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# Location privacy acceptance: attitudes to transport-based location-aware mobile applications on University campus

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## **Abstract**

Location-based services feature in many information systems however attitudes to location privacy, and the impact of user attitudes to transport app usage, are less common. This paper builds on a use-case, the implementation of UNISHUTTLE, a smartphone transport app developed by the authors, that provides users with real-time bus location and arrival information from an Automatic Vehicle Location (AVL) system. In exchange, the AVL system tracks and warehouses user interactions with the transport network. The paper describes a pre- and post-implementation survey of user attitudes toward location privacy, and explores how some app features of the transport app trade-off against privacy concerns.

**Keywords** Location privacy, mobility and transport applications.

## 1 INTRODUCTION

Location privacy differs from other online privacy concerns (Yao, 2007; Marshall, 1974). Transport apps use user-location data to provide services, so a critical determinant to adoption is the location privacy sensitivity of the target users. Using a single case (Yin 2014; Flyvbjerg, 2006), with pre- and post-implementation survey, our study is used to both validate our app design and further to test whether app use has any impact on attitudes to location privacy.

The key research questions addressed are, how aware are app users of location privacy and how willing are they to give up location privacy in exchange for services? If they do give up location privacy in exchange for services? What services, in this use-case, are they prepared to trade?

The constructs considered for this research were adapted from the research model of Junglas and Spitzmüller (2005), including user personality, privacy-related attitudes, trust in and concerns regarding location-based apps and perceived usefulness of app features.

The paper is structured as follows; in the next section we survey the literature, focusing on types of location-based tracking applications and conceptualizations of location-based privacy. In the same section, we describe the use-case, its scope and the app's purpose. In Section 3 we describe the experimental and methodological design. Section 4 presents the pre-implementation survey results and in Section 5, the post-implementation survey results. Finally, we conclude with some comments on the inferences from the study that condition future development.

## 2 LITERATURE & BACKGROUND

The literature on location-based information systems is mostly methods categorizing applications. The most common approaches distinguish applications that persistently request and/or send a user's location, and those that allow a user to choose to send their location. These categories are given different names by different authors and there are variations in definition depending on how recently articles were written. The most frequently used terms include 'Location Tracking' and 'Location Awareness' to classify applications (Hightower, 2001; Barkhuus and Dey, 2003; Burcea and Jacobsen, 2003; Harrison and Dey, 2009; Anuar and Gretzel, 2011). However, the terms 'Push & Pull' as well as 'Participatory Sensing' and 'Pervasive Location Awareness' are also used to describe various location-based applications however many of these studies pre-date widespread smartphone use.

'Location Tracking' is defined by Anuar and Gretzel (2011) as a type of application that "offers information about the user's whereabouts to entities other than the user". This is clarified by Burcea and Jacobsen (2003), Zhou (2008) and Harrison and Dey (2009), who provide further insight into the identities of the observing entities.

Typically, observing entities include the application server and possibly other users of the same application. This is similar to the definition given by Harrison and Dey (2009) of 'Pervasive Location Awareness', defined as 'applications that continually collect location information as part of a background process'. These two terms are also comparable to the popular term "Push (or Push-oriented) application" (Burcea and Jacobsen, 2003; Anuar and Gretzel, 2011). Push applications transmit information to users based on their location.

Push-oriented applications are used to keep tabs on a user's location by repeatedly querying the mobile device that returns an updated location. Information or services provided by such applications are then provided without the user having to specifically request them. Harrison and Dey (2009) use the example of Google Latitude to illustrate this technique. Google Latitude provided<sup>1</sup> users with the ability to show their location to other Google Latitude users. This was achieved when the user activated the application on their mobile device. The device then sent the user location to the server at set intervals and was made available to the other chosen users (Page and Kobsa, 2009; Nan and Guanling, 2010). As the user moved, the information they see changed to suit the new location.

Location privacy is especially sensitive as its loss implies the potential for bodily harm. Duckham and Kulik (2006) define location privacy as 'a special type of information privacy which concerns the claim of individuals to determine for themselves when, how, and to what extent location information about

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<sup>1</sup> Google latitude shutdown on August 9, 2013. Google still offers location reporting via Google+.

<sup>2</sup> Wollongong is a regional coastal city in New South Wales, Australia, 80 km south of Sydney. The UOW has

them is communicated to others'. Wang and Lin (2016) identified privacy as a crucial concern for location-based app development but also acknowledge the importance of app quality perceptions on privacy judgments. Such risk-benefit trade-offs are referred to as 'privacy calculus' (Xu et al., 2009).

Eklund et al (2010) proposed a Connected Mobility Digital Ecosystem (CMDE), defined as the combination of the mobile applications at the context of the University of Wollongong (UOW) campus with accessed to shared infrastructure. The authors used an ecosystem metaphor to conceptualize relationships between the actors in the campus community. The concept of a digital ecosystem resonates throughout the theme; the term is used to describe the complex social-technical systems that result from multiple, spontaneous interactions with a particular ICT-enabled environment.

Four location-sensitive context-aware applications (mobile apps) were proposed as part of the CMDE concept at the UOW campus: (Eklund et al., 2011): (1) UNISHUTTLE –the subject of this paper. (2) A car-pooling application – a service offering campus-specific demand-driven marketplace for car-pooling and ride-sharing (a sort of campus-based Uber). (3) A Freshman application – a 'helper' application for first-year university students. (4) Art Collection Tour Guide – a mobile application that customized tours of artworks on the UOW campus. Various elements of each of these were implemented over a 4-year period from 2010-2014.

The use-case is built around 3 bus route services. The routes are widely patronized by the University of Wollongong (UOW)<sup>2</sup> students and staff, as well as local residents. Figure 1 shows two of the three routes, the blue and orange lines, the third route is the express version of the blue line.

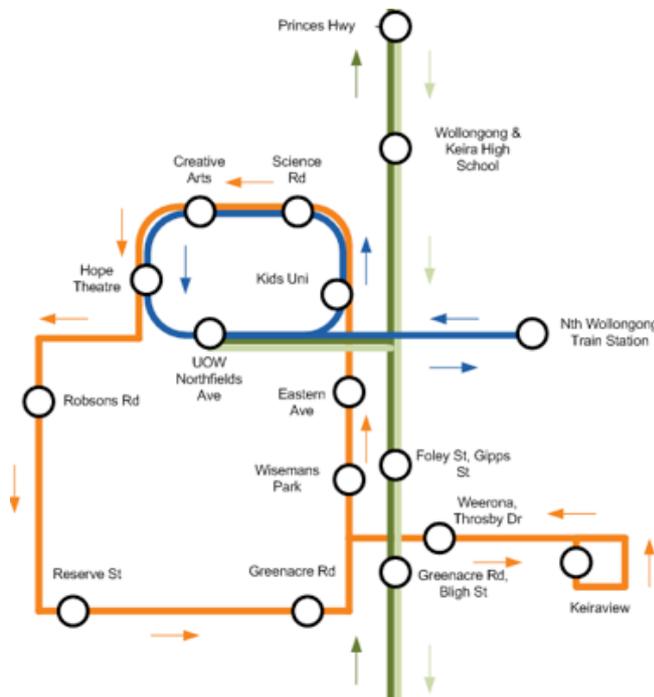


Figure 1: The free Shuttle Bus Network in the City of Wollongong, Australia.

Transport apps provide accurate information that has been shown to reduce the perceived waiting time and can therefore trade-off against longer bus headway (Mishalani et al., 2006).

The UNISHUTTLE system has several interdependent digital components – shuttle buses equipped with on-board devices, a web accessible server that centralizes data management and coordinates control, passengers carrying mobile devices (with the UNISHUTTLE app installed), and a transport authority (the bus operators), all agents interact with each other. Passengers' mobile devices inquire about shuttle bus travel times in real-time, the server computes information with the shuttle bus location input from the shuttles and passengers' own whereabouts.

<sup>2</sup> Wollongong is a regional coastal city in New South Wales, Australia, 80 km south of Sydney. The UOW has approximately 30,000 students and 2,500 faculty. The city's population is 250,000.

Following the discussion in Section 2, the UNISHUTTLE app is both push and pull, it includes location tracking of the app user's with a single observer, namely a location server that pulls and warehouses user location data from the app for future analytic use. There is no sharing of user location data with other system users. Bus location data is pushed to the location server by the on-board system on the bus. The location server pulls data from the Google map API. Map and bus data is pulled from the location server by the app. The timing of the next bus to arrive is a limited example of the limited 'Location Awareness'. This architecture was never explained to the app users nor could they have read or found out about it.

### 3 RESEARCH EVALUATION DESIGN

The study involved a pre-test – post-test. The survey was conducted November 2011 after a pilot pre-testing of the survey questionnaire. Observers approached respondents at bus stops. Participants needed an iPhone, since UNISHUTTLE was only an iOS app at that time, and had to be willing to download the app and complete the surveys. Once respondents gave their consent, observers opened the online survey questionnaire (on an tablet) and guided respondents through the questionnaires. The observers encouraged participants to download the app at the end of the survey: several participants preferred to download the app later when they had better Internet access.

Participants were given a four-week time window to interact with the UNISHUTTLE app. They were then sent a link to a second online questionnaire to complete the post-test evaluation. Several challenges were encountered during the study. Firstly, at that point in time, iPhone penetration among students was lower than in the wider population and it was therefore difficult to recruit test subjects who owned iPhones. Many passengers on the routes were students using non-Apple (mostly android) smart-phones. Therefore, a single platform iOS UNISHUTTLE app was a limiting factor. Secondly, the weather in November 2011 in Wollongong was particularly bad throughout the study, making it difficult to interact at the bus stops. To compensate an email was sent to students and staff to recruit test subjects, this had the desired effect. The test participants' email address was used as the unique identifier to link survey 1 and survey 2 as well as track the download of the app and its usage.

The pre-use survey included questions related to general bus shuttle use and need for additional information, expected usefulness of app features, and past mobile app behaviours. It also included questions regarding privacy (Milne and Culnan, 2002), privacy protection behaviours (Milne and Culnan, 2002) and privacy preferences (Marshall, 1974). In addition, it included privacy needs item and additional privacy questions, specifically about mobile apps and location-based services. Further, respondents were asked about their trust in institutions and willingness to use location tracking at different levels of spatial granularity. The post-use survey asked users about their app use and user experience, satisfaction and continuing use intentions, benefits derived from the app, user perceived usefulness of features and again all questions regarding privacy needs, concerns and perceptions. Also, respondents were asked to indicate their willingness to use a similar app in other contexts.

53 participants provided valid responses for survey 1. All downloaded the app. 27 respondents who downloaded the app interacted with it at least once. Only the responses of actual app users were considered. 18 respondents completed the entire study process. There are slightly more female respondents (53.8%) than men, in line with the general distribution of gender in the campus population<sup>3</sup>. Age ranges from 18 to 54 years, about half being born before 1990 and half after. About half are full-time students, almost 10% are full-time employees and the rest are part-time or casual employees. Not surprisingly, the test group is highly educated, with more than 70% completing at least some university education. All but one respondent had previously downloaded an app. Therefore, the survey population is considered to be typical of the target user group.

Respondents who completed Phase 1 and Phase 2 of the research, and who actually used the app, are more female (more than 55%) and younger (max. age = 32) than the overall sample. They all scored highly on agreeableness and conscientiousness as a measure of their personality. We use the well-known five-factor model (FFM) defined as openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (Goldberg, 1993, Hunter et al., 1978) and is widely used in many other studies technology acceptance (Barnett et al., 2015)].

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<sup>3</sup> <http://www.universityrankings.com.au/gender-balance-ratio.html>

## 4 RESULTS OF PRE-USE SURVEY (PHASE 1)

The respondents exhibited a range of shuttle bus use behaviors ranging from taking the shuttles more than 5 days a week to less often than one day a week, with 2-4 days a week being the most frequent usage across all 3 shuttle routes.

About 10% know exactly the frequency of shuttle buses, 70% have a general idea and 20% had no idea. 80% think the shuttle schedules are convenient and 80% think the shuttle schedules are reliable. The majority of respondents (more than 60%) are willing to wait 10 minutes or less for a shuttle bus to arrive. Only 2 respondents indicated they are willing to wait for 30 minutes, the alternative is to walk given the relatively short distances. A majority (more than 85%) indicated that they would use a wifi hotspot if it were available on a bus. Since the shuttle buses were equipped by the experiment with a wifi hotspot this seemed a popular feature.

The UNISHUTTLE app's function of announcing the arrival time of a bus at a given stop attracted 83% users, followed by the function of displaying the map that shows the position of buses, and the function that shows a map to simply pinpoint the bus stop locations as the least useful. Figure 2 shows the expected usefulness of the UNISHUTTLE app features.

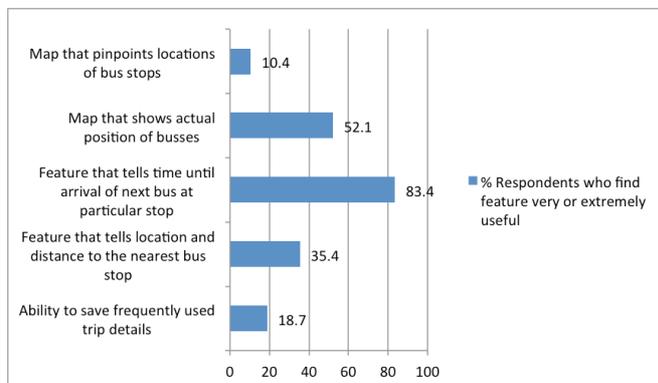


Figure 2: Usefulness of app functionality.

One of the UNISHUTTLE functions is to track users' location and keep record of their data footprint. In order to understand how users perceive the footprint tracking, participants were asked what level of trust they have in a mobile app in terms of their location information being safeguarded. About 19% indicated strong trust. The majority (60% plus) indicated some trust about 10% declared they were trust neutral. Only 8% reported some distrust and 2% strong distrust.

The survey also measured institutional trust to understand whether different types of app providers/endorsers would influence app use (see Figure 3). The results show that respondents trust the national government most, followed by universities/educational institutions and regional/state governments, when it comes to respecting their privacy and not sharing their personal information without permission.

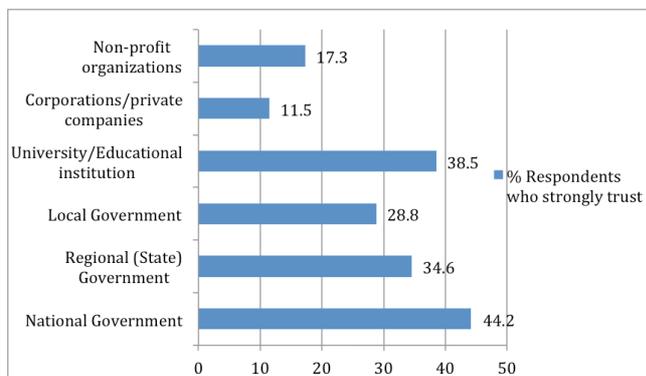


Figure 3: Institutional trust.

Regarding participants' sentiments on privacy, the results show that the respondents value privacy highly but this does not mean that they do not provide personal information. However, it seems that taking actions such as giving permission – having control to opt in – is important. Figure 4 shows the privacy needs. All the questions on privacy concerns display high percentage results in that group.

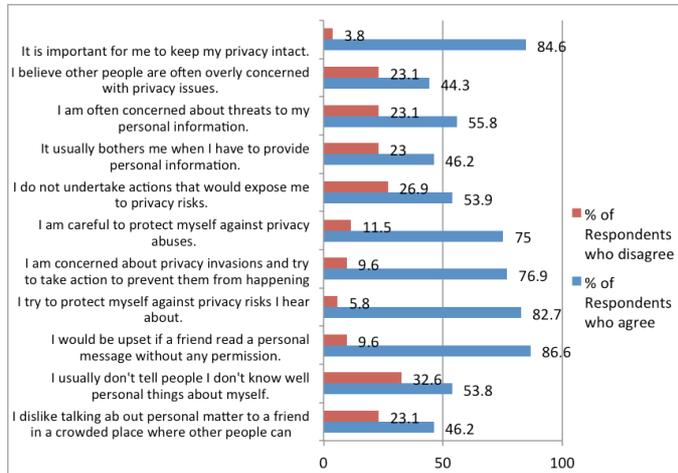


Figure 4: Overall privacy sentiment. — The first 4 items are from Marshall (1974), the second 4 from Milne and Culnan (2002), the remaining 3 items from Malhotra et al. (2004).

On privacy related to mobile applications, respondents are most concerned with providing too much information when downloading or registering a new app, followed by concerns about information sharing with third parties. Figure 5 shows mobile app related privacy perceptions.

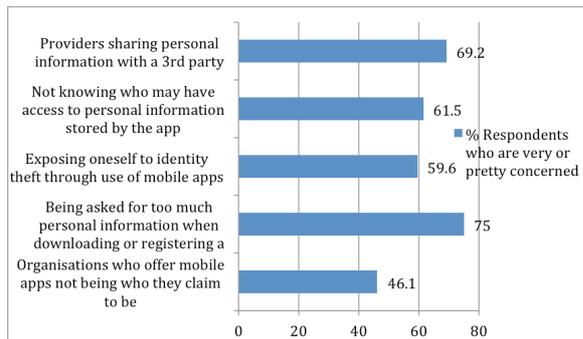


Figure 5: Privacy concerns about mobile apps.

The survey asked about specific behaviours respondents might have engaged in to protect their privacy when engaging with mobile apps. A majority of respondents have at times refused to give information. Over half actually abandoned app use or purchases due to mobile privacy concerns and a surprising 43% admitted to having provided false or fictitious information to safeguard their privacy. Figure 6 lists some of the actions to protect mobile app privacy.

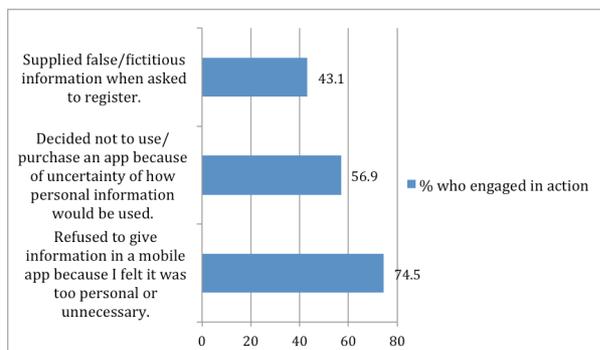


Figure 6: Actions to protect mobile app privacy.

As far as location-based privacy is concerned, respondents were mostly worried about information being used for other services. Only 42% were concerned about lack of their own awareness of tracking and 38% thought lack of location accuracy could lead to problems. Figure 7 shows the location-based privacy concerns. A majority of the respondents (more than 86%) had used location-based services before participating in the study. As far as willingness to have their location tracked, the results show that there is a clear drop in willingness to share this data with increasing granularity (location accuracy) of identification. Figure 8 shows the willingness to use location-based services at different levels of location granularity.

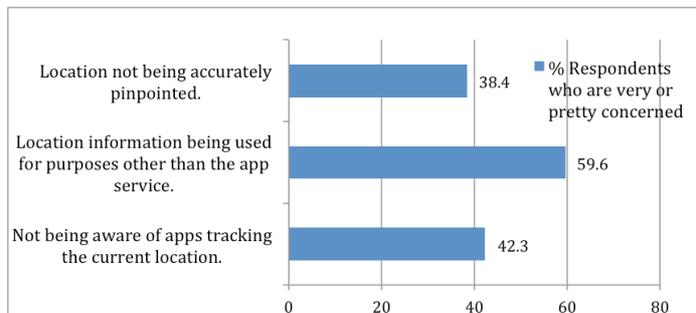


Figure 7: Location-based privacy concerns.

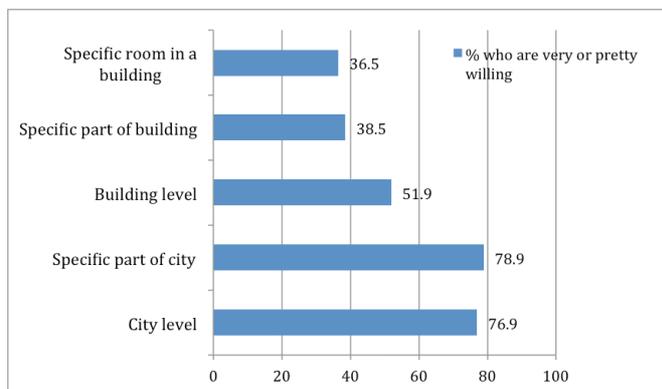


Figure 8: Willingness to use location-based services at different levels of location accuracy.

## 5 RESULTS OF POST-USE SURVEY (PHASE 2)

Of the respondents who used the app and completed the post-use survey, 44% used the app regularly, the same number used it a couple of times and 12% used it only once. These numbers correspond with the actual use behavior tracked as part of the study. On average, these respondents used the app for 28 minutes across 26.50 sessions, about 1 minute per session.

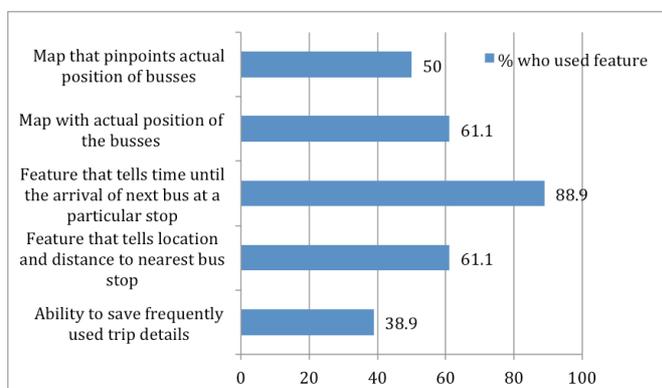


Figure 9: App feature usage.

Most of the respondents indicated that they used the feature (see Figure 9) that shows the bus arrival time at a stop (89%), followed by the map with the actual position of the buses and the feature that shows one's own position and distance to nearest bus stop.

Perceived Usefulness is a well-known idea from the TAM literature that has a recognised correlation to adoption (Venkatesh et al., 2003). Overall, respondents indicated that they found the app to be very or pretty useful (84%). 17% found it somewhat useful and nobody indicated that it was not useful. On specific features, the results are consistent with the use frequency questions and show that the feature that shows the arrival of the next bus was by far the most useful feature in the opinion of the majority of study participants, however other features were also assessed as very or pretty useful. Figure 10 shows the perceived usefulness of individual app features.

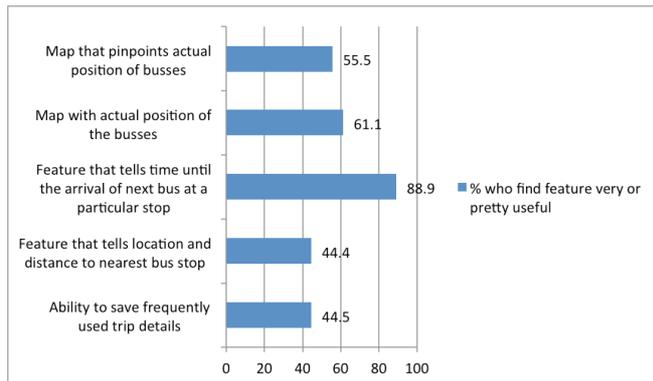


Figure 10: Perceived usefulness of the app features.

Ease of use is another well-known idea from the TAM literature that affects adoption (Venkatesh et al., 2003). The users evaluated the user experience positively (see Figure 11). Only the fun element was not evaluated as highly as the other aspects of the app.

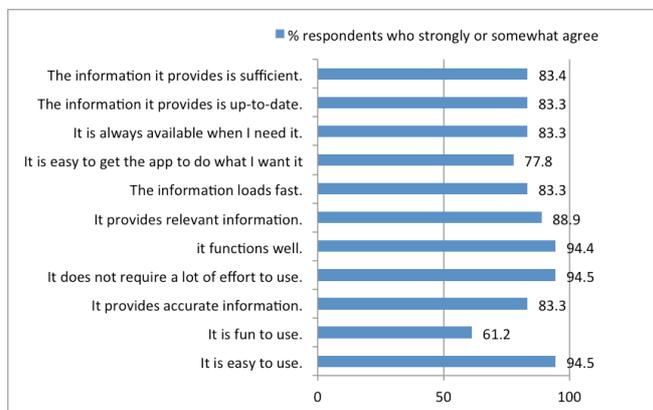


Figure 11: User Experience.

Almost all respondents indicated that the app reduced their likelihood of missing a bus. They also found it improved their ability to plan ahead. Surprisingly, waiting time was reduced only for 78%. Feelings of safety and entertainment were only experienced and reported by some users. Figure 12 gives the benefits derived from the app use (Feeling safe, easy of planning, reduce waiting time and

17% indicated that they trusted the app in terms of their information being safeguarded by it and 67% indicated some trust. Nobody indicated distrust.

39% indicated they were very satisfied with the app and 50% indicated they were somewhat satisfied. Nobody indicated dissatisfaction. The majority of users indicated that they would continue using the app (61% very likely, 22% somewhat likely). Importantly to adoption, 83% are very or somewhat likely to recommend the app to others.

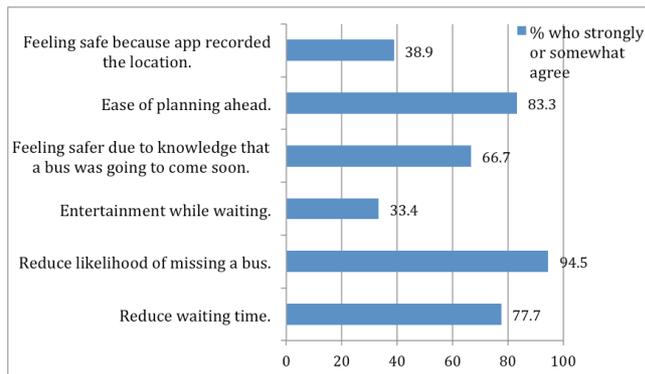


Figure 12: Benefits Derived From App Use.

In order to survey whether users will be willing to use similar apps developed, but used in different areas, participants were asked if they would like to use an app like UNISHUTTLE in a different context. The survey results show that the respondents are split in terms of whether they would like to use an app like UNISHUTTLE in a different context, although a majority thought that such an app could be used to track their private vehicle use for tax and emission tracking purposes. Figure 13 the willingness to use in other contexts.

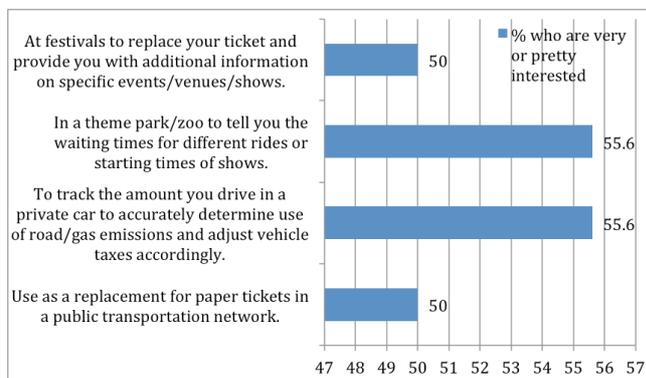


Figure 13: Willingness to use an app like UNISHUTTLE in other contexts.

A discriminant analysis was conducted to decide what distinguished those who used the app from those who downloaded it but did not use it. The goal of the discriminant analysis was to identify those variables that most strongly distinguished app users from non-users. The pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions show that the extent to which one uses the shuttles has a negative impact (-.490), while a positive attitude towards the shuttle schedules has a positive influence (.477) and knowledge of the schedules has a negative impact (-.411). Having previously downloaded an app also helped discriminate in a positive way (.328). The influence of general privacy perceptions was much weaker than these factors (-.275) and location-based privacy perceptions were an even weaker factor (-.118). Mobile privacy perceptions had almost no impact (.080). The resulting function was able to correctly classify cases into users or non-users 67% of the time, which is better than by chance, but not great. This suggests that there are other factors driving app use that we did not capture with the survey.

Paired *t*-tests were conducted to examine whether after using the UNISHUTTLE app, respondents' privacy views had been altered. This required constructing scales for the privacy measures collected both in Phase 1 and in Phase 2. Factor analyses and Cronbach's alpha (1951) were used to establish that the scales were uni-dimensional, internally consistent and reliable.

Need for privacy was identified with a single indicator: "It is important to me to keep my privacy intact". General privacy concerns were constructed using four privacy concern questions ("I try to protect myself against privacy risks I hear about"; "I am concerned about privacy invasions and try to take actions to prevent them from happening to me"; "I am careful to protect myself against privacy abuses"; "I am often concerned about threats to my personal information"). The Cronbach alpha for this scale is 0.901 indicating an acceptable measure of internal consistency within the scale. Mobile privacy was derived from the five questions asked about concerns regarding mobile applications (see

Figure 5). The Cronbach alpha for this scale is 0.893. Location-based privacy was constructed using two of the questions used in the survey about concerns regarding location-based services (Location information being used for purposes other than the app service; Not being aware of apps tracking the current location). The Cronbach alpha score for this scale is 0.741.

The paired *t*-tests revealed no significant differences. A look specifically at location-based privacy shows that the score indeed stayed the same for most, while it changed to the positive for some and to the negative for others. Overall, however, privacy sentiment is very stable (Table 1). Correlations with extent of use (time and number of sessions) also revealed no statistically significant patterns. *t*-tests and regression analyses were conducted to see whether differences in privacy concerns could be explained by socio-demographic differences. There were no significant differences between male and female respondents. Older respondents had greater general privacy concerns but did not differ from younger respondents regarding mobile app privacy and location-based services privacy concerns.

	$\Delta$ Rating	$\Delta$ Frequency	$\Delta$ Percentage
	-2.0	1	5.6
	-1.5	1	5.6
	-1.0	1	5.6
	-0.5	3	16.7
	0	7	38.9
	0.5	2	11.1
	1	2	11.1
	1.5	1	5.4
	2.0	0	0
Sum	<b>0</b>	<b>18</b>	<b>100.0</b>

Table 1. Change in privacy concerns manifest in pre- and post-survey data.

## 6 CONCLUSIONS

The key research questions our paper addresses are, how aware of location privacy are app users and how willing are they to give up location privacy in exchange for services? The results show that respondents evaluated positive user experience of the UNISHUTTLE app, they valued highly information sufficiency, up-to-datedness, ease of use, accuracy, usefulness and relevance the app provided. The app's main feature, prediction of shuttle bus arrival time, attracted nearly 90% users, followed by the feature that shows a map with the actual positions of all shuttle buses, which attracted more than 60% users. In this respect, the utility of the app to its purpose, catching public transport, largely outweighs personal privacy concerns.

On the question of if participants were to give up location privacy in exchange for services, what services in this use-case are they prepared to trade for location privacy? Here, the key finding is that the majority of respondents, regardless of demographic profile, exhibit concerns about personal privacy. However, this does not exclude them providing personal information. Namely, despite privacy concerns, there is trust in apps and a strong desire to use them. Having to provide personal information or having location tracked is per se not a problem when the information concerning location disclosure is fundamental to the app's purpose and function.

The rather complex experimental design resulted in only those with agreeable and conscientious personality traits completing both surveys. Due to this bias, the influence of personality on other study variables was therefore not pursued. Future research should address incentives to encourage a wider range of personality types to complete complex studies. As the quantity of survey data is limited, it cannot be said that attitudes towards location privacy changed in any statistically significant way after using the UNISHUTTLE app. For this reason future work needs to recruit a larger sample of users, and the most obvious way to achieve this is by extending the UNISHUTTLE app to the android platform.

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