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Travel satisfaction with dockless bike-sharing: Trip stages, attitudes and the built environment

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ABSTRACT

Using survey data collected among residents in Beijing, this paper presents an investigation of the difference in travel satisfaction between dockless bike-sharing and other travel modes. The effects of individual, spatial and trip attributes on travel satisfaction with dockless bike-sharing are also identified. Our analysis adds to the empirical support for higher satisfaction with trips by dockless bike-sharing than trips by private bicycles. The assess time for shared bicycles is negatively associated with travel satisfaction with dockless bike-sharing. In addition, travelers have higher satisfaction with dockless bike-sharing when used as the primary mode than as the first-mile/last-mile solution. Travel-related attitudes tend to play a more significant role in travel satisfaction with dockless bike-sharing than residential built environment. Travelers with a preference for bicycles and public transport and those who value the health or environmental influence of travel tend to evaluate dockless bike-sharing travel as more satisfying.

1. Introduction

Understanding travelers' experiences of and satisfaction with different travel modes is essential, as research has recognized that travel satisfaction relates to individuals' overall subjective well-being and provides insights into their preferences and attitudes (Bergstad et al., 2011; De Vos, Schwanen, Van Acker, & Witlox, 2019; Ettema, Friman, Gärling, & Olsson, 2016; Ettema, Gärling, Olsson, & Friman, 2010; Friman, Gärling, Ettema, & Olsson, 2017; Olsson, Gärling, Ettema, Friman, & Fujii, 2013). Across different geographical contexts, walking and using a private bicycle, as active slow modes, are consistently found to be the most satisfying travel modes, especially when compared to car and public transport use (Mao, Ettema, & Dijst, 2016; Susilo & Cats, 2014). Trip satisfaction differs not only by travel mode but also by trip-specific attributes including travel purpose, travel time and trip frequency. Previous studies have suggested that travel satisfaction can also depend on trip complexity (Mao et al., 2016). For different travelers and travel modes, there are distinctive determinants of trip satisfaction when considering multimodal and multistage trips (Susilo & Cats, 2014).

Travel satisfaction differs not only by trip characteristics but also by a range of personal characteristics. Given that different travelers have different travel needs and preferences, which may vary across sociodemographics such as age, gender, income level, household type, mode availability, health status, individuals' personalities and attitudes towards various travel modes, the satisfaction travelers obtain from travel can also demonstrate various patterns (Bergstad et al., 2011; Olsson et al., 2013; Páez & Whalen, 2010). In addition, there is a relationship between reported trip satisfaction and spatial attributes at an individual's home location (De Vos, Mokhtarian, Schwanen, Van Acker, & Witlox, 2016; Friman, Fujii, Ettema, Gärling, & Olsson, 2013).

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While many factors driving trip satisfaction have been addressed in the literature, little is known about how satisfaction with shared mobility (cars, bicycles) differs from satisfaction with privately owned vehicles. As one of the pinnacles of micromobility, dockless bike-sharing systems provide flexible short-term access to public bicycles without the constraint of geographically fixed bike-sharing stations. These systems are often characterized by a global positioning system (GPS) located on the bicycle and a mobile application for locating bicycles, unlocking bicycles, and processing cashless mobile payments. Individuals are required to pay the deposit to register as a member of a certain dockless bike-sharing company. When individuals want to use the dockless shared bicycles, they can find the available dockless shared bicycles for that company nearby using the corresponding mobile application. Individuals can choose an available bicycle, unlock it and process cashless mobile payment using the mobile application. Dockless shared bicycles can be parked where bicycle parking is allowed or in the designated geo-fencing areas if required, which is also displayed on the mobile application. Individuals then will need to lock the dockless shared bicycle and complete the payment for the trip expense with the mobile application when ending the journey. These features make dockless bike-sharing independent from docks and stations, which ensures higher flexibility and efficiency. Travelers' experience of their trips can be improved when they do not need to consider the presence of a dock along their riding routes or around their destinations (Chen, van Lierop, & Ettema, 2020a). On the other hand, dockless shared bicycles can have varying functional density so that high ridership areas can have more bicycles available in more convenient locations than in low ridership areas. The dockless model can also contribute to uncertainty regarding accessing bicycles in the same location (Peters & MacKenzie, 2019). These intrinsic characteristics of dockless bike-sharing may attract different groups of cyclists and generate different types of trips or trip chains compared with station-based bike-sharing and privately owned bicycles, hence contributing to a different evaluation of dockless bike-sharing trips.

Although an increasing number of studies related to travel satisfaction with different travel modes have been conducted since 2010, to our knowledge, there has been a lack of research investigating travelers' satisfaction level with dockless bike-sharing trips. The large expansion and wide-scale adoption of dockless bike-sharing systems have increasingly made them an unneglectable part of transportation systems in many regions worldwide (Zhang, 2018). Understanding how dockless bike-sharing systems are positioned among the travel satisfaction spectrum of urban mobility systems and what influences travel satisfaction with this transportation service can shed light on how to improve the loyalty towards dockless bike-sharing and encourage mode substitution for other modes. Additionally, understanding travel satisfaction with dockless bike-sharing trips as domain-specific life satisfaction can provide insights into assessing the impacts of dockless bike-sharing systems on well-being. These implications can contribute to relevant policy-making that stimulates active travel practices that include dockless bike-sharing. This study therefore aims to explore how dockless bike-sharing differs from other travel modes in terms of travel satisfaction and to analyze the contribution of individual- and trip-dimension attributes to travel satisfaction for dockless bike-sharing. Using survey data collected from residents in Beijing, we employed random effects modeling to compare the travel experience of individuals' trips using dockless bike-sharing for the whole trip or part of the trip with that of trips not involving dockless shared bicycles. In addition, a multivariate linear analysis was used to test the key factors influencing individuals' travel satisfaction with dockless bike-sharing for different travel purposes.

The remainder of this paper is organized as follows. In the next section, we present the travel satisfaction research literature and construct the study's theoretical framework for empirical analysis. We then introduce the study's context, data collection process and methodology. Subsequent sections highlight the analysis and results. The final section presents a discussion of the empirical outcomes, conclusions, unresolved issues as a guide for future research and potential policy implications.

2. Literature review

2.1. Travel satisfaction and its determinants

Travel behavior research has, to a great extent, regarded travel as an instrument that facilitates individuals' engagement in activities in different places. However, the research has also found that individuals often also value travel in itself as an experience. Travel satisfaction is regarded as domain-specific life satisfaction from the perceptive of subjective well-being (Ettema et al., 2010), and it has been used to refer to both satisfaction with travel in general and satisfaction with a specific trip (De Vos & Witlox, 2017). The measurement of travel satisfaction has been proposed to consist of two components: the cognitive judgment that is formulated as a cumulative appraisal of the travel and the affective responses – that is, the emotions or moods– experienced during the travel (Ettema et al., 2016a; Ettema et al., 2011).

Previous studies have provided valuable insights into the explanatory factors for the variations in travel satisfaction. At the individual level, travel satisfaction, regardless of the travel modes used during a trip, is commonly believed to depend on sociodemographics. Susilo and Cats (2014)'s research of eight European cities, for instance, suggested that different traveler groups, such as young, female, low-income or unemployed travelers, are attributed to disparate influential factors of satisfaction for individual trip stages in different travel modes. Previous studies often suggested that older people experience higher levels of travel satisfaction (e.g., Cao & Ettema, 2014; De Vos et al., 2016; St-Louis, Manaugh, van Lierop, & El-Geneidy, 2014; Ye & Titheridge, 2017). However, no significant association was found among age, gender, marriage status and commute satisfaction by Bergstad et al. (2011). Individuals' physical capability constraints (e.g., health limitations that could hamper individuals from engaging in active modes) and mobility constraints (e.g., time factors and difficulties in assessing certain transportation services) have been found to significantly decrease satisfaction with a trip (Kim, Park, & Lee, 2014; Mokhtarian, Papon, Goulard, & Diana, 2015; Nordbakke & Schwanen, 2014). Ye and Titheridge (2017)'s study on employers' commuting in Xi'an, China, revealed a connection between better self-reported health conditions and higher levels of travel satisfaction. In addition to sociodemographics, people's evaluation of trip experiences can be affected by the judgment or support of their surrounding friends and families (St-Louis et al., 2014), and people tend to be more satisfied with their trips when they are happier with their current life stage (Abou-Zeid & Ben-Akiva, 2012).

Individuals' travel-related attitudes have also been shown to influence travelers' evaluation of trips. Generally, people with a travel-liking attitude, for instance, valuing travel time, tend to have a higher overall satisfaction with their trips than their counterparts (St-Louis et al., 2014; Ye & Titheridge, 2017). With regard to mode-specific attitudes, a positive attitude or a preference towards a certain mode is commonly presented as being positively associated with travel satisfaction when using that mode (Cao & Ettema, 2014; De Vos et al., 2016; Mokhtarian et al., 2015). The mismatch between mode preference and mode reality, that is, when individuals travel with a nonpreferred mode, can also affect individuals' travel satisfaction (De Vos, 2018). In their study in Montreal, St-Louis et al. (2014) found that some travelers' dissatisfaction with their public transport or bicycle commute was not because of public transit, cycling services or infrastructure but related to their overall preference for driving. In contrast, in the Chinese context, Hu, Sobhani, & Ettema (2022) suggested a marginally significant effect of travel mode dissonance on lower travel satisfaction, and travel satisfaction was found to be more influenced by the actual mode use than their mode preferences. Valuing personal health or having concerns regarding environmental issues related to travel has also been found to contribute to higher commuters' satisfaction with walking or cycling trips (Manaugh & El-Geneidy, 2013).

Travel satisfaction can also be affected by spatial attributes. Studies exploring the relationship between the built environment and satisfaction with trips have identified accessibility and walkability (or bikeability) as the main predictors (Cao & Ettema, 2014; De Vos et al., 2016; Ettema & Smajic, 2015; Taniguchi, Gärling, & Friman, 2014). Especially for walking and cycling trips, Kim et al. (2014) analyzed the meso- and micro-scale environmental factors of pedestrian satisfaction in Seoul, Korea, and identified a positive significant influence of sidewalk width, street flatness and the availability of pedestrian crossings on satisfaction with walking trips. They also revealed that utilitarian pedestrians tended to enjoy their trips more in denser areas. Similar results were found for cycling trips, and cyclists' trip satisfaction has been found to be significantly associated with the presence of adequate cycling infrastructure, the landscape and land use of the surrounding environment (Calvey et al., 2015; Li et al., 2012; Willis et al., 2013). In addition, previous studies have further investigated the underlying mechanisms regarding the effect of the built environment on travel satisfaction. Mouratidis, Ettema, and Næss (2019) revealed a higher travel satisfaction in compact urban neighborhoods; this study also pointed out that the effect of the built environment on commute satisfaction were mainly indirect and mediated by trip duration and travel mode choice.

Compared with individual-level factors, trip characteristics such as trip frequency, trip duration and trip purpose are more frequently acknowledged. More frequent users tend to have lower travel satisfaction with their current trips than their counterparts, especially for car and public transport travelers (Susilo & Cats, 2014; Waygood, Friman, Taniguchi, & Olsson, 2019). However, there is an inconsistent finding in Italy reporting that satisfaction with public transport trips is not correlated with frequency of use (Diana, 2012). Longer travel times can cause fatigue in travelers and decrease their enthusiasm, thereby lowering their perception of trip quality and efficiency (Olsson et al., 2013; Wang, Mao, & Wang, 2020). Long bicycle trips can involve more painful mood than shorter ones due to a higher physical demand (Morris & Guerra, 2015). Recreational trips are generally evaluated with higher satisfaction scores than traveling for other purposes (Ettema, Gärling, Olsson, Friman, & Moerdijk, 2013). In addition to the integral attributes of trips, many trips consist of multiple legs or stages completed by different travel modes, which contributes to trip complexity in a multiepisode trip configuration. Overall trip satisfaction may be related to the characteristics of the primary mode of multistage trips (Abenoza, Cats, & Susilo, 2017; Cats, Abenoza, Liu, & Susilo, 2015). Additionally, it has generally been suggested that trip stages involving additional waiting times and transfers decrease overall trip satisfaction (Abenoza, Cats, & Susilo, 2019; Ettema, Abenoza, & Susilo, 2016b; Suzuki et al., 2014). Gao, Rasouli, Timmermans, and Wang (2020) also argued that overall trip satisfaction is often correlated with the satisfaction score of the trip stage with the lowest satisfaction.

2.2. *Travel satisfaction with dockless bike-sharing systems*

A consistent finding is that active travel modes, including cycling and walking, are generally associated with higher satisfaction with travel compared with car and public transport, and people seem to perceive their trips by public transport as the least attractive (de Kruijf, Ettema, & Dijst, 2019; De Vos & Witlox, 2017; Mao et al., 2016; Morris & Hirsch, 2016; St-Louis et al., 2014; van Lierop, Badami, & El-Geneidy, 2018). Higher satisfaction with walking and cycling can be ascribed to better opportunities to enjoy local scenery (Gatersleben & Uzzell, 2007). Additionally, the physical activity and health benefits associated with active travel can positively influence travelers' moods (Ekkekakis, Hall, & Petruzzello, 2008; Ettema et al., 2016a). Regarding the specific case of docked bike-sharing systems, relevant studies have suggested that users are generally satisfied with such systems because of adequate vehicle condition and facilities as well as the enjoyment experienced when riding shared bikes; younger people tend to have higher satisfaction levels with docked bike-sharing systems than older people (Soltani, Allan, Anh Nguyen, & Berry, 2019).

As a newer generation of bike-sharing systems with the initiative to encourage sustainable travel, dockless bike-sharing systems possess the features of active modes but with specific advantages and disadvantages compared to docked systems. The increased flexibility in accessing bicycles frees individuals from bicycle security and maintenance concerns. Compared with docked bike-sharing, dockless bike-sharing provides a more flexible route choice (Guo, Zhou, Wu, & Li, 2017). Moreover, its efficiency for trip chaining can contribute to an easier combination of dockless bike-sharing systems and public transport compared to the use of docked bicycles (Mobike Global, Beijing Tsinghua Tongheng Planning and Design Institute, & China New Urbanization Research Institute, 2017). On the other hand, however, dockless design raises issues of less certainty in accessing shared bikes at a fixed location and the unequal density levels of dockless shared bikes in different functional areas (Chang, Song, He, & Qiu, 2018; Gu, Kim, & Currie, 2019). These issues can disturb individuals' travel plans when they cannot find a bike at the same locations or in areas with low concentrations of dockless bike-sharing systems, which negatively affects their emotions during travel. Given that dockless bike-sharing systems differ from docked bike-sharing systems and private cycling in a number of respects, no studies, to the authors' knowledge, have empirically addressed travel satisfaction with dockless bike-sharing. A particular aspect concerns the use of dockless bike-sharing for "first-mile/last-mile" connections of public transit trips or transfers (Ai, Li, & Gan, 2019a; Chen, van Lierop, & Ettema, 2020b). Furthermore, the impact of dockless bike-sharing usage as the primary mode or as complementary trip stage in relation to other primary travel modes on overall trip satisfaction has not been explored.

This study is devoted to examining the travel satisfaction of dockless bike-sharing in single-modal or multimodal trips and in different trip stages. In addition, five categories of contributing factors at the individual and trip dimensions explaining the variations in the travel satisfaction of dockless bike-sharing were explored: personal and household sociodemographics, travel-related attitudes, social environment and life satisfaction, the residential built environment, and trip attributes.

Table 1
Sample characteristics.

Variables	Definitions	Mean (Std. Dev.)	No.	Pct.
Individual level (N = 489)				
Individual characteristics				
Age (years)	17–30			61.1%
	31–45			33.6%
	46–61			5.3%
Sex	Female		249	50.9%
	Male		240	49.1%
Education	High school/Secondary technical school and below		18	3.7%
	University/College Bachelors' degree		355	72.6%
	Master's degree and above		116	23.7%
Household income	low income (less than 12,000 yuan)		144	29.4%
	median income (12000–20000 yuan)		187	38.2%
	high income (more than 20,000 yuan)		158	32.3%
Employment	Full-time employed		364	74.4%
	Part-time employment, students, etc.		125	25.6%
Self-reported health	Poor and fair		172	35.2%
	Good		173	35.4%
	Very good and excellent		144	29.4%
Car ownership	No		130	26.6%
	Yes		359	73.4%
Social environment		3.83 (0.63)		
Travel attitude	Pro-car	0.00 (0.96)		
	Pro-e-bike or e-scooter	0.02 (0.99)		
	Pro-public transport	0.07 (0.98)		
	Pro-bicycle	0.20 (0.87)		
	Pro-walking	−0.02 (0.99)		
	Pro-environment or health	0.02 (0.99)		
	Anti-public transport	0.03 (0.95)		
	Anti-traveling	−0.02 (0.98)		
Residential neighborhood attributes				
Spatial location of home address	Outside the 4th ring road		266	54.4%
	Within the 4th ring road		223	45.6%
Cycle paths ratio		0.243(0.169)		
Pedestrian paths ratio		0.276(0.180)		
Trip level (n = N*2, N = 489, two reported trips per individual)				
Trip characteristics				
*1) The most recent trip **involving** the usage of dockless bike-sharing (489 reported trips)*				
Trip Primary mode	Dockless bike-sharing		303	62.0%
	Public transport		153	31.3%
	Car		13	2.7%
	Walking		15	3.1%
	Other (including e-bikes, private bicycles, motorcycles, etc.)		5	1.0%
*2) The most recent trip **not involving** the usage of dockless bike-sharing (489 reported trips)*				
Trip Primary mode	Public transport		203	41.5%
	Car		129	26.4%
	Walking		119	24.3%
	Other (including e-bikes, private bicycles, motorcycles, etc.)		38	7.8%

3. Methods and data

3.1. Data collection

The data used in this study come from an online survey collected from August 7, 2018, to November 31, 2018, among residents of Beijing, China. As a megacity with a population of 21.5 million (as of the end of 2018), Beijing's urban structure is marked by the six concentric ring roads centered around the Forbidden City. The dominant travel mode, public transport including metros and buses, accounted for 46% of all trips in 2018 (Beijing Transport Research Center, 2019). Dockless bike-sharing systems first appeared in June 2015 on the Peking University campus primarily for students' usage. It soon became a new part of Beijing's urban transport system and quickly expanded to other major cities all over China. In 2018, the city government of Beijing restricted the volume of operated shared bikes in the city to a total of 1.91 million bicycles from nine operators with an average of 1.42 million rides per day (Beijing Municipal Commission of Transport, 2018).

This online survey collected individuals' sociodemographic characteristics, social environment, travel attitudes, travel behavior in dockless bike-sharing usage, and recent trip experiences. The distribution of questionnaires was administered by a recruitment company (https://www.wjx.cn) among Beijing residents aged 16 and older from the recruitment company's large online survey panel with 2.6 million members in China. Individuals under age 16 were not allowed to register for dockless bike-sharing usage and were therefore excluded from sampling. The complete survey contains valid responses from 606 respondents, with a response rate of 6.44%. Respondents usually need 30 to 40 min to fill out the survey. Of the 606 individuals who responded to the questionnaire, 489 were from dockless bike-sharing users and 117 from nonusers. As this study pays particular attention to the travel satisfaction of dockless bike-sharing, only 489 dockless bike-sharing users were included in the analysis.

Table 1 presents a description of the respondents' characteristics. Our sample is targeting at dockless bike-sharing users therefore it is not representative of the residents in Beijing (Beijing Municipal Bureau of Statistics, 2019). For instance, the respondents in our study have a balanced sex distribution and consist of a majority of younger and middle-aged dockless bike-sharing users, while the residents in Beijing generally have an even distribution across the age groups of 15–29 years old (20.3%), 30–44 years old (28.3%), and 45–59 years old (23.9%). Our sample includes full-time employees, part-time employees, students, retirees, and homemakers. Nevertheless, the majority of the respondents were full-time employees (74.4%). 73.4% of the respondents reported owning at least one car, which is higher than the average situation in Beijing, with 51 cars for every 100 households in 2018. Our study oversampled individuals with a higher educational level, comparing to the statistic that only 38.8% of the residents in Beijing had at least a University or College Bachelors' degree. This may be related to a higher engagement of higher educated individuals in dockless bike-sharing adoption (Du & Cheng, 2018). It is also possible that higher educated individuals have a higher likelihood to expose to our online survey. Individuals with low, median, and high household incomes were captured in relatively equal proportions, and individuals living both in urban areas inside the fourth ring road and areas outside were involved.

The sample for the current analysis comprises 978 observations of trips made by 489 dockless bike-sharing users. Each respondent of the sample was asked to recall and report their experiences of two trips: one is the most recent trip that includes the usage of dockless bike-sharing for the whole or part of the trip; the other is the most recent trip not involving dockless bike-sharing. For each trip all travel modes used in trip legs were specified. We have specified in the questionnaire that a return trip is counted as two separate trips. The reported two trips including and excluding the usage of dockless bike-sharing systems for each respondent do not necessarily share the same origin and destination. The respondents were asked to specify the travel purpose and frequency of each trip. Due to the existence of multi-stage trips with different travel modes, the respondents stated their primary travel modes in their reported trips. Accordingly, we identified the primary modes as five categories: dockless bike-sharing, public transport, car, walking and other (including e-bikes, private bicycles, motorcycles, etc.) (see Table 1). Dockless bike-sharing accounts for the primary mode of a large percentage (62.0%) of the reported trips involving the usage of dockless bike-sharing, and public transport followed in the second place (31.3%). For trips not involving dockless bike-sharing, a larger number of trips were undertaken primarily by car and walking.

Table 2
The Satisfaction with Travel Scale (STS).

Positive deactivation—negative activation (STS: Positive deactivation)	
Time pressed (-4)	Relaxed (4)
Worried I would not be in time (-4)	Confident I would be in time (4)
Stressed (-4)	Calm (4)
Positive activation–negative deactivation (STS: Positive activation)	
Tired (-4)	Alert (4)
Bored (-4)	Enthusiastic (4)
Fed up (-4)	Engaged (4)
Cognitive evaluation (STS: Cognitive evaluation)	
Travel was worst I can think of (-4)	Travel was best I can think of (4)
Travel was low standard (-4)	Travel was high standard (4)
Travel worked poorly (-4)	Travel worked well (4)

3.2. Measurements

3.2.1. Trip satisfaction

This study applied a widely adapted measurement—the Satisfaction with Travel Scale (STS) (Ettema et al., 2011)—to evaluate individuals' trip experiences on both the cognitive and affective dimensions. STS comprises a cognitive assessment of the functionality of travel and a measurement of affect using two orthogonal dimensions of valence (varying from positive to negative) and activation (varying from activated to deactivated). Nine pairs of adjectives are presented in a counterbalanced order to collectively tap three dimensions of STS: three items—relaxation, confidence, calmness—measuring the positive deactivation dimension; three items—engagement, enthusiasm, alertness—measuring the positive activation dimension; and three items measuring cognitive travel satisfaction (see Table 2)(Ettema et al., 2011; Friman et al., 2013). The respondents were asked to rate these items on a nine-point scale ranging from −4 over 0 (neutral) to 4. Both the overall STS (the average score across the three dimensions) and the three dimensions (the average score for the contained three items) were calculated for further analysis. The scores vary from −4 over 0 (midpoint) to 4, with a higher score implying higher satisfaction.

The trip satisfaction for all 978 observations of trips made by 489 dockless bike-sharing users was evaluated. In addition, as this study pays special attention to travel satisfaction with dockless bike-sharing, for trips that include the usage of dockless bike-sharing, the respondents also stated their satisfaction with their travel at the stage using dockless bike-sharing. Before calculating the average scores of the nine STS items for the 978 observations of trips and the trip stage using dockless bike-sharing systems, we conducted reliability test for trips involving the usage of dockless bike-sharing systems, trips not involving dockless bike-sharing systems and dockless bike-sharing trip stages respectively. All three values of Cronbach's alpha (alpha > 0.8) indicated internal consistency. For the

Table 3
Derived factors—types of travel attitude (N = 606).

Factors	Indicators	Loadings
Pro-car	*I like driving*	*0.715*
	Without a car, I cannot handle my daily life	*0.678*
	Owning a car allows me to do more	*0.812*
	Owning a car gives me freedom	*0.821*
	I do not have any alternative for car use	*0.732*
	A car gives me prestige and status	*0.618*
Pro-e-bike or scooter	*I like riding e-bikes*	*0.891*
	If possible, I would rather use e-bikes than take public transport	*0.911*
	Riding e-bikes can sometimes be easier for me than other modes	*0.906*
	I think that traveling by e-bike is safer than all other modes	*0.805*
Pro-public transport	*I like to use public transport*	*0.807*
	If possible, I would rather use public transport than drive	*0.731*
	Public transport can sometimes be easier for me than other modes	*0.784*
	Public transport is unreliable	*−0.532*
	Traveling by public transport is safer than other modes	*0.456*
Pro-bicycle	*I like cycling*	*0.834*
	If possible, I would rather cycle than take public transport	*0.839*
	Cycling can sometimes be easier for me than other modes	*0.843*
	I think traveling by bicycle is safer than all other modes	*0.726*
Pro-walking	*I like walking*	*0.782*
	If possible, I would rather walk than take public transport	*0.791*
	Walking can sometimes be easier for me than other modes	*0.788*
	I think that traveling by foot is safer than all other modes	*0.661*
Pro-environment or health	*I am concerned about the environmental impacts of my daily travel*	*0.770*
	I am willing to change my travel mode if it is good for the environment	*0.795*
	I am concerned about the health impacts of my daily travel	*0.691*
	The trip to/from work is a useful transition between home and work	*0.537*
Anti-public transport	*Transferring to other buses or metros is annoying*	*0.664*
	It bothers me that public transport is too crowded	*0.846*
Anti-traveling	*Travel time is generally wasted time*	*0.761*
	I prefer to organize my errands so that I make as few trips as possible	*0.712*

Note. Adapted from "Exploring Dockless Bikeshare Usage: A Case Study of Beijing, China" by Z. Chen, D. van Lierop, and D. Ettema, 2020, *Sustainability, 12*, p. 1238.

single-modal trip using dockless bike-sharing, we equaled the trip satisfaction at the dockless bike-sharing stage of the trip to the trip satisfaction for the overall trip.

3.2.2. Individual-dimension attributes

To measure the variation in STS of dockless bike-sharing dependent on observable differences between individuals, a series of influential factors derived from the survey that comprises individuals' sociodemographics, life satisfaction and social environment, and travel attitudes were tested. The sociodemographic variables included age, sex, education status, household income, and self-reported health. Cognitive subjective well-being—life satisfaction—was assessed by means of the 5-item *Satisfaction with Life Scale (SWLS)* (Diener, Emmons, Larsen, & Griffin, 1985). The measure was constructed by the respondents' averaging ratings using a 7-point scale from "strongly disagree" to "strongly agree".

Social environment assesses the social norms and behavioral control towards dockless bike-sharing usage that individuals receive from their surroundings. We adopted Ma and Dill (2015)'s measurement scale to measure social support for dockless bike-sharing use. We calculated the average score of the respondents' extent of agreement, on a five-point scale from "strongly disagree" to "strongly agree", with the following five statements: (1) Most people who are important to me, for example, my family and friends, think I should use dockless shared bikes more; (2) Most people who are important to me would support me in using dockless shared bikes more; (3) The people with whom I live ride dockless shared bikes to get to places such as errands, shopping, and work/school; (4) Many of my friends ride dockless shared bikes to get to places such as errands, shopping, and work/school; and (5) Many of my coworkers/classmates ride dockless shared bikes to get to work/school. The Cronbach's alpha of these five statements regarding social environment had the value of 0.749 (alpha $>$ 0.7), indicating the internal consistency of social environment variable.

Travel attitudes were analyzed as latent variables adopted from a previously established exploratory factor analysis that we derived from the same survey including both the users and nonusers of dockless bike-sharing (for details, see Chen et al. (2020b)). We conducted a principal component analysis with varimax rotation, extracting eight significant latent factors from 31 observed items with respondents' ratings on a 5-point scale ranging from "strongly disagree" to "strongly agree" (see Table 3). We considered the absolute value of factor loadings greater than 0.40 to be more important and acceptable in our analysis (Peterson, 2000). Therefore, although all the 31 observed items are loaded to all factors, the rotated factor loading threshold of $\pm$0.40 was determined to identify the importance of each indicator to a certain factor and to identify the indicators that constitute eight different types of travel attitudes. The eight derived latent factors explained 64.8% of the total variance in the responses.

Three spatial attributes related to the respondents' residential neighborhood location and road network were explored. The spatial dataset of our study comprised the Points-of-Interest (POIs) dataset of China and the road networks from OpenStreetMap (OSM), which was updated in September 2018. We created a dummy variable to measure whether the respondents' self-reported residence locations were located inside the 4th ring road in Beijing. Considering the ring road structure, the urban areas inside the 4th ring roads are said to have a higher population density, a higher land use mix, and better connectivity and accessibility of public transport (Tian, Wu, & Yang, 2010). Furthermore, we calculated the total length, in kilometers, of all roads, bicycle paths and pedestrian-priority roads within the neighborhood. The neighborhood was profiled as the area within a 600-m radius from the residence location, given the criteria requiring an average distance of 500 to 600 m between bus stops in Beijing (Beijing Municipal Administration of Quality and Technology Supervision, 2018). We included the cycle path ratio (the percentage of the total length of bicycle paths to the total length of all roads) and the pedestrian path ratio (the percentage of the total length of pedestrian-priority roads to the total length of all roads) in the regression.

3.2.3. Trip-dimension attributes

Given the previous literature on the explanatory variables of travel satisfaction at the trip level, we added a set of trip characteristics to identify the most relevant trip-dimension attributes related to travel satisfaction with dockless bike-sharing. As each respondent reported their experiences of two trips that included and excluded the usage of dockless bike-sharing during travel, the respondents were asked to indicate their travel purpose, trip frequency, trip duration and the primary mode for both trips. In particular, for the most recent trip that involves dockless bike-sharing usage, the walking time to access dockless shared bicycles and the duration for dockless bike-sharing rides were included in the analysis. In addition, questions were asked about the usage of travel modes other than the primary mode to distinguish single-modal and multimodal trips.

3.3. Model specification and approach

One aim of this study is to examine the difference in travel satisfaction between dockless bike-sharing and other travel modes. As there are two observations at the trip level (978 trips) for each individual level (489 dockless bike-sharing users), to better describe the travel satisfaction both across trips and across individuals, we conducted a descriptive analysis on the trip experiences and adopted the random effects model to explore how dockless bike-sharing is distinct from other travel modes in its STS scores.

In the second step, to investigate the contribution of individual and trip characteristics to travel satisfaction with dockless bike-sharing, four multivariate linear regressions were carried out for the trips involving dockless bike-sharing usage (489 trips), in which both the three dimensions of STS (positive deactivation, positive activation and cognitive evaluation) and the overall STS of the trip stage using dockless bike-sharing were regressed on the abovementioned individual- and trip-dimension attributes.

4. Results

4.1. Descriptive results

4.1.1. Trip characteristics and satisfaction with single-modal and multimodal dockless bike-sharing trips

According to the travel modes involved, we classified dockless bike-sharing trips (489 trips) in our research sample into three different types of trips: (1) single-modal dockless bike-sharing trips, (2) multimodal trips with dockless bike-sharing as the primary mode; and (3) multimodal trips with other travel modes as the primary mode. Dockless bike-sharing trips often involve walking, as people need to walk to obtain shared bicycles. Hence, for trips that involve only dockless bike-sharing or dockless bike-sharing and walking, and for which the respondents stated dockless bike-sharing as the primary mode, we regard these trips as single-modal trips of dockless bike-sharing. Multimodal trips of dockless bike-sharing involve other travel modes, such as public transport and car, and therefore they are divided into two categories according to their primary modes. Table 4 presents a comparison between three types of dockless bike-sharing trips. Single-modal trips account for approximately half (49.3%) of the reported dockless bike-sharing trips, and 38.0% are multimodal dockless bike-sharing trips in which dockless bike-sharing was used by travelers as one of their secondary travel modes. This suggests that in multimodal travel, dockless bike-sharing usually serves as a complementary or integration role for other travel modes, mostly for public transport (31.3%), as displayed in Table 1.

On average, the respondents reported making dockless bike-sharing trips 4–6 times per week (Table 4). The average trip duration for multimodal dockless bike-sharing trips (over 30 min) tends to be longer than that for single-modal trips (24.13 min), with multimodal dockless trips with dockless bike-sharing as the primary mode having the longest average trip duration of 36.68 min. For single-modal dockless trips and multimodal trips with dockless bike-sharing as the primary mode, the cycling duration of the dockless bike-sharing stage accounts for 84.5% (20.39 min) and 79.5% (27.85 min) of the overall trip duration, respectively, whereas travelers, on average, spend only 13.74 min on cycling with shared bicycles when using dockless bike-sharing as complementary to other primary travel modes.

The distribution of travel purposes across different types of dockless bike-sharing trips is presented in Fig. 1. For all three types of dockless bike-sharing trips, the most frequent purpose for which dockless bike-sharing users travel is work or education commuting, especially for multimodal trips with dockless bike-sharing as (one of) the secondary modes. This might suggest that a large share of trips with dockless bike-sharing used as the "first-mile/last-mile" options or trip-chain connections tend to be traveled by commuters. Apart from commute trips, the respondents seem more likely to travel with dockless bike-sharing singularly to accomplish grocery shopping and recreational activities. A notably higher percentage of the respondents' single-modal trips (approximately 20%) were for grocery shopping compared with multimodal trips (less than 5%), while multimodal dockless bike-sharing trips more often involved travel for the purposes of sports and leisure.

In terms of overall satisfaction for three types of dockless bike-sharing trips, the average scores of the STS index and three STS-dimension indices are found to be positive, which suggests that travelers generally have a neutral to satisfactory evaluation of their dockless bike-sharing trips. Travelers using dockless bike-sharing as the primary mode, whether in single-modal or in multimodal trips, generally perceive their trips as more satisfying than traveling with other primary modes: the average STS index score for multimodal dockless bike-sharing trips with dockless bike-sharing as the primary mode is 2.097, for example, and it also has a lower standard deviation (1.084). Note that nine of the 489 respondents have missing values for the STS index of the whole trip that includes the usage dockless bike-sharing systems; therefore, there were 61 cases for the average STS index score for multimodal dockless bike-sharing trips with dockless bike-sharing as the primary mode and 178 cases for the average STS index score for multimodal dockless bike-

Table 4
Means and standard deviations of the STS index, STS-dimension indices and trip characteristics for different types of dockless bike-sharing trips.

Travel satisfaction	Single-modal trips		Multimodal trips		Multimodal trips	
	Dockless bike-sharing		Dockless bike-sharing primary		Other mode primary	
	No.	Mean (Sd.)	No.	Mean (Sd.)	No.	Mean (Sd.)
Dockless bike-sharing stage of the whole trip						
STS	241	1.941 (1.127)	62	1.995 (1.133)	186	1.357 (1.482)
STS: Positive deactivation	241	2.278 (1.654)	62	2.435 (1.338)	186	1.625 (1.990)
STS: Positive activation	241	1.296 (1.237)	62	1.489 (1.447)	186	0.930 (1.555)
STS: Cognitive evaluation	241	2.248 (1.193)	62	2.059 (1.408)	186	1.514 (1.683)
The whole trip						
STS	–	–	61	2.097 (1.084)	178	1.468 (1.572)
STS: Positive deactivation	–	–	61	2.426 (1.253)	178	1.788 (1.981)
STS: Positive activation	–	–	61	1.656 (1.366)	178	1.004 (1.682)
STS: Cognitive evaluation	–	–	61	2.208 (1.294)	178	1.612 (1.726)
Trip characteristics						
Trip duration (min)	241	24.13 (17.00)	62	36.68 (29.32)	186	31.65 (27.12)
Trip frequency (per week)	241	4.212 (3.183)	62	5.339 (3.719)	186	4.691 (3.635)
Trip cycling duration of dockless bike-sharing (min)	241	20.39 (12.88)	62	27.85 (17.81)	186	13.74 (8.171)

Note. The explanations of STS-related variables can be found in Table 2.

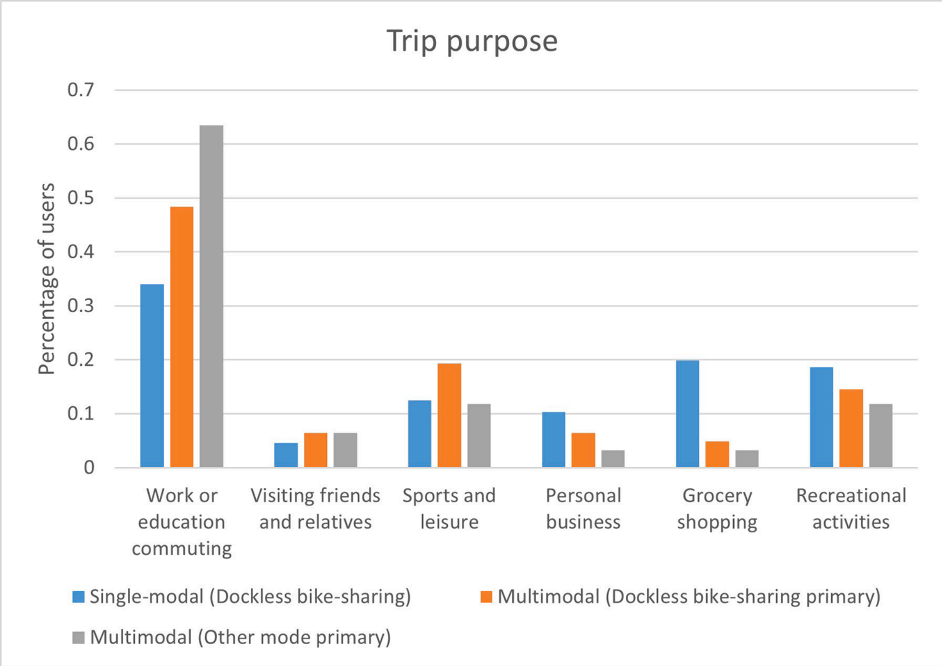

Fig. 1. The distribution of travel purposes across single-modal and multimodal dockless bike-sharing trips.

sharing trips with other modes as the primary mode, as showed in Table 4.

The average STS scores for the dockless bike-sharing stage of the whole trip indicate that travelers tend to be more satisfied with dockless bike-sharing during their travel when dockless bike-sharing is used as the primary mode. Higher STS levels for the dockless bike-sharing stage are found in single-modal trips (1.941) and multimodal trips with dockless bike-sharing as the primary mode (1.995), whereas the average STS score for the dockless bike-sharing stage of multimodal trips with other modes as the primary mode is 1.357. The case is the same for the three STS-dimension indices. This could be because the cycling duration is longer when dockless bike-sharing is applied in the primary trip stage, which enables dockless bike-sharing users to better enjoy their cycling experiences. Páez and Whalen (2010) claimed that active commuters prefer to spend more time on commute as they tend to value the intrinsic enjoyment of active travel modes for their own sake. Another possible explanation is that the assessment of dockless bike-sharing stages may be negatively affected by the respondents' experience with other (less satisfying) modes. For example, the time captivity related to public transport schedules, such as the punctuality of public transit services and time constraints related to transferring, may put pressure on travelers and make the transferring or first-mile/last-mile trip stages by dockless bike-sharing less satisfying.

4.1.2. Difference in travel satisfaction between dockless bike-sharing and other modes

To investigate to what extent dockless bike-sharing differs in travel satisfaction from other travel modes, we compared the last trip the respondents made by dockless bike-sharing and by alternative modes (public transport, car, walking and private bicycles). Table 5 shows a comparison of the STS and STS-dimension indices for these trip groups with specific primary modes. Consistent with previous studies, trips primarily undertaken by active modes are more satisfying compared with car and especially public transport. The average score of overall STS varies from 1.183 for trips by public transport to 1.972 for trips by dockless bike-sharing, with car (1.352), private bicycles (1.535), and walking (1.876) within the range. Even for trips with public transport as the primary mode, the average evaluations from the perspective of all three STS dimensions display no negative levels. In particular, our analysis reveals a satisfaction

Table 5
STS and STS-dimension indices for different travel modes.

Trip satisfaction	Trips with different travel modes									
	Primary mode: Dockless bike-sharing		Primary mode: Public transport		Primary mode: Car		Primary mode: Walking		Primary mode: Private Bicycles	
	No.	Mean (Sd.)	No.	Mean (Sd.)	No.	Mean (Sd.)	No.	Mean (Sd.)	No.	Mean (Sd.)
STS	302	1.972 (1.118)	349	1.183 (1.695)	141	1.352 (1.628)	133	1.876 (1.419)	16	1.535 (1.915)
STS: Positive deactivation	302	2.308 (1.580)	349	1.410 (2.156)	141	1.492 (2.362)	133	2.622 (1.807)	16	1.292 (2.624)
STS: Positive activation	302	1.369 (1.270)	349	0.660 (1.761)	141	0.938 (1.657)	133	0.962 (1.737)	16	1.250 (1.693)
STS: Cognitive evaluation	302	2.240 (1.212)	349	1.480 (1.804)	141	1.626 (1.663)	133	2.045 (1.404)	16	2.062 (2.016)

difference between trips by dockless bike-sharing and private bicycles. Trips by dockless bike-sharing have a higher overall average STS score than private bicycles, and dockless bike-sharing tends to score much higher in the positive deactivation of STS, suggesting a more relaxed, confident, and calm trip experience than cycling by private bicycles. Note that there are limited trips (16 trips) in total that are undertaken primarily by private bicycles in our analysis. Trips by dockless bike-sharing are rated even slightly higher in overall STS than walking. Travelers perceive trips by dockless bike-sharing as causing them to feel more engaged, enthusiastic, and alert (a higher average score on the positive activation dimension of STS) but less relaxed, confident and calm (a lower average score on the positive deactivation dimension of STS) than walking.

Table 6 gives the results for two random effects models that aim to further explore the significance of the difference in travel satisfaction between dockless bike-sharing and other modes. The dependent variable for Model 1 and 2 is the overall STS score of all reported trips in our sample. Several individual sociodemographics and trip characteristics were added as control variables in the modeling. Note that ten of the 978 trip observations have missing values for the trip frequency and overall STS index; therefore, they were not included in the modeling (also not included in Table 5 for consistency).

Various trip characteristics influence travel satisfaction. Specifically, compared to dockless bike-sharing, trips primarily undertaken by public transport and car display a strongly significant negative association with trip satisfaction, with the negative coefficient for the primary mode of public transport being larger than that for car. These revealed associations confirm the significance of higher trip satisfaction with dockless bike-sharing than car and especially public transport, as shown in Table 5.

A longer travel time lowers an individual's satisfaction when controlling for the primary mode used in the trips, which differs from Mao et al. (2016) findings in Beijing suggesting that the travel time variables are not significant for active travel modes. Model 1 displays a significant negative association between trip frequency and trip satisfaction. Repeated travel for this particular type of trip significantly reduces the evaluation of the current trip. When adding the trip purposes in the model as an explanatory variable, the trip frequency variable lost significance, suggesting that the negative significant effects of trip frequency were confounded by trip purpose. Compared with other travel purposes (including visiting friends and relatives; grocery shopping; sports and leisure; and recreational activities such as shopping, eating and drinking), commuters are generally the least satisfied group, and work or education commuting trips tend to have the highest trip frequency among other travel purposes despite travel modes.

Table 6
Results for random effects modeling. Dependent variable: STS.

	Model 1 968 reported trips, 489 individuals		Model 2 968 reported trips, 489 individuals	
	Coef.	Std.err.	Coef.	Std.err.
Intercept	**1.775****	**0.230**	**1.223****	**0.250**
Level 1 (trip)				
Trip purpose (ref = work or education commuting)				
Visiting friends and relatives	–	–	**0.628****	**0.194**
Sports and leisure	–	–	**0.846****	**0.162**
Personal business (medical, banking, etc.)	–	–	−0.074	0.203
Grocery shopping	–	–	**0.562****	**0.169**
Recreational activities (Shopping, eating, and drinking)	–	–	**0.676****	**0.148**
Trip primary mode (ref = dockless bike-sharing)				
Public transport	**−0.654****	**0.113**	**−0.500****	**0.115**
Car	**−0.509****	**0.139**	**−0.350***	**0.141**
Walking	−0.047	0.144	−0.150	0.143
Other (including e-bikes, private bicycles, motorcycles, etc.)	−0.142	0.221	−0.012	0.220
Trip duration	**−0.006****	**0.001**	**−0.007****	**0.002**
Trip frequency	**−0.030****	**0.010**	−0.005	0.012
Level 2 (individual)				
Age	**0.013***	**0.007**	**0.016***	**0.006**
Sex	0.191	0.109	0.165	0.106
Education (ref = University/college bachelors' degree and below)				
Master's degree and above	−0.001	0.130	0.037	0.126
Household income (ref = low income)				
Median income	−0.140	0.134	−0.075	0.131
High income	0.212	0.142	0.241	0.138
Variance				
Idiosyncratic	1.428	1.195	1.393	1.180
Individual	0.691	0.831	0.625	0.791
Theta	0.286		0.273	
Residuals	−0.000		0.000	
Residual Sum of Squares	1367.2		1326.6	

Note. "*" Significant at 0.05; "**" Significant at 0.01.

4.2. Multivariate linear regression results

To further investigate the key determinants of travel satisfaction with dockless bike-sharing, we conducted four multivariate linear regressions with three STS-dimension indices and an overall STS score of the trip stage using dockless bike-sharing serving as the dependent variables. The explanatory variables used in the models reflect a combination of trip characteristics, individual and household sociodemographics, life satisfaction and social environment, travel-related attitudinal factors, and the residential built environment. Table 7 presents the results of the models as well as goodness-of-fit statistics. Although the adjusted R square of the four models is moderate, significant associations are discovered between several explanatory variables and travel satisfaction with dockless bike-sharing.

Table 7
Multivariate linear regression results: STS at the trip stage using dockless bike-sharing.

	STS: Positive deactivation		STS: Positive activation		STS: Cognitive evaluation		STS	
	(1)		(2)		(3)		(4)	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Trip features								
Trip purpose (ref = work or education commuting)								
Visiting friends and relatives	**0.974****	**0.359**	0.015	0.265	0.035	0.272	0.341	0.243
Sports or leisure	**1.202****	**0.257**	0.337	0.189	0.243	0.194	**0.594****	**0.174**
Personal business (medical, banking, etc.)	0.564	0.328	**−0.510***	**0.241**	−0.066	0.248	−0.004	0.222
Grocery shopping	**0.949****	**0.270**	0.210	0.199	0.065	0.204	**0.408***	**0.183**
Recreational activities (Shopping, eating, and drinking)	**1.141****	**0.242**	0.313	0.178	0.335	0.183	**0.596****	**0.164**
Trip duration	0.001	0.004	0.005	0.003	0.0004	0.003	0.002	0.003
Trip frequency	0.031	0.026	0.00004	0.019	0.009	0.020	0.013	0.018
Trip primary mode (ref = dockless bike-sharing)								
Public transport	**−0.405***	**0.195**	−0.192	0.144	**−0.445****	**0.148**	**−0.348****	**0.132**
Car, walking and other	0.137	0.323	−0.249	0.238	−0.435	0.245	−0.182	0.219
Trip cycling duration	0.004	0.008	0.001	0.006	0.004	0.006	0.003	0.005
Dockless bike-sharing assess time	**−0.097****	**0.025**	**−0.056****	**0.018**	**−0.097****	**0.019**	**−0.083****	**0.017**
Sociodemographic attributes								
Age	0.010	0.010	**0.024****	**0.007**	0.008	0.007	**0.014***	**0.007**
Male (ref = female)	0.091	0.154	0.046	0.113	0.086	0.116	0.074	0.104
Education (ref = University/college bachelors' degree and below)								
Master's degree and above	−0.210	0.185	−0.112	0.136	−0.004	0.140	−0.109	0.125
Household income (ref = low income)								
Median income	−0.079	0.192	−0.061	0.141	−0.076	0.145	−0.072	0.129
High income	0.214	0.207	0.142	0.152	−0.007	0.156	0.116	0.140
Self-reported health (ref = Poor and fair)								
Good	0.206	0.189	0.231	0.139	0.180	0.143	0.206	0.128
Very good and excellent	**0.410***	**0.206**	**0.333***	**0.152**	0.211	0.156	**0.318***	**0.139**
Life satisfaction: SWLS	0.018	0.014	**0.031****	**0.010**	0.020	0.011	**0.023***	**0.010**
Social environment	**0.338***	**0.150**	**0.366****	**0.110**	**0.520****	**0.113**	**0.408****	**0.101**
Pro-car attitude	−0.011	0.084	0.002	0.061	0.010	0.063	0.0003	0.056
Pro-e-bike/e-scooter attitude	−0.101	0.078	0.048	0.058	0.059	0.059	0.002	0.053
Pro-public transport attitude	0.092	0.084	**0.143***	**0.062**	**0.149***	**0.064**	**0.128***	**0.057**
Pro-bicycle attitude	0.033	0.101	**0.212****	**0.074**	**0.265****	**0.076**	**0.170***	**0.068**
Pro-walking attitude	0.007	0.078	**0.135***	**0.057**	0.060	0.059	0.067	0.052
Pro-environment/health attitude	0.066	0.082	**0.185****	**0.060**	**0.177****	**0.062**	**0.142***	**0.055**
Anti-public transportation attitude	−0.027	0.082	**−0.159****	**0.060**	−0.043	0.062	−0.076	0.055
Anti-traveling attitude	−0.058	0.079	−0.016	0.058	−0.060	0.060	−0.045	0.054
Neighborhood attributes								
Spatial location of home (Within the 4th ring road)	−0.004	0.158	−0.098	0.116	0.056	0.119	−0.015	0.107
Cycle path ratio	−0.496	0.634	0.684	0.466	**1.133***	**0.479**	0.440	0.428
Pedestrian ratio	−0.357	0.596	−0.136	0.438	−0.735	0.451	−0.409	0.403
Intercept	−0.201	0.744	**−1.808****	**0.548**	−0.634	0.563	−0.881	0.503
N	489		489		489		489	
R^2	0.208		0.308		0.325		0.322	
Adjusted R^2	0.154		0.261		0.279		0.276	
Residual Std. Error (df = 455)	1.641		1.208		1.242		1.110	
F Statistic (df = 33; 455)	**3.866****		**6.560****		**7.106****		**7.005****	

Note: "*" Significant at 0.05; "**" Significant at 0.01.

4.2.1. Trip characteristics

Various trip characteristics are relevant for travel satisfaction with dockless bike-sharing, especially for the affective assessment of trips. Dockless bike-sharing trips for the purposes of sports and leisure, grocery shopping and recreational activities appear to score higher on overall STS than commuting trips. It is noted that the cognitive evaluation of dockless bike-sharing trip stages does not differ between travel purposes, but the significant positive effects of various travel purposes on the positive deactivation dimension of STS can be interpreted as dockless bike-sharing users feeling the least relaxed, confident, and calm when traveling for commuting. One interesting finding is that users are less engaged, enthusiastic, and alert (a significantly lower positive activation evaluation) in their dockless bike-sharing trip stage when traveling for personal business purposes than when commuting.

The cycling duration of the dockless bike-sharing stage, the overall trip duration, and trip frequency do not result in a difference in all STS dimensions. However, the access time for dockless bike-sharing, that is, the walking minutes to access dockless shared bicycles when needed, is found to have a strongly significant negative impact on STS and all STS dimensions. In light of the trip complexity, the positive deactivation and cognitive evaluation of the dockless bike-sharing trip stage are found to be negatively affected by the primary trip stage using public transport. A possible explanation is that when travelers undertake their trips primarily by public transport, they commonly ride dockless shared bikes as the "first-mile/last-mile" integration of public transit or for transfer in-between transit stations. It is possible that the combination with public transport can cause more stress, and the negative experience of public transport can carry over to the evaluation of dockless bike-sharing rides.

4.2.2. Individual dimension determinants

Travel satisfaction with dockless bike-sharing is rather similar among different sex, education levels and household income classes, with the exception of younger travelers, who tend to report a lower satisfaction of dockless bike-sharing, reflecting a less enthusiastic affect during the trip stage. Travelers with better health tend to view the dockless bike-sharing trip stage as more relaxing and to feel more enthusiastic during their travel; thus, they are more satisfied in general with dockless bike-sharing. Understandably, people with better physical health tend to have a preference for active modes (Kroesen & De Vos, 2020), and the effort required for active travel weights higher for less healthy people. Note that the association between health status and travel satisfaction with dockless bike-sharing is not reflected in cognitive evaluations.

The effect of life satisfaction is significantly positive for positive activation and overall STS for dockless bike-sharing. However, due to the cross-sectional nature of this analysis, the association between life satisfaction and satisfaction with dockless bike-sharing can be bidirectional; therefore, it could also be that travelers' satisfaction with their dockless bike-sharing travel positively affects their life satisfaction, as De Vos and Witlox (2017) and Ettema et al. (2016a) suggested that satisfaction with daily travel can both directly and indirectly affect affective and cognitive subjective well-being by mediating satisfaction with engagement in activities. Apart from life satisfaction, we found that the positive deactivation, positive activation, and cognitive evaluation dimensions of STS for the dockless bike-sharing trip stage increase with the social support travelers received for dockless bikes-sharing usage. It is likely that the appropriate encouragement and friendly social norms for dockless bike-sharing make travelers more open to enjoying trips taken by this mode.

Our analysis confirms an association between transport attitudes and travel satisfaction with dockless bike-sharing. Not only travelers with a pro-bicycle attitude but also those with a preference for public transport tend to be more satisfied with the dockless bike-sharing stages during their travel. They value their rides of dockless bike-sharing as more exciting and enthusiastic, and their cognitive assessment is also higher. A potential explanation is that, as dockless bike-sharing is promoted as a favorable option for complementing public transit services (Ai et al., 2019b), travelers with a preference for public transport could be more mentally prepared to accept dockless bike-sharing in their daily travel. In addition, having an attitude that values health concerns or an awareness of environmental impacts of travel is found to positively influence the positive activation, cognitive evaluation, and overall STS for the dockless bike-sharing trip stage. The causality of this relationship can go both ways (Derikx & van Lierop, 2021). It is difficult to determine whether individuals have a pro-health/environment attitude before adopting dockless bike-sharing or whether a pro-health/environment attitude is derived when individuals are satisfied with dockless bike-sharing travel. There is empirical evidence suggesting that people with a pro-environment or health travel attitude tend to be more appreciative of the pleasantness and physical exercise of active mobility (Manaugh & El-Geneidy, 2013). However, we found no transport attitudinal factors to have a significant association with the positive deactivation of dockless bike-sharing.

A general observation is that residential neighborhood attributes do not play an important role. This could be because this study pays attention to residential surroundings but not all dockless bike-sharing trip stages took place inside or close by residential neighborhoods. The average trip duration presented in Table 4 also suggests that travelers tend to leave their neighborhoods for their dockless bike-sharing trips. It is also possible that part of the neighborhood effect may be captured by dockless bike-sharing access time as the access of the shared bikes occurring in the residential neighborhood could reflect from the side the neighborhood design and walkability. Nevertheless, the cycle path ratio of the residential neighborhood is revealed to exert a significant positive association with the cognitive evaluation of the dockless bike-sharing trip stage.

5. Discussion and conclusion

Using survey data collected among residents in Beijing, this paper presented an investigation of the difference in travel satisfaction between dockless bike-sharing and other travel modes. As the data come from respondents who give different satisfaction scores across the modes they used, the comparison across modal satisfaction makes sense. In addition, the effects of individual and trip attributes on travel satisfaction with dockless bike-sharing were identified.

Our analysis suggests higher travel satisfaction with trips by active modes such as cycling and walking than trips by car and public transport, which is consistent with previous findings in varying contexts (e.g., Mao et al., 2016; Olsson et al., 2013; St-Louis et al., 2014). In particular, travel satisfaction with dockless bike-sharing stands out from general cycling. Beijing has a high concentration of dockless bike-sharing systems in functional areas (Beijing Municipal Commission of Transport, 2018). However, in other cities with a lower provision of dockless shared bicycles or different geofencing schemes, individuals might experience different accessibility to dockless bike-sharing systems. The ways in which travel satisfaction with dockless bike-sharing differs from conventional cycling and other existing travel modes might not display a constant pattern across different cities. This study takes the effects of trip stages into consideration of travel satisfaction with dockless bike-sharing. Travelers tend to be more satisfied with the dockless bike-sharing stage during their travel when dockless bike-sharing is used as the primary mode. It is possible that the time pressure of the access or egress trip stages or transfers makes the transferring or first-mile/last-mile trip stages by dockless bike-sharing less satisfying, which is similar to some findings of public transit studies (e.g., de Oña, de Oña, Eboli, & Mazzulla, 2013; Nwachukwu, 2014; van Lierop et al., 2018).

Taking into account the impacts of trip purpose on travel satisfaction with dockless bike-sharing, our examination confirmed a lower travel satisfaction for work or education commuting compared to trips for the purposes of sports and leisure, grocery shopping and recreational activities. It is likely that people's appreciation of travel echoes their expected experiences of the activities at the destination (Bergstad et al., 2011). In addition, commuting trips are commonly experienced as daily routines of repetitive routes, which may be less attractive due to adherence to fixed time schedules and mode captivity (Susilo & Cats, 2014). The access time to dockless shared bikes was found to be negatively associated with travel satisfaction with dockless bike-sharing. This might result in different evaluations of dockless bike-sharing trips among different contexts.

Psychological elements, including travel-related attitudes, life satisfaction, and social environment, seem to influence travel satisfaction with dockless bike-sharing more than other sociodemographic and environmental characteristics. Our finding of a strong positive association between having a positive attitude towards bicycles and public transport and travel satisfaction with dockless bike-sharing adds to the empirical support for a positive connection between travelers' mode preference and travel satisfaction with that mode (De Vos et al., 2016; Mokhtarian et al., 2015). Individuals who value the health and environmental influence of travel are found to evaluate dockless bike-sharing as more satisfying, which is consistent with previous studies on walking (Manaugh & El-Geneidy, 2013). A similar positive association between overall life satisfaction, social environment towards dockless bike-sharing, and travel satisfaction with dockless bike-sharing was found, consistent with previous studies on general cycling (Abou-Zeid & Ben-Akiva, 2011; St-Louis et al., 2014).

Residential neighborhood attributes were not found to play a significant role in travel satisfaction with dockless bike-sharing in our case. This finding is consistent with what Willis et al. (2013) revealed that the land use, connectivity and proportions of different types of streets could not predict the level of satisfaction with cycling for commuters. Although studying e-cycling in the Netherlands, de Kruijf et al. (2019) argued that greenness and the liveliness of the route environment show a positive influence on travel satisfaction with e-cycling for daily commuting. Therefore, instead of the residential neighborhood built environment, environmental factors along the actual cycling routes may contribute to satisfaction with dockless bike-sharing travel, which requires further investigation.

6. Future research directions and policy implications

The present research sheds light on future research directions. First, our observations of the respondents' trips involve limited trips undertaken primarily by private bicycles. We found slightly lower levels of satisfaction with private bicycles than dockless bike-sharing. It could be that the few private bicycle trips of dockless bike-sharing users cannot be representative of private bicycle trips in Beijing. The limited trips of private bicycles might also result from competition between e-bikes and regular bicycles. Therefore, future research could consider collecting bigger samples involving both dockless bike-sharing users and nonusers to compare travel satisfaction of dockless bike-sharing and other modes in the general population. In addition, future studies could be conducted in different cultural and spatial contexts that embody different densities and regulation schemes of dockless bike-sharing or different domination levels of private bicycles, to determine how dockless bike-sharing differs in terms of travel satisfaction compared with conventional cycling. Second, dockless bike-sharing systems have been suggested to substitute for walking at the access or (and) egress trip stages (Bao, He, Ruan, Li, & Zheng, 2017). Based on cross-sectional data, we found that dockless bike-sharing as a first-mile/last-mile solution produces lower travel satisfaction. Nevertheless, when comparing this type of dockless bike-sharing usage with the original first-mile/last-mile solution before the introduction of dockless bike-sharing systems, determining how travel satisfaction changes from a dynamic perspective requires further longitudinal research. Third, when dockless bike-sharing systems are used in trip chaining, it would be interesting for future studies to consider whether the order of travel modes (such as "public transport – dockless bike-sharing" compared to "dockless bike-sharing – public transport") makes a difference for travel satisfaction with dockless bike-sharing stages and overall satisfaction with the whole trips. Fourth, due to data limitations, the present research explored the impact of built environmental variables in residential neighborhoods. Future studies could comprehensively investigate the effects of meso-scale environmental factors (such as land use, population density and connectivity) and micro-scale environmental factors (such as crossings, cycle paths and greenery) along the cycling route on travel satisfaction with dockless bike-sharing. Finally, our study used survey to collect information on travel satisfaction of dockless bike-sharing users. However, there are new approaches to look at travel satisfaction, such as using twitter or application review datasets. Future research could consider using new approaches to evaluate travel satisfaction with dockless bike-sharing and making a detailed comparison of the findings on travel satisfaction with dockless bike-sharing between studies using surveys and studies using new methods for new insights.

The introduction of dockless bike-sharing has contributed to an increase in bicycle usage in many Chinese cities in recent years (Mobike Global et al., 2017). The findings of the current study suggest a high evaluation of dockless bike-sharing trip experiences.

Therefore, given this satisfaction with dockless bike-sharing, it is important for policy-makers to construct more cycle paths and promote a supportive social environment and cultural context in the long term, thereby not only benefitting the traveling experience and further affecting the subjective well-being of current dockless bike-sharing cyclists but also attracting more individuals to engage in sustainable travel based on its satisfying experiences. Policy-makers could also initiate schemes to encourage people to cycle more in their daily travel for reasons of physical health, thereby raising travelers' environmental and health awareness and improving peoples' perceptions of dockless bike-sharing travel experiences. Our results suggested a negative influence of the time spent accessing dockless shared bicycles on travel satisfaction with dockless bike-sharing. This result provides support for dockless bike-sharing systems' parking planning to address issues such as better integrating dockless bike-sharing parking areas with public transport stations or daily activity destinations. Local planners could also work with dockless bike-sharing operation companies to set up adequate redistribution schemes and obtain the right trade-off for more appropriate geofencing plans to ensure better access when and where needed. The information from this study can also help dockless bike-sharing providers better understand their users' needs. This information might help in building longer lasting dockless bike-sharing programs in cities.

CRediT authorship contribution statement

Zheyan Chen: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Dea van Lierop:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Dick Ettema:** Conceptualization, Methodology, Supervision, Writing – review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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