey on their computers as well as smart phones. It was distributed to potential participants via social media (Facebook), cell phone messages on WhatsApp, and through emails.

E. Sample

The sample was comprised of 135 completed surveys and 58 uncompleted surveys, with a completion rate of 69.9%. A possible explanation for the low completion rate could be linked to feedback received from a respondent:

> "I accidently closed the survey window after viewing the video. I was then unable to retake the survey as my responses had already been saved as incomplete."

However, no official data have been obtained to determine

the number of respondents that encountered similar issues.

The survey was shared via the survey link (104 with 40 incomplete), mailing (17 with 8 incomplete) and social media (13 with 10 incomplete). The results and analyses have been added in Sections IV and V.

F. Limitations of Study

Inherent to the limitations of the current study is the small sample size as well as the fact that it is not representative of the target population. Respondents took part in the survey on a voluntary basis. Because of this, ensuring representativity was always going to be a tough ask, as not all residents are willing to give up their time on a voluntary basis. Naturally, it is also clear that not all residents in Pretoria have access to social media or smart phones.

Lastly, the data for this study were collected during a period when the world was experiencing the global COVID-19 epidemic. As such, there is a possibility that the results may have been influenced by the experiences the respondents were living through at the time. Nevertheless, the data collected as part of this study serve as a good benchmark towards the implementation of autonomous shuttles in Pretoria and in South Africa.

IV. Results

A. Sample Description

The sample was made up of 135 respondents. Of the responses received, 66.7% came from participants who live in Pretoria (n = 90). The rest of the sample was made up of people who have lived in Pretoria in the past (29.6%, n = 40) and people who had never lived in Pretoria (3.7%, n = 5). Respondents that had never lived in Pretoria were directed straight to the end of the survey, and informed that only respondents who had lived in Pretoria could take part. Respondents were generally young (M = 29.35, SD = 8.87).

The average distance travelled from home to workplaces/ places of study was reported by respondents to be 16.28 km (M = 17.84, SD = 20.37, median = 10). The average door to door travel time from home to workplaces/places of study was 26.30 minutes (M = 26.30, SD = 22.07, median = 20). This is substantially lower than the average across all modes of transport reported by the City of Tshwane (CoT) in 2014 of 69.5 minutes in [21], indicating the sample generally lives closer to their places of work/study than the population. However, the high SD for the sample in both cases is indicative of the high degree of variation between respondents with many respondents tending to travel longer distances (left skewed, median = 10 and 20).

The most accessible modes of public transport by foot (shorter travel time) from home on the way to the places of work/study were buses (n = 95, M = 8.87, SD = 7.45, median = 5) and minibus taxis (n = 70, M = 9.79, SD = 8.61, median = 8), respectively. Minibus taxis and buses were also the most accessible modes of public transport when travelling from work/places of study homewards (n = 77, M = 9.71, SD = 9.56, median = 6) and (n = 59, M = 9.69, SD = 8.81, median = 6), respectively. The generally high SDs show the high variation in travel times with travel times tending to be higher (left skewed and the mean is greater than median). This further confirms the potential for ABs to reduce travel times for first and last mile trips. Generally, most of the respondents were car owners (66.2%, n = 86), with 66.9% being in possession of a driver's license. This is substantially higher than the 42,7% driver's license ownership reported for the CoT in 2014 in [21].

The most used modes of transport over the past year for the sample was a car either as a passenger or as a driver with 46.9% and 33.1% respectively. This is higher than the 42.2% and 5.8% reported for the CoT in 2014 in [21]. Additionally, 20.7% of the respondents used mini-bus taxies often or very often (n = 27), and most respondents indicated that they had never used the BRT system over the past year (83.8%, n = 109).

The sample data were over-represented with 72.3% of respondents working (part-time or fulltime). This percentage is substantially higher than the 23.6% reported in [21].

B. Automated Minibuses Perceived Usefulness

The question of where the respondents felt automated minibuses would be most useful to them was posed. The results for the respondents' perceived usefulness of ABs can be seen in Fig. 1. Respondents rated ABs the most useful as an alternative to current public transport modes (43.31%, n = 55). This was followed in second place by the option of usage between residential areas and other public transport nodes (other than BRT stations) with 34.62% (n = 45), and between residential areas and BRT stations with 27.69% (n = 36). The perceived usefulness for other operational modes tended toward 20%. The exception to this were the options "between schools and Gautrain bus stops" (n = 1) and "between big conference and accommodation facilities" (n = 1), that were provided additionally by respondents. Interestingly, only 2.31% of respondents saw no usefulness in ABs, indicating a general perception of usefulness by the users.

C. Intention to Use Public Transport More Due to Automated Minibus Services

The respondents were asked about their likelihood of using the BRT system as well as other public transport modes more, if the requirements were met for ABs to operate "between public transport nodes (including BRT stations), and parking places, workplaces, and residential areas". These results can be seen in Fig. 2.

Of the respondents that completed the survey, 75.4% reported that they would be either "likely" or "very likely" to use the BRT system more (n = 98). This figure contrasts substantially with the 40% that intended to use other modes of public transportation more (n = 52). This showed a substantial preference towards using the BRT system more.

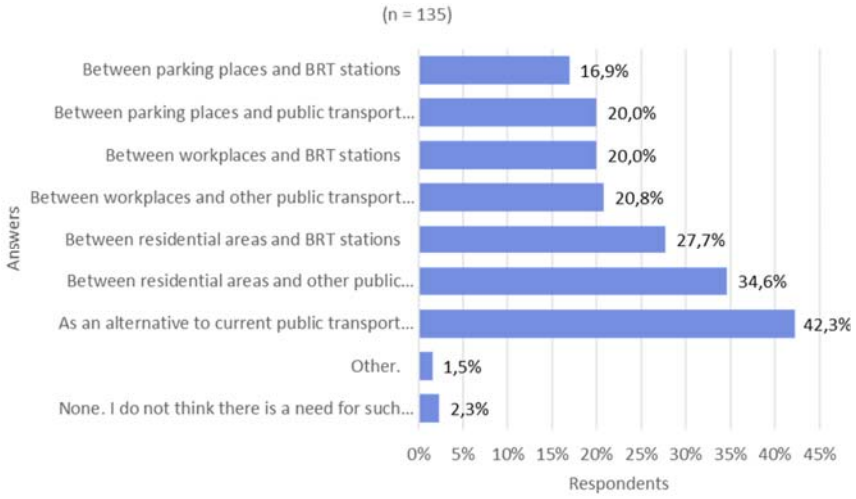

Fig. 1 Q7 - Where do you think automated minibuses would be most useful to you?

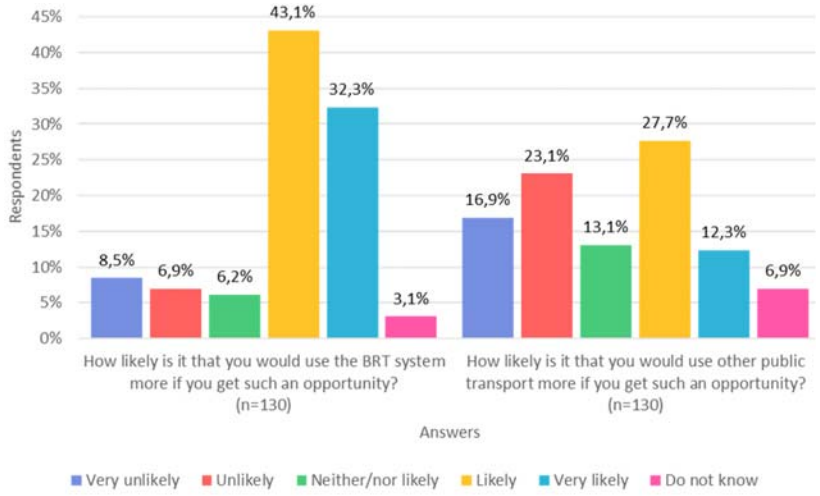

Fig. 2 Q8 - Intention to use Public Transport more due to Automated Minibus Services

D. Intention to Use during Protest and Despite Local Resistance

The respondents were asked about their intention to use ABs during protest action by the operators of other public transport modes, and despite objections from owners or operators of other public transport modes. The results for the respondents' intention to use the ABs under these specific conditions can be seen in Fig. 3.

Of the respondents that completed the survey, only 36.2% conveyed an intention to be either "likely" or "very likely" to use the ABs during protest action (n = 47). Similarly, 29.23% of the respondents purported to intend to use ABs despite the objection of the owners or operators of other public transport modes (n = 38). These values are generally lower than the intention to use more the modes in Subsection *C*. This indicates a possible reluctance to use ABs if general consensus is not reached with existing stakeholders or as an alternative during protests.

E. Acceptable Extent of Automation in Buses

Respondents were then asked about the extent to which they felt traditional buses should be automated in the future. The results can be seen in Fig. 4. The preferred extent by the majority of respondents was automated buses with a driver to "take over if he/she wants to or if necessary" with 39.23% (n = 51). Second was having automated buses that "only drive in their own lanes" with 23.08% (n = 30). Third was the no automation option where "buses should still have drivers" with 20% (n = 26).

F. Worries Linked to Automated Minibuses

The respondents were asked about their anticipated increase or decrease in worries when potentially driving in an automated minibus in comparison to a traditional bus with a driver. For the results, please refer to Fig. 5.

Around a third of the respondents reported that their worries relative to traffic safety accidents remained the same (30%, n = 39). The respondents that reported that they would either be "less" or "much less" worried about traffic safety accidents represented 39.2% of the respondents (n = 51). Respondents that reported to be either "more" or "much more" worried represented 23.9% (n = 31). Unsure respondents represented

6.9% (n = 9).

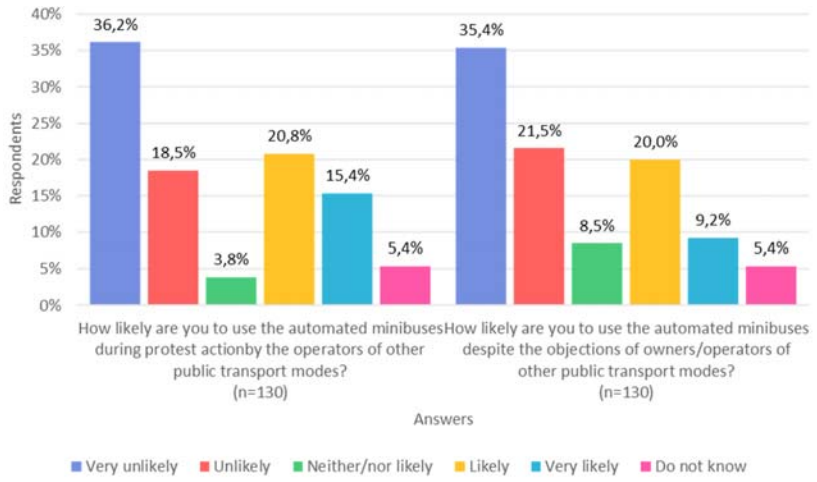

Fig. 3 Q9 - Intention to Use during Protest and Despite Local Resistance

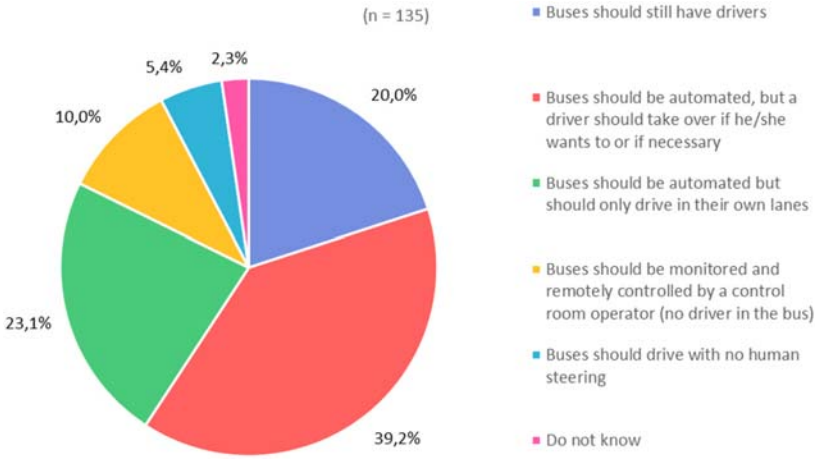

Fig. 4 Q11 – Extent of automation acceptable in traditional buses

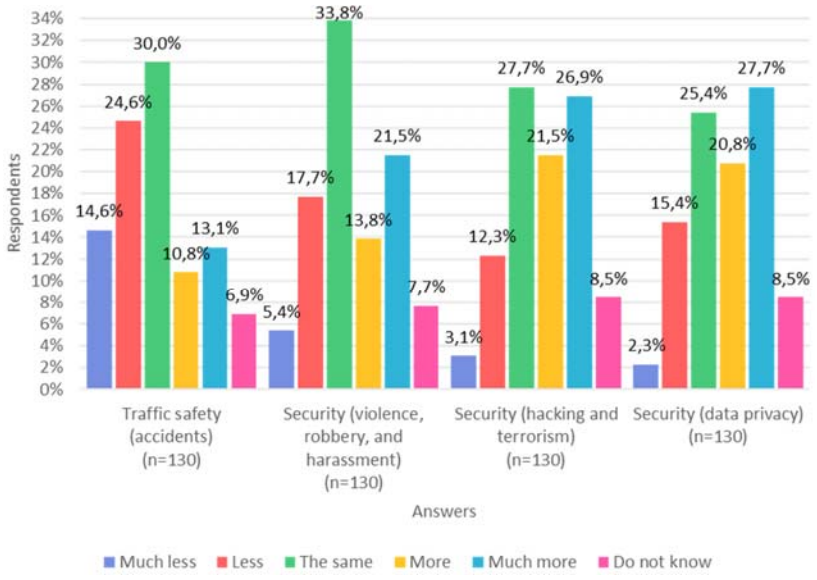

Fig. 5 Q12 - Worries Linked to Automated Minibuses

Slightly higher than a third of the respondents reported that their worries relative to security (violence, robbery, and harassment) remained the same (33.8%, n = 44). The respondents that reported that they would either be "less" or "much less" worried about violence, robbery, and harassment represented 23.1% of the respondents (n = 30). Respondents that reported to be either "more" or "much more" worried represented 35.3% (n = 46). Unsure respondents represented 7.7% (n = 10).

Slightly less than a third of the respondents reported that their worries relative to security (hacking and terrorism) remained the same (27.7%, n = 36). The respondents that reported that they would either be "less" or "much less" worried about hacking and terrorism represented 15.4% of the respondents (n = 20). Respondents that reported to be either "more" or "much more" worried represented 48.4 % (n = 63). Unsure respondents represented 8.5% (n = 11).

Slightly less than a third of the respondents reported that their worries relative to security (data privacy) remained the same (25.4%, n = 33). The respondents that reported that they would either be "less" or "much less" worried about data privacy represented 17.7% of the respondents (n = 23). Respondents that reported to be either "more" or "much more" worried represented 48.5 % (n = 63). Unsure respondents represented 8.5% (n = 11).

G. Trust in Authorities

The respondents were asked about the level of trust they had in the authorities' ability to minimize the risks of accidents. For the results, please refer to Fig. 6. Over half of the respondents either had "low trust" or "no trust" in the authorities' ability (55.4%, n = 72). Respondents that either had "high trust" or "very high trust" equated to 21.54% (n = 28). Unsure or unchanged respondents represented 23.08% (n = 30).

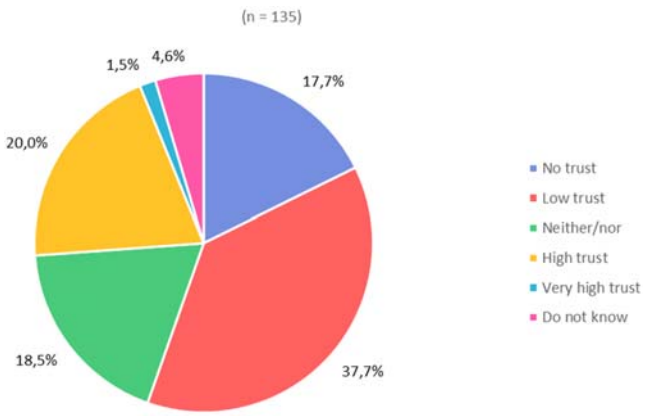

Fig. 6 Q13 - Trust in authorities

H. Considerations for Choosing Means of Transport

The respondents were asked about the factors that were most important when choosing a means of transport. The various factors considered, and the ranking of "very important" conditions can be seen in Table IV. The respondents conveyed that the most important factors were punctuality (73.31%, n = 94), security (71.54%, n = 93) and safety (71.54%, n = 93).

TABLE IV
RANKING OF VERY IMPORTANT FACTORS WHEN CHOOSING MEANS OF TRANSPORT

Ranking	Selection criteria	Percentage
1	Punctuality	72.31%
2	Security related to violence, robbery and harassment Safety (accidents)	71.54%
3	Frequency Security related to hacking terrorism	65.38%
4	Travel time Accessibility	63.08%
5	Cost	61.54%
6	Flexibility	49.23%
7	Comfort Environmental consideration	47.69%

V. FINDINGS

A. UA of Driverless Shuttles

The Pretoria residents sampled generally perceived ABs as useful. Of the respondents surveyed, only 2.31% of respondents saw no usefulness in ABs. This means that 97.69% of the respondent thought that ABs were of some use. This is substantially higher than the 51.1% reported for Norwegian respondents in [6] and the 85.3% amongst Germans in [12]. Furthermore, the Pretoria residents surveyed showed a high willingness to see some form of automation in public transport buses with 77.7% of respondents. This is much higher than the 39.9% of Norwegian respondents in [6]. Given South Africa's general lower income level relative to Norway and Germany, these results do not deviate from previous findings that residents from lower income countries are more open and accepting of AVs in [4].

B. Solution for Increased Interconnectivity

The reported use of public transport by respondents is relatively low. Most respondents generally used a car either as a driver or as a passenger. Evidence from this study seems to suggest that the proximity to public transport could partially explain the infrequent use of public transport. On average respondents conveyed that they would need to walk at least 8 minutes (depending on the mode used) to public transport nodes for the first or last mile.

Autonomous shuttles were found to be useful (and acceptable) to Pretoria residents as discussed in Subsection *A*. However, this finding can be taken a step further. They were also perceived as useful for providing interconnectivity between public transport nodes and parking places, work places and residential areas. The fact that 75.4% of respondents conveyed an intention to be either "likely" or "very likely" to use the BRT system more given that ABs offer interconnectivity services, shows that ABs could potentially resolve the interconnectivity challenges in Pretoria. It would be a solution that is acceptable to the Pretoria residents sampled for this study. In contrast, this is the case for much fewer respondents with other public transportation

modes (only 40% of respondents reported an intention to use other public transport modes more). This indicates a tendency by the respondents to use the BRT system more under conducive conditions.

There is no clear reason found for the noticeable difference between the intentions to use the BRT system more as opposed to other modes of public transport. One can only speculate that the novelty of the BRT system may make it a more attractive prospect as it is still in its rollout phase in Pretoria. This idea that users tend to overvalue technologies that they do not have experience with as elaborated in [3] comes to mind as most respondents (83.8% n = 109) reported to have never used the BRT system over the past year. Another possibility is the fact that the BRT system operates in dedicated lanes. This type of an operating model seems to have gained traction amongst the respondents of this survey. This is evidenced by the fact that 23.1% of the respondents (the second most of the proposed operating models) had a willingness to see ABs operating in dedicated lanes.

C. Combination with the Existing BRT System

The review of the modes of transports most used by the respondents over the last year indicates that the BRT system was one of the least used modes of public transport, with 83.8% of respondents having never used it. The respondents' average walking time to the BRT stations may provide an explanation for this fact. Surveyed respondents reported an average walking time of 15.18 minutes from home to the nearest BRT station, and 12.03 minutes from the BRT drop-off point to places of work or study. This suggests that respondents choose the convenience of a car (46.2% travelled with a car very often over the past year), instead of walking for this amount of time.

When quizzed about their intention to use the BRT system more if autonomous shuttles provided first and last mile services to and from BRT stations, 75.4% reported that they would be either "likely" or "very likely" to use the BRT system more. This is in addition to the fact that 27.69% respondents perceived ABs as being useful when they operate between residential areas and BRT stations. This confirms that ABs could be used with the BRT system, as this is a solution that is acceptable to the respondents. This is based on the reported intention to use and perceived usefulness of the users.

D. Increase in Public Transport Usage by Non-public Transport Users

The respondents that are frequent travelers by car and as pedestrians have been considered to assess the potential for non-public transport users to start using public transport more because of ABs. Frequent bicycles and motorbike/moped/ scooter users have not been considered because this constituency was small amongst respondents surveyed.

Generally, the frequent use of cars and walking was not found to be significant for the intention to use the BRT system and other modes of public transport more.

For the sampled Pretoria residents, the reported intention to use the BRT system more for frequent car users was 81%. This is slightly higher than the overall value for all respondents of 75.4%. Frequent walkers seemed to be slightly less willing to use the BRT system with a reported 72% intending to use the BRT system more. This seems to show a general willingness to use the BRT system more amongst frequent drivers and the walkers surveyed.

Given first and last mile services by ABs, frequent car users and walkers seemed to be willing to use other modes of public transport more. 48% of frequent drivers surveyed reported an intention to use other public transport more. Similarly, 56% of frequent walkers intended to use other modes of public transport more. Both percentages are slightly higher than the overall reported intention to use other public transport more of 40%. This seems to show a general willingness for frequent drivers and walkers that is higher than for the overall sample surveyed.

The evidence from the survey suggests that respondents that are frequent car users and travelers as pedestrians would be willing to use public transport more given interconnectivity services by autonomous shuttles. However, the sample surveyed displayed no significant difference between frequent and non-frequent drivers or walkers. This has the implication that differences between these groups (frequent and non-frequent car users/walkers) may have occurred randomly in statistical terms.

E. Use during Protest Action and Despite Objections

Public transport in South African cities is mired by violence particularly within the informal sector. Moreover, the existing stakeholders have been able to establish monopolies, as is the case with the various taxi routes. The implementation of ABs faces two challenges with this regard. Firstly, although ABs promise to reduce the impact of strikes on commuters [13], this may not necessarily be the case in South Africa. This is because protest action in South Africa is notoriously known to be violent. As such, despite the fact that ABs do not require bus drivers to operate, users may nevertheless not feel safe to travel with ABs during protest action. This point is highlighted by the comment of one of the respondents that can be seen below.

> "It will be difficult to implement a system like this in South Africa. When there is strike action, these automated buses will be vandalized by people striking which will not be safe for the passengers."

Secondly, established role-players tend to protect their "turf" against new competition. This manifests itself often with violence, as was the case with e-hailing services. Given the above, it was important to establish if residents of Pretoria could imagine using ABs under these prevailing conditions.

As would be expected, there was a substantial drop in the respondents' intention to use autonomous shuttles during protest action (36.2%) as opposed to what was reported in Subsection *B*. Similarly, respondents' intention to use autonomous shuttles despite the objections by the owners/ operators of other public transport modes was also lower at 29.23%. This indicates that one of the key factors to the successful implementation in South Africa will be minimizing

the degree of friction with some of the established role-players. Perhaps certain agreements to allow ABs to operate during strikes should be considered. Additionally, a greater deal of stakeholder involvement may be required to minimize objections from the existing stakeholders. This will ensure that ABs are not received in a similar (and violent manner) as was the case with e-hailing services. To this effect, a key to ensuring that user behavior is not affected under these prevailing conditions will be that users feel safe and the potential of violence is minimized. This may be intrinsically linked to the fact that a general trend was noted amongst the Pretoria residents surveyed, that the intention to use the driverless shuttles during protest action and despite objection increased progressively amongst respondents with a higher degree of trust in the authorities' ability to minimize the risks of accidents with ABs.

F. Perceived Safety of Driverless Shuttles

An empirical score for the perceived safety has been established. It considers the respondents' reported worry levels, and uses the corresponding level of importance as a moderating "weighting" factor. The weighting factor was obtained from the percentages for the corresponding worry (consideration) in Section IV. The increased or decreased levels of worry when using ABs were also obtained in the same section. Worries considered are: "security related to violence, robbery and harassment", "safety (accidents)" and "security related to hacking and terrorism". Worries about "data privacy" have not been considered as their importance when selecting modes of public transport was not evaluated in survey question 22. The perceived safety score equation can be seen in (1). The perceived safety score for the Pretoria residents that completed the survey can be seen in Table V.

The perceived safety score was evaluated by applying:

$$PS = \sum_{i=1}^{n} W_i(-S_{less,i}\, n + S_{more,i} n) \quad (1)$$

where *PS:* perceived safety score, where a higher score indicates a greater level of worry; W_i: represents the weighting factor for degree of importance for worry *i;* $S_{less,i}$: share of respondents "less" or "much less" worried about worry *i;* $S_{more,i}$: share of respondents "more" or "much more" worried about worry *i;* n: The total number of respondents surveyed about their increase/decrease in worries (130 in this case).

A negative value for PS would indicate a general state of decreased worry whereas, a positive value would indicate a general state of increased worry. From Table V, it can be seen that the respondents were generally in a state of increased worry with regard to using ABs as opposed to traditional buses. This state of worry was substantially affected by worries related to terrorism and hacking. This means that allaying the respondents' fears about terrorism and hacking would lead to respondents perceiving the shuttles as being safer and more acceptable to the respondents. It should be noted that for the sake of completeness, the assessment should also include worries about "data privacy".

With regard to mitigating the risk of incidents involving ABs, most respondents (55.4%) reported either "low trust" or "no trust" in the authorities' ability to reduce this risk. This is in a similar order to the 47% of South Africans living in the Western Cape in [12] and Norwegian respondents that reported a level of 50.9% in [6].

TABLE V
ANALYSIS OF WORRIES AND PERCEIVED SAFETY

Worry about Autonomous Buses	W_i	$S_{less,i}$	$S_{less,i}$ x n	$S_{more,i}$	$S_{more,i}$ x n	*PS*
Security 1 (violence, robbery and harassment)	0.7154	-0.231	-30.03	0.353	45.89	11.35
Safety (accidents)	0.7154	-0.392	-50.96	0.239	31.07	-14.23
Security 2 (hacking and terrorism)	0.6538	-0.154	-20.02	0.484	62.92	28.05
Total						25.17

G. Proposed Usage Concept in Pretoria

Based on the finding of the current research, a usage concept and potential location for autonomous shuttles in Pretoria has been identified and proposed. The location has been selected based on the author's personal knowledge of Pretoria.

The Pretoria East suburb of Silver Lakes has been proposed. It is a suburban area in Pretoria, and made up of complexes, security estates, leisure and recreational areas, office areas as well as schools. Residents' access and mobility needs (for example access to work opportunities in Pretoria and Johannesburg) are catered to via the M6 (Lynnwood road) and the N4 freeway as can be seen in Fig. 7. The population numbers in the study area from the 2011 census was reported as 11148 people over an area of 12.24 km^2 [23].

Two sections of road have been identified for the provision of first/last mile ABs services. The two sections are paved roads that provide access for the residents of the various security estates, to the M6 as can be seen in Fig. 7. They are dual carriageway roads, with one lane going in each direction. Their combined length is 3.6 km, and made up of section 2 (Ridge road) from the entrance of Oukraal apartments to Silver Lakes road (1.1 km) and section 1 (along Silver Lakes road) from Ridge road to the M6 (2.5 km). This route has been selected based on the following challenges identified in the study area including:

1) Residents of the estates are highly car dependent. With few public transport options, they have to commute by car for most of their mobility needs.
2) Heavy traffic is experienced along both roads during peak hours (weekday mornings from 5 am to 9 am and afternoons from 3:30 pm to 7:00 pm [24]) due to the high number of vehicles using this route. As such, residents often lose time on their daily commutes along this route sitting in traffic.
3) There are no first or last mile public transport services along this route. Subsequently, public transport commuters must travel their first/last mile commutes either by foot or as a passenger in a private vehicle.

The general approach was to attempt to increase the public transport usage as well as reduce the car reliance of residents

of the study area. This can be done by adopting the use of autonomous shuttles to provide first and last mile public transport services along the route defined above.

The proposed solution entails incorporating the preferences relayed by respondents, regarding the level of automation they are willing to see in the future. Emphasis has also been placed on incorporating the results of the UA study and the users' preference from Section IV, of having on-board human supervision (39.2% of respondents), and having ABs operate in separate dedicated lanes (23.1% of respondents). This ensures that the proposed solution incorporates the preferences of more than 60% of the respondents (39.2% and 23.1%).

The proposed solution can be seen in Fig. 8. The road cross-section is an adaptation of a standard drawing for Pretoria's BRT system. The main change is the incorporation of a bi-direction ABs travel way of 6 m as was the case in [25], which replaces the BRT bus travel way.

The spacing of the stops and/or stations is taken as approximately 1000 m, which is recommended as a minimum for BRT systems in South Africa in [27]. Finally, the ABs are to have human supervision at all times during operation. As 75.4% of the respondents in this study intend to use the BRT more given interconnectivity services with ABs, this concept should operate in conjunction with the future BRT route that services the Silver Lakes area

Assuming that the results from this study are transferable to residents of Silver Lakes, 75.4% (8405 residents) of the residents would likely use the future Silver Lakes BRT line more. Furthermore, applying such a concept to similar corridors could significantly increase usage of the BRT system.

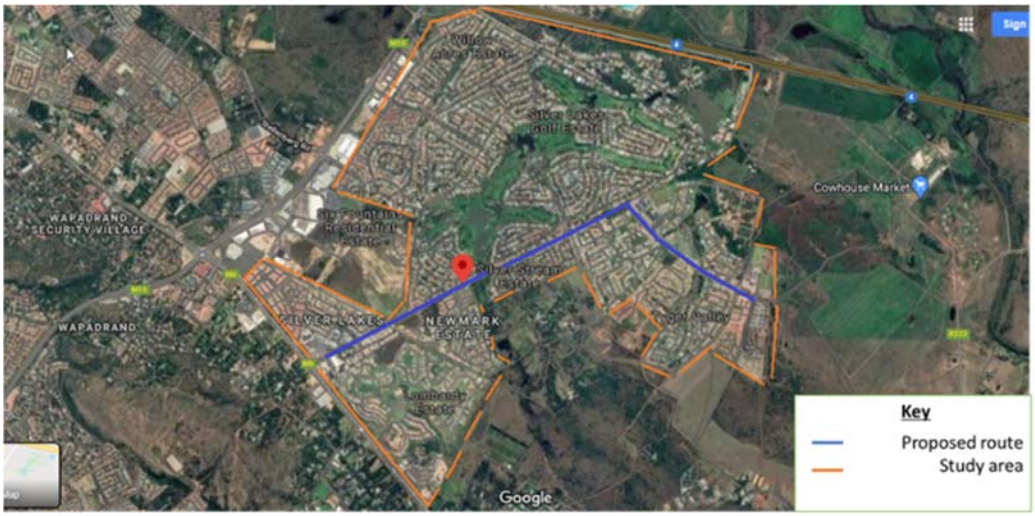

Fig. 7 Proposed location adapted from [22]

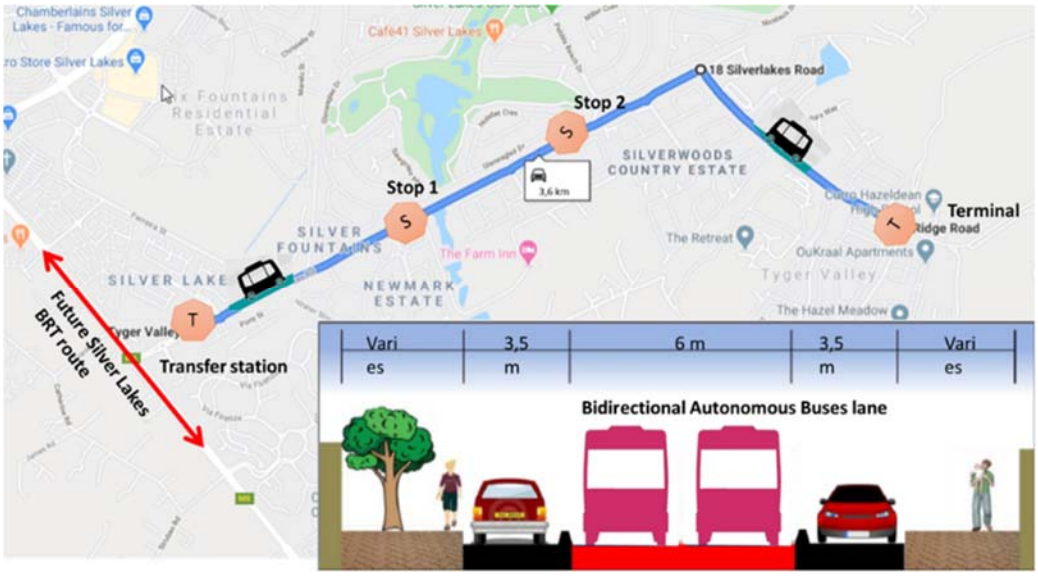

Fig. 8 Proposed autonomous bus route and solution adapted from [22], [25] and [26]

H.Reproducibility in Other Contexts

One of the main differences between public transport in developed and developing countries lies in the strength of the informal sector [28]. In lower-income countries, the informal sector tends to play a strong role in the public transport sector. This fact is true in South Africa, and was confirmed in this study, as minibus taxis were the most used mode of public transport by the respondents over the past year (20.7% used them often or very often).

The current study showed a sharp decrease in the intention to use the ABs when the respondents considered resistance from the owners and operators of other modes of public transport. Based on the results from this study in Subsection *E*, the potential decrease in intended usage could be as high as by 46.17%. This shows that a greater level of attention and engagement should take place with the established stakeholders and the informal sector when planning the implementation of autonomous shuttles in Pretoria. It is plausible that in other major African cities, similar attention to the informal sector and other established role-players will also be required.

VI. Conclusions and Recommendations

The main findings of the research can be summarized as:

- The UA of residents was high with only 2.31% of the respondents perceiving them as not useful (97.69% acceptance) substantially higher than Norwegian and German residents.
- Respondents' intention to use the BRT system more given first and last mile services by ABs was much higher (75.4%) than for other modes of public transport (40%).
- Respondents generally felt less safe when considering having to drive in ABs - fears about terrorism and hacking was most influential with this regard.
- A conceptual operational model for the incorporation of autonomous shuttles into the public transport system in Pretoria has been presented. This concept incorporates users' perceived usefulness and acceptance of autonomous shuttle, usage intention and their willingness to see more automation in the future. Further research should be undertaken with this concept considering a larger sample size.
- Reservations about the established role-players in informal public transport shows potential to deter potential ABs use.

Future research on the UA for automated shuttles in Pretoria could be undertaken by considering a more representative sample size as well as considering the Pretoria residents' willingness to pay for these services.

Similar studies could also be undertaken for the other major South African cities such as Johannesburg, Cape Town and Durban. The present study could serve as a starting point for similar studies in other major African cities. Further studies could also be undertaken to further elaborate the operational concept for ABs in public transport in Pretoria presented in this study.

VII. Critical Appraisal of Findings

Two main limitations have been identified about the findings of this study. Although they are significant, the findings in this study cannot be assumed a reflection of the whole Pretoria population. This is because the data collection had limitations based on the sample size as well as representability. Moreover, the data for this study were collected at a time when South Africans were under a COVID-19 enforced lockdown. As such, there is a possibility that the respondents' opinions were influenced with this regard.

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