Better Pen-and-Paper Surveys for Transportation Research in Developing Countries

A Modified, Stated Preference, Pivoting Approach

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In developing countries, the rapid pace of socioeconomic and technological change necessitates the use of quick-response survey methods. Transportation researchers often work with limited budgets in environments with relatively low rates of computer and Internet access. Such conditions can preclude the use of the computer-assisted survey methods that are preferred for conducting research in industrialized countries. This paper describes novel methods for low-cost and high-quality data collection in a data-poor environment. The context is a stated preference (SP) experiment to estimate adoption of bikeshare and electric bikeshare in Beijing, but the methods are transferable. Two main methodological contributions are described. The first is a unique survey design that allows SP pivoting to occur within a single pen-and-paper interview (PAPI). For small- to medium-sized surveys, this design is often more cost-effective than traditional pivoting methods that require either a multistage PAPI survey or computer-assisted interviews. The second contribution is the demonstration of the use of affordable GPS technologies and publicly available data for the purpose of survey protocol enforcement and quality control. The paper describes survey design features that are of particular value for nonmotorized or semimotorized transportation research.

In rapidly developing countries, publicly available data sets are either unavailable to researchers or outdated given the rapid pace of change. Moreover, because traditional data sets often do not take into account emerging technologies, researchers of new transportation modes must collect stated preference (SP) data through surveys. In industrialized countries, computer-assisted survey methods are standard, but in developing countries, pen-and-paper interview (PAPI) surveys persist. This paper describes novel methods for collecting low-cost and high-quality PAPI data in a data-poor environment. A method that captures some of the advantages of computer-assisted personal interviews (CAPIs) through a paper-based, single-interview survey mechanism is described. The context is an SP experiment to estimate new transportation technology adoption, but the methods are transferable to other domains. This paper focuses primarily on the new method employed, with a short description of the outcome of the study.

Although deployment of ad hoc surveys in rapidly changing environments is not new in the transportation domain or in other domains (*1, 2*), the methods described here control for weaknesses documented in previous approaches. During July and August 2012, a transportation mode choice survey was conducted in the four main urban districts of Beijing, focusing on adoption of bikeshare and electric bikeshare (e-bikeshare) systems, which either do not exist (e-bikeshare) or are being pilot tested (bikeshare) (*3, 4*). Two aspects of the survey approach make novel methodological contributions.

First, the survey approach employs a technique known as SP pivoting through a unique design that allows a PAPI survey to be conducted in a single, short interview. Traditionally, pivoting studies are conducted with adaptive CAPI programs, necessitating high fixed costs and computer access. In the case of PAPI, a two-stage survey is required, thus greatly increasing labor costs and incompletion rates. The SP pivoting design offers two analytical advantages over a traditional single-interview PAPI survey: the SP design captures inertia (i.e., a previous choice influences a future choice) and provides a reference point from which to make a mode choice. The approach also allows estimation of environmental variables and focuses on trip-link-level analysis.

Second, affordable GPS technologies and publicly available data were used to improve team management by a researcher in a foreign environment. The GPS units were not used to collect experimental data, but rather to monitor the activity of surveyors, enforce survey protocol, and improve data quality control.

Creating discrete choice models requires revealed preference (RP) data, SP data, or a combination of both (RPSP). Researchers may prefer to use RP data because they reflect revealed consumer choices. However, RP studies suffer from three main drawbacks: (*a*) difficulty in modeling the adoption of new technologies, especially those with no analogue in the existing market; (*b*) lack of sufficient attribute variation; and (*c*) increased burden on researchers by requiring observation or estimation of all factors for the entire relevant choice set. In developing countries, the rapid rate of socioeconomic and technological change mandates the frequent investigation of new technologies; but researchers are often limited by data availability and time and budget constraints. SP studies are well suited to the rapidly changing environments of developing countries. SP studies resolve all three RP problems, thus giving the researcher complete control over attribute variation and experimental design of the choice set. The drawbacks of SP studies include hypothetical

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response bias, poor incentive compatibility, and an inability to predict current market equilibrium. Numerous SP studies model new mode choice and changes in existing service (*5–9*). For a discussion of trade-offs between the RP and SP methods, see Louviere et al. (*10*) and Wardman (*11*).

Hybrid RPSP methods have been developed that combine RP and SP data. Early RPSP data enrichment methods combined data from separate RP and SP studies to enable sufficient attribute variation while still being able to model current equilibrium (*10, 12, 13*). A later method, known as RPSP pivoting, combined RP and SP choices in the same survey to improve response quality (*14–16*). The survey first collects information on an actual RP choice. A subsequent SP section is created with attribute levels based, or pivoted, on levels reported in the RP section. Pivoting increases realism by creating reference points by which respondents can evaluate new options. The RPSP pivoting method also accounts for inertia effects by including an original choice variable. Inertia describes the influence of existing travel habits, which often manifest in an unwillingness to change modes. The parameter of the original choice variable captures this latent preference (*17, 18*). Traditional pivoting approaches usually require real-time attribute generation through a CAPI system or through an onerous, two-part PAPI survey that increases surveyor and respondent burden. The research reported here approached SP pivoting by avoiding that two-part problem, thus enabling cost-effective and rapid data collection.

The following sections discuss a unique SP pivoting design that captures two of the advantages of RPSP pivoting: improved response realism and the measurement of inertia effects. Researchers without access to CAPI resources can use this design in a low-cost, single-interview PAPI survey.

SURVEY DEVELOPMENT AND ADMINISTRATION

The research was conducted through PAPI methods over a 1-month period in the summer of 2012. The study was conducted in the core districts of Beijing, a modern, urbanized environment. Because of time and budget constraints as well as limited computer resources, a PAPI survey method was developed that translates well to research in emerging economies. Despite the advantages of CAPI methods (*19–21*), PAPI survey mechanisms persist in developing countries. This persistence can be attributed to two factors: computer and Internet access is limited in developing countries and CAPI surveys have much higher fixed costs. The International Telecommunications Union estimated that in 2013, personal Internet adoption rates were significantly lower in developing countries (30.7%) than in developed countries (76.8%) (*22*). Growth of mobile broadband subscriptions, estimated to be 33% in 2012–2013, has been strong, but current mobile Internet access has been limited to 19.8% in developing countries. The lack of a well-connected populace could be mitigated by deploying field surveyors with mobile computing devices, but this deployment would increase hardware and labor costs. Caeyers et al. found that CAPI methods were cost-efficient when they were deployed in large-scale, long-term surveys (*23*). However, those methods are beyond the time and budgetary constraints of many studies, particularly in emerging economies with new transportation technologies. Because the project reported in this paper was constrained by time and budget, a PAPI method was developed that captures many of the advantages of CAPI pivoting surveys while maintaining the convenience of a PAPI mechanism.

A key distinction between the SP pivoting design and standard RPSP pivoting surveys is that the former shift the responsibility for pivoting from the surveyor to the respondent, allowing for the creation of fixed-design surveys that can be conducted in a single interview. Standard RPSP pivoting studies require the surveyor to generate choice scenarios dynamically based on the respondent's answers. The surveys normally proceed in two sections. In the first part, the RP section, the respondent describes a real trip. In the following SP section, the respondent is offered alternatives with attribute values that are functions of the attribute values observed in the RP choice. Train and Wilson (*16*) and Hensher and Rose (*14*) provide examples of RPSP pivoting studies. The SP pivoting design here differs in that it transferred the pivoting to the respondents. Respondents were asked to estimate attribute values (time and cost) for the SP options based on the distances of real trip links they recently took. This estimation increased the cognitive burden for the respondents, but the task was not unreasonably difficult because the respondents were familiar with the described trip. The SP design more accurately reflected the respondents' perception (and thus their choice process) of the attributes. The survey design enabled a cost- and time-efficient PAPI method and simultaneously achieved two of the analytical advantages of standard RPSP pivoting methods: the increased choice quality of reference-based valuation and the inclusion of a behavioral inertia variable.

SURVEY DESIGN EXAMPLE: BEIJING BIKESHARE STUDY

Although high-profile Western bikeshare systems have captured public attention, some of the most rapidly evolving and exciting trends in shared mode adoption have occurred in developing countries, such as China. Previous studies of bikeshare studies have not built discrete choice models based on SP data, an important tool for planners implementing systems in new markets. Recent works by Gebhart and Noland (*24*) and Buehler (*25*) have used RP data from system usage logs to develop bikeshare demand models. And a greater body of work has studied the topic of private e-bikeshare choice modeling for markets in China, Taiwan, and Vietnam (*8, 26–28*).

The survey described here is an example of SP pivoting design as well as a demonstration of methods that may be useful for bikeshare research. Through a series of steps, the survey defined the environmental attributes and asked respondents whether they would switch from their preferred existing mode (RP) to a new hypothetical mode (SP) (Figure 1). In Part 1 of the choice section, the respondent was asked to list trip links from the previous day that were shorter than 10 km and to provide their approximate distances, origins, and destinations. A trip link was defined as a period of continuous travel by one mode. A single trip consists of one or more links. This distinction allowed explicit investigation of the use of bikeshare for segments of trips, particularly to access transit (a stated goal of bikeshare promoters). Surveys that query whole trips instead of links cast bikeshare and transit as competitors by default. By investigating trip links, it is possible to determine whether each link fed transit, was conducted by transit, or did not involve transit. Respondents were asked to self-report trip distance in order to reduce the research burden and protect anonymity. However, self-reporting introduces response error and several respondents stated that it was difficult to estimate the distance.

In Part 2, the environmental characteristics were described and the respondent selected a mode from an exhaustive list of existing

Part 1			Part 2			Part 3				Part 4
Think back to yesterday. Tell me about all the trip links you made that were less than 10 km.			Now suppose that it is **sunny**, **15°C**, the air quality is **bad** and congestion is **bad.** Also suppose, even though this may or may not be the reality for the trip you indicated, that bike lanes are available for **all** of the trip. If you have access to an automobile, assume your license plate is **restricted**. Given these conditions, please indicate the transportation mode you would typically choose for each of the listed trips, and please indicate the approximate cost and travel time for each selected mode.			Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs and travel times are as follows:				Now please consider the costs and travel times as well as all the attributes described in Part 2: it is **sunny**, **15°C**, the air quality is **bad**, congestion is **bad** and bicycle lanes are available for **all** of the trip.
Trip Length (*approximate trip length to within 1 km*)	**Origin** *1=home* *2=work* *3=school* *4=store* *5=restaurant* *6=entertainment* *7=transit facility* *8=bus stop* *9=other*	**Destination** *1=home* *2=work* *3=school* *4=store* *5=restaurant* *6=entertainment* *7=transit facility* *8=bus stop* *9=other*	**What mode would you choose?** *1=bus* *2=subway* *3=car (drive alone)* *4=car (passenger)* *5=e-bike* *6=bike* *7=walk* *8=taxi* *9=motorbike* *10=other*	**What would the approximate trip cost be?** (*include fare, tolls, parking, and approximate fuel*)	**What would the approximate travel time be?**	**Public bike cost** (元)	**Public bike travel time** (分钟)	**Public e-bike cost** (元)	**Public e-bike travel time** (分钟)	**Which would you choose for each trip?** *1=same as Part 2* *2=public bike* *3=public e-bike*
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		

FIGURE 1 Example of SP pivoting survey instrument that includes four parts. Experimental variables, highlighted in boldface, vary across survey design versions (translated into English from original Mandarin version, except for symbols for cost and time in Part 3).

mode options (original mode choice). The respondent provided the estimated travel time and cost for the original mode choice. By first asking about the trip links of the previous day, the survey primed the respondent to evaluate the given environmental characteristics within a familiar context, a real trip link. The respondent would then be able to employ reference point valuation, a behavior that mimics real-world decision making (*14, 15*). The original mode choice entered the choice model as a variable, allowing modeling of behavioral inertia effects. One feature that distinguishes this approach from traditional methods is that Part 1 and Part 2 replace the RP section of a standard RPSP pivoting survey, enabling a pure SP survey framework, while maintaining the advantages of an RPSP pivoting survey.

In Part 3, the respondent was presented with the bikeshare and e-bikeshare options. The costs of the shared modes were predefined, and the respondent was asked to estimate the travel times for the shared modes based on experience. Thus, the travel times were pivoted off the responses in Part 1. The same hypothetical environmental conditions as in Part 1 persisted in Part 3. If the respondent was unable to estimate the travel time, a travel time was suggested by the surveyor based on the distance and the average modal travel speed, as reported in Beijing's 2011 annual transportation report (*29*).

All predefined variables were generated from a main effects orthogonal array in 18 treatments, which yielded 18 unique surveys (Table 1). The surveys were blocked in randomized order. The environmental characteristics (precipitation, temperature, and air quality) and roadway variables (congestion, license plate restriction, and bike lane presence) were entered into the survey instrument in Part 2 and again in Part 4. Shared bike costs were entered in Part 3. The final part of the survey queried respondent demographics. The self-reported and predefined fields constituted all the data used in the modeling. Unlike with traditional RP surveys, which often require researchers to estimate all unobserved attributes for the nonchosen modes, with the SP pivoting design method, data

TABLE 1 Environmental and Mode-Specific Variable Levels

	Factor Level		
Variable	1	2	3
Precipitation	Sunny	Light rain	Heavy rain
Temperature	−5°C	15°C	35°C
Air quality	Good	Medium	Bad
Congestion	Good	Medium	Bad
Presence of bike lanes	None	Half	All
License plate number restriction[a]	Restricted	Not restricted	NA
Shared bike travel cost (RMB)	0	1	2
Shared E-bike travel cost (RMB)	0	1	2

NOTE: NA = not available; RMB = renminbi.
[a]In Beijing automobiles are restricted from entering the core urban area (inside 5th Ring Road) once every 5 days on the basis of the last digit on license plate.

collection is completed at the time of the survey, significantly reducing the postprocessing work burden and time line.

SURVEYOR QUALITY CONTROL

An important aspect of conducting survey research, in developing and developed country environments, is the risk of surveyor error or fraud. This risk can be compounded by the language and cultural barriers a researcher experiences when managing a team in a foreign country. As a novel quality control measure, the surveyors carried small GPS loggers (Holux M-1200E) to ensure that surveyors' duties were executed as detailed by the survey protocol. This GPS logger allowed clear tracking of location and time while the surveys were conducted. Unlike many other GPS loggers, the Holux M-1200E can be entirely configured through a software interface, making operation simple for the end user, who is required only to power-on the device. The open-source BT747 software was chosen for this purpose (*30*).

Surveyors turned on the GPS unit at the start of each shift and returned the unit at the end of the shift. The GPS tracks were checked nightly to ensure surveying at appropriate areas and times. Figure 2 shows the cumulative survey activity, stratified across various locations in Beijing. Chinese law made it difficult to obtain high-quality geographic information system (GIS) information. To import free open-source panels from OpenStreetMap.org to ArcGIS, the ArcGIS Editor for OSM 2.0 was used (*31, 32*). Although ArcGIS is a commercial product, compatible free solutions from Google Earth and GRASS GIS are available (*33, 34*). Foreign researchers must also be careful in their use of GPS technologies in China because of the legal restrictions. It is not uncommon for illegal mapping to result in arrest (*35*). To this end, only Chinese citizens handled the GPS units for this study.

The use of GPS units proved to be an effective quality control measure. The tracks matched well with the road layer downloaded from OpenStreetMap.org (Figure 2). Satellite connections were good and yielded usable readings in all outdoor locations, including the central business district where buildings reach heights of 50 to 80 stories. The daily checks revealed that one surveyor had gone to the wrong district. This error was corrected in the scheduling of the subsequent surveyors. The tracks were also useful in the coding of the paper surveys. Because of surveyor error, it was unclear where several surveys had been conducted; the GPS tracks were used to verify the location and correctly code the data. Although it would be difficult to validate, it is likely that the use of GPS devices also discouraged surveyor fraud.

SURVEY SAMPLING METHOD

The intercept survey sampling method was designed to study the population most likely to use a bikeshare or e-bikeshare system. Respondents were stratified by district, day, time, and target mode. Since the target population was adult users of Beijing's transportation system, the respondents were sampled while in the act of using transportation. During one shift, a surveyor sampled users of one target mode (walk, bike, e-bike, bus, subway, taxi, or private automobile).

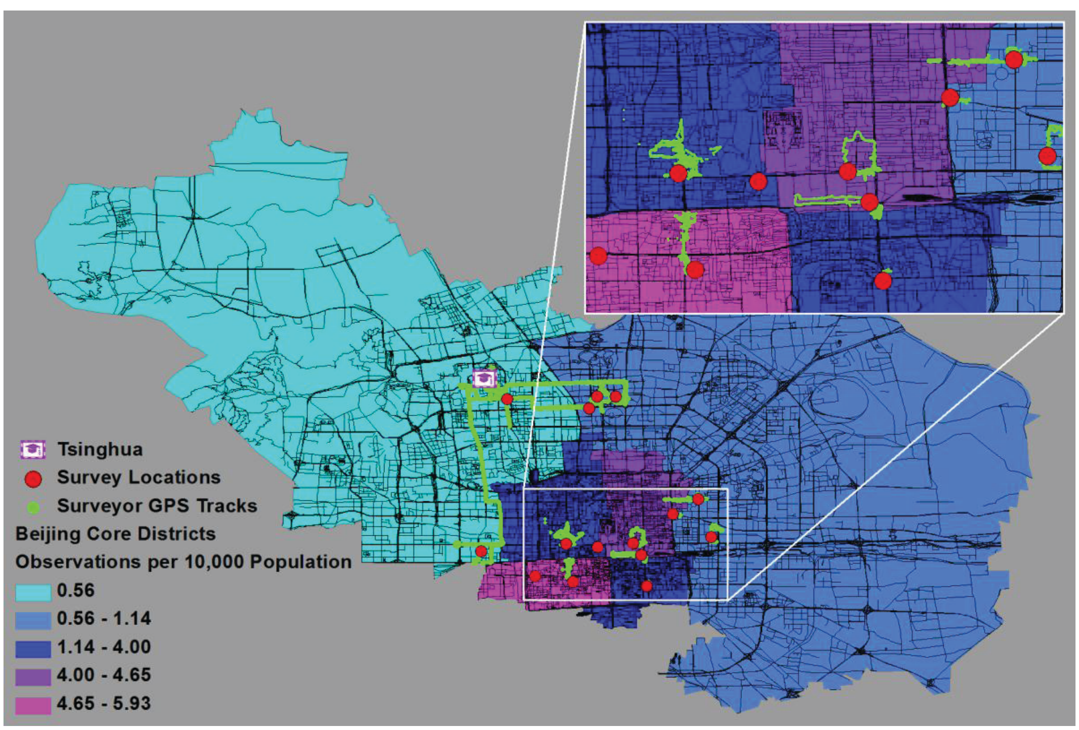

FIGURE 2 Survey activity: map depicts surveyor tracks, data collection points, and district boundaries, with tracks of 51 surveyor shifts shown in green. All shifts start and end at Tsinghua University. Because district boundaries before 2010 redistricting are used, two former districts, Xuanwu and Chongwen, are depicted as distinct entities. Two survey locations with no tracks near them include an underground subway and a location where the surveyor failed to turn on the device.

Surveying was conducted in the four districts of Beijing that were considered the most promising bikeshare and e-bikeshare markets. More than 60% of the residents live in the four core urban districts where sampling occurred: Haidian, Chaoyang, Dongcheng, and Xicheng (*36*). These districts were selected as the most viable markets for shared two-wheelers on the basis of density, connectivity to transit, and commerce. Recent bikeshare pilot programs have been deployed in the Chaoyang and Dongcheng Districts (*37*).

Surveying within each district occurred at multiple locations, times, and days and across all seven target modes. Each district was sampled throughout the week (including at least one weekend day), from 9 a.m. to 9 p.m. To avoid selection bias, surveyors were trained to use an objective method to decide whom to intercept. The surveyor would pick an arbitrary marker, such as a line in the sidewalk, and question the first candidate to cross the marker. Other potential respondents would be ignored until the survey was completed.

DATA COLLECTION AND SURVEY DESIGN EFFICACY

A total of 623 complete surveys were collected by the methods described above. An average of 2.29 trip links was observed per survey, for a total of 1,426 observed links. Labor input totaled 230 person-hours (including travel time) invested in the data collection, making this a relatively cost-effective strategy for collecting highly relevant data for a specific purpose.

The data were used to estimate a multinomial logit (MNL) choice model to identify factors that influence the potential adoption of bikeshare and e-bikeshare in Beijing (Table 2). The MNL model is a switching model that estimated the probability that a respondent would switch from an original mode choice to either bikeshare or e-bikeshare. The model did not build utility equations for all available modes. Therefore, the data collection effort was considerably reduced because it was not necessary to estimate time and cost attributes for all the nonchosen modes from Part 2 of the survey. After observations with missing data or nonsensical responses were removed, 1,181 trip link observations remained for model estimation.

Of the 42 parameters estimated, more than half were significant at the 5% level or better. Interestingly, the parameters that were not significant below this level varied between the two shared bike modes, revealing that distinct sets of factors influenced the choice of each mode. This result was not entirely surprising, since the experiences of riding a standard bike and riding an e-bike are quite different. The e-bike's motor greatly reduces the physical effort of riders, making them less sensitive to variables that correspond to exertion. This reduction was reflected in the differences in parameters for distance, air quality, and temperature. The model successfully revealed many variables that significantly affected the potential adoption of bikeshare and e-bikeshare, including distance, temperature, precipitation, air quality, congestion, education, gender, and age.

The SP pivoting framework enabled the study to achieve results that would not be possible with a pure RP or traditional SP survey. The

TABLE 2 MNL Estimation Results

	Shared E-bike		Shared Bike	
Variable	Parameter	*p*	Parameter	*p*
ASC_O	−6.31	.00	−4.39	.00
Distance (km)	−0.0854	.01	−0.175	.02
Air quality bad indicator × distance	Fixed	Fixed	Fixed	Fixed
Air quality medium indicator × distance	0.0194	.53	0.158	.04
Air quality good indicator × distance	−0.0153	.66	0.133	.06
Congestion indicator	−0.581	.01	0.169	.57
Congestion indicator × female indicator	0.812	.05	0.563	.25
License plate restriction indicator	−0.066	.72	0.415	.07
Heavy rain indicator	Fixed	Fixed	Fixed	Fixed
Light rain indicator	0.527	.02	0.78	.01
No rain indicator	1.17	.00	1.03	.00
Temperature cold indicator × distance	−0.0247	.49	−0.0907	.10
Temperature hot indicator × distance	0.000619	.98	−0.218	.00
Temperature comfortable indicator × distance	Fixed	Fixed	Fixed	Fixed
Original mode sheltered indicator	Fixed	Fixed	Fixed	Fixed
Original mode not sheltered indicator	0.308	.19	0.874	.01
Original trip link by bus	1.67	.00	0.632	.16
Original trip link was transit feeder	0.319	.14	−0.156	.54
Original trip link did not involve transit	Fixed	Fixed	Fixed	Fixed
Original trip link by subway	0.696	.11	−1.14	.27
Age	0.321	.00	0.0731	.07
Age squared	−0.00451	.00	−0.000907	.05
Higher education indicator	−0.686	.00	0.221	.40
Environmental concern indicator	0.811	.00	0.35	.11
Gender female indicator	−0.783	.02	−0.356	.39
Income	−0.132	.00	−0.0201	.54

NOTE: Number of observations = 1,181; number of parameters estimated = 42; log likelihood = 1,154.154; adjusted r^2 = .412.

research was able to capture the effects of behavioral inertia because the research used original mode choice as an explanatory variable. Users of sheltered modes (car, subway, or bus) were much less likely to transition to shared two-wheel modes compared with those who were already using unsheltered modes (bike, e-bike, or walk). This likelihood affected the choice of shared bike use approximately three times more than the choice of shared e-bike use.

The survey structure enabled the study to gain insight into the question of whether shared two-wheelers would compete with or complement transit. If a shared two-wheel mode was chosen, there were three ways in which the choice could interact with transit: transit replacement, transit feeder, or no interaction with transit. This determination was accomplished by querying trip links (instead of whole trips), trip end facilities, and original mode choice. This classification allowed for a nuanced understanding of the interaction between transit and the shared bike modes. For example, the research found that although e-bikeshare was attractive as a bus connector, it was more attractive as a replacement.

The more traditional aspects of the SP survey design also yielded meaningful results. Self-reported distance, despite reservations about its accuracy, entered the model significantly for both shared options. Intuitively, the study found that e-bikeshare users were much less sensitive to distance than bikeshare users were. The general SP framework allowed for tests of a wide range of environmental conditions and identification of environmental variables, such as weather and air quality, whose influences are distinct between modes. For example, e-bikeshare users were less sensitive to heat for long trips compared with bikeshare users. There was roughly equal disutility of rain. These are key factors for estimating actual environment-dependent market penetration over the life of a bikeshare system. Campbell provides a detailed analysis and discussion of policy and planning implications (*38*).

CONCLUSION AND LIMITATIONS

This paper has described the development of a survey method that enables low-cost, high-quality data collection that is well suited to the constraints of research in developing countries. The method leverages the efficiency of pure SP design and the benefits of RPSP pivoting. Data were collected on the potential introduction of bikeshare and e-bikeshare technologies in Beijing by employing a low-cost, ad hoc SP survey over a 1-month period. The survey had two novel methodological aspects that were relevant for primary data collection in developing countries: the PAPI single-interview SP pivoting design and the use of low-cost GPS units for quality control. The SP pivoting method captured the main advantages of a standard SP survey: the introduction of new technology options and sufficient attribute variation. The SP pivoting framework offered two advantages over the standard SP method: response quality was improved by giving respondents a reference point, and the original choice variable for actual trip links was used to model behavioral mode choice inertia. By querying trip links instead of trips, trip end facilities, and original mode choice, the study was able to model how the shared modes both complemented and competed with public transit. The use of GPS units reduced the risk of surveyor fraud and improved the quality of coding data.

These are methods that can be employed in a variety of domains that introduce new technologies. For low-cost and quick-implementation surveys, the SP pivoting framework can be used to improve response quality. However, the approach has several limitations. First, there is some evidence that PAPI data collection approaches introduce bias compared with CAPI approaches (*23*). The approach in this study relied on self-reported trip distances, which could be inaccurate or introduce bias. In the case of trips under 1 km, there was some indication that respondents rounded up to the nearest 1 km distance. The study focused on survey instrument development, but employed a relatively standard, stratified intercept sampling approach, which was less ideal than other approaches would have been. On balance, the approach suffered from some of the known challenges with survey research countered by high cost-effectiveness.

Bikeshare is perhaps the world's fastest growing mode of public transportation (*39*). As more systems come online, particularly in data-poor environments, it will be important for engineers and planners to understand how this new technology will be used and how it will impact existing transportation systems. This study is an important first step in establishing a methodological framework for evaluating this mode or other new transportation technologies.

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