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The development of a web-survey builder (STAISI): designing household travel surveys for data accuracy and reduced response burden

Brittany Chung[a], Siva Srikukenthiran[a*], Khandker Nurul Habib[a], Eric J. Miller[a]

Department of Civil Engineering, University of Toronto, Toronto, Canada, M5S 1A4

Abstract

This study investigates methods to improve survey data quality and reduce response burden by sharing lessons learned from developing a household web-based survey platform (STAISI), along with field tests using novel features built into the platform. The field tests experiment with voluntary self and proxy reporting methods using a custom-built feature in the platform. The paper also compares the performance of the announce-in-advance and prompted recall technique in a web-survey setting. Finally, the paper presents key features of the platform and user interface recommendations for designing surveys that collect detailed trip data.

Keywords: web survey; household travel surveys; response burden; proxy bias; prompted-recall; announce-in-advance

1. Introduction

In recent years, there has been an increasing use of web-based technologies in travel surveys because of their potential to decrease respondent burden and reduce operational costs. Many such surveys are custom-built since commercial survey builder platforms (e.g. Survey Monkey, Qualtrics, etc.) are not usually tailored for activity-travel data collection. Commercial platforms often lack features necessary for efficient data collection of detailed travel information, such as location piping between questions and the use of interactive maps for geospatial data collection. However, custom-built travel surveys also come with disadvantages. They can be costly, and edits to the survey are often difficult to make without a web-developer. Furthermore, custom-built surveys are often designed for a very specific use case and thus are often discarded after a single study since their features are not easily transferable to other travel surveys.

In response to the lack of flexible options for creating web-based travel surveys, a custom web tool (STAISI) was developed at the University of Toronto. It serves as a survey builder platform tailored for household-based activity travel data collection, which allows survey designers to easily create, edit, and manage their travel surveys. The platform was developed as part of an R&D project which aims to address the issues faced by southern Ontario's large-scale CATI-based household travel survey, the Transportation Tomorrow Survey (TTS). Part of the project explores how various survey methods, with web-surveys being one of the methods explored, can improve the accuracy and completeness of the data collected while minimizing response burden. Field tests of travel surveys using the STAISI web tool were conducted in the summer of 2017 to investigate methods of improving survey data accuracy. These field test surveys were distributed to a subset of respondents from the 2016 TTS who explicitly volunteered to participate in future travel studies.

* Corresponding author. Tel.: 416-946-8299
E-mail address: siva.srikukenthiran@mail.utoronto.ca

In the case of web-surveys, there exist many web-based technologies that can be utilized to improve the survey-taking experience and provide respondents with greater flexibility in how they respond to questions. For example, interactive web-based maps are easy to use and can improve the accuracy of the location data collected. Web surveys also allow for flexibility when collecting data from several household members, as members can self-report their information, since the survey can easily be passed around and can be completed when convenient. This contrasts with the traditional CATI approach used by the TTS, which has been shown to have issues with data accuracy, given that one household member is asked to respond for the entire household, introducing proxy bias (Hassounah, et al., 1993; Badoe & Stuart, 2002). Nevertheless, proxy-responses cannot be entirely avoided in household surveys without significantly reducing the survey's response rate.

Web-based methods also allow for easy implementation of some additional survey administration methods to improve data accuracy. These include notifying households of a predefined survey date in advance, compared to administering surveys on random days concerning trips made by household members on the prior day. The latter method, often referred to as the prompted recall method, has shown to result in underreporting of trips (Pierce, et al., 2002; Dumont, 2009).

This paper investigates methods of improving travel survey data accuracy and reducing response burden through web survey design and administration methods. To investigate the performance of these methods, travel surveys were designed in the STAISI platform and were tested in the field. The field tests focused on the impact of survey design on the collection of trip data, methods for reducing household proxy bias, and improving data quality through the comparison of pre-defined (announce-in-advance) and 'random day' (prompted recall) travel surveys. Given the importance of the collection of trip data and the high burden of collecting detailed data, the design process of "the trip question" in STAISI is also discussed, along with a few other key features and functions of the platform. Overall, the paper presents lessons learned from developing STAISI and the results of the field tests that can be applied to better design web-based household travel surveys.

2. Literature Review

With today's ever-increasing use of web applications, user-interface design and human-computer interaction have become a widely-studied area of research in recent years. These studies attempt to understand user behavior and, in turn, recommend design practices that improve the usability of web applications. As web-surveys fall under web applications, many of the design guidelines in the literature are relevant in the design of web-based travel surveys. However, it is important to note that general web applications and web-surveys may have different needs and purposes. For example, websites are generally designed to present information and, thus, need to allow for easy navigation. On the other hand, web-surveys are designed to collect information and, thus, their design must be sufficiently intuitive that users understand what is being asked of them and so that they can easily input their information in the interface. An added challenge of web survey design is that a survey is typically used only once per user, unlike a website, where users often make multiple visits, which help them learn the interface. Therefore, the interface of a survey needs to be intuitive from the start, with the user's required actions being obvious. As a result, simplicity in a web survey is key. On the other hand, when collecting detailed data such as in travel surveys, achieving a simplistic, intuitive survey design is not a trivial task.

Although web-surveys are widely used for many regional travel surveys, studies documenting the design of these travel survey interfaces are scarce in the literature. Regional travel surveys typically ask for specific details of trips made by a household the prior day such as: each trip's origin/destination location, travel mode and arrival/departure times. A review of several household travel surveys reveals that the web-based survey structure used to collect this trip data varies from survey to survey. Some travel surveys approach the trip question design in a linear fashion. For example, Utah's 2012 travel survey's trip question comprises of three pages/steps: 1) trip roster page where respondent lists all the places they visited on a particular day; 2) Google map geocoder page where respondents pinpoint the locations of each place they visited; 3) trip details page which walks through each trip chronologically and collects information such as each trip's travel mode and duration (Resource Systems Group Inc., 2013). Other web-surveys, such as Edmonton & Region's Household Travel Survey (2015), apply a more cyclic design, which essentially repeats a series of questions for each trip in chronological order. The Student Move TO (2016) survey's approach to collecting trip information falls somewhere between a cyclic and linear approach. Interestingly, the National Household Travel Survey (2016) collects all the information in one page; a panel form on the left allows for input of trip details, while an interactive map on the right allows for input of location data. Although there are many approaches to collecting this information, there is no empirical study that evaluates the effectiveness of these approaches.

Clearly, trip information collected from travel surveys is very specific and can significantly vary between respondents. Unfortunately, many household travel surveys have one member of the household report the trips made

by the entire household. Proxy-reporting comes with the benefits of faster data collection and reduced operational cost (Cobb & Krosnick, 2009). In the case of CATI surveys, fewer interviews are needed and follow-up interviews are not required to contact members who were unavailable at the time of the initial interview. However, it is well documented in the literature that proxy-respondents significantly underreport trips compared to self-respondents (Hassounah, et al., 1993; Badoe & Stuart, 2002; Bose & Giesbrecht, 2004; Wargelin & Kostyniuk, 2014). An analysis of the 1996 Transportation Tomorrow Survey (TTS) data revealed that self-respondents reported an average 2.818 trips/person compared to 2.235 trips/person for those responded through a proxy (Badoe & Stuart, 2002). Studies also found proxy respondents tend to omit home-based discretionary and non-home-based trips (Badoe & Stuart, 2002; Verreault & Morency, 2015). Underreported trips are also found to be more common for females relative to males since females typically take more discretionary trips (Richardson, 2005; Wargelin & Kostyniuk, 2014).

The current and most widely used method for correcting travel surveys for proxy bias is the application of adjustment factors to groups of under-reported trips to match the trip rate of the self-reported trips (Hassounah, et al., 1993; Stopher, et al., 2003; Verreault & Morency, 2015). However, given the flexibility of web surveys, a more proactive approach can be taken to reduce proxy bias, namely surveys can be revisited by respondents and can be completed at the respondent's time of convenience. Therefore, compared to CATI surveys, it would not be as difficult to reduce proxy responses and have more than one member of the household interviewed. The Edmonton & Region Household Travel Survey (2015) employed a mixed self and proxy reporting method for their web-travel survey; respondents had the option to independently complete their survey or have another household member complete it on their behalf. As this was a recent survey, studies on the effectiveness of this method are not yet available.

The TTS and many other travel surveys require respondents to report trips they have made in the last 24-hours. This is known as the prompted recall technique, where respondents are asked to recall what happened on a prior day. The alternative to the recall technique is the announce-in-advance technique. In this latter method, the surveyor announces to the respondents ahead of time that they will have to report their trips for a specified date in the future. Due to memory bias, it is rather evident that the prompted recall technique can result in underreporting of trips. Various studies in the literature have investigated the degree of underreporting of trips due to the prompted recall method by comparing prompted recall survey results with GPS-based travel studies. Dumont (2009) conducted a GPS-based prompted recall survey on approximately 90 students at the University of Toronto and found that 34% reported similar trip rates to the GPS records while 53% persons recorded on average 1.78 fewer trips than in the GPS records. A GPS household travel study at the University of Sydney (2003) and the Ohio Household Travel Survey (2002) also reported similar findings, where the number of self-reported trips was 30% less than what was captured by the GPS (Pierce, et al., 2002; Bullock, et al., 2003). Other than a handful of GPS-based studies, literature comparing the announce-in-advance and prompted-recall technique in web-based travel studies were not found.

As discussed, there is limited literature on methods to efficiently collect trip information through the strategic design of web surveys. This paper attempts to fill this gap by summarizing the lessons learned from the iterative development process of a web-based trip question. In addition, the paper explores the performance of the voluntary self and proxy reporting method through a custom survey feature built in STAISI (household question). The demographics and distribution of these voluntary self and proxy respondents are investigated to provide further insight on proxy bias in web-based travel surveys. Furthermore, since research on the use of announce-in-advance and prompted recall methods in web surveys is lacking, the paper presents a comparative study of these two methods.

3. Survey Builder Platform (STAISI)

Due to the various needs of household travel surveys and the lack of flexibility in existing commercial survey building platforms, an in-house survey building platform was built. The platform (STAISI) is equipped with the basic functions of a survey platform, as well as additional unique features tailored for household travel data collection. STAISI can manage multiple surveys and offers various administrative features such as editing and previewing surveys. The platform can manage survey invitations via emails or survey registration using a web link and a token.

As shown in Fig. 1, the platform is equipped with a variety of survey question types ranging from typical radio button questions to more complex questions such as the trip question and household question described in subsequent sections. Conditional logic can be set between questions on different pages, and responses from previous questions can be piped into other questions of the survey. For example, a respondent's home location collected at the beginning of the survey can be piped into the trip question which reduces the burden of repeatedly specifying the home location.

On the survey-taker's end, STAISI allows respondents to complete a survey in multiple sittings. This flexibility is achieved with a login/logout ability and the continual saving of all survey responses. In addition, as shown in Fig. 2, respondents are given instant verification of questions they answer with question bars turning green when a question

is complete or turning red if a question is missed. STAISI can also support different languages and can auto-adjust to various devices and screen-sizes.

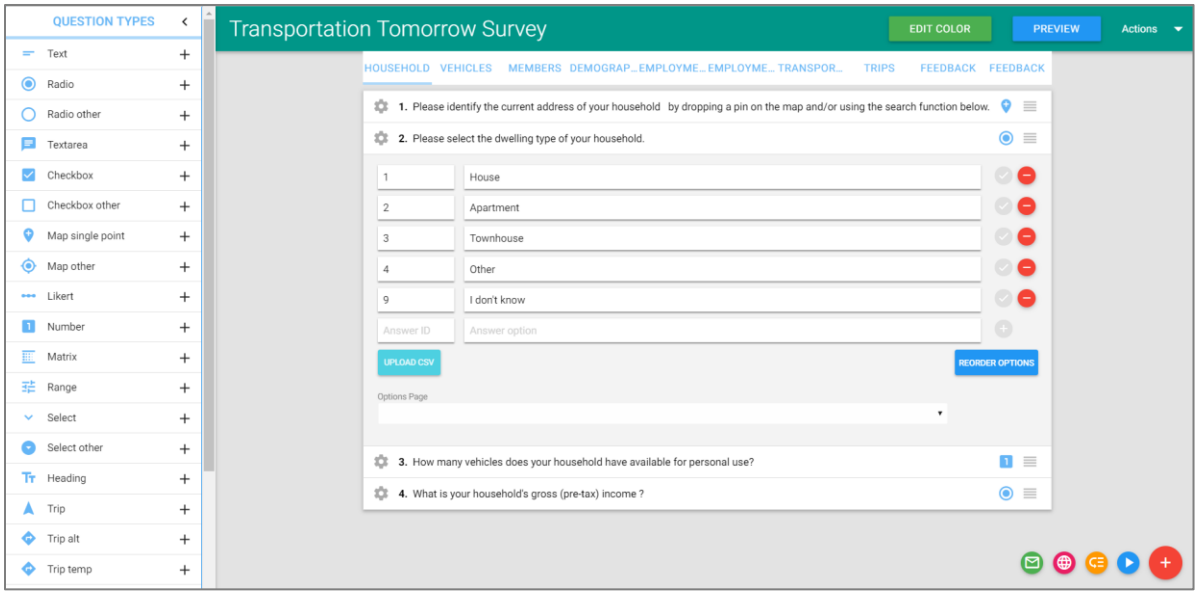

Fig. 1. STAISI survey builder interface

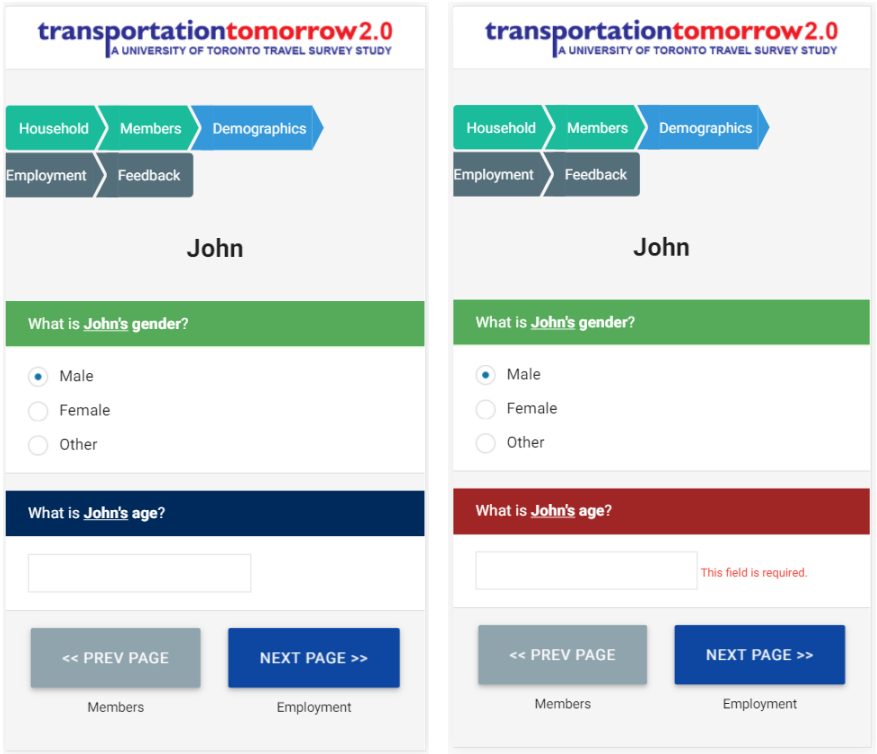

Fig. 2. Sample survey interface showing respondent's instant verification of question completion

3.1. Trip Question

Typical regional travel surveys collect household trip data for the purposes of modelling transportation in the region and policy planning. Detailed information for each trip such as location, trip purposes, modes and arrival/departure times are collected. Collecting such detailed information is challenging as it can be a cumbersome, lengthy process for respondents and can, therefore, deter many respondents from completing a survey. To minimize survey dropout rates, the trip question of the survey must be carefully designed to reduce response burden. This section provides a summary of the design process of the trip question in STAISI.

As discussed in the literature review, the trip question design and structure varies from survey to survey. Drawing inspiration from the design of existing surveys in the literature, several trip question designs were drafted. After some deliberation of the designs, two designs were coded in STAISI. As shown in Fig. 3, the first trip question design adopts a more cyclic approach while the second trip question starts off with a linear structure and ends with a cyclic structure. The concept behind the first design is to help respondents visually walk through their trip day, and the repetitive sequence lessens the learning-curve as there are fewer changes to the question's interface. However, it is noted that the repetitive structure may quickly lead to respondent fatigue, causing them to consciously omit trips. The second design asks respondents for a full list of trips at the beginning when the respondent's fatigue is presumably at their lowest; in theory, this would minimize the chance of respondents consciously omitting trips due to fatigue. Each of these designs is broken into small, step-by-step instructions, making the interface easier to learn.

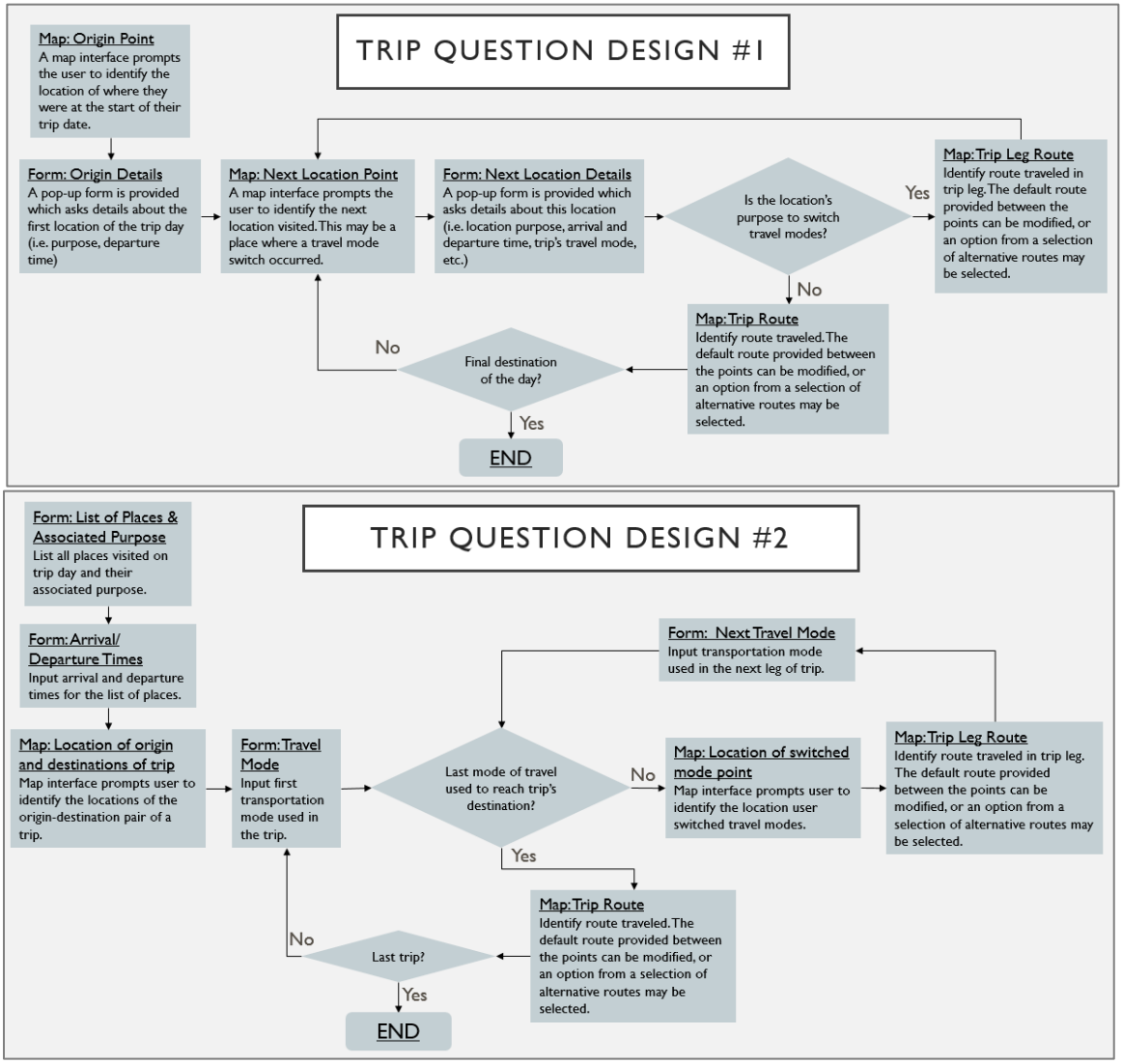

Fig. 3. Simplified structure of trip question designs

The trip questions also collect route information using an interactive map interface, as this data is important for more complicated transport choice models that have emerged in recent years. To reduce the added burden of entering route information, as shown in Fig. 4, a recommended route is displayed on the map and alternative routes are provided. For non-transit trips, respondents can adjust the routes on the map by dragging and dropping waypoints off the route segment.

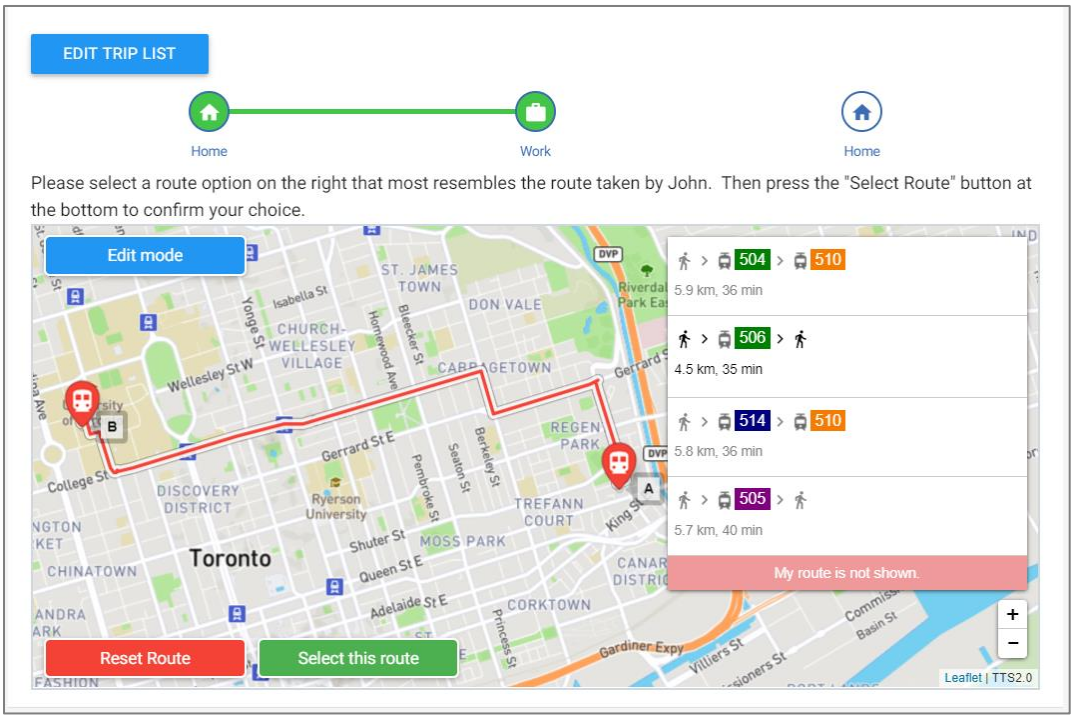

Fig. 4. Route collection interface of Trip Question Design #1

To gather feedback on the two designs, two focus groups were conducted in June 2017. The first focus group comprised of graduate students at the University of Toronto, and a second focus group was a public session of ten individuals who had previously completed the 2016 TTS. In the focus group session, each participant independently completed the two trip questions. Following the completion of each trip question, feedback was collected in a group setting. Participant's computer screens were recorded and were analyzed for usability issues. The age of the participants ranged from 22 to 73 years old, and the average age of the student and public focus group were 26 and 44 respectively. There was an even split between males and females.

The focus group revealed a slight preference towards the second trip question design. There was a general consensus that the participants liked to see all the trip information they entered visually laid out in front of them. Furthermore, they appreciate the short, simple instructions guiding them throughout the question. However, it was found that participants would prefer a more forgiving design, as they would like to edit their response for trips they may have forgotten. Several participants had troubles adjusting the routes on the map to match the routes they took as several small routes and alley ways are not coded in the Google Map's API. A review of the screen recordings revealed that participants struggling with adjusting the routes were often too zoomed out in the map; this increased the chances of waypoints being inaccurately placed. Interestingly, instead of moving the misplaced waypoints, many participants would create new waypoints to adjust the route.

As the second trip question designed was most favored by focus group participants, it was used in the field tests. Feedback on the design of the trip question was collected at the end of all field test surveys. The majority of the comments received were similar to those mentioned in the focus group; however, it was apparent that several respondents did not realize that the trip question involved multiple steps. They would scroll down to the next question on the page while only partially completing the trip question above. This common behavior is due to the fact all the questions on the previous survey pages were single-part questions where respondents would scroll down to proceed to the next question. Therefore, respondents would anticipate this scrolling design throughout the entire survey.

However, scrolling is not required in the trip question because once a step was completed the window of the trip question would transit to the next step.

3.2 Household Question

Given the advantages of web surveys compared to the CATI method, it is possible to survey more than one member of the household without significantly increasing the response burden. To test this method, a household question type was developed which allows the main respondent of the household to choose to respond on behalf of another household member in their current survey or have the household member respond for themselves in a separate survey (sub-survey). The household question is presented as Fig. 5. Sub-surveys invitations are sent automatically to the email addresses provided following the completion of the main survey. For instance, in the example shown in Fig. 5, John who is the main household respondent provided his partner's (Jill) email address. In the remainder of John's survey, he will answer questions about himself and his child Sam (Fig. 6 a). Once John's survey is complete, Jill is emailed a smaller sub-survey with questions relevant to her (Fig. 6 b). Questions are repeated for each member of the household and the respondent's names are piped into the questions for clarity. This feature is designed to help reduce proxy bias and improve the accuracy of the data collected. The performance of this household feature is investigated in the field tests discussed later in the paper.

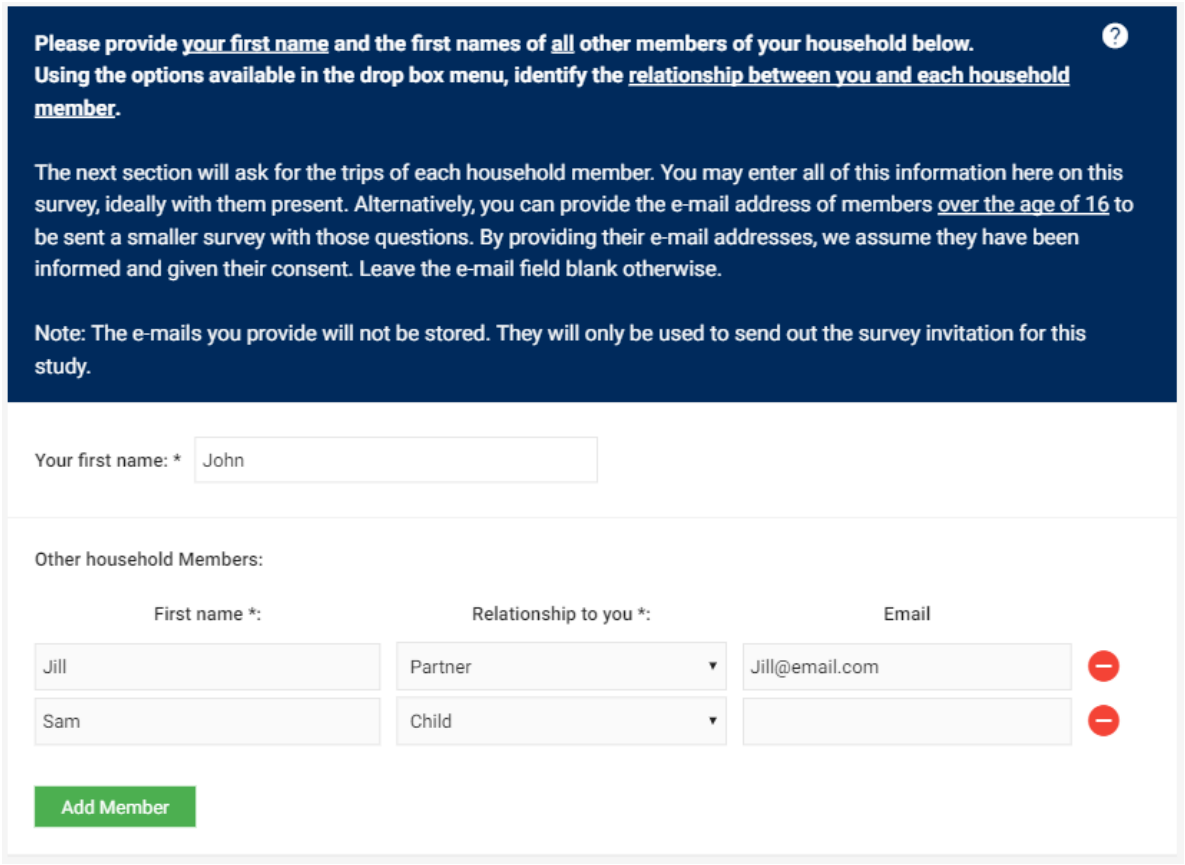

Fig. 5. Household question interface

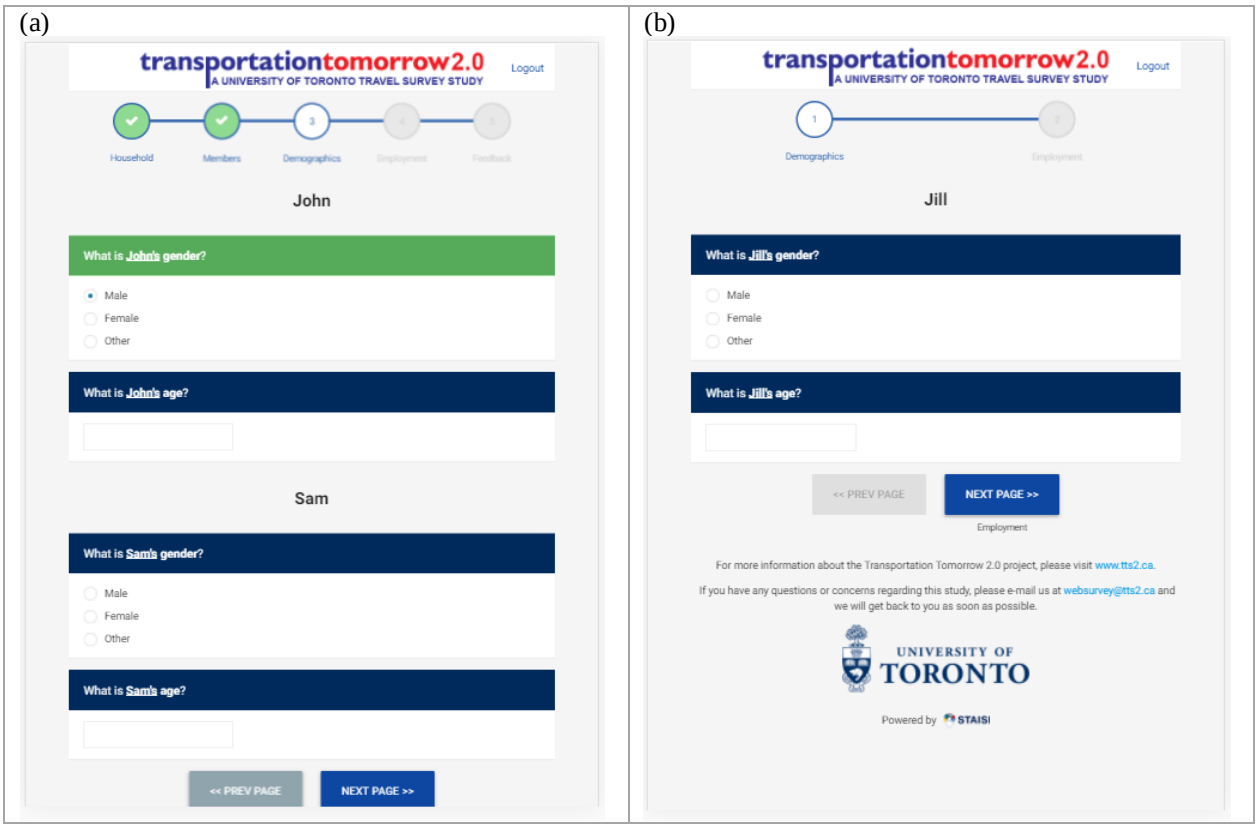

Fig. 6. (a) Main household survey; (b) Sub-survey

4. Field Tests

Household travel surveys were distributed in August 2017 to investigate the following survey administration methods: prompted recall, announce-in-advance, and the household question. The purpose of the field tests is to investigate if any of these methods have a significant impact on the completeness of the data and the burden on respondents. These are indirectly measured by respondent's reported trip rates and trip question completion times. Given the flexibility of the household question, the change in the demographic distribution of self and proxy respondents is investigated. The following subsections provide further details on the survey approach.

4.1 Description of Sample Frame and Survey Area

Surveys were distributed to a random selection of prior respondents of the 2016 TTS, who had indicated an interest in participating in future travel research. Nearly a third of respondents who completed the TTS volunteered, resulting in an approximate 42,000 email frame. For the portion of field tests conducted in August 2017, 7,700 of these households were randomly selected and sent field test survey invitations via email. As these respondents are a subset of the 2016 TTS sample frame, the households in the email frame and field test are in the Greater Golden Horseshoe Area (GGHA) in southern Ontario. Select respondent demographic and household statistics of the TTS 2016 sample frame, the email frame, and the field test are provided in

Table 1. The average demographics of the respondents from the TTS 2016 sample frame and those who started a survey in the field tests are nearly identical. However, it appears that households with few members tended to participate in the field test. Interestingly, the average age of the email frame population is slightly younger than the entire population of the TTS 2016 sample frame.

Table 1. Demographic and household characteristics of the TTS 2016 sample frame, email frame, and field test

	TTS 2016 Sample Frame	Email Frame	Field Test
Household Size [persons]			
Mean	2.43	2.43	2.07
Standard Deviation	1.31	1.27	1.10
Maximum	12	11	8
Minimum	1	1	1
Respondent's Age (years)			
Mean	44.34	40.03	44.43
Standard Deviation	23.31	21.50	21.00
Maximum	99	99	91
Minimum	0	0	0
Respondent's Gender (%)			
Male	48%	47%	50%
Female	52%	53%	50%

4.2 Survey Method

Two household travel surveys were created in STAISI:

1) Prompted recall: households reported trips on the day prior to them starting the survey; and
2) Announce-in-advance: households are given emails in advance notifying them of the study and a specified trip date of their survey

The household question was present in both surveys so that proxy bias could be evaluated in both the prompted-recall and announce-in-advance approaches. Survey questions were the same across both surveys and they were largely based on the 2016 TTS; however, additional data such as trip routes were collected for field test purposes. Furthermore, trip dates in surveys were not restricted to only weekdays, like in many regional travel surveys, as there was interest in a future study to compare weekend and weekday travel and data collection.

4.2.1 Prompted Recall

The prompted recall survey was made to mimic the 2016 TTS (with a few additions). As in the 2016 TTS, the survey asks for trips the household made the day before they started the survey. However, the TTS did send out letters and called households in advance to notify them of an upcoming survey. This method was not used in the prompted recall survey but was employed in the announce-in-advance survey.

To conduct the survey, an email was sent to the household with a brief description of the study and a link to their survey. The trip date in each survey was adjusted based on the day the household starts their survey; this method ensures the one-day gap between survey start date and trip date is maintained across all prompted recall surveys. Interestingly, it was found that some respondents open and start their surveys several days after receiving the email invitation. A total of 3300 email invitations to the prompted recall survey were sent out over a period of approximately two weeks.

4.2.2 Announce-in-Advance Method

The announce-in-advance survey asked the same set of survey questions as those in the prompted recall survey; however, instead of having a dynamic survey day based on the survey start date, respondents were given a predefined trip date in advance.

Initial invitation emails were sent to households informing them of the study; provided they agreed to participate, a travel survey was emailed to them five days later. A total of 5200 email invitations were sent out over a period of approximately two weeks, coinciding with the same survey period as the prompted-recall surveys. The household's designated trip date was also specified in the invitation email. A confirmation link was embedded in the email and clicked by the respondent to confirm their participation in the study. Reminder emails were sent a day prior to the trip

date that provided details of the trip data that would be collected in the survey to follow. The final email was sent on the evening of the household's corresponding trip date with a link to the survey. Similar to the prompted-recall survey, it was found that some of the announce-in-advance respondents started their surveys several days after their predefined trip date.

4.2.3 Proxy Bias

As stated earlier, both the prompted recall and announce-in-advance surveys included the household question to investigate proxy bias in both survey administration methods. Further details of the household question and its functions are described in Section 3.2. Since a single web-survey can be passed around to several members of the household, below each household member's trip question respondents were asked for the level of involvement the household member had in answering their trip question. This question had the following three response options to help differentiate self and proxy respondents:

1) Self-respondent: Household member answered their trip question by themselves
2) Partial-proxy respondent: Household member had somewhat of an input in answering their trip question
3) Proxy-respondent: Another household member answered the trip question on their behalf without consulting them

5. Results

The overall response rates of the two surveys are presented in Table 2. Approximately 15.5% of households who were invited to the prompted recall survey started the survey. Of the percentage of those who started the survey, only 68% of respondents followed through to the end of the survey. Relative to the prompted recall survey, the response rate of the announce-in-advance initial email was marginally greater at 17%, though the start rate of the survey was significantly less in relation to the number of email invitations sent out (10.5%). However, for those who started the survey, the announce-in-advance survey (76%) achieved a higher completion rate compared to the prompted recall survey (68%).

Table 2. Descriptive statistics of field test response rates

	Prompted Recall		Announce-in-advance (AIA)	
Total email invitations sent	3300	-	5200	100%
Households agreed to participate in first AIA email	N/A	N/A	885	17%
Households started survey	514	100%	547	100%
Households completed survey	350	68%	418	76%
Households that provided sub-survey emails (Households who received sub-survey emails [1])	93 (55)	18% (11%)	119 (83)	22% (15%)
Households that completed sub-surveys	8	2%	25	2%

1 Households who provided sub-survey emails that were the same as the head of household's email were not sent sub-surveys. At the time of the field test, STAISI had built in logic to prevent multiple survey invitations to be sent to the same email address. The fact that the head of the household would choose to send sub-surveys for other household members to themselves was a detail that was overlooked.

Approximately 20% of households used the sub-survey feature in both surveys. However, due to a program bug in STAISI, only 60-70% of the sub-survey emails were delivered. The remaining sub-surveys failed to deliver because email addresses provided for the sub-surveys were the same as email addresses that received the main survey invitation. Only after the field tests was it realized that a significant number of main survey respondents preferred to have sub-surveys sent to themselves instead of directly to other the household members' emails.

Regardless of this mishap, the sub-survey completion rate was relatively low. As shown in Table 3, the completion rate of sub-surveys delivered from the prompted recall survey and announce-in-advance survey are 15% and 30% respectively.

Announce-in-advance survey respondents appear to be twice as likely to start their sub-survey compared to prompted recall survey respondents. However, the sub-survey dropout rate after beginning the survey appears to be the same between the two surveys. The average demographics of sub-survey respondents in both surveys also appear very similar. Furthermore, it appears that households who provide sub-survey emails tend to be two-person households.

Table 3. Descriptive statistics of sub-survey respondents

Survey	Continuous Variables	Mean	Std. Dev.	Max.	Min.
Prompted Recall	Household size [persons]	2.1	0.3	3	2
	Sub-respondent's age [years]	51.4	16.6	75	26
	Sub-surveys sent per household	1.2	0.6	4	1
	Discrete variables	No. of Respondents		Percentage (%)	
	Sub-survey emails delivered	55		100%	
	Started sub-survey	11		20%	
	Completed sub-survey	8		15%	
Survey	Continuous Variables	Mean	Std. Dev.	Max.	Min.
Announce-in-advance	Household size [persons]	2.4	0.7	5	2
	Sub-respondent's age	51.5	12.4	72	28
	Sub-surveys sent per household	1.2	0.5	5	1
	Discrete Variables	No. of Respondents		Percentage (%)	
	Sub-survey emails delivered	83		100%	
	Started sub-survey	35		42%	
	Completed sub-survey	25		30%	

Table 4. Descriptive statistics of respondent types within the main survey (excludes sub-surveys)

Prompted Recall Survey					
Respondent Type	Percentage	Age [years]			
		Mean	Std. Dev.	Max.	Min.
Proxy - respondent	18%	43.5	21.0	86	11
Partial-proxy respondent	7%	45.4	17.6	73	11
Self-respondents:					
Head of household	60%	53.5	16.1	90	17
Other household members	16%	41.4	20.4	89	11
Respondent Type	Percentage	Gender ratio			
		Male		Female	
Proxy - respondent	18%	46%		54%	
Partial-proxy respondent	7%	49%		51%	
Self-respondents:					
Head of household	60%	55%		45%	
Other household members	16%	36%		64%	
Announce-in-advance survey					
Respondent Type	Percentage	Age [years]			
		Mean	Std. Dev.	Max.	Min.
Proxy - respondent	16%	36.4	21.1	90	11
Partial-proxy respondent	13%	42.8	16.6	75	11
Self-respondents:					
Head of household	55%	51.5	14.1	86	17
Other household members	16%	43.5	17.5	86	12
Respondent Type	Percentage	Gender ratio			
		Male		Female	
Proxy - respondent	16%	43%		57%	
Partial-proxy respondent	13%	40%		60%	
Self-respondents:					
Head of household	55%	55%		45%	
Other household members	16%	44%		56%	

As shown in Table 4, the demographics and distribution of proxy and self-respondents in the main surveys are largely similar between the two surveys. However, proxy respondents in announce-in-advance surveys tend to be younger than those in the prompted recall survey. Overall, the head of the household tends to be older than the other household members, and they also are slightly more likely to be male than female.

To investigate the effects of the survey administration methods and respondent attributes on the completeness of the trip data (indirectly measured by respondent trip rate) and burden on respondents (indirectly measured by the time respondents take to complete the trip question), a three-factor unbalanced ANOVA analysis was performed on the following variables:

- Independent variables:
  - (A) Survey method: announce-in-advance, prompted-recall
  - (B) Respondent type: proxy, self
  - (C) Respondent's age: 11-18, 19-29, 30-39, 40-49, 50-65, 65+
- Dependent variables: respondent's trip rate [trips/day], respondent's trip question response time [minutes]

It should be noted that all proxy and partial proxy respondents were grouped as proxy respondents in the analysis.

Descriptive statistics of the variables are presented in Table 5, and the ANOVA results are presented in Table 6. A 95% confidence level was adopted for the ANOVA analysis. As shown in Table 6, all three factors are shown to have statistically significant impacts on respondent's trip rates and their trip question response time. There are no significant interaction effects except for the joint effect of respondent type and respondent's age on the trip question response time variable.

As shown in the average response time per trip in Table 5, respondents notified of their trip date in advance reported on average 0.71 more trips and were able to input their trip information into the survey quicker than those who were given the prompted recall survey. As revealed in the literature, proxy respondents tend to under-report trips compared to self-respondents. The field test results also support this finding as self-respondents reported on average 0.51 more trips and were also able to enter their trip information more quickly.

The trip rate distribution against respondents' age resembles a bell curve skewed to the right. However, the trip question response time per trip does not follow the same distribution. Starting from the 19 to 29-year-old age group, the time needed by respondents to report a trip in the survey increases significantly with age. The average response time per trip for respondents aged 11 to 18 years is comparable to that of a 50+ year old respondent.

Table 5. Descriptive statistics of ANOVA variables

Categories	Variables	Trip Rate [trips/day]			Trip Question Response Time [min]			Average response time per trip [min/trip]
		Count	Mean	Variance	Count	Mean	Variance	
(A) Survey Method	Announce-in-advance	730	2.38	4.68	689	9.48	100.21	3.98
	Prompted Recall	559	1.67	3.48	546	7.76	86.36	4.65
(B) Respondent Type	Proxy	351	1.70	3.15	342	6.76	86.51	3.98
	Self	938	2.21	4.63	893	9.47	95.96	4.28
(C) Respondent's age [years]	11-18	88	0.91	2.43	88	5.06	81.04	5.56
	19 - 29	142	2.04	3.85	139	6.17	49.64	3.03
	30 - 39	201	2.72	4.73	190	9.66	94.42	3.55
	40-49	230	2.35	3.94	222	8.49	89.87	3.61
	50-65	386	2.23	4.42	366	10.16	114.35	4.55
	65+	242	1.47	3.69	230	8.81	89.75	6.00

Table 6. Three-factor ANOVA analysis

ANOVA: TRIP RATE				Alpha	0.05	
	SS	*df*	*MS*	*F*	*p-value*	*sig*
(A) Survey Method	77.07765	1	77.07765	19.6396	1.02E-05	yes
(B) Respondent Type	25.78859	1	25.78859	6.571005	0.01048	yes
(C) Respondent's Age	249.2769	5	49.85537	12.70329	4.59E-12	yes
(A) x (B)	0.216968	1	0.216968	0.055284	0.814149	no
(A) x (C)	1.810329	5	0.362066	0.092255	0.761379	no
(B) x (C)	39.46493	5	7.892985	2.011155	0.074449	no
(A) x (B) x (C)	4.14998	5	0.829996	0.211485	0.957733	no
Within	4964.623	1265	3.924603			
Total	5513.998	1288	4.281055			
ANOVA: TRIP QUESTION RESPONSE TIME				Alpha	0.05	
	SS	*df*	*MS*	*F*	*p-value*	*sig*
(A) Survey Method	441.2256	1	441.2256	4.848328	0.027861	yes
(B) Respondent Type	410.6681	1	410.6681	4.512553	0.033849	yes
(C) Respondent's Age	2561.326	5	512.2652	5.628934	3.88E-05	yes
(A) x (B)	5.344269	1	5.344269	0.058725	0.808564	no
(A) x (C)	257.4439	5	51.48879	0.565775	0.452089	no
(B) x (C)	1182.081	5	236.4161	2.597816	0.023987	yes
(A) x (B) x (C)	83.18204	5	16.63641	0.182806	0.96914	no
Within	110207.9	1211	91.00572			
Total	116916.4	1234	94.74585			

6. Discussion

Compared to the CATI method, web-surveys help to significantly reduce proxy bias. For example, if the field tests were conducted using the same proxy method as the TTS the percentage of proxy respondents would be approximately 52%; this estimation is based on the 2.07 average household size seen in the field test. However, in the case of this web-survey study, approximately 27% of respondents were either reported as proxy or partial-proxy respondents. Therefore, the flexibility of web-surveys appears to reduce proxy responses by almost half compared to the CATI method. Reducing proxy-responses in a survey is important as this can significantly improve quality of the collected trip data, as well as reduce respondent's survey completion time, as shown in the ANOVA results.

As discussed, the household question was developed in STAISI to further help minimize proxy-responses; however, its effectiveness is marginal. The results of the field tests reveal that only 20% of households are willing to use the feature to send out sub-surveys to other household members. However, the completion rate of these sub-surveys is relatively low; 14% for prompted recall surveys, and 30% for announce-in-advance surveys. Thus, the addition of this feature may decrease the number of complete household surveys. Interestingly, the sub-survey response rates appear to be significantly higher for announce-in-advance surveys (42%) compared to prompted recall surveys (20%). This significant difference may be attributed to the fact the email notifications to the household in advance of the survey increase the awareness of the survey to the other members of the household. Therefore, when receiving a sub-survey e-mail, they may be less apprehensive to open the email and take the survey. Furthermore, with the advanced notification of their travel day and the data to be collected by the survey, these respondents may keep track of their trip information beforehand. As they have already put in effort into the study before starting the survey, these respondents may be more inclined to complete the survey. Therefore, if the household question is to be used in a survey, it is better paired with the announce-in-advance survey method than the prompted recall method.

On the other hand, the prompted recall survey's response rate is almost double the response rate of the announce-in-advance survey. While the prompted recall method may produce a greater quantity of responses, the ANOVA analysis reveals that the method can compromise the quality of the trip data collected. Respondents of prompted recall surveys reported approximately 30% fewer trip on average than announce-in-advance respondents. In addition, respondents appear to require significantly more time to complete the trip question, which is a sign of additional

burden. Based on these results, the announce-in-advance method of surveying is recommended for household travel surveys.

The results of the field tests also reveal that the time taken to complete the trip question is also highly dependent on the respondent's age. Therefore, it is important to be mindful of the variation of respondents when designing a household travel survey. Furthermore, the development process of the trip question also reveals that a forgiving and flexible design is important as many respondents may realize they had forgotten to enter short trips after the fact.

7. Conclusion

This paper investigates methods to improve survey data quality and reduce response burden by sharing the lessons learned from the iterative development process of a web-based survey platform (STAISI), along with statistical analysis of field tests examining various survey methods. The field tests experimented with voluntary self and proxy reporting methods through a custom survey feature (household question). In addition, the paper compares the performance of the announce-in-advance and prompted recall survey administration methods. The effect of these methods on the completeness of trip data collected and respondent burden is analyzed through a three-factor ANOVA analysis.

The results of the study reveal that the use of web-surveys compared to the CATI method can significantly reduce the proportion of proxy responses in a household travel survey. An ANOVA analysis also provides evidence that a reduction in proxy responses can increase the travel survey's data quality in terms of reported trip rates, as well as reduce respondent's survey completion time. The study also shows that the announce-in-advance method can also significantly improve survey data quality and reduce response burden. However, compared to the prompted recall method, the announce-in-advance method produces a lower overall response rate. In terms of the household question, it appears to best perform with the announce-in-advance method; however, it should be noted that sub-survey completion rates are low, and thus can reduce the number of complete household surveys.

The study indicates that the announce-in-advance design is useful in household travel surveys as it has potential to improve the quality of trip data collected and decrease survey drop-off rates. However, in both field test surveys, it was found that drop-off rates were highly concentrated at the trip question. Given the importance of the collection of trip data, further field tests should be conducted to evaluate which design elements and features could be used to decrease the trip question completion time. As the trip question in STAISI is currently still undergoing design iterations, it would be an opportune time to test and compare the survey results in this study to surveys with newer iterations of the trip question. A study focusing on trip question design could provide travel survey designers evidence-based design guidelines to better their trip data collection process.

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