University students' adoption and post-adoption behaviors of new mobility services in China : three empirical essays

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RÉSUMÉ

Au cours de la dernière décennie, avec le développement des technologies de l'information et de la communication (TIC) et la diffusion rapide du smartphone, les nouveaux services de mobilité basés sur des applications, comme les véhicules de tourisme avec chauffeurs (VTC, comme Uber, Didi), les vélos en libre-service sans stations (VLSsS, comme Ofo, Mobike), se sont développés rapidement dans le monde entier. La société américaine de VTC Uber, pionnière dans le domaine, a été créée en 2009, et lancée officiellement pour la première fois à San Francisco en 2011. À la fin de 2017, Uber opérait dans plus de 700 villes dans environ 80 pays à travers le monde (Shaheen et al., 2018). De même, en février 2018, deux gérants chinois de VLSsS, Ofo (créée en 2014, et lancée officiellement pour la première fois à Pékin en 2015) et Mobike (créée en 2015, et lancée officiellement pour la première fois à Shanghaï en 2016) ont lancé leurs services en Asie, Australie, Europe et États-Unis, dans respectivement plus de 250 villes (dans 21 pays) et plus de 200 villes (dans 13 pays) (Aguilera and Boutueil, 2018). L'essor de ces NSM est particulièrement dynamique en Chine. Selon China Internet Network Information Center (2018), le nombre d'utilisateurs de VTC et de VLSsS a atteint, respectivement, 287 millions et 221 millions.

La compréhension des besoins des utilisateurs dans chaque contexte national voire local est désormais un enjeu majeur pour les acteurs des nouveaux services de mobilité. Elle l'est aussi pour la recherche, qui s'intéresse depuis quelques années aux conséquences de l'émergence de ces nouveaux services sur les pratiques et les politiques de mobilité (Aguilera and Boutueil, 2018). Elle l'est, enfin, pour les pouvoirs locaux et nationaux qui doivent réguler ces nouveaux services et les intégrer à leurs politiques de transport.

La littérature sur les nouveaux services de mobilité, en particulier les vélos en libre-service (VLS, y compris les vélos en libre-service avec stations (VLSaS) et VLSsS) et les VTC, s'est développée rapidement durant les dernières années. Cependant, les analyses sur les comportements d'adoption et de post-adoption de ces deux services et leurs facteurs influents sont encore limitées et fragmentaires.

Tout d'abord, la majorité des recherches ont porté sur la probabilité d'adoption (c'est-à-dire d'utilisation ou non) de ces deux services (Alemi et al., 2018; Bachand-Marleau et al., 2012; Fishman et al., 2015), et seules quelques études ont examiné les comportements de post-adoption, tels que la fréquence d'utilisation (c'est-à-dire l'utilisation plus ou moins, également appelée l'intensité d'adoption) (Alemi et al., 2019; Guo et al., 2017), et les choix de modes de déplacement des individus après leur adoption de ces nouveaux services (c'est-à-dire à la fois le choix entre ces nouveaux services, par exemple VTC et VLS, et aussi par rapport à d'autre modes de transport traditionnels, par exemple la marche, le vélo privé, le taxi, les transports en commun, etc.) (Gehrke et al., 2019; Tang et al., 2019). En outre, il convient de noter que la quasi-totalité des études précédentes sur les VLS concernaient des VLSaS.

Deuxièmement, l'un des comportements de post-adoption les plus stratégiques concerne l'intention de continuer à utiliser le service, qui a été largement étudiée dans la littérature sur l'innovation, en particulier dans le cas des services basés sur Internet tels que l'e-commerce, les sites de réseaux sociaux, l'e-learning et les services de paiement mobile (Bhattacherjee, 2001a; Mouakket, 2015; Roca et al., 2006; Zhou, 2013). Cette dimension conditionne la viabilité à long terme de ces services, même si leur adoption initiale est un premier pas important vers leur succès (Bhattacherjee, 2001b). Or, à notre connaissance, aucune étude n'avait examiné cette question dans la

littérature sur les deux NSM considérés ici.

Troisièmement, plusieurs thèses ont systématiquement exploré différents aspects des comportements d'adoption et de post-adoption de ces deux NSM et leurs facteurs influents. Par exemple, Fishman (2014) a étudié les obstacles et les facilitateurs de l'adoption des VLSaS en Australie. Henao (2017) a analysé les impacts des VTC sur les transports, y compris les véhicules-kilomètres parcourus, la substitution modale, le stationnement, et le comportement de déplacement aux États-Unis. Et Alemi (2018) a présenté une analyse en profondeur de l'adoption et de la fréquence d'utilisation des VTC, et de leurs impacts sur l'utilisation d'autres modes de déplacement aux États-Unis. Cependant, à notre connaissance, aucune thèse ne s'est intéressée au cas chinois.

Enfin, un grand nombre d'études ont souligné que les étudiants universitaires (plus généralement, les jeunes, parfois appelés *Millenials*) sont fortement utilisateurs d'Internet et sont aussi les primo-adoptants de services basés sur Internet (Lee, 2014; Yang, 2005), et l'un des plus grands groupes d'utilisateurs des VTC et des VLS (Alemi et al., 2018; Chen et al., 2017; Guo et al., 2017; Rayle et al., 2016). Ils préfigurent ainsi une partie des utilisateurs de demain (Zhou, 2014). Cependant, dans la littérature sur les comportements d'adoption et de post-adoption de ces deux nouveaux services, à notre connaissance, seuls Alemi (2018) et Tarabay and Abou-Zeid (2019) se sont penchés sur la population des jeunes ou des étudiants, dans le cas des VTC aux États-Unis et au Liban, respectivement.

Pour combler les lacunes de recherche susmentionnées, cette thèse propose trois essais empiriques portant d'une part sur les étudiants chinois, d'autre part sur deux types de nouveaux services de mobilité (à savoir les VLSsS et les VTC), et enfin sur les comportements d'adoption et de post-adoption des nouveaux services de mobilité (tels

que la fréquence d'utilisation, les choix de mode entre ces nouveaux services et les modes de transport traditionnels, l'intention de continuer à utiliser, etc.)

Dans ce contexte, une enquête originale a été menée à l'Université de Nankin en novembre 2017, portant sur les mobilités quotidiennes des étudiants et leurs pratiques de nouveaux services de mobilité. Parmi les 1432 étudiants qui ont rempli des questionnaires valides, environ 90% ont utilisé les VLSsS et plus de 60% les VTC.

Le premier essai (Chapitre 2) examine les facteurs influençant la fréquence d'utilisation des VLSsS en utilisant un modèle LOG (logit ordonné généralisé). Après une revue de la littérature, les résultats montrent que, premièrement, les étudiants en master ou en doctorat, les étudiants qui se spécialisent en sciences naturelles et en génie, et les étudiants qui ont un revenu mensuel plus élevé, sont plus susceptibles d'avoir une fréquence d'utilisation plus élevée. Deuxièmement, la possession de vélos diminue la probabilité d'être des utilisateurs fréquents des VLSsS. Troisièmement, tant l'intensité de l'utilisation de l'Internet mobile que la fréquence des déplacements quotidiens ont un impact positif sur la fréquence d'utilisation des VLSsS. Enfin, les primo-adoptants, les étudiants qui ont utilisé les VLSsS pour des raisons économiques et les étudiants qui ont utilisé les VLSsS pour les déplacements domicile-travail, sont également plus enclins à avoir une fréquence d'utilisation plus élevée. En outre, il convient de noter qu'en raison de la violation de l'hypothèse de cotes proportionnelles, les facteurs liés au niveau d'études, au revenu mensuel, et au moment de l'adoption n'ont qu'un impact partiel sur la fréquence d'utilisation.

Le deuxième essai (Chapitre 3) étudie le rôle des VLSsS dans les choix des modes de transport des étudiants pour leurs déplacement d'études et d'achats, et les facteurs influents *via* deux modèles LM (logit multinomial). Après une revue de la littérature,

les résultats montrent que les femmes et les étudiants qui se spécialisent en sciences naturelles et en génie sont moins susceptible d'utiliser les VLSsS pour les déplacements d'études, tandis que les étudiants en master ou en doctorat sont plus susceptibles d'utiliser les VLSsS pour les déplacements d'achats. Les étudiants qui habitent dans les zones 2 et 4 du campus de Xianlin sont plus susceptibles d'utiliser les VLSsS pour les déplacements d'études. La possession d'un permis de conduire diminue la probabilité pour les étudiants de choisir les VLSsS pour leurs déplacements d'études. Un niveau plus élevé d'adoption des VTC augmente la propension des étudiants à utiliser les VLSsS pour les déplacements d'études et d'achats. L'intensité de l'utilisation de l'Internet mobile a un impact positif sur la probabilité d'utiliser les VLSsS pour les déplacements d'études et d'achats. En outre, la fréquence de ces déplacements a un impact négatif sur la probabilité des étudiants de choisir les VLSsS pour chacun de ces motifs.

Le troisième essai (Chapitre 4) applique deux modèles PMSS (modèle probit avec sélection d'échantillon) pour étudier les facteurs qui influencent l'adoption et l'intention de continuer à utiliser les VTC. Après une revue de la littérature, les résultats démontrent que les impacts des caractéristiques individuelles sur l'adoption et l'intention de continuer à utiliser sont variés. Premièrement, les étudiants en master ou en doctorat, les étudiants qui habitent dans les centres urbains, les étudiants titulaires d'un permis de conduire, et les utilisateurs des VLSsS sont plus susceptibles d'adopter les VTC. Deuxièmement, les étudiants dont la fréquence des déplacements quotidiens est plus élevée sont moins susceptibles d'avoir une intention positive de continuer. Troisièmement, les étudiants qui ont un revenu plus élevé, qui ont une plus grande intensité d'utilisation de l'Internet mobile, et ceux qui utilisent des services de covoiturage, sont plus susceptibles d'adopter les VTC et d'avoir l'intention de

continuer à utiliser ces services dans un proche avenir. Quatrièmement, les femmes et les étudiants qui ont une carte de transport en commun sont plus susceptibles d'adopter les VTC, mais d'avoir une intention non-positive de continuer. De plus, les comportements actuels d'utilisation des VTC ont également des impacts importants et significatifs sur l'intention de continuer à utiliser les VTC. Celle-ci est plus élevée chez les utilisateurs fréquents, les étudiants qui ont utilisé les VTC pour plus de commodité et de rapidité, ceux qui ont utilisé les VTC pour faire des achats et des loisirs, et ceux qui ont utilisé ces services pour remplacer les trajets en taxi ou effectuer des trajets supplémentaires.

Quatre principaux résultats ressortent de ces travaux. Premièrement, l'intensité de l'utilisation de l'Internet mobile a un impact positif sur tous les aspects mesurant les comportements d'adoption et de post-adoption des VLSsS comme des VTC. Deuxièmement, plusieurs caractéristiques individuelles (comme le genre, le domaine d'études, la possession d'un permis de conduire, la fréquence des déplacements quotidiens) ont des impacts différents sur les différents comportements d'adoption et de post-adoption de ces deux services. Troisièmement, certaines caractéristiques individuelles (comme le genre, le degré d'études, le domaine d'études, le revenu mensuel, le lieu de résidence, la possession d'un permis de conduire) ont un impact partiel sur la fréquence d'utilisation et le choix du mode des VLSsS. Enfin, et quatrièmement, les comportements actuels d'utilisation des VLSsS ou des VTC ont des impacts non négligeables sur les comportements de post-adoption de ces deux services.

Cette thèse comporte un certain nombre de limites. Tout d'abord, elle se concentre uniquement sur un échantillon d'étudiants à Nankin, et il est encore difficile de savoir si et comment ces impacts peuvent varier dans d'autres villes de Chine. Pour cela, il

faudra mener une enquête à plus grande échelle parmi les étudiants de différentes villes de Chine. Deuxièmement, le développement de nouveaux services de mobilité est très rapide, et les comportements d'adoption et de post-adoption de ces services chez les étudiants peuvent évoluer avec le temps. Par conséquent, il est important de réexaminer ces problèmes à Nankin et ailleurs dans le monde dans le futur.

1. GENERAL INTRODUCTION

1.1. Background

Over the last decade, with the development of Information and Communication Technologies (ICT) and the rapid diffusion of the smartphone, new app-based mobility services, particularly ride-sourcing services (RSS, like Uber, Didi) and free-floating bike-sharing services (FFBSS, like Ofo, Mobike), have expanded rapidly around the world. The pioneer among pioneers, the North American RSS company Uber, was founded in 2009 and first officially launched in San Francisco in 2011. By the end of 2017, Uber was operating in more than 700 cities in approximately 80 countries around the world (Shaheen et al., 2018). Similarly, as of February 2018, two Chinese FFBSS giants, Ofo (founded in 2014 and first officially launched in Beijing in 2015) and Mobike (founded in 2015, and first officially launched in Shanghai in 2016) have launched their services in Asia, Australia, Europe, and the US, with respectively more than 250 cities (in 21 countries) and more than 200 cities (in 13 countries) (Aguilera and Boutueil, 2018). In particular, these new mobility services are booming nowhere more than in China. According to the China Internet Network Information Center (2018), numbers of RSS and FFBSS users have reached 287 million and 221 million respectively. In this context, understanding the needs of users in each national or even local context is a major challenge for providers of new mobility services. This is also relevant for research, which in recent years has been interested in the consequences of the emergence of these new services for mobility practices and policies (Aguilera and Boutueil, 2018).

1.2. Literature Review and Research Gaps

In the fields of transportation studies, the literature on the new mobility services, particularly, bike-sharing services (BSS, including station-based bike-sharing services (SBBSS) and FFBSS) and RSS, has grown rapidly over the past few years. However, evidence on the adoption and post-adoption behaviors of these two services and on the factors influencing them is still limited and fragmentary.

First of all, the majority of the research has focused on the likelihood of adoption (i.e. use or not) in both services (Alemi et al., 2018; Bachand-Marleau et al., 2012; Fishman et al., 2015), and only a few studies have looked at post-adoption behaviors, such as frequency of use (also known as intensity of adoption) (Alemi et al., 2019; Guo et al., 2017) and individuals' travel mode choices after their adoption of these new services (i.e. mode choice between new services like BSS and RSS and other traditional transportation modes such as walking, private bike, private car, taxi, public transport, etc.) (Gehrke et al., 2019; Tang et al., 2019). In addition, it should be noted that almost all previous studies on BSS have looked at SBBSS and the literature on FFBSS is sparse.

Secondly, the literature does not cover one of the most important aspects of post-adoption behavior, continuance intention to use, which has been extensively studied in the literature on adoption and post-adoption behaviors around innovation, especially for internet-based services (IBS) such as e-commerce, social media, e-learning and mobile payment services (Bhattacherjee, 2001a; Mouakket, 2015; Roca et al., 2006; Zhou, 2013). The fact is that the long-term viability and ultimate success of this IBS depend on continuity of use rather than first-time use, although obviously the initial adoption of an IBS is an important first step (Bhattacherjee, 2001b). To our knowledge, there has been no study of this issue in the literature on adoption and post-adoption behaviors of

relating to these two services.

Thirdly, several PhD dissertations have systematically explored adoption and post-adoptions behaviors relating to these two services and the factors influencing them. For example, Fishman (2014) studied the obstacles and drivers in the adoption of SBBSS in Australia. Henao (2017) analyzed the impacts of RSS on transport, including vehicle miles traveled (VMT), mode replacement, parking, and travel behavior in the US. And Alemi (2018) presented a comprehensive analysis of the adoption and frequency of use of RSS and their impacts on the use of other travel modes in the US. However, to our knowledge, there are still no PhD theses that have focused on these in China.

Last but not least, many studies have observed that university students (or more generally young people, also known as Millennials) were the early adopters and heavy users of smartphone and new Internet-based services (Lee, 2014; Yang, 2005), and one of the largest user groups of both BSS and RSS (Alemi et al., 2018; Chen et al., 2017; Guo et al., 2017; Rayle et al., 2016), as well as the future elites and leaders in all walks of life (Zhou, 2014). However, in the literature on the adoption and post-adoption behaviors relating to these two new services, to our knowledge only Alemi (2018) and Tarabay and Abou-Zeid (2019) have examined these issues of RSS, respectively in the US and Lebanon.

To fill in the research gaps described above, this thesis aims to advance our understanding of these topics through three empirical essays, focusing first on Chinese university students, second on two types of new mobility services (i.e. FFBSS and RSS), and third on both adoption and post-adoption behaviors relating to new mobility services (such as frequency of use, mode choice between the new services and traditional modes of transport, continuance intention to use, etc.).

1.3. Survey and Data

To this end, in November 2017, I conducted an original survey at Nanjing University on university students' daily travel behaviors and their use of new mobility services (the details of survey can be seen in **Appendix**). The results of the survey show that among 1432 students who completed valid questionnaires, first that some 90% of respondents had used FFBSS in Nanjing, and over 10% of respondents had chosen FFBSS as their main mode of transportation for both commuting and non-commuting trips; second that more than 60% of respondents had used RSS in Nanjing, but only some 60% of RSS users have a positive continuance intention around the use of these services in the near future.

1.4. Outline

Based on the data from the above survey, in this thesis I examine the adoption and post-adoption behaviors relating to new mobility services and the factors influencing them. The thesis is composed of three empirical essays. The first essay (Chapter 2) examines the factors influencing the frequency of use of FFBSS. The second essay (Chapter 3) studies the role of FFBSS in students' mode choices for commuting and shopping trips and the factors influencing them. The third essay (Chapter 4) investigates the factors that influence the adoption of RSS and adopters' continuance intention to use these services in the near future. Each of these three essays is an independent paper which is ready for submission or has been submitted to peer-reviewed journals, such as the Journal of Public Transportation, Transportation Research Record: Journal of the Transportation Research Board, and Travel Behaivour and Society.

2. FACTORS INFLUENCING THE FREQUENCY OF USE OF FREE-FLOATING BIKE-SHARING SERVICES AMONG UNIVERSITY STUDENTS IN NANJING, CHINA

Paper prepared for submission to the *Journal of Public Transportation*

2.1. Abstract

In the past three years, free-floating bike-sharing services (FFBSS) have expanded rapidly around the world, especially in China. The use of these services in that country is no longer an issue, with more than 200 million Chinese now using FFBSS. Instead, researchers and operators need to pay more attention to the frequency of use of these new services. This paper therefore examines the factors that influence the frequency of use of FFBSS among university students in Nanjing, China. The results of a generalized ordered logit model reveal that: first, graduate students, students who major in natural sciences and engineering, and students who have a higher level of monthly income, are more likely to show higher frequency of use; second, bike ownership decreases the likelihood of students showing higher frequency of use; third, both intensity of mobile Internet usage and frequency of daily travel have a positive impact on frequency of use of FFBSS; and last, earlier adopters, students who have used FFBSS for economic reason, and students who have used FFBSS for commuting trips, are also more inclined to show higher frequency of use. In addition, it should be noted that factors relating to level of education, monthly income, and time of adoption only have a partial impact on the frequency of use, on account of the violation of the proportional odds assumption.

Keywords: Free-Floating Bike-Sharing Services, Frequency of Use, Influential Factors,

Generalized Ordered Logit Model, University Students, China

2.2. Introduction

Bike-sharing can be traced back over 50 years, to the introduction of the White Bikes in the Netherlands (DeMaio, 2009; Shaheen et al., 2010). Known as the first generation of bike-sharing services, the White Bikes were dockless, unlocked, and free-of-charge for public use. Nevertheless, things did not go as planned. Many bikes were thrown into the canals or appropriated for private use, with the result that the program was short-lived. In order to solve the problems of the White Bikes, the second generation of bike-sharing services (the coin-deposit system with docking stations) was introduced in the 1990s. Here again, the lack of a time limit for bike use and user anonymity meant that bike theft and vandalism could not be controlled. A few years later, an updated bike-sharing system (i.e., the third generation of bike-sharing services) gradually emerged, along with the development of information and communication technologies (ICT). ICT made possible cashless payment and real-name registration, which on the one hand reduced the rate of bike theft and on the other facilitated the use of bike-sharing services. As a result, bike-sharing services spread quickly from Europe to Asia Pacific, and to North and South America. According to statistics summarized by Fishman (2016), the number of cities operating bike-sharing services group from 13 in 2004 to 855 as of 2014. In January 2014, there were approximately 946,000 shared bikes all over the world, 750,500 of them in China.

While docking stations had successfully reduced theft rates, they had also limited the further development of bike-sharing services. Multiple studies demonstrated that people were less likely to use bike-sharing services if there was no docking station near their origin or destination (Bachand-Marleau et al., 2012; Fishman et al., 2014; Fishman

et al., 2015). ICT again provided the solution. In 2015, a Chinese start-up company, Ofo, introduced the world's first free-floating bike-sharing service (FFBSS). Unlike the previous three generations mentioned above, the use of FFBSS is heavily dependent on the smartphone. The dockless bikes report their locations to the central server through an embedded GPS sensor and communication module. Users can easily locate bikes via smartphone apps. After finding a bike, users can unlock the bike by scanning its QR code, and then start their ride. At the same time, all the transactions, including deposits and fee payments, can be completed on the smartphone with mobile payments such as Alipay and Wechat Pay. Since the operating method is more flexible and effective than before, FFBSS have expanded rapidly in the past 3 years. Up to December 2017, the two Chinese FFBSS giants Ofo and Mobike were not only providing services in some 30 big cities in China (including Beijing, Shanghai and Nanjing), with over 200 million users, but has also expanded to 21 other countries (including USA, UK and France) (China Internet Network Information Center, 2018). In addition, according to the Bike-Sharing World Map (2018), at the end of 2017 there were more than 450,000 shared bikes in the world, four-fifths of which were FFBSS in Nanjing, one of the biggest cities in China.

In the field of research on bike-share, the adoption of bike-sharing services and the factors influencing it have been one of main topics of study over the past decade. Because of the relatively low adoption rates with previous bike-sharing services, researchers have paid much more attention to the likelihood of adoption (i.e. use or not) than to the intensity of adoption (i.e. up frequency of use). On the former point, the large number of Chinese FFBSS users (over 200 million as mentioned above) shows that the likelihood of adoption is no longer a key issue for the further development of FFBSS in China. On the other hand, there is growing interest in how frequently people

use these services, since a frequent user is more valuable than a nominal adopter. In this paper, therefore, I examine the factors that influence the frequency of use of FFBSS among university students in Nanjing, China. University students were chosen for this study for three reasons: (1) university students have been largely demonstrated to have been Internet pioneers and early adopters of Internet-related services (Lee, 2014; Yang, 2005); (2) multiple studies have shown that university students are the largest group of bike-sharing users (Chen et al., 2017; Guo et al., 2017); (3) university students are predictive of some of tomorrow's users, so it is instructive for urban and transportation planners to gain a good understanding of their current practices so as to better meet the future challenges of urban mobility (Zhou, 2014).

In the following sections, I present the relevant literature on factors that influence the frequency of use of bike-sharing services. This is followed by an explanation of the data collection methods and variables used in this study. I then present the econometric models, followed by a presentation and discussion of the results. The paper closes with conclusions and recommendations for the future research.

2.3. Literature Review

The literature on bike-sharing services is extensive and growing rapidly. Multiple articles can be found on the adoption of bike-sharing services and the factors influencing it (Bachand-Marleau et al., 2012; Chen et al., 2017; Chen et al., 2018; Efthymiou et al., 2013; Feng and Li, 2016; Fishman et al., 2015; Guo et al., 2017; Therrien et al., 2014; Yang and Long, 2016; Zhang et al., 2015). Most have focused on the likelihood of adoption (i.e. use or not), but only a few studies have looked at the intensity of adoption (i.e. continuing frequency of use). In addition, almost all the aforementioned studies considered station-based bike-sharing services (SBBSS).

Because of the lack of sufficient direct evidence on FFBSS, the following review focuses on four categories of factors that influence the frequency of use of BSS (both SBBSS and FFBSS).

Firstly, the socioeconomic and demographic characteristics of users of BSS have been a frequent focus of attention for operators and researchers (Fishman, 2016; Fishman et al., 2013). However, evidence on how those characteristics influence the frequency of use of BSS has been limited and fragmentary. Gender is a significant characteristic. Guo et al. (2017) found that males were generally 7% more likely to use SBBSS frequently than females. Income is another significant characteristic. Zhang et al. (2015) found that an increase in monthly income was accompanied by an increase in SBBSS usage, except for the group with incomes of 1,500 to 3,000 CNY and the group with incomes of 7,500 CNY or more. Study level is another factor that has been identified as a significant characteristic. Chen et al. (2018) demonstrated that individuals with a Master's or Ph.D. degree were more likely to be frequent users of SBBSS. As for other characteristics such as age, employment status, marital status, there is no evidence showing that they had significant impacts on the frequency of use of BSS. In addition, it should be noted that the aforementioned three studies were all based on SBBSS. There is therefore a need to clarify how socioeconomic and demographic characteristics influence frequency of use in the specific case of users of FFBSS.

Secondly, BSS has been seen as a very important tool for promoting bicycle use and reducing car dependence. In consequence, many researchers have sought to explore the relationship between vehicle ownership (bike, car) and the frequency of BSS use. With regard to bike ownership, Bachand-Marleau et al. (2012) found that bicycle ownership was associated with a 5.6 times reduction in the number of uses of SBBSS over a season

in Montreal, Canada. However, studies in China reached opposite results: people who had a private bicycle or an electric bicycle at home used SBBSS more frequently (Guo et al., 2017; Zhang et al., 2015). With regard to car ownership, Zhang et al. (2015) showed that individuals who owned a car were more likely to use SBBSS frequently than non-car-owners. In contrast, a recent study by Chen et al. (2017) concluded that, compared with individuals from families with two or more cars, individuals from families without a car were more likely to be frequent users of SBBSS. According to the aforementioned studies, vehicle ownership has been identified as a significant factor for the frequency of BSS use, but the findings regarding its effect (whether positive or negative) remain inconsistent. There is therefore a need to clarify the impact of vehicle ownership on the frequency of use of FFBSS.

Thirdly, intensity of Internet use has been confirmed as a key factor for predicting usage of Internet-based services. In particular, numerous studies have demonstrated that the frequency of Internet use has a positive effect on the frequency of e-shopping (Farag et al., 2006; Loo and Wang, 2018). However, little is still known about how the intensity of Internet use influences the frequency of use of FFBSS. To our knowledge, only a recent study by Chen et al. (2018) provides direct evidence that people who used more than 500 MB of mobile Internet data per month were more likely to be frequent users of FFBSS than those using between 301 and 500 MB. Furthermore, as a new Internet-based mobility service, the frequency of use of FFBSS is associated not only with individuals' intensity of Internet use but also with their daily travel frequency. However, no previous study has examined the impact of individuals' daily travel frequency on their frequency of use of FFBSS. It therefore makes sense to investigate the combined impacts of the intensity of Internet use and of daily travel frequency on the frequency of use of FFBSS.

Lastly, there is strong evidence suggesting that factors associated with FFBSS use such as user attitudes (e.g. rationality, satisfaction, familiarity and perception) and trip purpose influence the frequency of use of BSS. With regard to user attitudes, Bachand-Marleau et al. (2012) found that individuals who used SBBSS for reasons such as "avoiding maintenance", "attraction to the design of the shared bike", and "avoiding risk of theft" were more likely to be frequent users of SBBSS. Zhang et al. (2015) showed that user satisfaction with the quality of SBBSS had a positive impact on how often they used them. Chen et al. (2017) demonstrated that frequent users of SBBSS were familiar with the rental process and with the distribution of docking stations. Guo et al. (2017) revealed that the frequency of use of SBBSS was positively correlated with users' perceptions of SBBSS such as "familiarity with bike-sharing", "satisfaction with bike-sharing fees", "encouragement of green travel", "saving travel time by bike-sharing", "flexible route by bike-sharing", and "great effort on the introduction to the public". Regarding trip purpose, Chen et al. (2017) found that people who had used SBBSS for "business" or "shopping" on their most recent trip were more likely to be frequent users. Chen et al. (2018) made a comparison between the use of SBBSS and the use of FFBSS in Hangzhou, China. They found that individuals who used SBBSS for purposes of "eating out", "business" and "commuting" were more likely to be frequent users of SBBSS; and individuals who used FFBSS for purposes of "eating out", "business", "commuting", "going to school", "returning to work/school", "shopping" and "leisure" were more likely to be frequent users of FFBSS. In addition to user attitudes and trip purposes, the time of adoption is also an important factor for FFBSS users. Transportation researchers have already sought to identify the characteristics of early adopters of BSS and their usage patterns (Shaheen et al., 2011; Therrien et al., 2014) . However, there is no specific evidence on how time of adoption influences the

frequency of use of BSS, or in other words, whether early adopters are likely to be frequent users. In order to better understand the impacts of FFBSS use characteristics on the frequency of use of FFBSS, therefore, we need to look not only at user attitudes and trip purpose, but also at time of adoption.

Based on the literature review, I introduce four types of explanatory variables – socioeconomic and demographic characteristics, vehicle ownership, intensity of Internet use and daily travel frequency, and FFBSS use characteristics – to analyze factors that influence the frequency of use of FFBSS among university students. Using survey data from Nanjing, China, this research aims to enrich the existing literature on the adoption of BSS and the factors influencing it, and to widen our understanding of the contribution of FFBSS to sustainable mobility in people's day-to-day lives.

2.4. Data and Variables

The data used for this study come from a survey conducted in Nanjing University in November 2017, which was about university students' daily travel behaviors and their use of new mobility services. The survey was designed by the author and was adapted to the Chinese setting with the help of colleagues from Nanjing University's School of Architecture and Urban Planning.

Before the official launch of the survey, the questionnaire was pretested with 40 students at Nanjing University, in order to validate the interpretation of terminology and the intent of the questions. Following the pretest, the data collection protocol for the survey was determined as follows. An offline to online (O2O) method was used to collect data. On the offline side, 2,000 one-page invitation letters were distributed by intercepting students on the street in front of 5 principal dining halls from 11 am to 1

pm and 5 pm to 7 pm on Thursday 16th and Friday 17th November 2017. On the online side, the questionnaire was available on the Wen Juan Xing (https://www.wjx.cn), the most famous online survey platform in China, from Thursday 16th to Sunday 26th November 2017. And the QR code was a bridge between the invitation letter and the questionnaire. Students could use their smartphone or other devices to scan the questionnaire's QR code printed in the invitation letter, and then complete the questionnaire online. In order to increase the response rate, all respondents who completed the questionnaire were offered an electronic red envelope valued at 5 CNY as a token of appreciation.[1] By the deadline, a total of 1432 students had completed a valid questionnaire. Of these, 1251 (called adopters) had already used FFBSS in Nanjing. This very high adoption rate (87.36%) confirms that use or non-use is not an issue among Chinese university students. Researchers should therefore pay more attention to frequency of use and the factors influencing it, in order to improve the frequency of use of FFBSS in urban China.

Frequency of use is an element of post-adoption behavior. In this study, therefore, only the 1251 adopters of FFBSS were retained, in order to investigate the factors influencing their frequency of use. As shown in **Table 2.1**, frequency of use presents an ordinal structure, it is coded on a 5-point scale from the lowest to the highest level (see Table 1): 1 = level 1 (less than 1 day per month), 2 = level 2 (1-3 days per month), 3 = level 3 (1-3 days per week), 4 = level 4 (4-6 days per week), and 5 = level 5 (7 days

[1] The electronic red envelope is a mobile application deveoped by Chinese Internet giants like Tencent and Alibaba. The concept of this application is based on the Chinese tradition of *hongbao* (red envelope or red packet), where money is given to family and friends as a gift. The application allows users to give monetary gifts in the form of virtual 'credits' to other users of the application. Money is deposited into a user's Wechat Pay or Ali Pay account, which can be used for purchases. The app allows withdrawals from that account. There are two types of 'red envelope' offered by the app: the pairwise red packets, whereby money is sent in a private chat between two users, and the group red packets, where money is distributed in a group chat. The 'grouped' red envelope can then be posted to a group chat and the application randomly assigns the amount in each envelope to each recipient.

per week).

Table 2.1 Descriptive Statistics of Selected Variables

	Type	Frequency	Percent
Dependent variable			
Frequency of use			
1 = Level 1 (less than 1 day per month)	Ordinal	136	10.87
2 = Level 2 (1-3 days per month)		292	23.34
3 = Level 3 (1-3 days per week)		450	35.97
4 = Level 4 (4-6 days per week)		257	20.54
5 = Level 5 (7 days per week)		116	9.27
Explanatory variables			
(1) Socio-economic and demographic characteristics			
Gender			
1 = Male	Binary	585	46.76
Study level			
1 = Graduate student	Binary	883	70.58
Field of study			
1 = Social and human sciences	Multinomial	447	35.73
2 = Natural sciences and engineering		761	60.83
3 = Others		43	3.44
Marital status			
1 = Single	Binary	806	64.43
Monthly income			
1 = Low level (less than 1,000 CNY)	Multinomial	155	12.39
2 = Middle level (1,000 CNY - 2,000 CNY)		705	56.35
3 = High level (more than 2,000 CNY)		272	21.74
4 = Others (do not know/refusal)		119	9.51
(2) Vehicle ownerships			
Bike ownership			
1 = Yes	Binary	569	45.48
Car ownership			
1 = Yes	Binary	27	2.16
(3) Intensity of mobile Internet usage and frequency of daily travel			
Intensity of mobile Internet usage			
1 = Low level (less than 1 GB)	Multinomial	268	21.42
2 = Middle level (1 GB - 3 GB)		442	35.33
3 = High level (more than 3 GB)		504	40.29
4 = Others (do not know)		37	2.96
Frequency of daily travel			
1 = High level (≥34)	Binary	597	47.72
(4) FFBSS usage behaviors			
Time of adoption			
1 = New user (less than 3 months)	Multinomial	424	33.89
2 = Follower (3 months - 6 months)		332	26.54
3 = Pioneer (more than 6 months)		495	39.57
Reason for use			
1 = Convenient & Rapid	Multinomial	681	54.44
2 = Convenient & Economical		323	25.82
3 = Convenient & Ecological		107	8.55
4 = Convenient & Healthy		58	4.64
5 = Rapid & Economical		30	2.40
6 = Others		52	4.16
Trip purpose			
1 = Study	Binary	987	78.90

1 = Work	Binary	577	46.12
1 = Shopping	Binary	766	61.23
1 = Leisure and recreation	Binary	850	67.95
1 = Visiting friends and relatives	Binary	413	33.01

In order to examine factors influencing the frequency of use, four types of explanatory variables are considered in this research: socioeconomic and demographic characteristics, vehicle ownership, intensity of Internet use and frequency of daily travel, and FFBSS usage behaviors. More detailed descriptive statistics for these variables are also presented in **Table 2.1**.

In the general population, gender, age, employment status, marital status and income level are essential socioeconomic and demographic characteristics of a person. However, they do not accurately reflect the characteristics of university students. On the basis of previous studies on university students (Tamim et al., 2003; Zhan et al., 2016; Zhou, 2012), therefore, partial adjustments were made in this study. First, instead of chronological age (for instance, ≤ 22 years old vs. > 22 years old), level of education (undergraduate vs. graduate) is used to measure the age differences among students. Second, the respondents' field of study (social sciences and humanities vs. natural sciences and engineering), which profoundly influences their career choices, is considered with respect to the impact of employment status. Third, in order to understand the impact of marital status, students are divided into two groups, single and married. Fourth, to better reflect their economic status, students were asked about their monthly resources, including financial supports from their families, scholarships from the university, incomes for their part-time jobs, etc. To sum up, the first type of explanatory variables in this research comprises five aspects relating to the socioeconomic and demographic characteristics of the students: gender, study level, field of study, marital status and economic status.

The second type of explanatory variable is vehicle ownership, which includes two elements: bike ownership and car ownership. In previous studies, people were usually asked whether they have a bike/car in their household. However, this way of formulating the question is not suitable for the sample of university students who come from different parts of the country, since a student who has a bike back home in Shanghai, for example, cannot ride it in Nanjing. In this research, therefore, students are asked whether they have a vehicle that could be used for daily travel in Nanjing.

The third type of explanatory variable is the intensity of students' Internet use and their daily travel frequency. Similarly with the study by Chen et al. (2018), the intensity of student Internet use is measured by their monthly mobile Internet data consumption. In terms of daily travel frequency, there are eight questions in the survey: "How often do you go to your (1) principal place of study; (2) principal place of work; (3) principal place of shopping; (4) secondary place of shopping; (5) principal place of leisure and recreation; (6) secondary place of leisure and recreation; (7) principal place for visiting friends and relatives; and (8) secondary place for visiting friends and relatives?" The possible answers are: "never", "less than 1 day per month", "1-3 days per month", "1-3 days per week", "4-6 days per week", and "7 days per week". Because of the absence of a question about the students' overall travel frequency, the six levels of travel frequency are first coded as follows: 0 = "never", 0.5 = "less than 1 day per month", 2 = "1-3 days per month", 8 = "1-3 days per week", 20 = "4-6 days per week", and 28 = "7 days per week". From this, I then create the daily travel frequency index, which is calculated as the sum of the frequency of travel to the aforementioned eight places. Finally, on the basis of their daily travel frequency index, students are divided into two groups: low level and high level.

With regard to FFBSS usage behaviors (the fourth type of explanatory variables), three attributes were included: time of adoption, reason for use and trip purpose. The first FFBSS (named Ding Ding Bike) was launched in Nanjing on 18 December 2016 (Bike-Sharing World Map, 2018). Based on the time of adoption (the answer to the question "How long have you used FFBSS in Nanjing?"), students were divided into three categories: new users = "less than 3 months", follower = "3 - 6 months", and pioneer = "more than 6 months". With regard to the reason for use, students were asked "What are your two main reasons for using FFBSS in Nanjing?" The possible answers are: "convenient", "rapid", "economical", "ecological", "healthy", and "other". The results showed that "convenient & rapid" (54.44%), "convenient & economical" (25.82%), "convenient & ecological" (8.55%), "convenient & healthy" (4.64%), and "rapid & economical" (2.40%) were the five main pairs of reasons. The students were therefore classified into six groups, on the basis of their reasons for use: "convenient & rapid", "convenient & economical", "convenient & ecological", "convenient & healthy", "rapid & economical", and "other". As for trip purpose, students were asked to indicate whether they used FFBSS for five main types of trips (study-related, work-related, shopping-related, leisure and recreation-related, visiting friends and relatives-related).

2.5. Econometric Models

Given the ordinal structure of the dependent variable – frequency of FFBSS use by students – the ordered logit model (OLM) was deemed to be a natural choice for model estimation (Cameron and Trivedi, 2005). It can be written in terms of the cumulative probability equation as follows (**Equation 2.1**):

$$\Pr(Frequency_i > j) = \frac{\exp(\alpha_j + X_i\beta)}{1+[\exp(\alpha_j + X_i\beta)]}, \quad j = 1,2,3,4 \tag{2.1}$$

where

- $j = 1, 2, 3, 4$, which indicates the response category of frequency of use from "less than 1 day per month" ($j = 1$) to "4 - 6 days per week" ($j = 4$);

- α_j is the jth threshold parameter (cutoff points);

- X_i are all the explanatory variables in **Table 2.1** describing student i;

- β represents the regression coefficients associated with all the explanatory variables.

Using the OLM entails an important assumption, the so-called proportional odds assumption (POA) or parallel regression assumption (PRA). This means that each of the coefficients should be the same for each level of frequency of use j. However, the results of the Brant test (Brant, 1990) (see **Table 2.2**) show that five variables violate the POA, which is related to study level, monthly income and time of adoption.

Table 2.2 Brant Test of Parallel Regression Assumption

Variable	Chi-square	P-value	DF	Violation of assumption ($p<0.05$)
All	122.24	0.001	78	Yes
Gender (Male)	0.70	0.873	3	No
Study level (Graduate student)	8.91	0.030	3	Yes
Field of study (Natural sciences and engineering)	1.32	0.724	3	No
Field of study (Others)	1.37	0.713	3	No
Marital status (Single)	5.26	0.154	3	No
Monthly income (Middle level)	15.50	0.001	3	Yes
Monthly income (High level)	12.05	0.007	3	Yes
Monthly income (Others)	4.85	0.183	3	No
Bike ownership	0.98	0.807	3	No
Car ownership	4.41	0.220	3	No
Intensity of mobile Internet usage (Middle level)	0.98	0.806	3	No
Intensity of mobile Internet usage (High level)	1.78	0.618	3	No
Intensity of mobile Internet usage (Other)	3.97	0.265	3	No
Frequency of daily travel (High level)	1.65	0.649	3	No
Time of adoption (Follower)	8.91	0.031	3	Yes
Time of adoption (Pioneer)	26.72	0.000	3	Yes

Reason for use (Convenient & Economical)	2.13	0.546	3	No
Reason for use (Convenient & Ecological)	0.58	0.901	3	No
Reason for use (Convenient & Healthy)	5.19	0.159	3	No
Reason for use (Rapid & Economical)	0.39	0.943	3	No
Reason for use (Other)	7.27	0.064	3	No
Trip purpose (Study)	1.32	0.723	3	No
Trip purpose (Work)	2.29	0.515	3	No
Trip purpose (Shopping)	4.41	0.220	3	No
Trip purpose (Leisure and recreation)	1.63	0.652	3	No
Trip purpose (Visiting friends and relatives)	1.53	0.675	3	No

Due to the violation of POA in our data, the generalized ordered logit model (GOLM), also called the partial proportional odds model (PPOM), is used instead of the OLM in this research (Williams, 2006, 2016). In the GOLM, some of the coefficients can be identical for each level of frequency of use j, if the POA are not violated; other coefficients can be different, if the POA are violated. The cumulative probability equation of the GOLM is given as follows (**Equation 2.2**):

$$\Pr(Frequency_i > j) = \frac{\exp\,(\alpha_j + X_i^a \beta^a + X_i^b \beta_j^b)}{1 + [\exp\,(\alpha_j + X_i^a \beta^a + X_i^b \beta_j^b)]}, \quad j = 1,2,3,4 \tag{2.2}$$

where

- $j = 1, 2, 3, 4$, which indicates the frequency of use response category from "less than 1 day per month" ($j = 1$) to "4 - 6 days per week" ($j = 4$);

- α_j is the jth constant coefficient;

- X_i^a is a set of the explanatory variables in Table 1 describing student i that do not violate the POA;

- β^a represents the regression coefficients associated with the non-violated variables,

which are the same across values of j;

- X_i^b is a set of the explanatory variables in Table 1 describing student i that violate the POA;

- β_j^b represents the regression coefficients associated with the violated variables, which are different across values of j.

2.6. Results and Discussions

Based on the GOLM as mentioned above, initially the "gologit2" module in STATA 13 written by Williams (2006) is used to estimate the impact of all the explanatory variables on the frequency of use of FFBSS among university students. Since gender, marital status, car ownership, and three types of non-commuting trips: shopping, leisure and recreation, and visiting friends and relatives, are not significant at the 90% confidence level, I remove them from the list of explanatory variables. Finally, the results of the fitted GOLM are shown in **Table 2.3**

Table 2.3 Results of Generalized Ordered Logit Model

	j = 1[1]	j = 2	j = 3	j = 4
(1) Socio-economic and demographic characteristics				
Study level (ref. Undergraduate student)				
Graduate student	0.738[2]***[3]	0.197	0.193	-0.163
Field of study (ref. Social and human sciences)				
Natural sciences and engineering	0.313***	Same[4]	Same	Same
Other	0.891***	Same	Same	Same
Monthly income (ref. Low level)				
Middle level	0.619**	0.307	-0.200	-0.280
High level	0.624**	0.056	-0.149	-0.427
Other	0.200	0.200	Same	Same
(2) Vehicle ownership				
Bike ownership				
Yes	-0.627***	Same	Same	Same
(3) Intensity of mobile Internet usage and frequency of daily travel				
Intensity of mobile Internet usage (ref. Low level)				
Middle level	0.324**	Same	Same	Same

High level	0.707***	Same	Same	Same
Other	0.768**	Same	Same	Same
Frequency of daily travel				
High level	0.314***	Same	Same	Same
(4) FFBSS usage behaviors				
Time of adoption (ref. New user)				
Follower	0.493**	0.487***	-0.014	0.026
Pioneer	1.260***	0.739***	0.013	-0.114
Reason for use (ref. Convenient & Rapid)				
Convenient & Economical	0.221*	Same	Same	Same
Convenient & Ecological	0.037	Same	Same	Same
Convenient & Healthy	0.407	Same	Same	Same
Rapid & Economical	0.761**	Same	Same	Same
Other	-0.490*	Same	Same	Same
Trip purpose				
Study				
Yes	1.661***	Same	Same	Same
Work				
Yes	0.386***	Same	Same	Same
Constant	-1.084***	-2.053***	-3.116***	-4.300***
Number of observations	1251			
Pseudo R-squared	0.1019			

Notes:
1. j = 1: level 1 versus level 2, level 3, level 4, level 5; j = 2: level 1, level 2 versus level 3, level 4, level 5; j = 3: level 1, level 2, level 3 versus level 4, level 5; j = 4: level 1, level 2, level 3, level 4 versus level 5.
2. Log odds ratio of the explanatory variable.
3. Level of significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
4. Same: variable follows parallel regression assumption.

Socio-economic and demographic characteristics have important impacts on student frequency of FFBSS use. First, the result of the model j = 1 shows that compared with undergraduate students, frequency of use among graduate students is likely to be higher, whereas in the other three models (j = 2, j = 3, and j = 4), study level has no significant impact on frequency of use. These results indicate that the relationship between study level and frequency of use does not follow the proportional odds assumption. This finding is partly consistent with the finding by Alemi et al. (2019) that older millennials are more likely to be frequent users of ride-sourcing services. Second, in all four models, frequency of use is likely to be higher among students who major in natural sciences and engineering. This finding provides evidence that the field of study has an impact on post-adoption behavior with respect to FFBSS. Third, similarly to the impact of

study level, the results show that increasing the monthly income raises the likelihood of higher frequency of use in the j = 1 model, whereas monthly income has no significant impact on frequency of use in the other three models (j = 2, j = 3, and j = 4). These results are partly in line with the previous studies on SBBSS (Zhang et al., 2015).

In terms of vehicle ownership, the results of all four models show that bike ownership decreases the propensity to higher frequency of FFBSS use. This finding is consistent with Bachand-Marleau et al. (2012) but runs counter to previous studies on SBBSS in China (Guo et al., 2017; Zhang et al., 2015).

With regards to intensity of mobile Internet usage and frequency of daily travel, the results of all four models show that students with a higher intensity of mobile Internet usage and a higher frequency of daily travel are more likely to have a higher frequency of FFBSS use. The former confirms that heavy users of Internet are more inclined to be heavy users of Internet-based mobility services like FFBSS. The latter reflects the fact that FFBSS facilitate day-to-day travel for students, especially those with greater mobility needs.

As for FFBSS usage behaviors, all three factors have substantial impacts on frequency of use. First, the results show that in the j = 1 and j = 2 models, the earlier adopters are more likely to have higher frequency of use, although this impact disappears in the j = 3 and j = 4 models. This finding provides empirical evidence for the importance of early adopters in the innovation diffusion theory. Secondly, the results of all four models reveal that, compared with students who give their reasons for use as “Convenient & Rapid”, students who use FFBSS because they are “Convenient & Economical”, and “Rapid & Economical”, are more likely to show higher frequency of FFBSS use. This finding provides evidence that at the time of the survey, the price war among the FFBSS

platforms to some extent encouraged students to use these services more frequently. Lastly, the results show that, in all four models, students who have used FFBSS for commuting trips (both study-related and work-related) are more likely to show higher frequency of use of FFBSS. This suggests that FFBSS have taken up an important role in day-to-day student travel.

2.7. Conclusion

In the past three years, FFBSS have developed rapidly around the world. Especially in China, these services have covered all major cities, with more than 200 million users, an indication that use or non-use is no longer a big issue for Chinese FFBSS platforms. At the same time, many people have doubts about the frequency of use of FFBSS. For this reason, the important question for researchers and operators is to understand the factors that influence the frequency of FFBSS use and how to encourage adopters to increase this frequency.

To this end, this paper applies a generalized ordered logit model to identify factors that influence the frequency of use of FFBSS among university students in Nanjing, China. The modeling results can be summarized as follow. Firstly, graduate students, students who major in natural sciences and engineering, and students who have a higher level of monthly income, are more likely to exhibit higher frequency of FFBSS use. Secondly, bike ownership decreases the likelihood of students having a higher frequency of FFBSS use. Thirdly, both intensity of mobile Internet usage and frequency of daily travel have a positive impact on the frequency of FFBSS use. Lastly, earlier adopters, students who have used FFBSS for economic reasons, and students who have used FFBSS for commuting trips, are also more inclined to exhibit a higher frequency of FFBSS use. In addition, it should be noted that because of the violation of the

proportional odds assumption, the factors relating to study level, monthly income and time of adoption only have a partial impact on the frequency of use of FFBSS.

There are also some limitations in this study which could merit investigation in the future. Firstly, we know that nearly all Chinese students live in dormitories inside campuses that are provided by the universities. Moreover, the majority of Chinese universities have dual campuses (one in the city center, the other in the suburbs), and their suburban campuses are very large, with different residential zones. Yet the impact of the location of different campuses and of the environment of different residential zones within a single campus on the frequency of FFBSS use are not considered in this paper. Secondly, the factors that influence frequency of use of FFBSS may vary across different latent groups of students. This issue could be re-examined by estimating a latent-class model that captures the disparities in students' tastes and preferences.

3. THE ROLE OF FREE-FLOATING BIKE-SHARING SERVICES IN THE MODE CHOICES OF UNIVERSITY STUDENTS AND THE FACTORS INFLUENCING THEM: AN EMPIRICAL STUDY ON COMMUTING AND SHOPPING TRIPS IN NANJING, CHINA

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3.1. Abstract

This paper examines the role of free-floating bike-sharing services (FFBSS) in the mode choices of university students for commuting and shopping trips and the factors influencing them, in Nanjing, China. Based on an original survey conducted in Nanjing University in November 2017 concerning university students' daily travel behaviors and their current/future uses of new mobility services, six categories of factors (i.e. socio-economic and demographic characteristics, the built environment, availability of mobility options, adoption of shared mobility services, general conditions, and travel characteristics) are investigated in this study, using two multinomial logit models. The results show that females and students majoring in natural sciences and engineering are less likely to use FFBSS for commuting trips, while graduate students are more likely to use FFBSS for shopping trips. Students who live in zone 2 and 4 of Xianlin campus are more likely to use FFBSS for commuting trips. Holding a driver's license decreases the likelihood of students choosing FFBSS for commuting trips. A higher rate of adoption of ride-sourcing services increases the propensity of students to use FFBSS

for both commuting and shopping trips. Intensity of mobile Internet usage has a positive impact on the likelihood of using FFBSS for both commuting and shopping trips. In addition, the frequency of commuting and shopping trips has a negative impact on the likelihood of students choosing FFBSS for commuting and shopping trips respectively.

Keywords: Free-Floating Bike-Sharing Services, Mode Choices, Influential Factors, Multinomial Logit Model, University Students, China

3.2. Introduction

"Today's students will be tomorrow's elites and leaders in society in all walks of life, shaping and making many policies and decisions that will profoundly influence and change our world" (Zhou, 2014). In the field of transportation studies, the travel behavior of university students has garnered increasing attention over the past decade, with students' mode choices and the factors influencing them being priority topics. However, our understanding of these topics still remains limited.

First, a significant proportion of the literature on mode choices in the general population shows that the impact of single factors on travel mode choices varies according to trip purpose (Dieleman et al., 2002; Feng et al., 2014; Hatamzadeh et al., 2019; Zhang, 2004). However, the current literature on the mode choices of university students has mainly focused on commuting, and little is known about whether and how there is variation between commuting and other purposes (such as shopping). Hence, it is relevant to examine students' mode choices and the factors influencing them with respect to different trip purposes.

Second, as noted by Zhan et al. (2016), most students in China have no income and rely on their parents to pay their tuition fees and living expenses. In order to reduce students'

accommodation expenses and facilitate campus management, the universities provide dormitories and canteens for all students to live on campus, with government subsidies to lower student living costs. Meanwhile, there are also many amenities, stores, etc. around the campus. Thus, most of routine student activities for study and living take place on or around campus. In China, therefore, the university campus is a special community which differs from other countries, generating different travel patterns among university students as well. However, to the best of our knowledge, only one article, written by Zhan et al. (2016), has addressed the question of university students' mode choice practices in China. That study focused on students' travel behaviors in trips from inside to outside campuses. However, as mentioned above, the majority of students' daily trips take place on or around the campus. We therefore need to learn more about Chinese university students' mode choice for trips on or around campuses.

Third, building sustainable university campuses and encouraging active modes among students (i.e. walking and biking) is a common objective for university managers and urban/transportation planners as well as researchers in the field (Balsas, 2003). To this end, in 2014 a group of Peking University graduates established Ofo, the first free-floating bike-sharing service (FFBSS) operator in China, to meet demand for internal transportation on campus. This new, innovative, flexible, shared cycle-share system has grown rapidly in China from nothing to a substantial fleet of 23 million bikes with more than 221 million users, covering over 200 cities and regions as of the end of 2017 (China Internet Network Information Center, 2018; Gu et al., 2019). Meanwhile, there is a growing literature dedicated to understanding the patterns of adoption and use for these new services among the general population in China (Chen et al., 2020; Du and Cheng, 2018; Li et al., 2018). However, the literature on FFBSS adoption and usage patterns among university students is still limited. In addition, the aforementioned literature has

mainly focused on the FFBSS itself, on factors such as likelihood of use, frequency of use, etc. But, no studies have looked at mode choice between FFBSS and other traditional modes of transportation (e.g. walking, private bike, public transit, etc.). It therefore makes sense to seek to clarify mode choice between FFBSS and traditional modes of transportation with special attention to university students' daily trips on and around the campus.

To that end, this paper examines the role of FFBSS in university students' mode choices and the factors influencing them on the basis of an empirical study on commuting and shopping trips in Nanjing, China. The data for this study are extracted from the Nanjing Survey on University Students' Daily Travel Behaviors and Their Practice of New Mobility Services. It is worth noting that this empirical study focuses on the students of Xianlin Campus (i.e. the principal campus of Nanjing University, located in Qixia District, Nanjing) and their trips on/around the campus. On the basis of the data, six categories of factors (i.e. socio-economic and demographic characteristics, built environment, availability of mobility options, adoption of shared mobility services, general conditions, and travel characteristics) are investigated in this study, using two multinomial logit (MNL) models (one for commuting trips and the second for shopping trips).

In the next section, I present the relevant literature on these topics. This is followed by a presentation of the data and methods used in this study (i.e. city context, survey and data, variables and descriptive statistics, and econometric model). After that, I present and discuss the results of the econometric models. Finally, this paper ends with conclusions, recommendations for affected actors, and prospects for future research.

3.3. Literature Review

A review of the literature finds no direct reference to the role of FFBSS in the mode choices of university students and the factors influencing them. I therefore review six categories of factors (socio-economic and demographic characteristics, built environment, availability of mobility options, adoption of shared mobility services, general contexts, and travel characteristics) which may influence these topics, by combining the literature on university students' mode choices for commuting trips (as far as we know, there is no study focused on shopping trips), FFBSS adoption and usage patterns, etc.

The factors in the first category are socio-economic and demographic characteristics. For now, their impacts on university students' mode choices remain limited and ambiguous. In terms of gender, several studies found that males were more likely to use active modes (such as walking and cycling) and public transportation for commuting trips (Akar et al., 2013; Danaf et al., 2014; Zhou, 2012), while others argued that women were more likely to commute to university by active modes, public transportation and carpooling (Moniruzzaman and Farber, 2018; Nguyen-Phuoc et al., 2018). But, in a study in Hamilton, Canada (McMaster University), Whalen et al. (2013) found that there were no gender differences in mode choice among university students commuting to school. On the other hand, Zhan et al. (2016) found that gender had a significant impact on students' mode choice for off-campus travel in China. With regard to study level, Zhou (2012) found that undergraduate students were more likely to use active modes (walking and bike) to commute to campus. This result was confirmed by Akar et al. (2013), who found that in comparison with driving, graduate students were less likely to use modes and more likely to choose the bus. Study level was also examined

by Danaf et al. (2014), who did not find significant differences between undergraduate and graduate students. Moreover, a recently study in Danang, Vietnam, demonstrated that the probability of a student using public transportation to commute to university fell from year to year during their time there (Nguyen-Phuoc et al., 2018). Similarly, Nguyen-Phuoc et al. (2018) found that compared with first-year students, second-year students were more likely to bike, and third year students more likely to walk, respectively. For their part, Zhan et al. (2016) classified this category in three stage (basic learning stage, professional learning stage and practical learning stage), but did not find significant differences among these three stages. The field of study is another characteristic of university students. Danaf et al. (2014) studied the impact of faculty (agricultural and food sciences, arts and sciences, etc.) on students' mode choice, but found no significant differences. The other studies on student mode choice did not consider this characteristic (Akar et al., 2013; Moniruzzaman and Farber, 2018; Nguyen-Phuoc et al., 2018; Whalen et al., 2013; Zhan et al., 2016; Zhou, 2012). In addition to gender, study level, and field of study, several studies also examined the impact of students' income level on their mode choice. Danaf et al. (2014) found that students from higher family income brackets were more likely to use the car than the bus or jitney, and to use the jitney than the bus. Moniruzzaman and Farber (2018) found that increasing income reduced the propensity to choose active modes, public transportation and carpooling. And Nguyen-Phuoc et al. (2018) found that students from richer households were less likely to cycle. However, in the case of China, Zhan et al. (2016) found that students' family income did not have an impact on their mode choice.

The second category of factors relate to the built environment of students' residential location, which has been extensively explored in the literature. Akar et al. (2013)

studied bike trails/lanes and bus stops. They found that being within 0.5 miles of a bike trail or lane increased the probability of cycling, and the propensity to use transit increased if there was a bus stop within 0.5 miles of the residential location. Moniruzzaman and Farber (2018) measured several characteristics of the built environment around the place of residence. They found first of all that street networks and intersection densities contributed positively to the propensity to use active modes; secondly, street density was likely to increase the propensity to use public transit; thirdly, street density had a positive impact on the likelihood of carpooling whereas the impact of intersection density and land use mix was negative. Whalen et al. (2013) found that street density increased the likelihood of choosing car and transit, whereas sidewalk density reduced the likelihood of choosing these motorized modes. Zhan et al. (2016) explored the impact of public transit station coverage ratio (PTSCR, which reflects public transportation access on the campus) on students' mode choice in China. They found that for non-bike-owning students, the proportion of students from low PTSCR campuses choosing the bicycle (19.3%) is much higher than those among students from middle and high PTSCR campuses (middle PTSCR, 1.5%; and high PTSCR, 5.6%). And Zhou (2012) found that living near a direct bus line to UCLA significantly increased the propensity of students to choose active modes (biking or walking).

The third category of factors is the availability of mobility options. In terms of bike ownership, Moniruzzaman and Farber (2018) found that bike ownership increased the likelihood of using active modes, a finding that confirmed that of Zhan et al. (2016). However, things were different in Vietnam. Nguyen-Phuoc et al. (2018) found that students who had a bike were more likely to cycle, but were less likely to walk to university. Moreover, the study by Whalen et al. (2013) found that bike ownership has

no impact on students' commuting mode choice. With reference to car use, both Danaf et al. (2014) and Moniruzzaman and Farber (2018) found that car ownership increased students' likelihood of commuting by car. However, the study by Whalen et al. (2013) again found that car ownership made no difference to students' commuting mode choice. As for possession of a transit pass, both Moniruzzaman and Farber (2018) and Zhou (2012) found that transit pass owners were more likely to choose active modes, public transit, and carpooling, rather than driving. In addition to the above three mobility options, some others such as a motorcycle license, motorcycle ownership, and possession of a parking permit have also been shown to make a difference to students' commuting mode choice (Nguyen-Phuoc et al., 2018; Zhou, 2012).

The fourth category of factors relates to the adoption of shared mobility services. Over the past decade, the development and adoption of shared mobility services (such as bike-sharing, car-sharing, carpooling, ride-sourcing) have reshaped urban mobility (Aguilera and Boutueil, 2018; Machado et al., 2018). Several studies have examined the impacts of the adoption of these new mobility services on other travel modes. For instance, Zhu et al. (2013) studied the change in travel behavior after the introduction of station-based bike-sharing services (SBBSS) in Shanghai, and showed that SBBSS were largely replacing walking and public transport. On the basis of a comprehensive travel and residential survey conducted in seven major U.S. cities, which included questions on the adoption and use of car-sharing and ride-sourcing services, Clewlow and Mishra (2017) found that 26% of ride-sourcing adopters reduced their personal driving, and ride-sourcing services served as a substitute for bus services and a complement to commuter rail. However, in the literature on students' mode choices and the factors influencing them, studies on the impacts of the adoption of shared mobility services remain limited. To our knowledge, only Moniruzzaman and Farber (2018)

examined this issue, finding that practitioners of car-sharing were more likely to use active modes, public transport and carpooling than driving.

The fifth category of factors relate to the general context. In the literature, several researchers have argued that transport expenditure has a non-negligible impact on travel behavior in developing countries (Olvera et al., 2008; Venter, 2011). The impact is also substantial for university students in developing countries like China, where most of university student have no income and rely on their parents to provide their living costs. Spending on transportation may be a significant proportion of their personal budget for most students, and limits the likelihood of their choosing the private car as a travel mode (Zhan et al., 2016). However, this factor has been excluded in studies about the mode choice of university students. In addition to spending on transport, Internet usage is another contextual factor that may affect mode choice among today's university students. This is because the Internet plays a considerable role in the everyday life of university students (Jones et al., 2009), and multiple studies have found that they were more inclined to choose Internet-related services than traditional services (such as e-shopping, online banking, FFBSS, etc.) (Lee, 2014; Li et al., 2018; Yang, 2005). However, this factor is not examined in the existing literature on influential factors associated with students' mode choice, because these studies only focus on mode choice among traditional travel modes and do not cover Internet-based shared mobility services (like FFBSS).

The sixth category of factors is travel characteristics. Travel time and travel cost have been extensively explored in the literature. For instance, it has been found that both travel time and travel cost had a negative impact on the likelihood of choosing active modes and public transportation (Akar et al., 2013; Danaf et al., 2014). However, in the

study by Nguyen-Phuoc et al. (2018), these negative effects were significant for travel time, but not for travel cost. Conversely, although Whalen et al. (2013) also considered travel time in their model, they did not find a significant negative impact. In addition to the above two characteristics, Moniruzzaman and Farber (2018) found that increasing travel distance reduced the likelihood of using active modes and public transport. Two similar pieces of evidence were provided by Nguyen-Phuoc et al. (2018) and Zhou (2012) respectively: the former reported that students with a shorter travel distance (less than 2km) were more likely to walk or bike to university, and the latter showed that a greater commuting distance increased the likelihood of carpooling and telecommuting. This impact of travel distance was also confirmed in a study of non-commuting trips by university students (Zhan et al., 2016). Finally, travel frequency is also considered in the literature. For example, Moniruzzaman and Farber (2018) found a positive correlation between students' commuting frequency and their propensity to travel using active modes, public transport, and carpooling.

On the basis of a review of the studies above, this paper firstly (re)-examines the impacts of the above listed six categories of factors on university students' mode choice for commuting trips between FFBSS and the traditional modes of transportation in China, and secondly provides supplementary insight into the topic of university students' mode choices and the factors influencing them, by means of a comparison between commuting trips and shopping trips.

3.4. Data and Methods

3.4.1. City Context

The research area of this study is Nanjing, which is the capital of Jiangsu Province in China and the second largest city in the East China region, with an area of 2543 square

kilometers and a total population of over 8 million in 2015 (Nanjing Bureau of Statistics, 2016). It is one of three major national education and research centers (the two others are Beijing and Shanghai), with over 720,000 university or college students studying in Nanjing at the end of 2018 (Nanjing Bureau of Education, 2019). In addition, the development of FFBSS in Nanjing is far ahead of other cities (Du and Cheng, 2018). This background information is important to providing new evidence and achieving a greater understanding of the role of FFBSS in university students' mode choices and the factors influencing them in China.

3.4.2. Survey and Data

The data used for this study come from a survey conducted at Nanjing University in November 2017 on university students' daily travel behaviors and their use of new mobility services. The survey was designed by the author and was adapted to the Chinese setting with the help of colleagues from Nanjing University's School of Architecture and Urban Planning.

The survey questionnaire consists of three parts. The first is about the travel habits of university students. In this part, students were asked about their residential location and their travel habits (main geographical location, trip frequency, main mode of transport) in relation to five trip purposes: "Study", "Work", "Shopping", "Leisure and Recreation" and "Visiting Friends and Relatives". The second part is about their use of new mobility services, focusing on the cases of free-floating bike-sharing services and ride-sourcing services. For each service, students were first asked whether they knew about the service before the survey. If not, they were asked whether they would use this service in the future. If they knew about the service, they were asked how often they had used it. If the answer was "Never", they were asked two questions (reason for not using,

intention to use in the future). Those who had already used the service were asked a further six questions (time of adoption, reason for use, trip purpose, mode shift, transfer pattern, intention to continue use). The third part of the questionnaire consists of additional information about the respondents, including socio-demographic features (gender, study level, field of study, monthly income, etc.), mobility options (bike ownership, car ownership, possession of a driver's license, of a public transit pass, etc.), ICT usage (monthly consumption of mobile Internet data, etc.), and so on.

Before the official launch of the survey, the questionnaire was pretested with 40 Nanjing University students, in order to validate the interpretation of terminology and the intent of the questions. Following the pretest, the data collection protocol for the survey was determined as follows. An offline to online (O2O) method was used to collect data. On the offline side, 2,000 one-page invitation letters were distributed by intercepting students on the street in front of 5 main dining halls from 11 am to 1 pm and 5 pm to 7 pm on Thursday 16th and Friday 17th November 2017. On the online side, the questionnaire was available on the Wen Juan Xing (https://www.wjx.cn), the most famous online survey platform in China, from Thursday 16th to Sunday 26th November 2017. And the QR code was a bridge between the invitation letter and the questionnaire. Students could use their smartphone or other devices to scan the questionnaire's QR code printed in the invitation letter, and then completed the questionnaire online. In order to increase the response rate, all respondents who completed the questionnaire were offered an electronic red envelope valued at 5 CNY as a token of appreciation.[2]

[2] The electronic red envelope is a mobile application deveoped by Chinese Internet giants like Tencent and Alibaba. The concept of this application is based on the Chinese tradition of *hongbao* (red envelope or red packet), where money is given to family and friends as a gift. The application allows users to give monetary gifts in the form of virtual 'credits' to other users of the application. Money is deposited into a user's Wechat Pay or Ali Pay account, which can be used for purchases. The app allows withdrawals from that account. There are two types of 'red envelope' offered by the app: the pairwise red packets, whereby money is sent in a private chat between two users, and the group red packets, where money is distributed in a group chat. The 'grouped' red envelope can then be posted to

In the end, a total of 1,432 valid questionnaires were completed.

To better understand the role of FFBSS in university students' mode choices and the factors influencing them, this study focuses firstly on students at Xianlin Campus (**Figure 3.1**), which is the main campus in Nanjing, located in Qixia District, Nanjing, and secondly on their commuting and shopping trips on/around the campus.

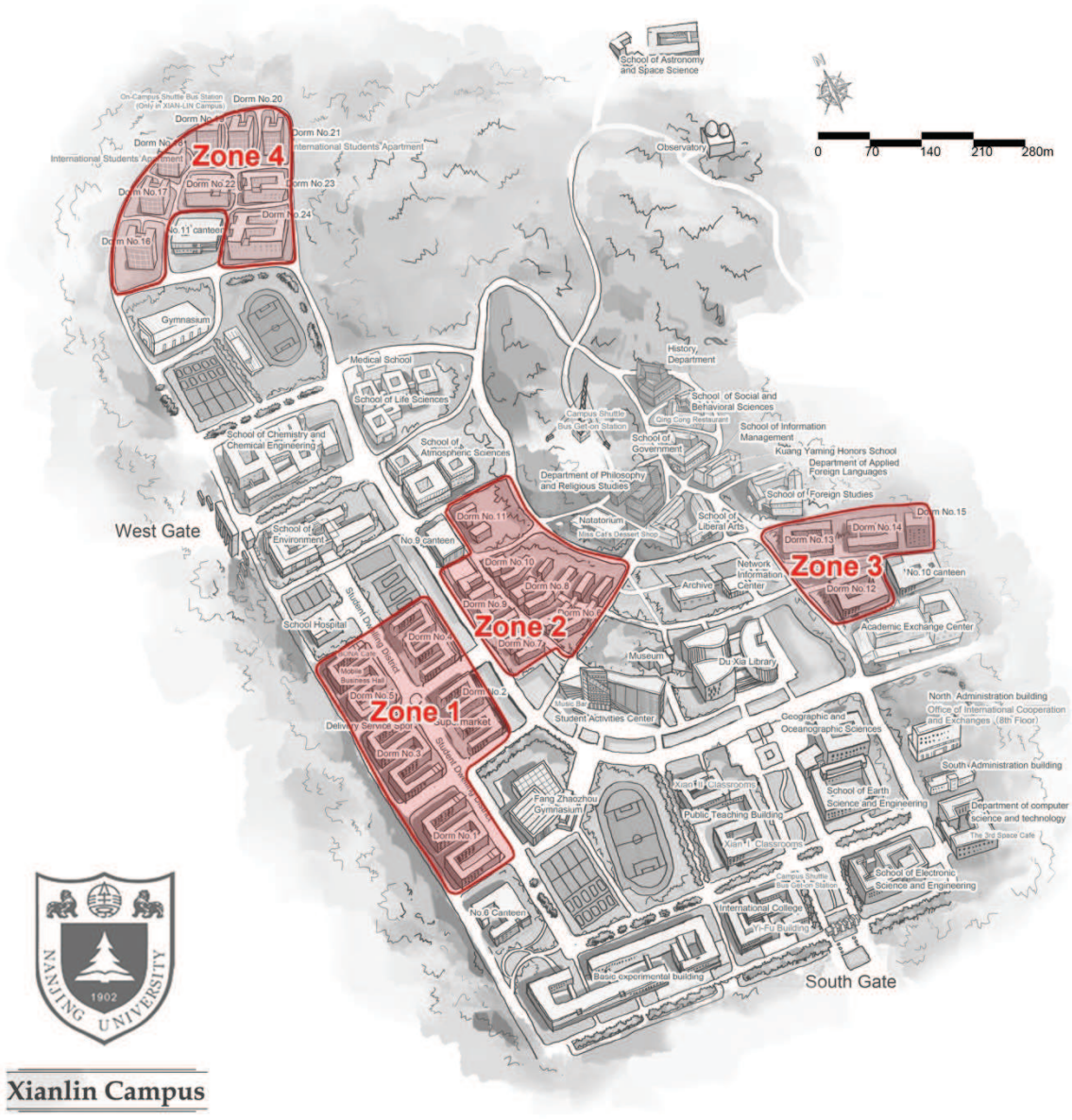


Figure 3.1 Map of Nanjing University's Xianlin Campus

a group chat and the application randomly assigns the amount in each envelope to each recipient.

3.4.3. Variables and Descriptive Statistics

The dependent variables in this study are students' mode choices for commuting and shopping trips, respectively. As shown in **Figure 3.2**, walking occupies a dominant position in both types of trip. A relatively higher proportion of students chose walking or riding a private bike for commuting trips, whereas they were more inclined to use public transportation for shopping trips. In addition, it is surprising that more than 10% of students used FFBSS as their principal mode of transportation for both trip types of trip.

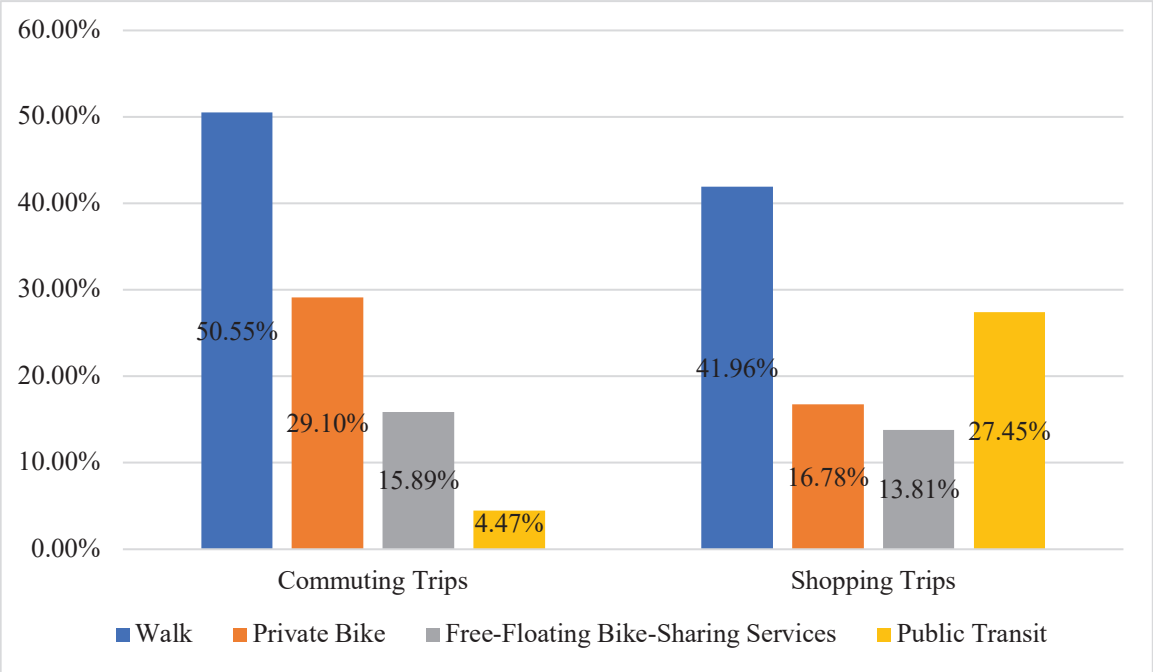


Figure 3.2 Breakdown of Students' Mode Choices for Commuting and Shopping Trips

In order to examine the factors influencing students' mode choices, six categories of explanatory variables are considered in this research. The first category is socio-economic and demographic characteristics, which includes four variables: gender, study level, field of study and income level. By contrast with the literature, where

family income was used to measure students' income level (Zhan et al., 2016), in this study students' income level comprises their total monthly monetary resources, which may include financial supports from their families, scholarships from faculty or university, and incomes from part-time jobs, etc. The second category is the built environment. Since all the students in this study lived in dormitories on campus, in this study the students' residential location is divided into four zones (see **Figure 3.1**), which shows that even when the focus is within the campus, the built environment still makes a difference to mode choice for students living in different zones. The third category is the availability of mobility options, which includes four variables: private bike ownership, car ownership, possession of a driver's license, possession of a public transit pass. The fourth category is adoption of shared mobility services, which includes two variables: adoption of ride-sourcing services and adoption of FFBSS. The adoption level for each service is divided into three levels: low level applies to students who do not know about or have never used these services; middle level applies to students who have used RSS and FFBSS at a frequency of "1-3 days per month" and "from 1 day per month to 3 days per week", respectively; and high level applies to students who have used RSS and FFBSS at a frequency of "more than 1 day per week", and "more than 4 days per week", respectively. The fifth category is general context, which includes two elements: monthly transportation expenditure and monthly mobile Internet usage. The sixth category is travel characteristics. In this category, trip frequency for each related trip purpose is classified into two levels (high level or not), where a frequency of "7 days per week" for commuting and "more than 1 day per week" for shopping, are respectively classified as high level.

The detailed descriptive statistics for these variables per mode of transportation for commuting and shopping trips are presented in **Table 3.1**. Since all the students have a

mode choice for commuting trips, the analysis of descriptive statistics that follows can be based on the cumulative statistics relating to commuting trips. The majority of respondents are female (54.91%), undergraduate students (65.54%), students majoring in natural sciences and engineering (57.29%). Over half the respondents (53.72%) own a private bike, and nearly 90% of them (88.77%) have a public transit pass. In addition, while car ownership rate is extremely low (1.88%), about half of them (48.16%) possess a driver's license. The adoption rates for shared mobility services are relatively high in that some 60% (59.98%) and 90% (88.48%) of respondents have used RSS and FFBSS in Nanjing, respectively. More than half the respondents' (51.73%) report monthly transportation expenditure of less than 50 CNY, while only some 20% (22.34%) of respondents' monthly Internet usage is less than 1 G. Nearly 40% of respondents make daily commuting trips, while over half (50.34%) make shopping trips less than one day per week.

Table 3.1 Descriptive Statistics of Selected Variables per Mode of Transportation for Commuting and Shopping Trips

	Commuting Trips (N= 1007)					Shopping Trips (N=572)				
	W[1]	PB	FFBSS	PT	Total	W	PB	FFBSS	PT	Total
(1) Socio-economic and demographic characteristics										
Gender	0.0172					0.002				
Male	49.12	29.74	18.50	2.64	454	43.10	17.24	17.93	21.72	290
Female	51.72	28.57	13.74	5.97	553	40.78	16.31	9.57	33.33	282
Study level	0.000					0.000				
Graduate student	39.55	35.61	18.48	6.36	660	28.65	20.76	18.42	32.16	342
Undergraduate student	71.47	16.71	10.95	0.86	347	61.74	10.87	6.96	20.43	230
Field of study	0.000					0.009				
Natural sciences and engineering	51.47	31.72	15.94	0.87	577	37.80	18.90	17.07	26.22	328
Otherwise	49.30	25.58	15.81	9.30	430	47.54	13.93	9.43	29.10	244
Income (CNY/month)	0.214					0.759				

Low (Less than 1,500)	51.63	29.41	15.90	3.05	459	43.00	15.67	14.00	27.33	300
Middle (1,501-2,000)	51.39	24.70	18.73	5.18	251	39.53	14.73	14.73	31.01	129
High (More than 2,001)	47.57	32.04	13.11	7.28	206	41.05	24.21	11.58	23.16	95
Do not know or refusal	49.45	32.97	14.29	3.30	91	43.75	14.58	14.58	27.08	48
(2) Built environment										
Residential location	0.000					0.000				
Zone 1 (Building 1-5)	76.17	12.77	10.21	0.85	235	66.27	6.51	8.88	18.34	169
Zone 2 (Building 6-11)	61.58	21.67	16.26	0.49	203	48.39	12.90	15.32	23.39	124
Zone 3 (Building 12-15)	76.77	10.32	12.90	0.00	155	42.67	6.67	21.33	29.33	75
Zone 4 (Building 16-24)	18.46	50.51	20.51	10.51	390	16.40	32.80	13.76	37.04	189
Otherwise	58.33	25.00	12.50	4.17	24	33.33	13.33	20.00	33.33	15
(3) Availability of mobility options										
Private bike ownership	0.000					0.000				
Yes	31.24	52.87	11.46	4.44	541	26.16	22.33	9.68	30.82	279
No	72.96	1.50	21.03	4.51	466	57.00	1.02	17.75	24.23	293
Car ownership	0.461					0.706				
Yes	57.89	21.05	10.53	10.53	19	57.14	14.29	0.00	28.57	7
No	50.40	29.25	15.99	4.35	988	41.77	16.81	13.98	27.43	565
Possession of driver's license	0.004					0.000				
Yes	45.98	34.02	14.85	5.15	485	29.96	20.60	16.85	32.58	267
No	54.79	24.52	16.86	3.83	522	52.46	13.44	11.15	22.95	305
Transit pass ownership	0.106					0.558				
Yes	50.45	28.86	15.66	5.03	894	42.02	15.96	13.94	28.08	495
No	51.33	30.97	17.70	0.00	113	41.56	22.08	12.99	23.38	77
(4) Adoption of shared mobility services										
Ride-sourcing services adoption	0.035					0.000				
Low (Do not know or never use)	56.08	28.04	13.15	2.73	403	52.06	15.36	10.86	21.72	267
Middle (1-3	46.63	30.4	18.06	4.85	371	37.1	17.3	16.34	29.2	202

days per month)		6				3	3		1	
High (More than 1 day per week)	47.21	28.76	17.17	6.87	233	25.24	19.42	16.50	38.83	103
Free-floating bike-sharing services adoption	0.000					0.000				
Low (Do not know or never use)	58.62	32.76	0.00	8.62	116	59.04	22.89	0.00	18.07	83
Middle (From 1 day per month to 3 days per week)	46.78	48.81	1.36	3.05	295	45.78	25.90	1.20	27.11	166
High (More than 4 days per week)	50.84	18.62	26.17	4.36	596	35.60	10.53	23.84	30.03	323
(5) General contexts										
Transportation expenditure (CNY/month)	0.001					0.001				
Low (Less than 50)	52.98	28.21	16.70	2.11	521	48.04	16.31	14.80	20.85	331
Middle (51-100)	48.08	30.31	16.38	5.23	287	31.91	16.31	13.48	38.30	141
High (More than 101)	48.70	24.35	15.65	11.30	115	27.12	16.95	15.25	40.68	59
Do not know	46.43	36.90	9.52	7.14	84	48.78	21.95	4.88	24.39	41
Internet usage (G/month)	0.042					0.005				
Low (Less than 1)	51.56	32.44	12.00	4.00	225	44.78	16.42	5.22	33.58	134
Middle (1-3)	48.68	32.84	12.90	5.57	341	44.02	20.11	13.04	22.83	184
High (More than 3)	51.26	24.24	20.71	3.79	396	38.16	14.04	20.61	27.19	228
Do not know	53.33	26.67	15.56	4.44	45	46.15	19.23	3.85	30.77	26
(6) Travel characteristics										
Commuting frequency	0.003									
High (7 days per week)	53.87	30.67	13.47	2.00	401	/	/	/	/	/
Otherwise	48.35	28.05	17.49	6.11	606	/	/	/	/	/
Shopping frequency						0.000				
High (More than 1 day per week)	/	/	/	/	/	60.56	18.66	14.44	6.34	284
Otherwise	/	/	/	/	/	23.61	14.93	13.19	48.26	288
Notes: 1. W = Walk, PB = Private Bike, FFBSS = Free-Floating Bike-Sharing Services, PT = Public										

Transit; 2. Chi-square t-test.

Once the respondents' global characteristics are understood, I follow Zhou (2012) in using a series of Chi-square t-tests to determine whether there are differences in mode choice amongst these characteristics. As can be seen in **Table 3.1**, there are significant differences in mode choice amongst the majority of variables for both commuting and shopping purposes, except for income level, car ownership and possession of a public transit pass.

3.4.4. Econometric Model

In the literature on the mode choices of university students and the factors influencing them, the multinomial logit (MNL) model has been chosen by a majority of researchers (Akar et al., 2013; Danaf et al., 2014; Moniruzzaman and Farber, 2018; Whalen et al., 2013; Zhou, 2012). In this study, therefore, I also use the MNL to examine the role of FFBSS in university students' mode choices and the factors influencing them in Nanjing, China. According to Cameron and Trivedi (2005), the MNL model is based on the theory of random utility. In the case of this study, a student i chooses a mode of transportation j amongst the available choice set k (walk, private bike, FFBSS, and public transit) where the student obtains the highest utility. The utility that the student obtains from the chosen mode j can be expressed as follows (**Equation 3.1**):

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{3.1}$$

where V_{ij} is called a systematic utility and ε_{ij} is the random component of the utility which is assumed to meet the independence of irrelevant alternatives (IIA). The probability that a student i chooses a mode of transportation j is (**Equation 3.2**):

$$P_{ij} = \Pr\left(U_{ij} > U_{ik}\right), \forall\, k \neq j$$

$$= \Pr\left(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}\right), \forall\, k \neq j \quad (3.2)$$

The systematic utility is typically specified as a function of the observable explanatory variables (socio-economic and demographic characteristics, built environment, availability of mobility options, adoption of shared mobility services, general contexts, and travel characteristics). Therefore (**Equation 3.3**):

$$V_{ij} = \beta X_{ij} \quad (3.3)$$

where X_{ij} is the vector of explanatory variables and β is a vector of coefficients of those explanatory variables.

Equation 3.1 can therefore be expressed as follows (**Equation 3.4**):

$$U_{ij} = \beta X_{ij} + \varepsilon_{ij} \quad (3.4)$$

And the logit choice probability in **Equation 3.2** is expressed as the following closed-form (**Equation 3.5**):

$$P_{ij} = \frac{e^{\beta X_{ij}}}{\sum_k e^{\beta X_{ij}}} \quad (3.5)$$

The models in this paper are estimated by "mlogit" module in STATA 13 (Cameron and Trivedi, 2005).

3.5. Results and Discussions

Two MNL models are estimated in this paper, respectively for commuting and shopping trips. To obtain the best-fit MNL models, all explanatory variables that make a

difference to mode choice for at least one of the trip purposes (according to the results of Chi-square t-test) are considered in the initial models. Then, since some of these variables are insignificant at the 90% confidence level, such as field of study (in shopping trips), possession of a driver's license (in shopping trips), they are removed from the list of explanatory variables in the shopping trips model. Finally, the results of the fitted MNL models are shown in **Table 3.2**. McFadden's pseudo R-squared for commuting and shopping trips are 0.399 and 0.358, respectively, which provide good levels of fit. In addition, the results of the Small-Hsiao test demonstrate that our MNL models pass the IIA test (Small and Hsiao, 1985).

Table 3.2 Results of Multinomial Logit Models for Commuting and Shopping trips

	Commuting Trips			Shopping Trips		
	PB[1]	FFBSS	PT	PB	FFBSS	PT
(1) Socio-economic and demographic characteristics						
Gender (ref. Female)						
Male	0.519[2]**[3] (1.681)[4]	0.669*** (1.952)	-0.017 (0.982)	-0.168 (0.845)	0.167 (1.182)	-0.847*** (0.428)
Study level (ref. Undergraduate students)						
Graduate student	0.415 (1.514)	0.271 (1.311)	1.939* (6.951)	-0.323 (0.723)	1.257** (3.517)	-0.334 (0.715)
Field of study (ref. Otherwise)						
Natural sciences and engineering	-0.061 (0.940)	-0.468** (0.626)	-2.371*** (0.093)	/	/	/
(2) Built environment						
Residential location (ref. Zone 1)						
Zone 2	0.189 (1.208)	0.882** (2.418)	-1.391 (0.248)	0.553 (1.739)	0.182 (1.200)	0.418 (1.520)
Zone 3	-0.941* (0.389)	0.013 (1.013)	-15.187 (2.54e-07)	0.604 (1.829)	-0.041 (0.958)	0.658 (1.931)
Zone 4	1.987*** (7.296)	2.104*** (8.201)	2.511** (12.318)	2.682*** (14.618)	0.583 (1.792)	1.578*** (4.849)
Otherwise	-1.015 (0.362)	0.728 (2.071)	0.629 (1.877)	0.782 (2.186)	1.162 (3.198)	1.530 (4.622)
(3) Availability of mobility options						
Private bike ownership (ref. No)						
Yes	4.164*** (64.376)	0.257 (1.293)	0.249 (1.283)	4.021*** (55.778)	0.221 (1.247)	0.720** (2.056)
Possession of driver's license (ref. No)						

Yes	-0.136 (0.872)	-0.572** (0.563)	-0.000 (0.999)	/	/	/
(4) Adoption of shared mobility services						
Ride-sourcing services adoption (ref. Low)						
Middle	-0.032 (0.968)	0.500** (1.648)	0.576 (1.779)	-0.142 (0.867)	0.592* (1.808)	0.533* (1.705)
High	-0.195 (0.822)	-0.007 (0.992)	0.438 (1.550)	0.355 (1.427)	0.711 (2.037)	0.962** (2.618)
Free-floating bike-sharing services adoption (ref. Low)						
Middle	-0.412 (0.662)	14.063 (1281571)	-2.509*** (0.081)	-0.591 (0.553)	13.304 (599816.6)	0.434 (1.544)
High	-1.199*** (0.301)	17.055 (2.55e+07)	-1.604*** (0.201)	-0.780* (0.458)	16.704 (1.80e+07)	1.243*** (3.469)
(5) General contexts						
Transportation expenditure (ref. Low)						
Middle	0.025 (1.026)	-0.138 (0.870)	0.858* (2.359)	0.204 (1.227)	-0.150 (0.860)	0.622** (1.863)
High	-0.731** (0.481)	-0.304 (0.737)	1.160** (3.192)	0.455 (1.577)	0.444 (1.560)	0.933* (2.543)
Do not know	0.379 (1.461)	-0.663 (0.514)	1.319* (3.740)	0.118 (1.125)	-1.458* (0.232)	0.358 (1.431)
Internet usage (ref. Low)						
Middle	0.405 (1.501)	0.122 (1.129)	0.848* (2.337)	0.326 (1.386)	0.651 (1.918)	-0.601* (0.548)
High	0.331 (1.393)	0.522* (1.685)	0.314 (1.369)	0.475 (1.608)	1.454*** (4.280)	-0.026 (0.974)
Do not know	-0.742 (0.475)	-0.001 (0.998)	-0.399 (0.670)	-0.423 (0.654)	1.262 (3.535)	0.191 (1.210)
(6) Travel characteristics						
Commuting (ref. Otherwise)						
High	-0.127 (0.880)	-0.454** (0.634)	-1.124** (0.324)	/	/	/
Shopping (ref. Otherwise)						
High	/	/	/	-0.215 (0.806)	-0.765** (0.465)	-3.107*** (0.044)
Constant	-4.102*** (0.016)	-18.826 (6.66e-09)	-3.805*** (0.022)	-4.453*** (0.011)	-19.018 (5.50e-09)	-0.896* (0.407)
McFadden's pseudo R-squared	0.399			0.358		
Small-Hsiao test	Accept			Accept		
Number of observations	1007			572		

Notes:
1. PB = Private Bike, FFBSS = Free-Floating Bike-Sharing Services, PT = Public Transit;
2. Coefficient of explanatory variables;
3. Level of significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$;
4. Odds ratio of explanatory variables.

3.5.1. Commuting Trips

Socio-economic and demographic characteristics have important impacts on students' mode choice for commuting trips. First, males are more likely to choose PB and FFBSS for commuting. This result provides new evidence to support the claim by Akar et al. (2013) that being female was negatively associated with cycling choice. Secondly, compared to undergraduate students, graduate students are more likely to choose PT for commuting. This result is also consistent with the finding of Akar et al. (2013). Thirdly, students who major in natural sciences and engineering are less likely to commute by FFBSS and PT. This finding provides (to our knowledge) the first evidence that the field of study has a significant impact on students' mode choice.

In terms of the built environment, students' mode choice patterns for commuting vary across different zones of their residential location. Compared to students lived in zone 1, students living in zone 4 were more likely to use PB, FFBSS, and PT. This is because zone 4 is a long way from the classroom building zones, with the result that students are more inclined to choosing a faster mode of transportation than walking to get to classes on time. In addition, the results show that students lived in zone 2 are more likely to choose FFBSS, and students lived in zone 3 are less likely to choose PB. These results can be explained as follows: for the former, zone 2 is close to No.9 canteen where there are many FFBSS available for use by students living in this zone; for the latter, the 80% of students resident in zone 4 studied in four schools/departments (Department of Computer Science and Technology, School of Electronic Science and Engineering, School of Earth Sciences and Engineering, and School of Geographic and Oceanographic Sciences) which are close to where they live and easily accessible on foot.

With regards to the availability of mobility options, students who have a private bike are more likely to commute by PB. This result is largely consistent with the literature (Moniruzzaman and Farber, 2018; Nguyen-Phuoc et al., 2018; Zhan et al., 2016). In addition, the results show that possession of driver's license decreases the likelihood of choosing FFBSS for commuting. Possession of a driver's license can be considered as a pro-car attitude/behavior, which was found to have negative effects on the likelihood of use and the frequency of use of FFBSS (Chen et al., 2020). This finding provides new evidence to enhance our understanding of the negative effect of pro-car attitudes/behaviors for the use of FFBSS.

Regarding adoption of shared mobility services, the results show that compared to students who did not know about or had never used RSS, students who had used these services at a frequency of "1-3 days per month" are more likely to choose FFBSS as their commuting mode. This finding contributes to the literature, which suggested that there was a complementary relationship between these services (Bakó et al., 2020). Moreover, it was also found that compared with students who did not know about or had never used FFBSS, students who had used these services at a high frequency are less likely to choose PB and PT for commuting trips. These results provide evidence to support the view that bike-sharing services are a substitute for other active modes and public transit (Zhu et al., 2013).

Both the variables relating to general contexts have an impact on students' mode choice for commuting trips. Higher spending on transportation increases the likelihood of choosing PT and decreases the propensity to use PB. These findings can be explained as follows: students who have a high level of transportation expenditure are likely to choose a more convenient and quicker mode of transportation like public transit rather

than the private bike (which requires finding a parking place). The results show that Internet usage has a positive impact on the use of FFBSS and PT as mode of transportation for commuting. In the former case, it is not surprising that big Internet users are more inclined to be heavy users of Internet-based mobility services like FFBSS. A possible explanation for the latter could be that big Internet users are also likely to choose a more convenient and quicker mode of transportation like public transit.

As for travel characteristics, the frequency of commuting trips has a negative impact on the likelihood of choosing FFBSS and PT as mode of transportation for commuting. This might be because greater commuting frequency could increase student travel costs if they use FFBSS and PT, and this cost is important for students.

3.5.2. Shopping Trips

The impacts of socio-economic and demographic characteristics on shopping trips are quite different from the impacts on commuting trips. Firstly, males are less likely to choose PT for shopping trips. Secondly, graduate students are more likely to use FFBSS for shopping. These provide new evidence in support of the claim that gender and study level have an impact on students' mode choice for non-commuting trips as well. Finally, field of study has no significant impact on students' mode choice for shopping trips.

The impact of the built environment on shopping trips is less complex. Students living in zone 4 are more likely to choose PB and PT for shopping trips. This is similar to the impact of this factor in mode choice for commuting trips. However, it should be noted that the impact of residential location on the choice of FFBSS for shopping trips is no longer significant.

In terms of the availability of mobility options, private bike ownership increases the likelihood of students using PB and PT for shopping trips, respectively. The former is consistent with our finding in commuting trips. The latter might suggest that there is a complementary relationship between PB and PT, especially for shopping purpose. In addition, the results show that possession of a driver's license has no significant impact on students' mode choice for shopping trips. This differs from our previous finding with regard to commuting trips.

With respect to the adoption of shared mobility services, its impact on students' mode choice for shopping trips is more comprehensive than for commuting trips. For RSS adoption, similarly with commuting trips, students who had used these services at a frequency of "1-3 days per month" were more likely to choose FFBSS for their shopping trips. Furthermore, the results also show that higher levels of RSS adoption are associated with a higher propensity to choose PT for shopping trips. This provides evidence in support of the claim by Hall et al. (2018) that RSS was a complement for PT. For FFBSS adoption, similarly with our finding in commuting trips, students who had used FFBSS at a high frequency were less likely to choose PB for shopping trips. However, things are a little different for the impact on PT. The results show that frequent users of FFBSS are more likely to use PT for shopping trips, while they are less likely use PT for commuting trips. This might suggest that FFBSS is not only a substitute but also a complement for PT in different kinds of trip.

Both the variables relating to general context also have an impact on students' mode choice for shopping trips. Higher transportation spending increases the propensity of students to choose PT for shopping trips. This result is consistent with our finding in commuting trips. However, the impact of transportation expenditure on the likelihood

of using PB is no longer significant. For Internet usage, similarly with our finding with respect to commuting trips, heavy Internet users are more inclined to use FFBSS for shopping trips. However, the impact on PT is the opposite of what was found for commuting trips. Internet usage diminishes the likelihood of choosing PT. This might be because PT use among big Internet users varies across different types of trip.

Finally, with regard to travel characteristics, the frequency of shopping trips has a negative impact on the likelihood of choosing FFBSS and PT as a mode of transportation for shopping. This might reflect the fact that the impacts of trip frequency on students' mode choice for different trip purposes are consistent.

3.6. Conclusion

This paper examines the role of FFBSS in university students' mode choices and the factors influencing them by means of an empirical study of commuting and shopping trips in Nanjing, China. The results of the analyses are summarized below.

For descriptive analyses of university students' mode choices, firstly, active modes (i.e. walking, private bike, FFBSS) occupy dominant positions in both commuting trips (95.53%) and shopping trips (72.55%). Secondly, public transit plays a bigger role in shopping trips (27.45%) than commuting trips (4.47%), and is the second most popular mode of transportation in shopping trips. Thirdly, FFBSS play a non-negligible role in both commuting trips (15.89%) and shopping trips (13.81%).

With regard to the econometric analyses of the influential factors in university students' mode choices, firstly, factors such as gender and study level have a completely different impact between commuting and shopping trips. Secondly, factors such as field of study and possession of a driver's license only make a significant difference to commuting

trips. Thirdly, factors such as trip frequency have a similar impact on both types of trips. Fourthly, despite some similarities, the effect of factors such as residential location, private bike ownership, RSS adoption, FFBSS adoption, transportation expenditure, Internet usage are different between commuting and shopping trips.

Based on the results above, this study has some implications for affected actors (e.g. university managers, urban/transportation planners and operators). Firstly, to encourage students to use active travel modes, infrastructure quality needs to be improved (e.g. construction of sidewalks and bike lanes, dedicated parking spaces for private bikes and FFBSS. Secondly, conditions need to be improved for the spread of FFBSS on campus and the availability of these services needs to be increased. Thirdly, the quality of public transit around the campus needs to be improved.

There are still aspects that require further investigation. Firstly, this study only focuses on Xianlin Campus at Nanjing University, so it would be desirable to explore students' mode choices on different campuses (e.g. city center vs. suburban areas), at single or multiple universities, and in a single city or multiple cities. Secondly, this study only focuses on students' trips on and around campus, so it would be interesting to examine the role of FFBSS in students' middle/long distance travel mode choices (e.g. FFBSS as a feeder mode to rail transit).

4. FACTORS INFLUENCING ADOPTION AND CONTINUANCE INTENTION TOWARDS THE USE OF RIDE-SOURCING SERVICES: AN EMPIRICAL STUDY AMONG UNIVERSITY STUDENTS IN NANJING, CHINA

Paper prepared for submission to *Travel Behaviour and Society*

4.1. Abstract

This paper applies two probit models with sample selection (PMSS) to identify the factors that influence adoption and continuance intention towards the use of ride-sourcing services (RSS) with a focus on university students in Nanjing, China. The results show that the impacts of individual characteristics on adoption and continuance intention are varied. First, graduate students, students who live in urban centers, students who have a driver's license, and users of free-floating bike-sharing services, are more likely to adopt RSS. Second, students with a higher frequency of daily travel are less likely to have a positive continuance intention. Third, students with higher incomes, with greater intensity of mobile Internet usage, and who are users of car-pooling services, are more likely to adopt RSS and to have a positive continuance intention towards the use of these services in the near future. Fourth, female students and students who have a public transit card are more likely to be RSS adopters, while their counterparts are more likely to have a positive continuance intention. In addition, current RSS use patterns also have important and significant impacts on continuance intention towards the use of RSS, with the result that the probability of having a positive continuance intention is higher among frequent users, students who indicate

"Convenient & rapid" as two main reasons for using the service, those who have used RSS for "Shopping" and "Leisure and recreation" trips, and those who have used these services as substitutes for "Taxi" or as an induced "New trip".

Keywords: Ride-Sourcing Services, Adoption, Continuance Intention, Influential Factors, Probit Model with Sample Selection, University Students, China

4.2. Introduction

Since the beginning of the 21st century, with the development of Information and Communication Technologies (ICT) and the rapid diffusion of the smartphone, shared mobility services have developed rapidly around the world. Ride-sourcing services (RSS), also known as ride-hailing services, on-demand ride services, or transport network companies such as Uber and Lyft in the United States and Didi Chuxing in China, are some of the most representative examples of these services (Aguilera and Boutueil, 2018; Gössling, 2018; Machado et al., 2018). According to Shaheen et al. (2018), as of November 2017, the American RSS giant Uber was operating in more than 700 cities in approximately 80 countries around the world. However, it is surprising to note that these eighty or so countries did not include China, the most populous country in the world. In fact, Uber enter the Chinese market as far back as August 2013. However, only three years later, on 1st August 2016, Uber announced that it had sold its Chinese business to domestic rival Didi Chuxing, and had officially exited the Chinese market. Many sources have explained that the reason for Uber's failure in China was because it did not properly understand its Chinese clientele (Wang, 2016; Wirtz and Tang, 2016). So, understanding the needs of users in each national or even local context is a major challenge for RSS providers. This is also relevant for research, which in recent years has been interested in the consequences of the emergence of new

services for mobility practices and policies (Aguilera and Boutueil, 2018).

The literature on RSS has grown rapidly over the past five years. A number of scholars have focused on understanding adoption and post-adoption behavior patterns relating to RSS (such as frequency of use and changes in people's travel mode choices after their adoption of RSS) in the United States and the factors influencing them (Alemi et al., 2018; Alemi et al., 2019; Grahn et al., 2019; Sikder, 2019). However, little is known about these things in other countries, particularly China. Furthermore, as one of the most important post-adoption behaviors, continuance intention towards use, which is largely studied in the literature on adoption and post-adoption behaviors relating to innovation, especially to internet-based services (IBS) such as e-commerce, social media, e-learning, and mobile payment services (Bhattacherjee, 2001a; Mouakket, 2015; Roca et al., 2006; Zhou, 2013). This is because, while the initial adoption of IBS is an important first step toward their success, their long-term viability and success depend on continued use rather than first-time use (Bhattacherjee, 2001b). To our knowledge, however, there are no studies on this issue in the literature about adoption and post-adoption behaviors relating to RSS.

To this end, adoption and post-adoption behaviors relating to RSS are considered as a two-step process in this study. Adoption refers to whether or not individuals have already used RSS, and post-adoption concerns the question of whether adopters of RSS have a positive intention to continue to use these services in the near future (i.e. the continuance intention to use RSS). The aim of this study is to contribute to the research literature and expand our understanding of adoption and post-adoption behaviors relating to RSS (particularly in China) by investigating factors that influence the adoption and continuance intention to use RSS, with a special focus on university

students, who are largely seen as early adopters and heavy users of new smartphone and Internet-based services (Lee, 2014; Yang, 2005), and as one of the largest groups of RSS users (Alemi et al., 2018; Rayle et al., 2016), as well as the future elites and leaders of society in all walks of life (Zhou, 2014). This study addresses the following questions: first, whether and how individual characteristics (such as socio-economic and demographic characteristics, availability of mobility options, general contexts, and use of other shared mobility services) influence respectively adoption and continuance intention relating to the use of RSS; second, in addition to individual characteristics, whether and how current RSS use behaviors influence continuance intention towards the use of RSS in the near future. To address these questions, two probit models with sample selection (PMSS) are applied to the analysis of data from an original survey conducted in Nanjing, China, in November 2017, on daily travel patterns and use of shared mobility services (including RSS) among Nanjing University students.

The remainder of this paper is organized as follows: after a brief literature review in Section 4.3., Section 4.4. describes the data collection and methods of analysis. Then, Section 4.5. discusses the results of two PMSS models followed. Finally, the conclusions and prospects for future research are presented in Section 4.6..

4.3. Literature Review

The literature on RSS has grown rapidly over the past five years. Adoption and post-adoption behaviors relating to RSS and the factors influencing them are one of the main research themes. To better address the two research questions previously set out (in the introduction), this literature review mainly concentrates on the research on two questions set out below. It should be noted that the existing literature on post-adoption behaviors relating to RSS has mainly focused on frequency of use and the change in

individuals' travel mode choices after their adoption of RSS. To our knowledge, none of them has examined the issue of continuance intention with respect to the use of RSS.

The first question is whether and how individual characteristics (such as socio-economic and demographic characteristics, availability of mobility options, general contexts, and use of other shared mobility services) influence adoption and post-adoption behaviors relating to RSS.

To begin with, several studies have examined the impacts of socioeconomic and demographic characteristics on both adoption and frequency of use. They reached a common understanding that younger adults, men, workers, individuals with higher educational and income levels, who were single or childless, and resident in urban areas, were more likely to be adopters of RSS and use these services frequently (Deka and Fei, 2019; Dias et al., 2017; Grahn et al., 2019; Sikder, 2019; Tirachini and del Río, 2019). However, a series of studies by Alemi and colleagues (Alemi et al., 2018; Alemi et al., 2019) came up with some different results: the likelihood of adoption in California was higher among women, and none of the socioeconomic and demographic characteristics had an impact on frequency of use. In addition to frequency of use, some researchers also found that household income and household type had an impact on changes in individuals' travel mode choices after their adoption of RSS (Gehrke et al., 2019; Tang et al., 2019).

Secondly, a number of studies have demonstrated that the availability of mobility options influences not only adoption but also post-adoption practices relating to RSS (such as frequency of use and changes in individuals' travel mode choices). Dias et al. (2017) found that in the Puget Sound region of the United States, the probability of the adoption and frequent use of RSS was lower in multi-vehicle households. These

findings have been confirmed by other studies in the United States, which are based on the 2017 National Household Travel Survey (NHTS) (Deka and Fei, 2019; Grahn et al., 2019; Sikder, 2019). In addition, one of these three studies found that drivers were less likely to be frequent users of RSS (Deka and Fei, 2019), while the others showed that monthly transit users were more likely to be RSS adopters and to use these services frequently (Grahn et al., 2019; Sikder, 2019). In a study on the Greater Boston Region, Gehrke et al. (2019) found that public transit pass holders were more likely to use RSS as a substitute for public transit modes and for new trips, but less likely to use these services as a substitute for active travel modes. They also investigated whether personal bike owners and car owners were more likely to use RSS respectively instead of active travel modes and vehicles.

Thirdly, since RSS are an Internet-based shared mobility service, the general contexts of individuals relating to the use of smartphones and the Internet, together with their travel habits, have also been confirmed as key factors for predicting adoption and post-adoption behaviors relating to RSS. With respect to the use of smartphones and the Internet, Dias et al. (2017) found that smartphone ownership had a positive impact on the adoption and frequency of use of RSS. Similarly, Alemi and his colleagues showed that the likelihood of RSS adoption was higher among frequent users of social media and individuals who used a smartphone to plan their day-to-day travel (e.g. destination and route, mode choice) (Alemi et al., 2018; Alemi et al., 2019). Further, they also highlighted that individuals who used smartphones to determine their destination and route were more likely to be RSS adopters and also to use these services frequently (Alemi et al., 2019). As to travel habits, Alemi et al. (2019) confirmed that frequent users of taxi services were more likely to be both adopters and frequent users of RSS. They also proved that the frequency of long-distance trips (such as non-car long-

distance business trips and long-distance leisure trips by plane) are positively associated with the adoption of RSS but not with the frequency of use of these services. Their explanation was that business travelers were more likely to be in a situation where they do not have access to their own car.

Last but not least, numerous studies have explored whether and how the use of other shared mobility services influences adoption and post-adoption practices relating to RSS. Alemi and his colleagues found that the use of car-sharing services had a positive impact on the likelihood of use of RSS, but not on the frequency of use (Alemi et al., 2018; Alemi et al., 2019). In addition, the assumption that the use of car-sharing services and bike-sharing services had positive impacts on both the adoption and frequency of use of RSS was largely confirmed by Sikder (2019).

Apart from the above four types of individual characteristics, some studies focused on whether and how current use behaviors influence post-adoption behaviors relating to RSS, which will be the second question covered in this literature review. Gehrke et al. (2019) found that RSS trip characteristics (such as trip cost, day of week, time of day, reason for use) had significant impacts on the substitution of RSS for sustainable travel options (e.g. public transit modes, active transportation modes). For instance, they proved that the probability of RSS being used to replace both public transit modes was greater for lower costs trips, for two reasons ("Quicker than transit" and "Weather"), whereas it was lower for higher costs trips at weekends and in cases where the reason was "Transit unavailable". Tang et al. (2019) pointed out that existing practices relating to the use of RSS play an important role in changes to individuals' travel mode choices after their adoption of RSS. For example, they found that the probability of RSS being used instead of the private car was higher among individuals who used RSS for certain

reasons (“Limitations on private car” and “Parking issue”), while it was lower among those who used these services for other reasons (“Lack of public transportation”, “Time saving”, and “Economical”). At the same time, the hypothesis that this probability was diminished by travel time was confirmed. Furthermore, they also showed that this probability was higher among individuals who used RSS for commuting trips, whereas it was lower among those who used these services for entertainment and business trips.

4.4. Data and Methods

4.4.1. Survey Design and Data Collection

As a part of a Franco-Chinese joint research project (between the City, Mobility and Transport Laboratory at the University of Paris-East and the School of Architecture and Urban Planning at Nanjing University), which focused on a comparison of university students’ daily travel patterns and use of shared mobility services in France and in China, this study is based on the Chinese conducted for a case study in Nanjing, which is the capital of Jiangsu Province in China and the second largest city in the East China region, with an area of 2543 square kilometers and a total population of over 8 million (Nanjing Bureau of Statistics, 2016). As a national research and education center, Nanjing had over 720 thousand university students in 2018 (Nanjing Bureau of Education, 2019). In addition, the development of shared mobility services (such as free-floating bike-sharing services, RSS) in Nanjing is far ahead of other cities (Du and Cheng, 2018).

The survey was designed by the author and was adapted to the Chinese setting with the help of colleagues from Nanjing University’s School of Architecture and Urban Planning. The survey questionnaire is in three parts. The first is about the travel habits of university students. In this part, students were asked about their residential location and their travel habits (main geographical location, trip frequency, main mode of

transport) in relation to five trip purposes: “Study”, “Work”, “Shopping”, “Leisure and Recreation” and “Visiting Friends and Relatives”. The second part is about their use of new mobility services, focusing on the cases of free-floating bike-sharing services and ride-sourcing services. For each service, students were first asked whether they knew about the service before the survey. If not, they were asked whether they would use this service in the future. If they knew about the service, they were asked how often they had used it. If the answer was “Never”, they were asked two questions (reason for not using, intention to use in the future). Those who had already used the service were asked a further six questions (time of adoption, reason for use, trip purpose, mode shift, transfer pattern, intention to continue use). The third part of the questionnaire consists of additional information about the respondents, including socio-demographic features (gender, study level, field of study, monthly income, etc.), mobility options (bike ownership, car ownership, possession of a driver’s license, of a public transit pass, etc.), ICT usage (monthly consumption of mobile Internet data, etc.), and so on.

Before the official launch of the survey, the questionnaire was pretested with 40 Nanjing University students, in order to validate the interpretation of terminology and the intent of the questions. Following the pretest, the data collection protocol for the survey was determined as follows. An offline to online (O2O) method was used to collect data. On the offline side, 2,000 one-page invitation letters were distributed by intercepting students on the street in front of 5 main dining halls from 11 am to 1 pm and 5 pm to 7 pm on Thursday 16th and Friday 17th November 2017. On the online side, the questionnaire was available on the Wen Juan Xing (https://www.wjx.cn), the most famous online survey platform in China, from Thursday 16th to Sunday 26th November 2017. And the QR code was a bridge between the invitation letter and the questionnaire. Students could use their smartphone or other devices to scan the questionnaire’s QR

code printed in the invitation letter, and then completed the questionnaire online. In order to increase the response rate, all respondents who completed the questionnaire were offered an electronic red envelope valued at 5 CNY as a token of appreciation.[3] In the end, a total of 1,432 valid questionnaires were completed.

4.4.2. Variables and Descriptive Statistics

To better understand adoption and continuance intention around the use of RSS, two dependent variables were defined as follows. First, respondents who had already used RSS were considered adopters of RSS, while others (unfamiliar with RSS or who knew about them but had not yet used them before the survey) were deemed non-adopters. Second, among the adopters of RSS, respondents who said that they would use these services in the near future were considered adopters with positive continuance intention, whilst the rest (who said that they would not use RSS or did not know whether they would use them) were defined as adopters with non-positive continuance intention. As shown in **Figure 4.1**, about 62% of respondents had already used RSS in Nanjing. This adoption rate among university students in Nanjing was twice as high as in the general population in China (China Internet Network Information Center, 2018). In addition, this rate was also much higher than that of young people in other countries (approximately 40%), such as the United States and Lebanon (Alemi et al., 2018; Tarabay and Abou-Zeid, 2019). Moreover, among the RSS adopters, about 40% had a non-positive continuance intention towards use of these services in the near future. This

[3] The electronic red envelope is a mobile application deveoped by Chinese Internet giants like Tencent and Alibaba. The concept of this application is based on the Chinese tradition of *hongbao* (red envelope or red packet), where money is given to family and friends as a gift. The application allows users to give monetary gifts in the form of virtual 'credits' to other users of the application. Money is deposited into a user's Wechat Pay or Ali Pay account, which can be used for purchases. The app allows withdrawals from that account. There are two types of 'red envelope' offered by the app: the pairwise red packets, whereby money is sent in a private chat between two users, and the group red packets, where money is distributed in a group chat. The 'grouped' red envelope can then be posted to a group chat and the application randomly assigns the amount in each envelope to each recipient.

result shows that for RSS operators, improving the continuance intentions of existing adopters is as important as attracting new customers, which is consistent with the position advanced by Bhattacherjee (2001b).

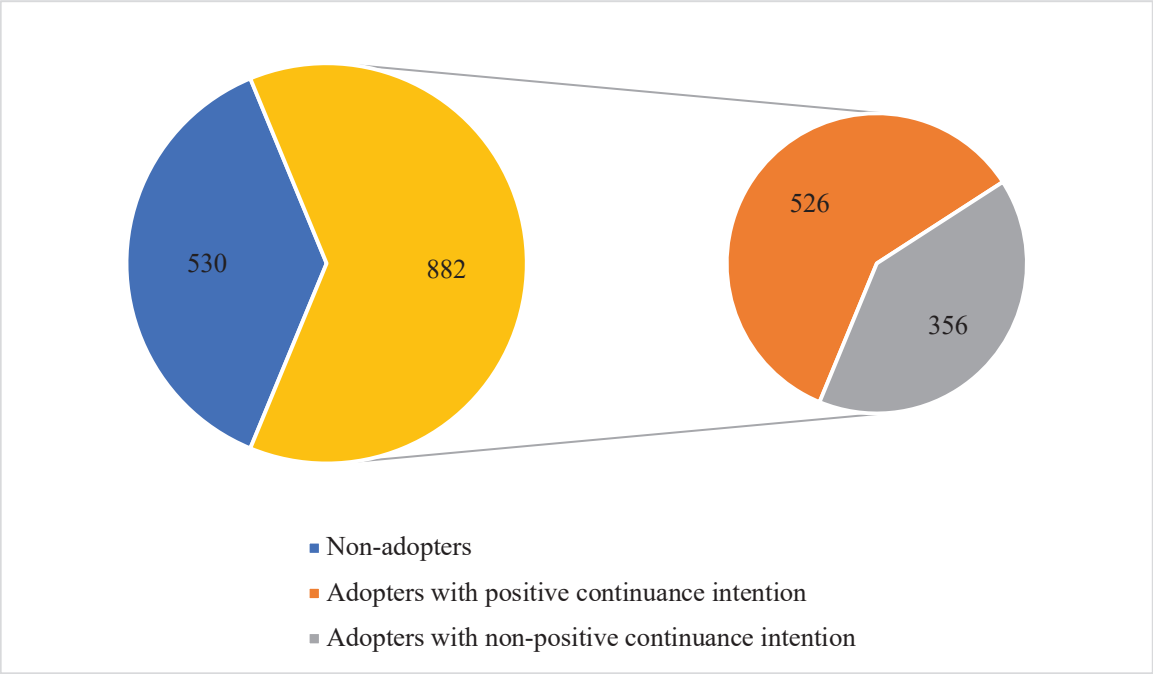


Figure 4.1 Proportion of Adoption and Continuance Intention towards RSS

In order to answer this study's first research question, four categories of explanatory variables relating to individual characteristics are considered: socio-economic and demographic characteristics, availability of mobility options, general contexts, and use of other shared mobility services. The detailed descriptive statistics of explanatory variables relating to individual characteristics are presented in **Table 4.1**. The results for the full sample in this study demonstrate that the sample is representative of the population of students at Nanjing University with regards to the distribution of socio-economic and demographic characteristics. More than half of the respondents owned a bike, and about 90% owned a public transit pass. Furthermore, while car ownership rate was extremely low (less than 2%), nearly half held a driver's license. The majority of respondents had a high level of mobile Internet usage, and the adoption rates of other

Internet-based shared mobility services are therefore relatively high among respondents (over four-fifths and one-third for free-floating bike-sharing services and car-pooling services respectively).

Table 4.1 Descriptive Statistics of Explanatory Variables Related to Individual Characteristics

Variable	Non-adopters	Adopters with non-positive continuance intention	Adopters with positive continuance intention	Total
(1) Socio-economic and demographic characteristics				
Gender				
Male	41.81	22.36	35.83	653
Female	33.86	27.67	38.47	759
Study level				
Graduate student	30.51	25.81	43.68	957
Undergraduate student	52.31	23.96	23.74	455
Field of study				
Natural sciences and engineering	36.92	24.61	38.47	837
Otherwise	38.43	26.09	35.48	575
Employment status				
Have a (full-time or part-time) job or an internship	30.80	28.69	40.51	237
Otherwise	38.89	24.51	36.60	1175
Marital status				
Single	41.11	25.80	33.08	934
In a relationship or married	30.54	24.06	45.40	478
Monthly income				
Low (Less than 1,500 CNY)	41.03	27.08	31.89	624
Middle (1,501-2,000 CNY)	36.96	23.78	39.26	349
High (More than 2,001 CNY)	25.90	25.90	48.20	305
Do not know or refusal	49.25	18.66	32.09	134
Residential location				
Urban center	31.56	28.12	40.31	320
Otherwise	39.29	24.36	36.36	1092
(2) Availability of mobility options				
Bike ownership				
Yes	37.62	23.35	39.03	638
No	37.47	26.74	35.79	774
Car ownership				
Yes	34.38	15.62	50.00	32
No	37.61	25.43	36.96	1380
Possession of driver's license				
Yes	30.00	26.03	43.97	730
No	45.60	24.34	30.06	682
Public transit pass ownership				
Yes	35.60	26.42	37.97	1264
No	54.05	14.86	31.08	148

(3) General contexts				
Intensity of mobile Internet usage				
Low (Less than 1G)	43.38	30.43	26.09	322
Middle (1.01G-3G)	32.57	26.97	40.46	482
High (More than 3G)	35.97	21.22	42.81	556
Do not know	63.46	19.23	17.31	52
Frequency of daily travel				
Low	39.07	22.93	38.00	471
Middle	37.84	25.16	37.00	473
High	35.68	27.56	36.75	468
(4) Use of other shared mobility services				
Free-floating bike-sharing services				
Yes	34.33	25.36	40.31	1171
No	53.11	24.48	22.41	241
Car-pooling services				
Yes	16.14	22.91	60.96	502
No	49.34	26.48	24.18	910

In addition to individual characteristics, four categories of explanatory variables relating to current RSS practices (frequency of use, reasons for use, trip purposes, and modal shift and induced travel) are also considered, with the purpose of answering the second research question of this study. As presented in **Table 4.2**, some 40% of adopters have used RSS at least once a month. It is surprising that this proportion of frequent users is lower than for young people in other countries (Alemi et al., 2018; Tarabay and Abou-Zeid, 2019). This is probably attributable to the fact that the majority of Chinese students' daily trips take place on or around campus (Zhan et al., 2016), and they do not need to use RSS frequently. Approximately three-fifths of adopters indicated "Convenient & Rapid" as their two main reasons for use. Again, this result is different from students in other countries. For example, for a sample of students at the American University of Beirut, Tarabay and Abou-Zeid (2019) noted that "Economical" was the most important reason given for use of RSS in Lebanon. Among the five main trip purposes, "Leisure and recreation" was the most popular, with about two-thirds of adopters having used RSS for this purpose, which is consistent with the abovementioned study by Tarabay and Abou-Zeid (2019). In addition, it is not

surprising that over half of Chinese student adopters had used these services for "Shopping" trips, which is attributable to the extremely low rate of car ownership among students in China. So they usually use a RSS to carry heavy or bulky bags back from shopping trips. Last but not least, regarding the change in students' travel mode choices after their adoption of RSS, as expected a large proportion of adopters decreased their use of taxi (54%) and public transit (42%), which is consistent with previous studies in the general population in China (Tang et al., 2019). Moreover, the results also show that a non-negligible proportion of adopters diminished their use of active modes (walking and cycling), and were induced into new trips as well. To give an illustration, in China, the adoption of RSS has changed the travel mode choices of students more widely than in the general population (Tang et al., 2019).

Table 4.2 Descriptive Statistics of Explanatory Variables Related to the Current RSS Use Behaviors

Variable	Adopters with non-positive continuance intention	Adopters with positive continuance intention	Total
(a) Frequency of use			
Frequently			
Yes (At least 1 day per month)	9.94	90.06	342
Otherwise	59.63	40.37	540
(b) Reasons for use			
Two main reasons			
Convenient & Rapid	41.11	58.89	523
Convenient & Economical	35.71	64.29	182
Rapid & Economical	38.10	61.90	105
Otherwise	50.00	50.00	72
(c) Trip purposes			
Study			
Yes	28.93	71.07	159
No	42.88	57.12	723
Work			
Yes	31.44	68.56	264
No	44.17	55.83	618
Shopping			
Yes	26.02	73.98	492
No	58.46	41.54	390
Leisure and recreation			
Yes	30.60	69.40	598
No	60.92	39.08	284
Visiting friends and relatives			

Yes	26.46	73.54	291
No	47.21	52.79	591
(d) Modal shift and induced travel			
Walk			
Yes	19.14	80.86	209
No	46.95	53.05	673
Bike			
Yes	15.60	84.40	141
No	45.07	54.93	741
Public transit			
Yes	26.23	73.77	366
No	50.39	49.61	516
Car			
Yes	32	136	168
No	45.38	54.62	714
Taxi			
Yes	27.66	72.34	470
No	54.85	45.15	412
New trip			
Yes	13.79	86.21	145
No	45.59	54.41	737

4.4.3. Methods

In this study, adoption and continuance intention around the use of RSS are considered as a two-step process. The first concerns whether individuals have already used RSS, the second whether RSS users have a positive continuance intention towards the use of these services in the near future. Since the latter can only be observed for RSS adopters, the exclusion of non-adopters would artificially inflate the coefficients associated with the exogenous variables included in the model of adopters' continuance intention if there are common unobserved factors that influence both adoption and continuance intention. Therefore, an extension of Heckman's sample selection model (Heckman, 1979), named the Probit Model with Sample Selection (PMSS) (Lee et al., 2004; Van de Ven and Van Praag, 1981) is used to better understand the factors that influence adoption and continuance intention towards the use of RSS in an unbiased way.

In the PMSS model, I assume that the error terms of both equations (selection and probit) follow a bivariate normal distribution. Thus, the probability that a student has already

used RSS and shows a positive continuance intention can be written as the product of the probability of adoption $Prob(y_1 = 1|x)$ and the probability of showing a positive continuance intention $Prob(y_2 = 1|z, y_1 = 1)$, each of which has its own model (**Equation 4.1**):

$$Prob(y_1 = 1, y_2 = 1|x, z) = Prob(y_1 = 1|x) * Prob(y_2 = 1|z, y_1 = 1) \quad (4.1)$$

where y_1 represents the adoption of RSS ($= 0$ for non-adopters, and $= 1$ for adopters), y_2 represents the adopters' continuance intention ($= 0$ for adopters with non-positive continuance intention and $= 1$ for adopters with positive continuance intention). Further, x and z refer to the explanatory variables respectively associated with adoption and continuance intention. With the assumption of joint normality for the error terms in the PMSS model, the associated probabilities can be estimated using a bivariate normal distribution via the "heckprobit" module in Stata 13 (Cameron and Trivedi, 2005).

4.5. Results and Discussions

To answer the two research questions in this study, two PMSS models are calibrated. In Model 1, only the four categories of explanatory variables relating to individual characteristics are examined, and used in order to answer the first research question. Then, in Model 2 the four categories of explanatory variables relating to individual characteristics together with the four categories of explanatory variables relating to current RSS practices are investigated, in order to answer the second research question. Since employment status, marital status, bike ownership, and car ownership are not significant at the 90% confidence level in the field study, we remove them from the list of explanatory variables in both Model 1 and Model 2. At the same time, some variables

strongly correlated with trip purposes (i.e. study, work, visiting friends and relatives) and modal shift and induced travel (walking, cycling, public transit, car) are also removed in Model 2, since they have a non-significant impact at the 90% confidence level. Finally, the results of two fitted PMSS models are shown in **Table 4.3**. The correlation parameter (ρ) is significant in both models, which confirms correlation between the selection errors and the probit equation and therefore that the use of PMSS model in this study is reasonable.

Table 4.3 Results of Probit Models with Sample Selection

Variable	Model 1		Model 2	
	Individual characteristics only		Individual characteristics and current RSS use behaviors	
	Adoption	Continuance intention to use	Adoption	Continuance intention to use
Individual characteristics				
(1) Socio-economic and demographic characteristics				
Gender (Ref. Female)				
Male	-0.170[1]**[2]	0.158**	-0.183**	0.174*
Study level (Ref. Undergraduate student)				
Graduate student	0.314***	/	0.367***	/
Monthly income (Ref. Low)				
Middle	0.096	0.150*	0.098	0.094
High	0.362***	0.080	0.353***	-0.015
Do not know or refusal	-0.137	0.335**	-0.152	0.470***
Residential location (Ref. Otherwise)				
Urban center	0.168**	/	0.177**	/
(2) Availability of mobility options				
Possession of driver's license (Ref. No)				
Yes	0.197***	/	0.189**	/
Public transit pass ownership (Ref. No)				
Yes	0.366***	-0.324**	0.353***	-0.321*
(3) General contexts				
Intensity of mobile Internet usage (Ref. Low)				
Middle (1.01G-3G)	0.190**	0.073	0.195**	0.074
High (More than 3G)	0.101	0.265***	0.102	0.298**
Do not know	-0.443**	0.142	-0.401*	0.002
Frequency of daily travel (Ref. Low)				
Middle	/	-0.072	/	-0.246**
High	/	-0.166**	/	-0.216**
(4) Use of other shared mobility services				
Free-floating bike-sharing services (Ref. No)				
Yes	0.153**	/	0.207**	/
Car-pooling services (Ref. No)				
Yes	0.885***	0.127*	0.873***	/
Usage characteristics				
(a) Frequency of use				
Frequently (Ref. Otherwise)				

Yes	/	/	/	1.119***
(b) Reasons for use				
Two main reasons (Ref. Convenient & Rapid)				
Convenient & Economical	/	/	/	-0.060
Rapid & Economical	/	/	/	-0.031
Otherwise	/	/	/	-0.293*
(c) Trip purposes				
Shopping (Ref. No)				
Yes	/	/	/	0.293***
Leisure and recreation (Ref. No)				
Yes	/	/	/	0.284***
(d) Modal shift and induced travel				
Taxi (Ref. No)				
Yes	/	/	/	0.340***
New trip (Ref. No)				
Yes	/	/	/	0.404***
Constant	-0.842***	0.706***	-0.899***	-0.105
Correlation parameter (ρ)	-1***		-0.715***	
Model loglikelihood	-1336.669		-1209.599	
AIC (BIC)	2727.338 (2869.163)		2487.199 (2665.793)	
Notes: 1. Log odds ratio of the explanatory variable. 2. Level of significance: * p < 0.10, ** p < 0.05, *** p < 0.01.				

4.5.1. The Impacts of Individual Characteristics on Adoption and Continuance Intention Around the Use of RSS

The impacts of individual characteristics on adoption and continuance intention are shown in the results of Model 1 in **Table 4.3**.

Socio-economic and demographic characteristics have significant impacts not only on the adoption of RSS, but also on continuance intention around the use of RSS. The first finding is that women are more likely to be adopters of RSS, but on the other hand are less likely to have a positive continuance intention towards the use of these services in the near future. The former point is line in with the findings of Alemi et al. (2018), and the latter is consistent with the findings relating to other IBS, e.g. online social media (Lin et al., 2017). Next, students who have a higher level of monthly income are more likely to adopt RSS, and to have a positive continuance intention around the use of these

services in the near future. This result coincides with the findings of previous studies on the adoption of IBS (Alemi et al., 2018; Hsu et al., 2015). Furthermore, similarly to the studies by Alemi et al. (2018) and Sikder (2019), this research also showed that the likelihood of adopting RSS is higher among older young people (i.e. graduate students) and those who live in urban centers.

The availability of mobility options also has significant impacts on adoption and continuance intention with respect to the use of RSS. Specifically, students who have a driver's license are more likely to adopt RSS, which can be explained by the fact that these students show a higher level of interest than their counterparts in car use. Yet, as seen above, only a very small percentage of Chinese students (about 2% in our sample) own a car. As a consequence, students with a driver's license tend to adopt RSS to meet their car use needs. Similarly, students who possess a public transit pass are more likely to adopt RSS, but on the other hand are less likely to have a positive continuance intention to the use of these services in the near future. This comes down to the fact that these students usually use public transit for their day-to-day travel needs, and will resort to RSS only when the buses or trains are running infrequently or are not available. This provides new evidence in support of the claim that RSS is a complement to public transit (Hall et al., 2018; Young et al., 2020).

Both variables relating to general contexts are significant in Model 1. As we can see, students who exhibit a higher intensity of mobile Internet usage are more likely to adopt RSS and to have a positive continuance intention around the use of these services in the near future. In a sense, these results consolidate our knowledge that familiarity of with the Internet and frequency of Internet use are positively correlated with the adoption of RSS and other IBS (e.g. e-working and e-shopping), from the first step of adoption to

the second step of continuance intention (Alemi et al., 2018; Loo and Wang, 2018). In contrast with the impact of the intensity of mobile Internet usage, another general context variable, the frequency of daily travel, does not have a significant impact on the adoption of RSS and a negative impact on continuance intention. A possible explanation for this finding is that students with a higher frequency of daily travel are more concerned about travel costs and prefer to use a cheaper mode of transportation (e.g. public transit) than RSS for their daily travel.

In addition, the impact of the use of other shared mobility services on RSS adoption and continuance intention is also tested in this study. The likelihood of adopting RSS is higher among users of free-floating bike-sharing services, which is consistent with the findings of Sikder (2019). Similarly, car-pooling users are more likely to adopt RSS and also to have a positive continuance intention around the use of RSS in the near future. Consequently, there is a complementary relationship between these two car-based shared mobility services on the one hand, and the outcome of increasing returns in the adoption of different shared mobility services on the other hand.

4.5.2. The Impacts of Current RSS Practices on RSS Continuance Intention

Apart from the impacts of individual characteristics, the results of Model 2 (see **Table 4.3**) demonstrate the impacts of current RSS use behaviors on continuance intention towards the use of RSS in the near future. In terms of frequency of use, students who have used RSS frequently are much more likely to have a positive continuance intention around the use of these services in the near future, consistent with the results of studies on the other Internet-based services, which showed that frequency of past usage has a positive impact on adopters' continuance intention (Mirkovski et al., 2018). With regard to reasons for use and trip purposes, the propensity to a positive continuance

intention is greater among students who indicated “Convenient & Rapid” as two main reasons and those who used RSS for “Shopping” and “Leisure and recreation” trips. These findings suggest that continued RSS use can meet both subjective and objective needs with respect to day-to-day student travel. Moreover, regarding modal shift and induced travel, it is shown that students who have used RSS to replace the “Taxi” or for an induced “New trip” are more likely to have a positive continuance intention. What is more, the view that RSS is a disaster for the traditional taxi industry but an important complement to the existing urban transport system, a source of increased space-time accessibility for students, is also confirmed.

4.6. Conclusion

This paper employs two PMSS models to identify the factors that influence adoption and continuance intention towards the use of RSS with a focus on university students in Nanjing, China. The results of the analyses are summarized as below.

The results of Model 1 show that in general individual characteristics have significant impacts on the adoption of RSS, as well as on continuance intention towards their use in the near future. All in all, they vary in their impacts across these two steps, forming four distinct groups. The first consists of factors that merely influence the adoption of RSS. To be specific, graduate students, students who live in urban centers, students who hold a driver’s license, and users of free-floating bike-sharing services, are more likely to adopt RSS. The second group contains factors that only influence continuance intention towards the use of RSS. Students with a higher frequency of daily travel are substantially less likely to express a positive continuance intention. Subsequently, factors that influence both adoption and continuance intention in the same direction are shown in the third group. That is to say that students with higher incomes, with a higher

intensity of mobile Internet usage, and who are users of car-pooling services, are more likely to adopt RSS and to have a positive continuance intention towards the use of these services in the near future. Finally, the fourth group comprises factors that affect both adoption and continuance intention in different directions. Specifically, women and students who have a public transit card are more likely to be RSS adopters, while they are less likely to express a positive continuance intention.

Moreover, existing RSS practices, with the exception of individual characteristics, also have important and significant impacts on continuance intention towards the use of RSS in the near future. As for the results of Model 2, they suggest that the probability of a positive continuance intention is higher among frequent users, students who indicate "Convenient & rapid" as two main reasons, those who have used RSS for "Shopping" and "Leisure and recreation" trips, and those who have used these services as a replacement for the "Taxi" or for an induced "New trip".

On the basis of these results, this study has implications for RSS operators and the government. For RSS operators, it indicates that improving continuance intentions among existing adopters is as important as attracting new customers. In order to achieve this goal, operators need to pay closer attention to the individual characteristics of their existing or potential customers, as well as the latter's current or potential RSS practices. Furthermore, it points to the importance of developing differentiated marketing strategies, particularly in the knowledge that some characteristics have countervailing impacts on adoption and continuance intention with respect to the use of RSS. For the government, the study should emphasize the positive contribution that RSS can make to improving space-time access for citizens (particularly university students) and for meeting their daily travel needs, while at the same time raising concerns about the

negative effects of the development of RSS (such as road congestion and air pollution). In order to reduce these negative effects, the government needs to further develop the public transit system, and encourage the spread and adoption of the car-pooling versions of RSS (e.g. Uber Pool, which can increase car occupancy rate).

Nevertheless, this study still has certain limitations, and further research is needed to fill certain gaps. Firstly, this study focuses only on a sample of students in Nanjing, and it is still unclear whether and how these impacts may differ in other cities in China. There is therefore a need for a larger scale survey among students in different cities in China. Secondly, shared mobility services are developing rapidly, so RSS adoption and post-adoption practices among students may change over time. It would therefore be worthwhile to reinvestigate these issues in Nanjing in the future.

5. GENERAL CONCLUSION

Over the last decade, new app-based mobility services such as FFBSS and RSS have expanded rapidly around the world. However, in the fields of transportation studies, the literature on the adoption and post-adoption behaviors of these new mobility services and the factors influencing them is still limited and fragmentary. Drawing on an original survey conducted in Nanjing University in November 2017 on the day-to-day travel practices of university students and their current and future uses of new mobility services, this thesis provides a comprehensive examination of university students' adoption and post-adoption behaviors with respect to new mobility services in China and the factors influencing them, through three empirical essays.

The first essay (Chapter 2) examines the factors that influence the frequency of use of FFBSS by means of a GOL (generalized ordered logit) model. After a literature review, the results show: firstly, that graduate students, students majoring in natural sciences and engineering, and students who have a higher level of monthly income, are more likely to show higher frequency of use; secondly, that bike ownership decreases the likelihood of high frequency of use among students; thirdly, that both intensity of mobile Internet usage and frequency of daily travel have a positive impact on the frequency of FFBSS use; lastly, earlier adopters, students who have used FFBSS for economic reasons, and students who have used FFBSS for commuting trips, also have a propensity to higher frequency of use. In addition, it should be noted that because of the violation of the proportional odds assumption, the factors relating to study level, monthly income, and time of adoption only have a partial impact on frequency of use.

The second essay (Chapter 3) studies the role of FFBSS in students' mode choices on

commuting and shopping trips and the factors influencing them. Via two MNL (multinomial logit) models. After a literature review, the findings show that women and students who major in natural sciences and engineering are less likely to use FFBSS for commuting trips, while graduate students are more likely to use FFBSS for shopping trips. Students who live in zone 2 and 4 of Xianlin campus are more likely to use FFBSS for commuting trips. Possession of a driver's license decreases the likelihood of students choosing FFBSS for commuting trips. A higher level of adoption of ride-sourcing services increases the propensity of students to use FFBSS for both commuting and shopping trips. Intensity of mobile Internet usage has a positive impact on the likelihood of using FFBSS for both commuting and shopping trips. In addition, higher frequency of commuting and shopping trips has a negative impact on students' likelihood of choosing FFBSS for commuting and shopping trips respectively.

The third essay (Chapter 4) employs two PMSS (probit model with sample selection) models to investigate the factors that influence adoption and continuance intention towards the use of RSS. After a literature review, the results show that the impacts of individual characteristics on adoption and continuance intention are varied. First, graduate students, students who live in urban centers, students who have a driver's license, and users of free-floating bike-sharing services, are more likely to adopt RSS. Second, students with a higher frequency of daily travel are less likely to express a positive continuance intention. Third, students with higher incomes, with higher intensity of mobile Internet usage, and users of car-pooling services, are more likely to adopt RSS and to have a positive continuance intention towards the use of these services in the near future. Fourth, female students and students who have a public transit card are more likely to be RSS adopters, while their counterparts are more likely to having a positive continuance intention. Likewise, existing RSS use patterns also have

important and significant impacts on continuance intention for RSS, with the probability of a positive continuance intention being higher among frequent users, students who indicate "Convenient & rapid" as two main reasons for using such services, those who have used RSS for "Shopping" and "Leisure and recreation" trips, and those who have used these services as a replacement for the "Taxi" or for an induced "New trip".

The **Table 5.1** summarizes the impacts of the factors that influence students' adoption and post-adoption behaviors in relation to new mobility services. Although this thesis focuses only on a sample of students in Nanjing, and some results remain difficult to interpret, a number of findings are highlighted below as meriting the attention both of transportation researchers and public policy makers to think more deeply about the future of urban mobility in China.

Table 5.1 Summary of Impacts of Factors Influencing Adoption and Post-adoption Practices Around New Mobility Services in All Three Essays

	Free-floating bike-sharing services		Ride-sourcing services	
	Frequency of use	Mode choice	Adoption	Continuance intention to use
(I) Individual characteristics				
(1) Socio-economic and demographic characteristics				
Gender (male)	///[1]	Partial positive (commuting)	Negative	Positive
Study level (graduate student)	Partial positive	Partial positive (shopping)	Positive	///
Field of study (natural sciences and engineering)	Positive	Partial negative (commuting)	///	///
Monthly income (a higher level)	Partial positive	///	Positive	Positive
(2) Built environment				
Residential location				
(zone 2)	---[2]	Partial positive (commuting)	---	---
(zone 4)	---	Partial positive (commuting)	---	---
Residential location (urban center)	---	---	Positive	///
(3) Availability of mobility options				
Bike ownership (yes)	Negative	///	///	///
Possession of driver's license (yes)		Partial negative (commuting)	Positive	///
Public transit pass	---	///	Positive	Negative

ownership (yes)				
(4) Adoption of other shared mobility services				
Free-floating bike-sharing services adoption (yes)	---	---	Positive	///
Ride-sourcing services adoption (a higher level)	---	Positive	---	---
Car-pooling services adoption (Yes)	---	---	Positive	Positive
(5) General contexts				
Intensity of mobile Internet usage (a higher level)	Positive	Positive	Positive	Positive
Frequency of daily travel (a higher level)	Positive	---	///	Negative
Frequency of commuting trips (a higher level)	---	Negative (commuting)	---	---
Frequency of shopping trips (a higher level)	---	Negative (shopping)	---	---
(II) Current FFBSS/RSS use behaviors				
Time of adoption (a higher level)	Partial positive	---	---	---
Frequency of use (a higher level)	---	---	///	Positive
Reason for use				
(convenient & economical)	Positive	---	---	///
(rapid & economical)	Positive	---	---	///
(otherwise)	///	---	---	Negative
Trip purpose				
Study	Positive	---	---	///
Work	Positive	---		///
Shopping	///	---	---	Positive
Leisure and recreation	///	---	---	Positive
Mode shift and induced travel				
Taxi	---	---	---	Positive
New trips	---	---	---	Positive
Notes: 1. ///: Not significant in the model 2. ---: Not considered in the model				

First of all, intensity of mobile Internet usage has a positive impact on all the four adoption and post-adoption behaviors relating to FFBSS and RSS. This finding reflects the important role of the Internet in people's everyday lives in China. According to the recent report by the China Internet Network Information Center (2020), as of March 2020, China had 904 million Internet users. Among these, the proportions using instant messaging, Internet news, online shopping, online payment, online video, and online government services were respectively, 99.2%, 80.9%, 78.6%, 85.0%, 94.1%, and

76.8%. It would therefore be worth pursuing extensive research on how the Internet, in particular, mobile Internet, is reshaping people's daily mobility behaviors.

Secondly, the results demonstrate that numerous traditional mobility options (such as private bike, public transportation) are available for young Chinese people to use for their daily mobility, while a number of new mobility services (such as FFBSS, RSS, and car-pooling services) also play an important role in their daily travel practices. These forms of multimodality and intermodality practices put the onus on both governments and transportation operators to provide comprehensive solutions, such as mobility-as-a-service (Maas) systems, in order to improve travel flexibility and reduce the time devoted to mobility.

Thirdly, whereas the rate of car ownership in our sample was extremely low (about 2%), over half of the respondents held a driver's license. At the same time, more than 60% of the respondents had used RSS in Nanjing, and 60% of RSS users expressed a positive continuance intention towards the use of these services in the near future. These results reflect the fact that it is still beyond the means of most Chinese students to own a private car, and the adoption of RSS can help to provide the flexibility offered by the private car. However, it is worth mentioning that the private car has now become one of three "must-have" items (the two others are a house and money) for marriage in Chinese culture. In consequence, it is still difficult to predict whether young Chinese will choose to buy a car as soon as they can afford one, or whether the new mobility services, linked with public transportation, will enable them to remain non-motorized.

Fourthly, China was once considered as the "Kingdom of the Bicycle", with bikes dominating city streets across the country. Since the mid-1990s, however, China's dramatic rise in economic prosperity and urbanization has seen many people shift to

motor vehicles as their primary modes of transportation (Zhang et al., 2014). Nonetheless, in this thesis, approximately 45% of respondents had a private bike. Furthermore, some 90% of respondents had used FFBSS in Nanjing, and over 10% of respondents had chosen FFBSS as their main mode of transportation for both commuting and non-commuting trips. These results suggest that the bicycle is making a comeback in China among the young urban population thanks to FFBSS.

Lastly, in this thesis, several individual characteristics (such as gender, field of study, possession of a driver's license, frequency of daily travel) have different impacts on different adoption and post-adoption practices vis-à-vis these two services. Likewise, individual characteristics (such as gender, study level, field of study, monthly income, residential location, possession of a driver's license) have a partial impact on the frequency of use and the mode choice of FFBSS. In addition, existing FFBSS/RSS use patterns have non-negligible impacts on post-adoption behaviors relating to these two services. These findings call for further research in order to track the dynamics of the adoption and post-adoption behaviors relating to new mobility services, and for the development of more comprehensive guidelines regarding the future of these new mobility services as an alternative to the private car.

Appendix. Survey: Nanjing University Students' Daily Travel Behaviors and Practices of New Mobility Services

A.1. Territorial Context of the Thesis: Municipality of Nanjing

The research area of this thesis is Nanjing, located along the Yangtze River and about 300 km upstream from Shanghai, which is the capital of Jiangsu Province in China and the second largest city in the East China region (see **Figure 0.1**). Since 2015, the municipality of Nanjing includes 11 administrative districts, with an area of 2543 square kilometers and a total population of over 8 million, which can be divided into three categories: city center (Gulou, Xuanwu, Qinhuai, Jianye, and Yuhuatai), outskirts (Qixia, Pukou, and Jiangning), and exurb (Luhe, Lishui, and Gaochun) (see **Figure 0.2**) (Nanjing Bureau of Statistics, 2016). It is one of the three major national education and research centers (the two others are Beijing and Shanghai), with over 720 million university or college students studying in Nanjing at the end of 2018 (Nanjing Bureau of Education, 2019). And almost all of these universities and colleges have at least two campuses (one is in the city center, and the other in the outskirts or exurb).

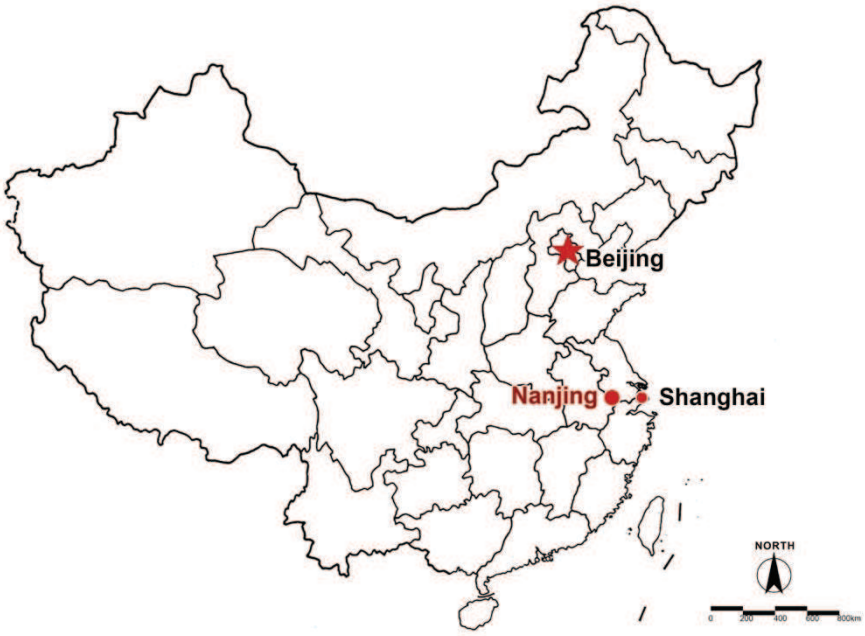


Figure 0.1 Location of Nanjing in China

Figure 0.2 Map of Nanjing and Location of the Two Campuses of Nanjing University

A.2. Sample Scope

The survey used in this thesis is an original survey conducted by the author in

November 2017 at Nanjing University (NJU). Established in 1902, NJU is one of the best research universities in China, with 3.8 million full-time students in 31 schools. Like other Chinese universities, NJU also has two main campuses (see **Figure 0.2**), the Xianlin campus (see **Figure 0.3**) in the northeast of Nanjing, and the Gulou campus (see **Figure 0.4**) in the city center of Nanjing. To better understand the adoption and post-adoption behaviors of new mobility services among university students at NJU, all full-time students have been targeted for this survey.

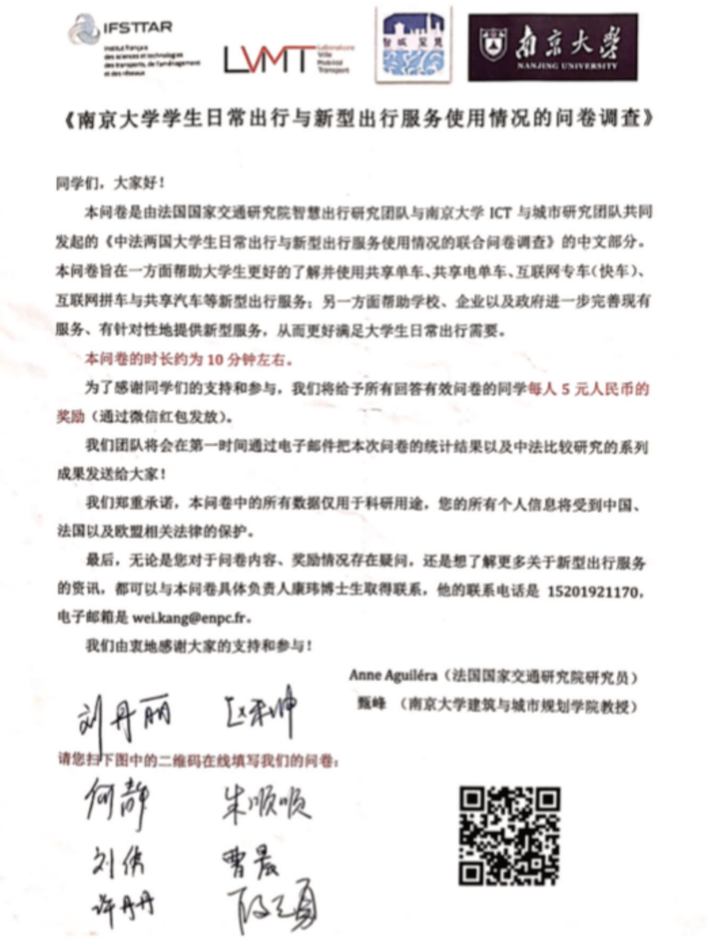
Figure 0.3 Map of Nanjing University's Xianlin Campus

Figure 0.4 Map of Nanjing University's Gulou Campus

A.3. Sampling Method

An innovative sampling method, called offline to online to (O2O) method, was used to

collect the data. On the offline side, like in traditional intercept survey, 2000 one-page invitation letters **(see Figure 0.5)** were distributed by intercepting students on the street in front of five principal dining halls (four in Xianlin campus, and one in Gulou campus) during lunch and dinner over two days (from 11 am to 1 pm and 5 pm to 7 pm on Thursday 16th and Friday 17th November 2017). Then, students were proposed to take this invitation letter, and when available, scan the questionnaire's QR code, which was printed in the invitation letter, and finally answer the questionnaire online (on the Wen Juan Xing, https://www.wjx.cn) (**see Figure 0.6**). All respondents who completed the questionnaire were offered an electronic red envelope valued at 5 CNY as a token of appreciation (**see Figure 0.7**).



《南京大学学生日常出行与新型出行服务使用情况的问卷调查》

同学们，大家好！

本问卷是由法国国家交通研究院智慧出行研究团队与南京大学 ICT 与城市研究团队共同发起的《中法两国大学生日常出行与新型出行服务使用情况的联合问卷调查》的中文部分。本问卷旨在一方面帮助大学生更好的了解并使用共享单车、共享电单车、互联网专车（快车）、互联网拼车与共享汽车等新型出行服务；另一方面帮助学校、企业以及政府进一步完善现有服务、有针对性地提供新型服务，从而更好满足大学生日常出行需要。

本问卷的时长约为 10 分钟左右。

为了感谢同学们的支持和参与，我们将给予所有回答有效问卷的同学每人 5 元人民币的奖励（通过微信红包发放）。

我们团队将会在第一时间通过电子邮件把本次问卷的统计结果以及中法比较研究的系列成果发送给大家！

我们郑重承诺，本问卷中的所有数据仅用于科研用途，您的所有个人信息将受到中国、法国以及欧盟相关法律的保护。

最后，无论是您对于问卷内容、奖励情况存在疑问，还是想了解更多关于新型出行服务的资讯，都可以与本问卷具体负责人康玮博士生取得联系，他的联系电话是 15201921170，电子邮箱是 wei.kang@enpc.fr。

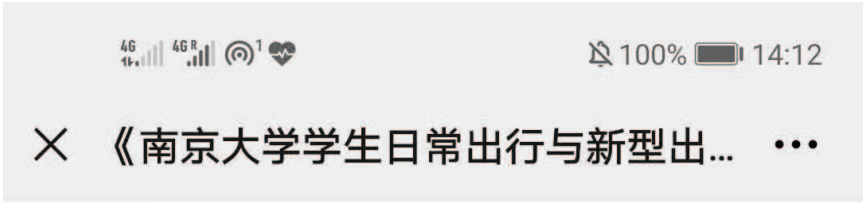
我们由衷地感谢大家的支持和参与！

Anne Aguiléra（法国国家交通研究院研究员）

甄峰 （南京大学建筑与城市规划学院教授）

请您扫下图中的二维码在线填写我们的问卷：

Figure 0.5 Invitation Letter



同学们，大家好！

本问卷是由法国国家交通研究院智慧出行研究团队与南京大学ICT与城市研究团队共同发起的《中法两国大学生日常出行与新型出行服务使用情况的联合问卷调查》的中文部分。本问卷旨在一方面帮助大学生更好的了解并使用共享单车、共享电单车、互联网专车（快车）、互联网拼车与共享汽车等新型出行服务；另一方面帮助学校、企业以及政府进一步完善现有服务、有针对性地提供新型服务，从而更好满足大学生日常出行需要。

本问卷的时长约为10-15分钟。

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我们由衷地感谢大家的支持和参与！

Figure 0.6 Online Questionnaire

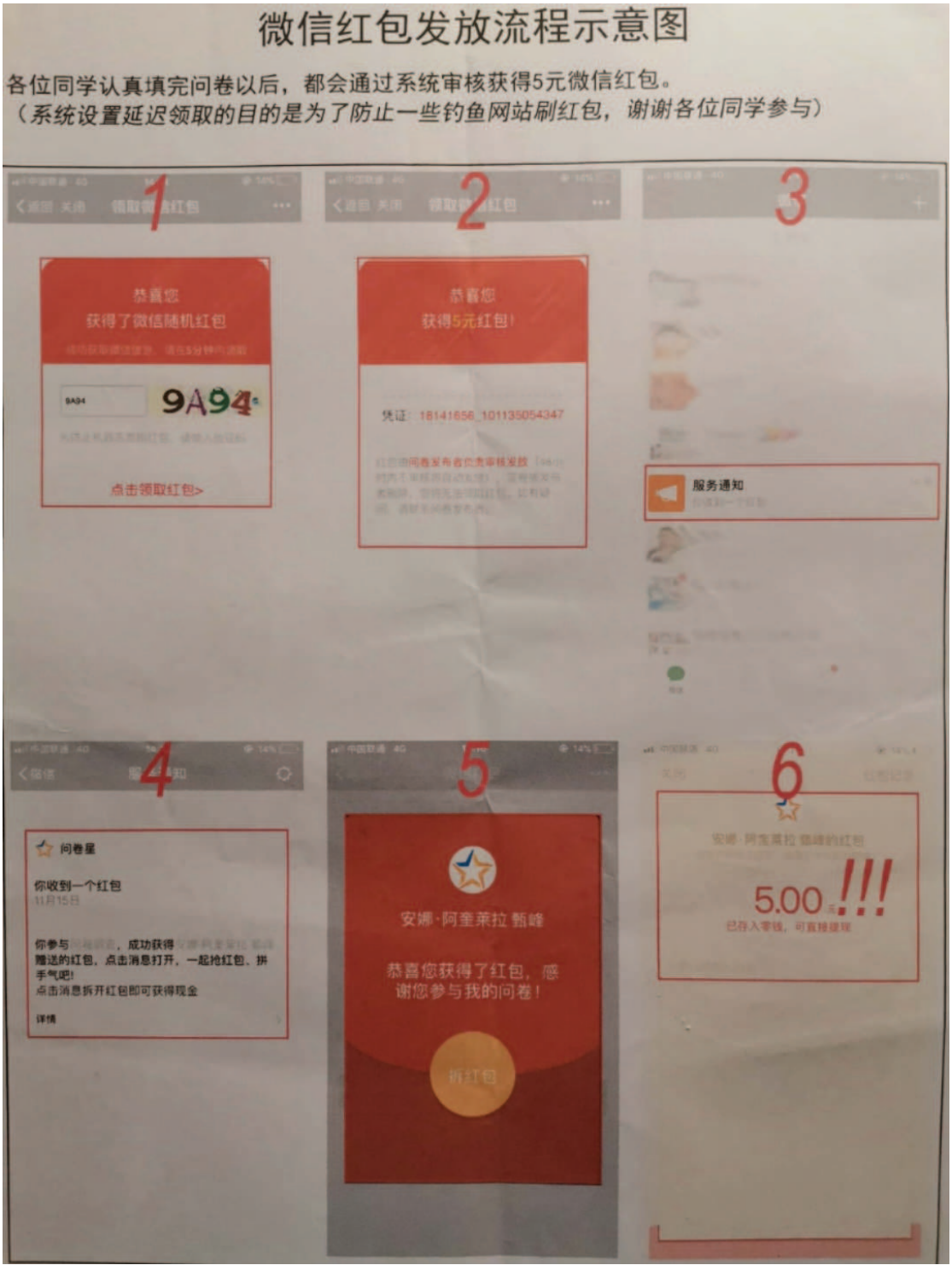

Figure 0.7 Electronic Red Envelope

After a brief presentation of our sampling method, it is worth mentioning that like in

traditional intercept surveys (Rayle et al., 2016), our sample is not completely representative of the students of NJU. In addition, according to our knowledge, both the university students and the new mobility services have been ignored in the traditional travel survey such as Nanjing Residents Travel Survey (conducted by the Nanjing Urban and Transport Planning and Designing Institution Limit Cooperation, and sponsored by the Nanjing Transport Planning Committee). Hence, it was not possible to find a reference group, which would have been used to check the representativeness of our sample.

A.4. Questionnaire

The details of questionnaire can be seen as follows.

Part 1: Travel Habits in Nanjing

1.1. Accommodation
Q1. Where do you live during this academic year? (1) Dormitory of Gulou campus (316/22.07%) (2) Dormitory of Xianlin campus (1100/76.82%) (3) Parent's house (2/0.14%) (4) Otherwise (14/0.98%) Total: 1432 If Q1=(2), answer Q2. Q2. Which zone does your dormitory locate in? (1) Zone 1 (Buildings 1-5) (247/22.45%) (2) Zone 2 (Buildings 6-11) (216/19.64%) (3) Zone 3 (Buildings 12-15) (165/15%) (4) Zone 4 (Buildings 16-24) (447/40.64%) (5) Otherwise (please indicate) (25/2.27%) Total: 1100 If Q1=(3) or (4), answer Q2bis. Q2bis. What's your home address? (District/Road/Residential quarter)

1.2 Study
Q3. Which zone do you most frequently go to for your studies? (1) Gulou campus (314/21.93%)

(2) Xianlin campus (1105/77.16%)
(3) Otherwise (please indicate) (13/0.91%)
Total: 1432

Q3b. How often do you go there?
(1) Less than 1 day per month (24/1.68%)
(2) 1-3 days per month (52/3.63%)
(3) 1-3 days per week (180/12.57%)
(4) 4-6 days per week (660/46.09%)
(5) 7 days per week (516/36.03%)
Total: 1432

Q3c. Which mode of transportation you mainly use to get there?
(1) Walk (811/56.63%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (549/38.34%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (7/0.49%)
(4) Public transit (bus, metro, etc.) (19/1.33%)
(5) University bus (inter-campus, intra-campus) (39/2.72%)
(6) Otherwise (please indicate) (7/0.49%)
Total: 1432

If Q3c=(2), answer Q3d2.

Q3d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (313/57.01%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (16/2.91%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (175/31.88%)
(4) University bike-sharing services ("Small red bike") (3/0.55%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (34/6.19%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (6/1.09%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)
(8) Otherwise (please indicate) (2/0.36%)
Total: 549

If Q3c=(3), answer Q3d3.

Q3d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (5/71.43%)
(2) Taxi (including Didi Taxi) (0/0%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (1/14.29%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (0/0%)
(5) Car-sharing services (like Evcard, Gofun) (1/14.29%)
(6) Otherwise (please indicate) (0/0%)
Total: 7

1.3 Work

Q4. Do you have a paid job?
(1) Yes (241/16.83%)

(2) No (1191/83.17%)
Total: 1432

If Q4=(1), answer Q5, Q5b, Q5c, Q5d

Q5. What's your home address?
(District/Road/Danwei)

Q5b. How often do you go there?
(1) Less than 1 day per month (3/1.24%)
(2) 1-3 days per month (22/9.13%)
(3) 1-3 days per week (59/24.48%)
(4) 4-6 days per week (95/39.42%)
(5) 7 days per week (62/25.73%)
Total: 241

Q5c. Which mode of transportation you mainly use to get there?
(1) Walk (119/49.38%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (81/33.61%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (1/0.41%)
(4) Public transit (bus, metro, etc.) (35/14.52%)
(5) University bus (inter-campus, intra-campus) (3/1.24%)
(6) Otherwise (please indicate) (2/0.83%)
Total: 241

If Q5c=(2), answer Q5d2.

Q5d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (42/51.85%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (5/6.17%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (28/34.57%)
(4) University bike-sharing services ("Small red bike") (1/1.23%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (3/3.7%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (2/2.47%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)
(8) Otherwise (please indicate) (0/0%)
Total: 81

If Q5c=(3), answer Q5d3.

Q5d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (1/100%)
(2) Taxi (including Didi Taxi) (0/0%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (0/0%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (0/0%)
(5) Car-sharing services (like Evcard, Gofun) (0/0%)
(6) Otherwise (please indicate) (0/0%)
Total: 1

1.4 Shopping
(i.e. Food, Clothing, Book/music/DVD/video games, High-Tech/IT,etc.)

(Zone 1)

Q6_1a. Which zone do you most frequently go to for shopping?
(1) Gulou campus and its environs (217/15.15%)
(2) Xianlin campus and its environs (635/44.34%)
(3) Xinjiekou commercial district (329/22.97%)
(4) Hunan road commercial district (11/0.77%)
(5) Zhongyangmen commercial district (7/0.49%)
(6) Fuzimiao (18/1.26%)
(7) Hexi's new city plaza (4/0.28%)
(8) Hexi's wanda plaza (0/0%)
(9) Jiangning commercial center (2/0.14%)
(10) Qiaobei commercial district (1/0.07%)
(11) Xianlin center (78/5.45%)
(12) Maqun (32/2.23%)
(13) Xueze road (50/3.49%)
(14) Otherwise (please indicate) (5/0.35%)
(15) I never go outside of my residence for shopping (43/3%)
Total: 1432

Q6_1b. How often do you go there?
(1) Less than 1 day per month (202/14.54%)
(2) 1-3 days per month (726/52.27%)
(3) 1-3 days per week (306/22.03%)
(4) 4-6 days per week (90/6.48%)
(5) 7 days per week (65/4.68%)
Total: 1389

Q6_1c. Which mode of transportation you mainly use to get there?
(1) Walk (442/31.82%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (295/21.24%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (21/1.51%)
(4) Public transit (bus, metro, etc.) (617/44.42%)
(5) University bus (inter-campus, intra-campus) (9/0.65%)
(6) Otherwise (please indicate) (5/0.36%)
Total: 1389

If Q6_1c=(2), answer Q6_1d2.

Q6_1d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (110/37.29%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (21/7.12%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (141/47.8%)
(4) University bike-sharing services ("Small red bike") (0/0%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (18/6.1%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (5/1.69%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)

(8) Otherwise (please indicate) (0/0%)
Total: 295

If Q6_1c =(3), answer Q6_1d3.

Q6_1d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (3/14.29%)
(2) Taxi (including Didi Taxi) (5/23.81%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (9/42.86%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (2/9.52%)
(5) Car-sharing services (like Evcard, Gofun) (2/9.52%)
(6) Otherwise (please indicate) (0/0%)
Total: 21

Q6_1e. What do you often purchase? (Multiple answers possible)
(1) Food (1154/83.08%)
(2) Clothing (685/49.32%)
(3) Book/music/DVD/video games (183/13.17%)
(4) High-Tech/IT (125/9%)
(5) Other, please indicate: (44/3.17%)
Total: 1389

(Zone 2)

Q6_2a. Which zone do you second most frequently go to for shopping?
(1) Gulou campus and its environs (108/7.78%)
(2) Xianlin campus and its environs (224/16.13%)
(3) Xinjiekou commercial district (455/32.76%)
(4) Hunan road commercial district (16/1.15%)
(5) Zhongyangmen commercial district (4/0.29%)
(6) Fuzimiao (53/3.82%)
(7) Hexi's new city plaza (2/0.14%)
(8) Hexi's wanda plaza (8/0.58%)
(9) Jiangning commercial center (6/0.43%)
(10) Qiaobei commercial district (1/0.07%)
(11) Xianlin center (189/13.61%)
(12) Maqun (74/5.33%)
(13) Xueze road (135/9.72%)
(14) Otherwise (please indicate) (5/0.36%)
(15) I only go outside of my residence for shopping in zone 1 (109/7.85%)
Total: 1389

Q6_2b. How often do you go there?
(1) Less than 1 day per month (432/33.75%)
(2) 1-3 days per month (679/53.05%)
(3) 1-3 days per week (133/10.39%)
(4) 4-6 days per week (25/1.95%)
(5) 7 days per week (11/0.86%)
Total: 1280

Q6_2c. Which mode of transportation you mainly use to get there?
(1) Walk (204/15.94%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (159/12.42%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (23/1.8%)
(4) Public transit (bus, metro, etc.) (885/69.14%)
(5) University bus (inter-campus, intra-campus) (4/0.31%)
(6) Otherwise (please indicate) (5/0.39%)
Total: 1280

If Q6_2c=(2), answer Q6_2d2.

Q6_2d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (38/23.9%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (12/7.55%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (92/57.86%)
(4) University bike-sharing services ("Small red bike") (2/1.26%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (13/8.18%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (2/1.26%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)
(8) Otherwise (please indicate) (0/0%)
Total: 159

If Q6_2c =(3), answer Q6_2d3.

Q6_2d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (0/0%)
(2) Taxi (including Didi Taxi) (8/34.78%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (12/52.17%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (2/8.7%)
(5) Car-sharing services (like Evcard, Gofun) (1/4.35%)
(6) Otherwise (please indicate) (0/0%)
Total: 23

Q6_2e. What do you often purchase? (Multiple answers possible)
(1) Food (900/70.31%)
(2) Clothing (714/55.78%)
(3) Book/music/DVD/video games (188/14.69%)
(4) High-Tech/IT (115/8.98%)
(5) Other, please indicate: (29/2.27%)
Total: 1280

1.5 Leisure and recreation
(i.e. Restaurant/bar, Cinema/show/match/exhibition, Sport/gymnasium, etc.)

(Zone 1)

Q7_1a. Which zone do you most frequently go to for leisure and recreation?
(1) Gulou campus and its environs (200/13.97%)
(2) Xianlin campus and its environs (421/29.4%)

(3) Xinjiekou commercial district (345/24.09%)
(4) Hunan road commercial district (14/0.98%)
(5) Zhongyangmen commercial district (5/0.35%)
(6) Fuzimiao (38/2.65%)
(7) Hexi's new city plaza (2/0.14%)
(8) Hexi's wanda plaza (4/0.28%)
(9) Jiangning commercial center (3/0.21%)
(10) Qiaobei commercial district (0/0%)
(11) Xianlin center (192/13.41%)
(12) Maqun (80/5.59%)
(13) Xueze road (48/3.35%)
(14) Otherwise (please indicate) (7/0.49%)
(15) I never go outside of my residence for leisure and recreation (73/5.1%)
Total: 1432

Q7_1b. How often do you go there?
(1) Less than 1 day per month (380/27.96%)
(2) 1-3 days per month (774/56.95%)
(3) 1-3 days per week (158/11.63%)
(4) 4-6 days per week (30/2.21%)
(5) 7 days per week (17/1.25%)
Total: 1359

Q7_1c. Which mode of transportation you mainly use to get there?
(1) Walk (331/24.36%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (228/16.78%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (32/2.35%)
(4) Public transit (bus, metro, etc.) (756/55.63%)
(5) University bus (inter-campus, intra-campus) (10/0.74%)
(6) Otherwise (please indicate) (2/0.15%)
Total: 1359

If Q7_1c=(2), answer Q7_1d2.

Q7_1d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (73/32.02%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (19/8.33%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (120/52.63%)
(4) University bike-sharing services ("Small red bike") (3/1.32%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (8/3.51%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (4/1.75%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (1/0.44%)
(8) Otherwise (please indicate) (0/0%)
Total: 228

If Q7_1c =(3), answer Q7_1d3.

Q7_1d3. It's mainly: (Only one answer)

(1) My private car (or a relative's or a friend's private car) (3/9.38%)
(2) Taxi (including Didi Taxi) (9/28.13%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (16/50%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (4/12.5%)
(5) Car-sharing services (like Evcard, Gofun) (0/0%)
(6) Otherwise (please indicate) (0/0%)
Total:32

Q7_1e. Which activities do you often choose for leisure and recreation? (Multiple answers possible)
(1) Restaurant/bar (846/62.25%)
(2) Cinema/show/match/exhibition (916/67.4%)
(3) Sport/gymnasium (248/18.25%)
(4) Other, please indicate: (44/3.24%)
Total: 1359

(Zone 2)

Q7_2a. Which zone do you second most frequently go to for leisure and recreation?
(1) Gulou campus and its environs (110/8.09%)
(2) Xianlin campus and its environs (169/12.44%)
(3) Xinjiekou commercial district (407/29.95%)
(4) Hunan road commercial district (24/1.77%)
(5) Zhongyangmen commercial district (12/0.88%)
(6) Fuzimiao (87/6.4%)
(7) Hexi's new city plaza (5/0.37%)
(8) Hexi's wanda plaza (11/0.81%)
(9) Jiangning commercial center (8/0.59%)
(10) Qiaobei commercial district (4/0.29%)
(11) Xianlin center (167/12.29%)
(12) Maqun (129/9.49%)
(13) Xueze road (83/6.11%)
(14) Otherwise (please indicate) (12/0.88%)
(15) I only go outside of my residence for leisure and recreation in zone 1 (131/9.64%)
Total: 1359

Q7_2b. How often do you go there?
(1) Less than 1 day per month (548/44.63%)
(2) 1-3 days per month (584/47.56%)
(3) 1-3 days per week (79/6.43%)
(4) 4-6 days per week (9/0.73%)
(5) 7 days per week (8/0.65%)
Total: 1228

Q7_2c. Which mode of transportation you mainly use to get there?
(1) Walk (171/13.93%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (124/10.1%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (22/1.79%)

(4) Public transit (bus, metro, etc.) (898/73.13%)
(5) University bus (inter-campus, intra-campus) (12/0.98%)
(6) Otherwise (please indicate) (1/0.08%)
Total: 1228

If Q7_2c=(2), answer Q7_2d2.

Q7_2d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (25/20.16%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (14/11.29%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (75/60.48%)
(4) University bike-sharing services ("Small red bike") (0/0%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (7/5.65%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (3/2.42%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)
(8) Otherwise (please indicate) (0/0%)
Total: 124

If Q7_2c =(3), answer Q7_2d3.

Q7_2d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (1/4.55%)
(2) Taxi (including Didi Taxi) (9/40.91%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (9/40.91%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (2/9.09%)
(5) Car-sharing services (like Evcard, Gofun) (1/4.55%)
(6) Otherwise (please indicate) (0/0%)
Total: 22

Q7_2e. Which activities do you often choose for leisure and recreation? (Multiple answers possible)
(1) Restaurant/bar (857/69.79%)
(2) Cinema/show/match/exhibition (791/64.41%)
(3) Sport/gymnasium (130/10.59%)
(4) Other, please indicate: (32/2.61%)
Total: 1228

1.6 Visiting friends and relatives

(Zone 1)

Q8_1a. Which zone do you most frequently go to for visiting friends and relatives?
(1) Gulou campus and its environs (154/10.75%)
(2) Xianlin campus and its environs (205/14.32%)
(3) Xinjiekou commercial district (142/9.92%)
(4) Hunan road commercial district (15/1.05%)
(5) Zhongyangmen commercial district (6/0.42%)
(6) Fuzimiao (32/2.23%)
(7) Hexi's new city plaza (8/0.56%)
(8) Hexi's wanda plaza (21/1.47%)

(9) Jiangning commercial center (48/3.35%)
(10) Qiaobei commercial district (14/0.98%)
(11) Xianlin center (19/1.33%)
(12) Maqun (28/1.96%)
(13) Xueze road (32/2.23%)
(14) Otherwise (please indicate) (71/4.96%)
(15) I never go outside of my residence for visiting friends and relatives (637/44.48%)
Total: 1432

Q8_1b. How often do you go there?
(1) Less than 1 day per month (416/52.33%)
(2) 1-3 days per month (298/37.48%)
(3) 1-3 days per week (61/7.67%)
(4) 4-6 days per week (12/1.51%)
(5) 7 days per week (8/1.01%)
Total: 795

Q8_1c. What's your main mode of transport for going there?
(1) Walk (121/15.22%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (89/11.19%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (27/3.4%)
(4) Public transit (bus, metro, etc.) (544/68.43%)
(5) University bus (inter-campus, intra-campus) (8/1.01%)
(6) Otherwise (please indicate) (6/0.75%)
Total: 795

If Q8_1c=(2), answer Q8_1d2.

Q8_1d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (24/26.97%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (5/5.62%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (54/60.67%)
(4) University bike-sharing services ("Small red bike") (0/0%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (6/6.74%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (0/0%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (0/0%)
(8) Otherwise (please indicate) (0/0%)
Total: 89

If Q8_1c =(3), answer Q8_1d3.

Q8_1d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (13/48.15%)
(2) Taxi (including Didi Taxi) (5/18.52%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (5/18.52%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (2/7.41%)
(5) Car-sharing services (like Evcard, Gofun) (1/3.7%)

(6) Otherwise (please indicate) (1/3.7%)
Total: 27

Q8_1e. Who do you often visit? (Multiple answers possible)
(1) Parents (79/9.94%)
(2) Relatives (156/19.62%)
(3) Friends (623/78.36%)
(4) Other, please indicate: (18/2.26%)
Total: 795

(Zone 2)

Q8_2a. Which zone do you second most frequently go to for visiting friends and relatives?
(1) Gulou campus and its environs (90/11.32%)
(2) Xianlin campus and its environs (120/15.09%)
(3) Xinjiekou commercial district (99/12.45%)
(4) Hunan road commercial district (23/2.89%)
(5) Zhongyangmen commercial district (16/2.01%)
(6) Fuzimiao (38/4.78%)
(7) Hexi's new city plaza (6/0.75%)
(8) Hexi's wanda plaza (15/1.89%)
(9) Jiangning commercial center (31/3.9%)
(10) Qiaobei commercial district (5/0.63%)
(11) Xianlin center (36/4.53%)
(12) Maqun (17/2.14%)
(13) Xueze road (32/4.03%)
(14) Otherwise (please indicate) (30/3.77%)
(15) I only go outside of my residence for visiting friends and relatives in zone 1 (237/29.81%)
Total: 795

Q8_2b. How often do you go there?
(1) Less than 1 day per month (353/63.26%)
(2) 1-3 days per month (168/30.11%)
(3) 1-3 days per week (30/5.38%)
(4) 4-6 days per week (5/0.9%)
(5) 7 days per week (2/0.36%)
Total: 558

Q8_2c. What's your main mode of transport for going there?
(1) Walk (66/11.83%)
(2) Two wheels (bike, e-bike, motorcycle, etc.) (52/9.32%)
(3) Cars (private car, taxi, ride-sourcing services, car-pooling services, car-sharing services, etc.) (26/4.66%)
(4) Public transit (bus, metro, etc.) (402/72.04%)
(5) University bus (inter-campus, intra-campus) (6/1.08%)
(6) Otherwise (please indicate) (6/1.08%)
Total: 558

If Q8_2c=(2), answer Q8_2d2.

Q8_2d2. It's mainly: (Only one answer)
(1) My private bike (or a relative's or a friend's private bike) (10/19.23%)
(2) Station-based bike-sharing services (like Nanjing Public Bike) (10/19.23%)
(3) Free-floating bike-sharing services (like Ofo, Mobike) (25/48.08%)
(4) University bike-sharing services ("Small red bike") (0/0%)
(5) My private e-bike (or a relative's or a friend's private e-bike) (5/9.62%)
(6) Free-floating e-bike-sharing services (like Number-7, Xqchuxing) (1/1.92%)
(7) My private motorcycle (or a relative's or a friend's private motorcycle) (1/1.92%)
(8) Otherwise (please indicate) (0/0%)
Total: 52

If Q8_2c =(3), answer Q8_2d3.

Q8_2d3. It's mainly: (Only one answer)
(1) My private car (or a relative's or a friend's private car) (7/26.92%)
(2) Taxi (including Didi Taxi) (5/19.23%)
(3) Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar) (8/30.77%)
(4) Car-pooling services (like Didi Hitch, Didachuxing) (4/15.38%)
(5) Car-sharing services (like Evcard, Gofun) (1/3.85%)
(6) Otherwise (please indicate) (1/3.85%)
Total: 26

Q8_2e. Who do you often visit? (Multiple answers possible)
(1) Parents (44/7.89%)
(2) Relatives (91/16.31%)
(3) Friends (459/82.26%)
(4) Other, please indicate: (7/1.25%)
Total: 558

Part 2: Practices of New Mobility Services in Nanjing

2.1 Free-floating bike-sharing services (FFBSS)
(1) Such as, Mobike, Ofo, etc.
(2) Excluding Station-based bike-sharing services (like Nanjing Public Bike)
(3) Excluding Free-floating e-bike-sharing services (like Number-7, Xqchuxing)

Q9. Do you know FFBSS?
(1) Yes (1422/99.3%)
(2) No (10/0.7%)
Total: 1432

Q10. How often do you use FFBSS in Nanjing?
(1) Never (156/10.97%)
(2) Less than 1 day per month (137/9.63%)
(3) 1-3 days per month (295/20.75%)
(4) 1-3 days per week (454/31.93%)
(5) 4-6 days per week (262/18.42%)
(6) 7 days per week (118/8.3%)

Total: 1422

If Q10=(1), answer Q16, Q17
If Q10=(2)(3)(4)(5)(6), answer Q11, Q12, Q13, Q14, Q15, Q17

Q11. How long have you been using FFBSS in Nanjing?
(1) Less than 3 months (426/33.65%)
(2) 3-6 months (337/26.62%)
(3) 6 months-1 year (368/29.07%)
(4) More than 1 year (135/10.66%)
Total: 1266

Q12. What are the two main reasons for you to use FFBSS in Nanjing? (Two answers)
(1) Convenient (1195/94.39%)
(2) Rapid (733/57.9%)
(3) Economical (381/30.09%)
(4) Ecological (130/10.27%)
(5) Healthy (77/6.08%)
(6) Others (please indicate) (16/1.26%)
Total: 1266

Q13. Do you use FFBSS for the following types of trips in Nanjing? (One answer per row)

	No	Yes, only go there	Yes, only come back from there	Yes, both go there and back
Study	266/21.01%	133/10.51%	27/2.13%	840/66.35%
Work	681/53.79%	92/7.27%	33/2.61%	460/36.33%
Shopping	489/38.63%	164/12.95%	61/4.82%	552/43.6%
Leisure and recreation	407/32.15%	153/12.09%	61/4.82%	645/50.95%
Visiting friends and relatives	849/67.06%	83/6.56%	34/2.69%	300/23.7%

Q14. Do you have the following changes in your daily travel, after you have used FFBSS in Nanjing? (One answer per row)

Frequency of…	Increase	Decrease	No change
A. Walk	108/8.53%	751/59.32%	407/32.15%
B. Private bike	85/6.71%	625/49.37%	556/43.92%
C. Private e-bike	30/2.37%	461/36.41%	775/61.22%
D. Private motorcycle	25/1.97%	434/34.28%	807/63.74%
E. Public transit	77/6.08%	439/34.68%	750/59.24%
F. Private car	33/2.61%	295/23.3%	938/74.09%
G. Taxi	35/2.76%	484/38.23%	747/59%
H. Trips	493/38.94%	71/5.61%	702/55.45%

Q15. You use FFBSS mainly for…(Only one answer)

(1) Go to destination directly (724/57.19%)
(2) Access to or egress from public transit (bus, metro, etc.) (537/42.42%)
(3) Make connections with other modes of transport (excluding public transit), please indicate: (5/0.39%)
Total: 1266

Q16. Why don't you use FFBSS? (Only one answer)
(1) I don't need it (105/67.31%)
(2) I don't know how to use it (12/7.69%)
(3) This is no station nearby (0/0%)
(4) It's expensive (4/2.56%)
(5) It's dangerous (3/1.92%)
(6) Others, please indicate: (32/20.51%)
Total: 156

Q17. Do you intend to use FFBSS in the next 3 months?
(1) Yes (1161/81.08%)
(2) No (130/9.08%)
(3) I don't know (141/9.85%)
Total: 1432

2.2 Ride-sourcing services (RSS)
(1) such as, Didi Express, Didi Premier, Yongche, Ucar, etc.
(2) Excluding e-taxi (like Didi Taxi)
(3) Excluding car-pooling services (like Didi Hitch, Didachuxing)
(4) Excluding car-sharing services (like Evcard, Gofun)

Q18. Do you know RSS?
(1) Yes (1223/85.41%)
(2) No (209/14.59%)
Total: 1432

Q19. How often do you use RSS in Nanjing?
(1) Never (329/26.9%)
(2) Less than 1 day per month (546/44.64%)
(3) 1-3 days per month (309/25.27%)
(4) 1-3 days per week (35/2.86%)
(5) 4-6 days per week (4/0.33%)
(6) 7 days per week (0/0%)
Total: 1223

If Q19=(1), answer Q25, Q26
If Q19=(2)(3)(4)(5)(6), answer Q20, Q21, Q22, Q23, Q24, Q26

Q20. How long have you been using RSS in Nanjing?
(1) Less than 3 months (291/32.55%)
(2) 3-6 months (150/16.78%)
(3) 6 months-1 year (150/16.78%)
(4) More than 1 year (303/33.89%)
Total: 894

Q21. What are the two main reasons for you to use RSS in Nanjing? (Two answers)
(1) Convenient (737/82.44%)
(2) Rapid (673/75.28%)
(3) Economical (302/33.78%)
(4) Ecological (12/1.34%)
(5) Safe (50/5.59%)
(6) Others (please indicate) (14/1.57%)
Total: 894

Q22. Do you use RSS for the following types of trips in Nanjing? (One answer per row)

	No	Yes, only go there	Yes, only come back from there	Yes, both go there and back
Study	732/81.88%	56/6.26%	16/1.79%	90/10.07%
Work	627/70.13%	109/12.19%	25/2.8%	133/14.88%
Shopping	395/44.18%	109/12.19%	111/12.42%	279/31.21%
Leisure and recreation	287/32.1%	130/14.54%	100/11.19%	377/42.17%
Visiting friends and relatives	598/66.89%	75/8.39%	42/4.7%	179/20.02%

Q23. Do you have the following changes in your daily travel, after you have used RSS in Nanjing? (One answer per row)

Frequency of…	Increase	Decrease	No change
A. Walk	26/2.91%	212/23.71%	656/73.38%
B. Private bike	15/1.68%	145/16.22%	734/82.1%
C. Private e-bike	11/1.23%	129/14.43%	754/84.34%
D. Private motorcycle	8/0.89%	126/14.09%	760/85.01%
E. Public transit	32/3.58%	372/41.61%	490/54.81%
F. Private car	12/1.34%	170/19.02%	712/79.64%
G. Taxi	36/4.03%	476/53.24%	382/42.73%
H. Trips	148/16.55%	42/4.7%	704/78.75%

Q24. You use RSS mainly for…(Only one answer)
(1) Go to destination directly (838/93.74%)
(2) Access to or egress from public transit (bus, metro, etc.) (52/5.82%)
(3) Make connections with other modes of transport (excluding public transit), please indicate: (4/0.45%)
Total: 894

Q25. Why don't you use RSS? (Only one answer)
(1) I don't need it (263/79.94%)
(2) I don't know how to use it (16/4.86%)
(3) This is no vehicle of RSS nearby (0/0%)
(4) It's expensive (16/4.86%)
(5) It's dangerous (27/8.21%)
(6) Others, please indicate: (7/2.13%)

Total: 329

Q26. Do you intend to use RSS in the next 3 months?
(1) Yes (569/39.73%)
(2) No (317/22.14%)
(3) I don't know (546/38.13%)
Total: 1432

Part 3: Additional Information

Q27. You are:
(1) A man (666/46.51%)
(2) A woman (766/53.49%)
Total: 1432

Q28. What's your year of birth? (For example, 1991)

Q29. Where did you attend the Gaokao (the national university entrance exam)? (Province/City/District)

Q30. Where did you live during the 2016-2017 academic year? (Province/City/District)

Q31. What's your current grade?
(1) 1st year of Bachelor (131/9.15%)
(2) 2nd year of Bachelor (111/7.75%)
(3) 3rd year of Bachelor (87/6.08%)
(4) 4th year of Bachelor (124/8.66%)
(5) 5th year of Bachelor (11/0.77%)
(6) 1st year of Master (399/27.86%)
(7) 2nd year of Master (218/15.22%)
(8) 3rd year of Master (187/13.06%)
(9) 1st year of PhD or more (164/11.45%)
Total: 1432

Q32. What's your school or department?
(1) School of Liberal Arts (62/4.33%)
(2) School of History (31/2.16%)
(3) Department of Philosophy (Religious Studies) (46/3.21%)
(4) School of Journalism and Communication (23/1.61%)
(5) School of Law (48/3.35%)
(6) School of Business (108/7.54%)
(7) School of Foreign Studies (37/2.58%)
(8) School of Government (43/3%)
(9) School of Information Management (76/5.31%)
(10) School of Social and Bebavioral Sciences (37/2.58%)
(11) Department of Mathematics (23/1.61%)
(12) School of Physics (46/3.21%)
(13) School of Astronomy and Space Sciences (15/1.05%)
(14) School of Chemistry and Chemical Engineering (150/10.47%)

(15) Department of Computer Science and Technology (55/3.84%)
(16) School of Electronic Science and Engineering (67/4.68%)
(17) School of Engineering and Applied Sciences (41/2.86%)
(18) School of the Environment (82/5.73%)
(19) School of Earth Sciences and Engineering (42/2.93%)
(20) School of Geographic and Oceanographic Sciences (97/6.77%)
(21) School of Atmospheric Sciences (18/1.26%)
(22) School of Life Sciences (56/3.91%)
(23) Medical School (57/3.98%)
(24) School of Management and Engineering (24/1.68%)
(25) Kuang Yaming Honors School (17/1.19%)
(26) Institute for International Students (1/0.07%)
(27) School of Software Engineering (22/1.54%)
(28) School of Architecture and Urban Planning (54/3.77%)
(29) School of Marxism (12/0.84%)
(30) Others (42/2.93%)
Total: 1432

Q33. Are you married or in a relationship?
(1) Yes (485/33.87%)
(2) No (947/66.13%)
Total: 1432

Q34. Do your parents live in Nanjing?
(1) Yes (60/4.19%)
(2) No (1372/95.81%)
Total: 1432

Q35. What is your approximately monthly income?
(1) ≤ 1000 CNY (186/12.99%)
(2) 1001-1500 CNY (446/31.15%)
(3) 1501-2000 CNY (355/24.79%)
(4) 2001-3000 CNY (216/15.08%)
(5) ≥ 3001 CNY (94/6.56%)
(6) I don't want to answer (135/9.43%)
Total: 1432

Q36. How much do you spend approximately each month for your daily travel in Nanjing?
(1) ≤ 50 CNY (695/48.53%)
(2) 51-100 CNY (433/30.24%)
(3) 101-200 CNY (138/9.64%)
(4) ≥ 201 CNY (51/3.56%)
(5) I don't know (115/8.03%)
Total: 1432

Q37. Do you have a driver's license?
(1) Yes (740/51.68%)
(2) No (692/48.32%)
Total: 1432

Q38. Do you have the following items in Nanjing?

	Yes	No
A. Bike	649/45.32%	783/54.68%
B. E-bike	69/4.82%	1363/95.18%
C. Motorcycle	10/0.7%	1422/99.3%
D. Car	32/2.23%	1400/97.77%

Q39. Do you have a public transit pass in Nanjing?
(1) Yes (1281/89.46%)
(2) No (151/10.54%)
Total: 1432

Q40. Do you have a habit of car-pooling (i.e. sharing a car trip (as a driver or a passenger) with someone outside your household (i.e. a friend, a neighbor, a classmate, a person contacted via an Internet site, someone met in the street, etc.) for your trips within Nanjing?
(1) Yes (673/47%)
(2) No (759/53%)
Total: 1432

Q41. Do you have a smartphone?
(1) Yes (1420/99.16%)
(2) No (12/0.84%)
Total: 1432

Q42. What's your monthly mobile Internet consumption?
(1) ≤ 100M (19/1.33%)
(2) 101M-500M (116/8.1%)
(3) 501M-1G (190/13.27%)
(4) 1.01G-3G (488/34.08%)
(5) ≥3.01G (566/39.53%)
(6) I don't know (53/3.7%)
Total: 1432

Q43.How often do you use the Internet (fixed and mobile) for?
A. Shopping
(1) Never (40/2.79%)
(2) Less than 1 day per month (112/7.82%)
(3) 1-3 days per month (496/34.64%)
(4) 1-3 days per week (473/33.03%)
(5) 4-6 days per week (165/11.52%)
(6) 7 days per week (146/10.2%)
Total: 1432

B. Leisure and recreation
(1) Never (29/2.03%)
(2) Less than 1 day per month (69/4.82%)
(3) 1-3 days per month (151/10.54%)
(4) 1-3 days per week (256/17.88%)

(5) 4-6 days per week (249/17.39%)
(6) 7 days per week (678/47.35%)
Total: 1432

C. Communicate with friends and relatives
(1) Never (12/0.84%)
(2) Less than 1 day per month (36/2.51%)
(3) 1-3 days per month (56/3.91%)
(4) 1-3 days per week (183/12.78%)
(5) 4-6 days per week (164/11.45%)
(6) 7 days per week (981/68.51%)
Total: 1432

Q45. In the past 3 months, have you already used one or more of the new mobility services (below) anywhere (in China or abroad)?

	Yes	No
A. Station-based bike-sharing services (like Nanjing Public Bike)	413/28.84%	1019/71.16%
B. Free-floating bike-sharing services (like Ofo, Mobike)	1184/82.68%	248/17.32%
C. University bike-sharing services ("Small red bike")	244/17.04%	1188/82.96%
D. Free-floating e-bike-sharing services (like Number-7, Xqchuxing)	174/12.15%	1258/87.85%
E. Ride-sourcing services (like Didi Express, Didi Premier, Yongche, Ucar)	836/58.38%	596/41.62%
F. Car-pooling services (like Didi Hitch, Didachuxing)	507/35.41%	925/64.59%
G. Car-sharing services (like Evcard, Gofun)	85/5.94%	1347/94.06%

A.5. Main Descriptive Statistics

In the end, a total of 1432 valid questionnaires were completed. The rates of valid questionnaires and sampling are 71.6% (1432/2000) and 3.74% (1432/38267) respectively, which show that the sampling method of this survey is quality and efficiency, compared to other studies focused on university students (Whalen et al., 2013; Zhou, 2012).

The descriptive statistics of the survey are presented in the details of questionnaires (violet numbers). Moreover, several main descriptive statistics can be summarized and

analyzed as follows:

First, the distributions of socio-economic characteristics of students, such as gender (Q27), study level (Q31), and field of study (Q32), show that our sample can be considered as quasi-representative.

Second, public transit and private bikes play important roles in students' daily mobilities, since about 90% of respondents have a public transit pass and nearly half of respondents have a private bike. Interestinlgy, only about 2% of respondents own a private car, although over half of respondents hold a driver's license. The former shows that a private car is still unaffordable for most Chinese university students. However, the rate of driver's license suggests their intention to buy a car in the future.

Third, over 99% of respondents have a smartphone, and the high-level frequency of online activities, such as shopping, leisure and recreation, and communication with friends and relatives, confirm that the smartphone and mobile Internet play very important roles in Chinese university students' daily lives.

Fourth, several new mobility services such as free-floating bike-sharing services, and ride-sourcing services, are very popular among the respondents. The adoption rates of these two services are 83% and 58% respectively. On the contrary, other services, like car-pooling services, station-based bike-sharing services, free-floating e-bike-sharing services, and car-sharing services, are less adopted by the respondents.

Lastly, about 90% of respondents have already used FFBSS in Nanjing, and over 10% of respondents have chosen these services as their main mode of transportation for both commuting (study) and non-commuting trips (shopping, recreation, and visiting). For RSS, more than 60% of respondents have already used these services in Nanjing, but

30% of them do not have a positive continuance intention in the near future.

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Les comportements d'adoption et de post-adoption des nouveaux services de mobilité chez les étudiants en Chine : Trois essais empiriques

Mots-clés : nouveaux services de mobilité, comportement d'adoption et de post-adoption, étudiants, Chine.

Résumé : Au cours de la dernière décennie, les nouveaux services de mobilité (NSM), tels que les vélos en libre-service sans station (VLSsS) et les véhicules de tourisme avec chauffeurs (VTC), se sont développés rapidement dans le monde entier, en particulier en Chine. Cependant, les connaissances académiques sur les comportements d'adoption et de post-adoption de ces NSM et leurs facteurs influents sont encore limitées et fragmentaires. Basée sur une enquête originale, cette thèse vise à faire avancer notre compréhension de ces sujets à travers trois essais empiriques, en se concentrant d'une part sur les étudiants chinois, d'autre part sur deux types de NSM (VLSsS et VTC), et enfin sur quatre types de comportements : l'adoption, la fréquence d'utilisation, les choix de mode, et l'intention de continuer à utiliser. Le premier essai examine les facteurs influençant la fréquence d'utilisation des VLSsS en utilisant un modèle logit ordonné généralisé. Le deuxième essai étudie le rôle des VLSsS dans les choix modaux des étudiants pour les déplacements d'études et d'achats, et leurs facteurs influents *via* deux modèles logit multinomiaux. Le troisième essai applique deux modèles probit avec sélection d'échantillon pour étudier les facteurs qui influencent l'adoption et l'intention de continuer à utiliser les VTC. Les résultats montrent que, premièrement, les impacts des caractéristiques individuelles varient selon les différents comportements d'adoption et de post-adoption ; deuxièmement, les comportements actuels d'utilisation des VLSsS ou des VTC ont des impacts non-négligeables sur les comportements de post-adoption de ces deux types de services.

University students' adoption and post-adoption behaviors of new mobility services in China: Three empirical essays

Keywords: new mobility services, adoption and post-adoption behaviors, university students, China.

Abstract: Over the last decade, new mobility services (NMS) such as free-floating bike-sharing services (FFBSS), and ride-sourcing services (RSS) have expanded rapidly around the world, particularly in China. However, knowledge on adoption and post-adoption behaviors of NMS and their influential factors is still limited and fragmentary. Based on an original survey, this thesis aims to advance our understanding of these topics through three empirical essays by focusing firstly on Chinese university students, secondly on two types of NMS (FFBSS, and RSS), and thirdly on four types of adoption and post-adoption behavior: adoption, frequency of use, mode choice, and continuance intention to use. The first essay examines the factors influencing the frequency of use of FFBSS by using a generalized ordered logit model. The second essay studies the role of FFBSS in students' mode choices on commuting and shopping trips, and their influential factors via two multinomial logit models. And the third essay applies two probit models with sample selection to investigate the factors that influence the adoption and continuance intention to use RSS. The results show that, firstly, the impacts of individual characteristics are varied across different adoption and post-adoption behaviors; secondly, the current FFBSS or RSS use behaviors also have non-negligible impacts on post-adoption behaviors of these two kinds of service.