DEVELOPMENT OF A WEB SURVEY BUILDER (TRAISI)

DESIGNING HOUSEHOLD TRAVEL SURVEYS FOR DATA ACCURACY AND REDUCED RESPONSE BURDEN

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Transportation Tomorrow Survey 2.0

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EXECUTIVE SUMMARY

In recent years, there has been an increasing use of web-based technologies in travel surveys because of their potential to decrease respondent burden, improve data quality, and lower costs. Many such surveys are custom-built since commercial survey builder platforms (e.g. Survey Monkey, Qualtrics, etc.) that are not usually tailored for activity-travel data collection. These platforms lack features that allow efficient data collection of specific travel information, such as location piping between questions and the use of interactive maps for geospatial data collection. As an alternative approach to travel survey development, a custom web platform (TRAISI) was developed. TRAISI was developed as part of an R&D project (TTS 2.0) that has a goal to overcome the issues of the Transportation Tomorrow Survey (TTS), a large-scale CATI-based household travel survey in the Greater Toronto Area. Along with many other issues, the CATI method used by the TTS has been shown to have issues with location accuracy and household proxy bias, as one household member responds for the entire household. A TTS 2.0 review paper conducted in 2016, "Web Tool Design for Household Travel Surveys", revealed that web-based technologies may help to address these issues. This report acts as a follow-up, as well as an extension to that report.

This report investigates methods to improve survey data quality and reduce response burden by sharing lessons learned from developing a household web-based survey platform (TRAISI), 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 report also compares the performance of the announce-in-advance and prompted recall technique in a web-survey setting. The effect of these methods on the completeness of trip data collected and response burden is analyzed through ANOVA analysis. Finally, the report presents key features of the platform and user interface recommendations for designing surveys that collect detailed trip data.

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.

Given the advantages of web surveys, it is possible to survey more than one member of the household without significantly increasing the response burden. One of the field tests presented in this report involves having the main household respondent decide which members of their household will self-report or proxy-report their trips. The platform is equipped with a "household question" feature that automatically sends separate smaller surveys (i.e. sub-surveys) via e-mail to household members who are chosen to be self-respondents. This household question 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. Therefore, 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 on the question that collected data about the trips taken.

Various usability studies conducted on several iterations of the trip question design reveal some usability issues and considerations to be focussed on for future iterations of the platform. It is found that older respondents and larger household are more likely to leave the survey when it came to the trip question. Although a large majority of respondents typically complete the survey over a desktop, a responsive design is needed to address usability issues due to smaller screen sizes on mobile and tablets. Usability concerns and survey abandonment is particularly pronounced in small

screen devices when respondents are asked to input their trip routes in the interactive map. Waypoints are difficult to place and small walk/bikeways, in particular, are not mapped into the Google Maps API. However, an ANOVA analysis of the field test results reveal that asking for trip routes, beyond just the transit routes asked in the TTS, does not significantly add to the survey burden or significantly decrease respondent's trip rates. Overall, collecting trip route information through a web-survey is a feasible option, although inputting routes of walk and bike trips should be omitted as it increases respondent frustration.

Based on the usability and field test findings, it is evident that additional improvements are needed for the current trip question in TRAISI, such as simplifying the timeline design and allowing respondents to copy trips between household members. Other remaining work includes re-evaluating the current TTS questionnaire as various issues, such as the limited occupation and trip purpose options, were apparent in the 2016 TTS and field tests.

Development of a Web Survey Builder (TRAISI)

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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, this report presents a custom web tool (TRAISI – TRavel and Activity Internet-Survey Interface - pronounced "tray-see") being 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 is developed for the R&D project (TTS 2.0) which aims to address the issues faced by southern Ontario's large-scale CATI-based household travel survey, the Transportation Tomorrow Survey (TTS). This report is part of the series of web-based survey progress reports submitted for the TTS 2.0 project; the prior two reports include "Current State of Web-Based Survey Methods" (Loa, et al., 2015) and "Web Tool Design for Household Travel Surveys" (Chung, et al., 2016).

This report explores how web-based travel surveys can be designed to improve the accuracy and completeness of the data collected while minimizing response burden. Field tests of travel surveys using the TRAISI web tool were conducted in the summer and fall 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. 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 TRAISI is also discussed, along with a few other key features and functions of the platform. Overall, the report presents lessons learned from developing TRAISI and the results of the field tests that can be applied to better design web-based household travel surveys.

The remainder of the report is organized as follows. Section 2 is a summary of the relevant literature on methods to design web-based household travel surveys for data accuracy and reduced response burden; this includes a review of trip data collection designs, methods to minimize proxy bias, and the effectiveness of the announce-in-advance technique. Section 3 provides a brief overview of TRAISI's current features and highlights the design and development of its novel features such as its trip question. Section 4 summarizes the survey method and results of the field tests conducted in the summer and fall of 2017. Finally, Section 5 provides a brief comparison of the 2016 TTS and the field test results to highlight key findings and common issues.

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 report attempts to fill this gap by summarizing the lessons learned from the iterative development process of a web-based trip question. In addition, the report explores the performance of the voluntary self and proxy reporting method through a custom survey feature built-in TRAISI (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 are lacking, the report presents a comparative study of these two methods.

3 "TRAISI" SURVEY BUILDING PLATFORM

Due to the various needs of household travel surveys and the lack of flexibility in existing commercial web-based survey-building platforms, an in-house platform has been developed. The platform (TRAISI – TRavel and Activity Internet-Survey Interface) is equipped with the basic functions of a web-based survey platform, as well as additional unique features tailored for household travel data collection. The following sections provide a brief overview of TRAISI's general features as well as highlight some of its unique features, namely the "household question" and "trip question".

It should be noted that the report discusses the state of the platform as it existed at the time of this report's writing. There is ongoing work to further expand and improve the platform.

3.1 General Features

TRAISI 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 Figure 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.

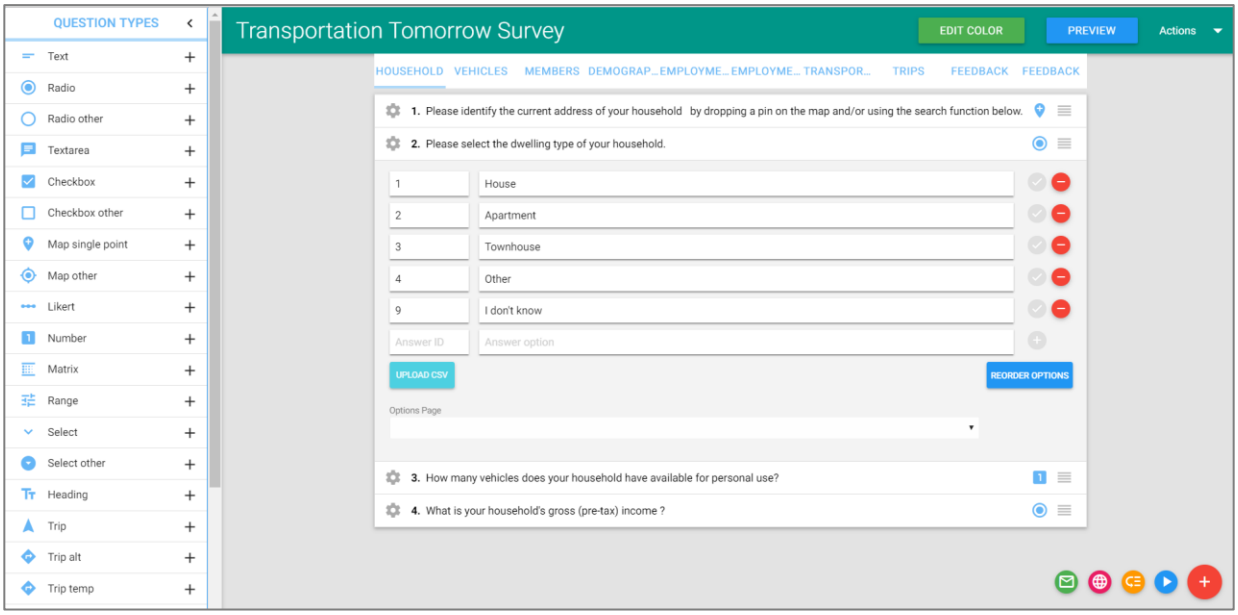

FIGURE 1. TRAISI SURVEY BUILDER INTERFACE

On the survey-takers end, TRAISI 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 Figure 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. TRAISI can also support different languages and can auto-adjust to various devices and screen sizes.

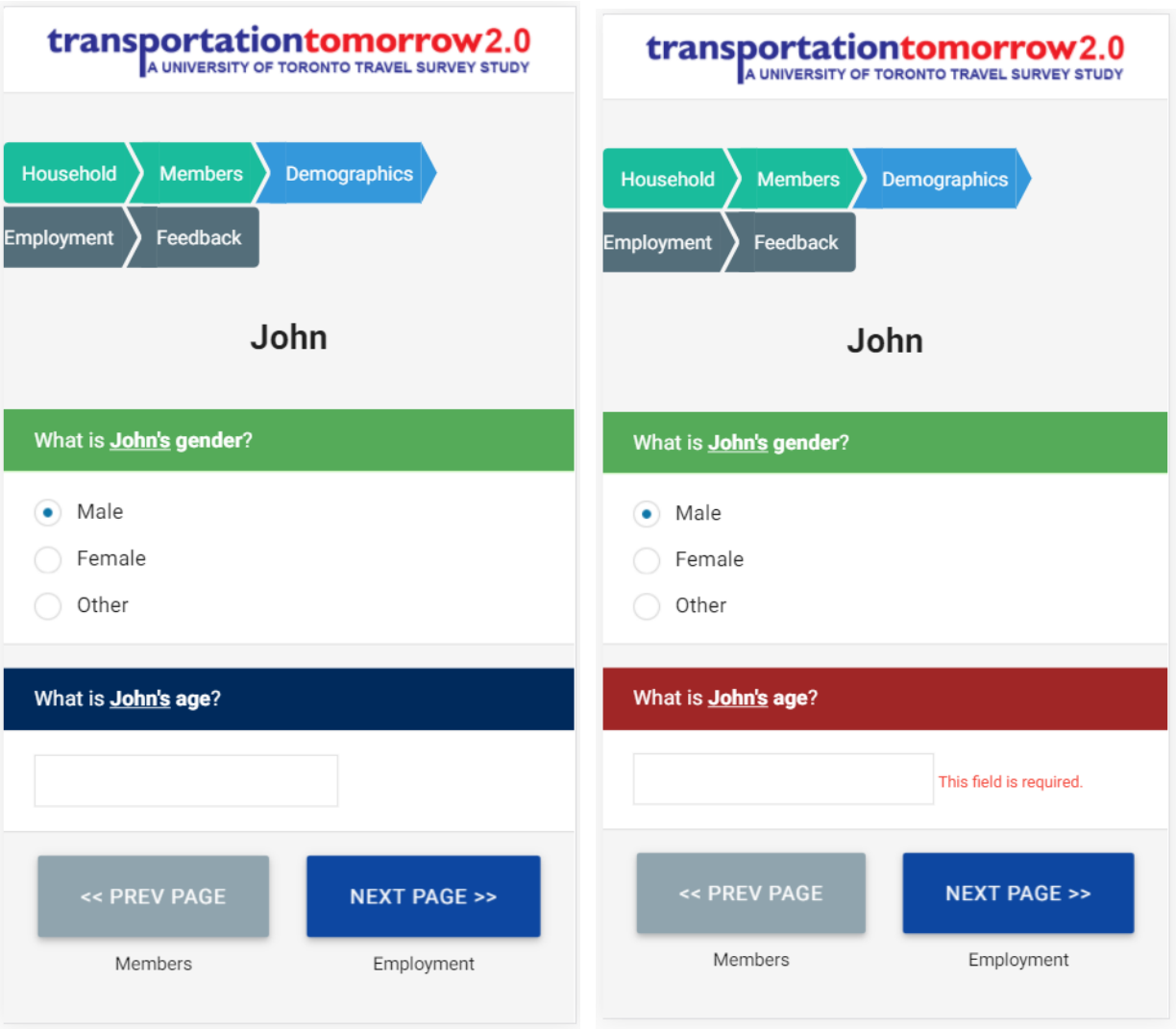

FIGURE 2. SAMPLE SURVEY INTERFACE SHOWING RESPONDENT'S INSTANT VERIFICATION OF QUESTION COMPLETION

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 FIGURE 3. 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 FIGURE 3, 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 (

FIGURE 4 A). ONCE JOHN'S SURVEY IS COMPLETE, JILL IS EMAILED A SMALLER SUB-SURVEY WITH QUESTIONS RELEVANT TO HER (

Figure 4 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 report.

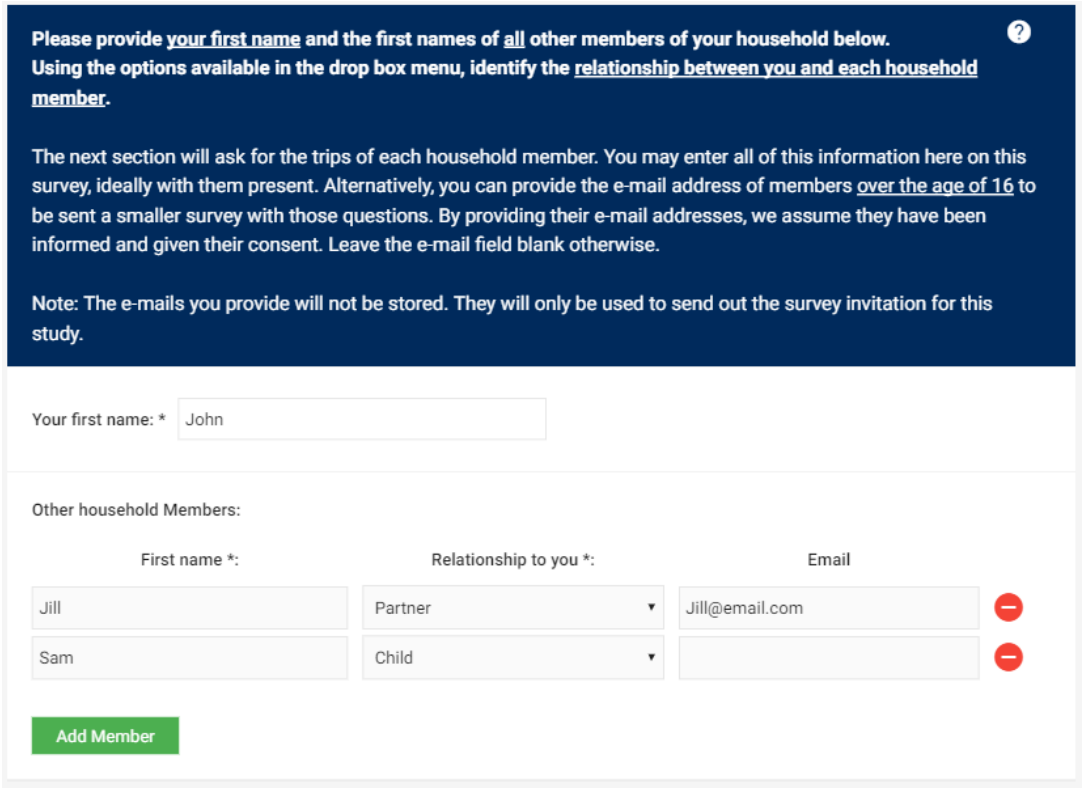

FIGURE 3. HOUSEHOLD QUESTION INTERFACE

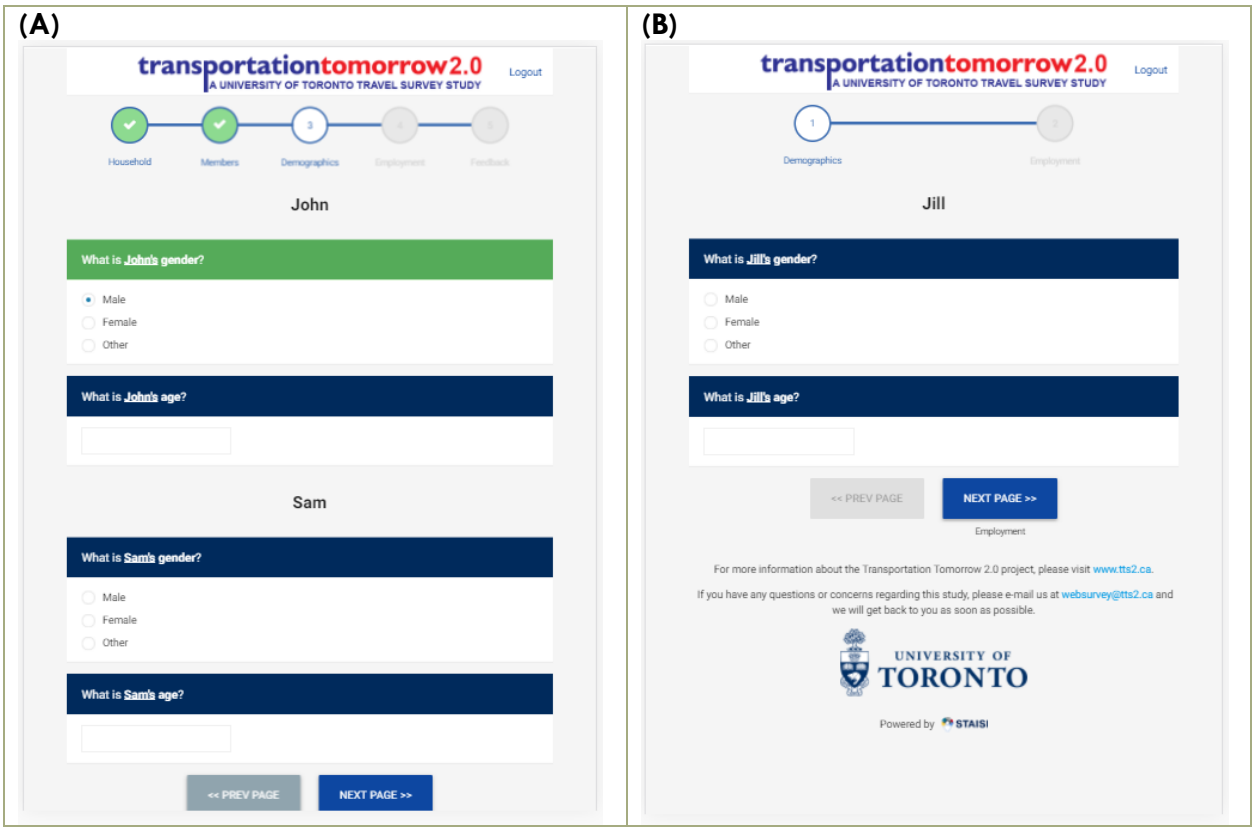

FIGURE 4. (A) MAIN HOUSEHOLD SURVEY; (B) SUB-SURVEY

3.3 Trip Question

Regional travel surveys typically collect household trip data for the purposes of modelling transportation in the region and policy planning. Detailed information for each trip collected includes location, trip purposes, modes and arrival/departure times. Collecting such detailed information is challenging as it can be a cumbersome, lengthy process and therefore, can deter many respondents from completing the survey. To minimize survey dropout rates, the trip question of the survey must be carefully designed to reduce response burden. Therefore, several trip question designs were created in TRAISI and were extensively tested for usability issues. The designs and key lessons learned from the usability tests are discussed in the following sections.

3.3.1 Designs and Development Process

An iterative approach, as depicted in Figure 5, was taken when designing and developing the trip question in TRAISI. The design process began with a literature review of household travel survey designs and usability studies in web design; refer to the preceding TTS 2.0 report, "Web Tool Design for Household Travel Surveys" (Chung et al., 2016), for a summary of the literature findings. Then drawing inspiration from the literature review findings, several designs were drafted. Due to limited web programming resources, only a select few designs were developed and integrated into TRAISI. These designs underwent extensive usability testing which included numerous in-house workshops, public focus groups, and mouse tracking studies.

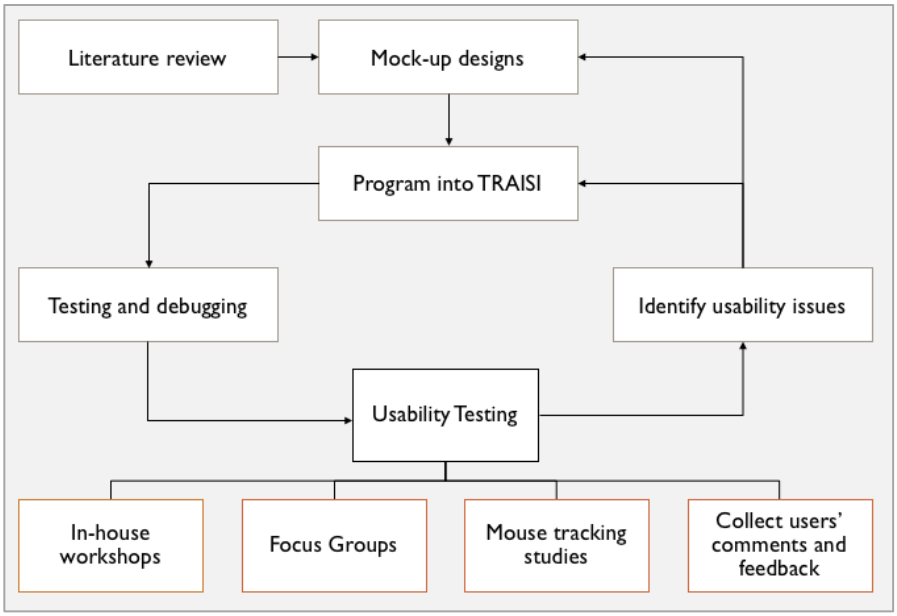

FIGURE 5. TRIP QUESTION DESIGN PROCEDURE

Initially, two designs were developed: trip question #1 and trip question #2. As shown in Figure 6, trip question #1 adopts a more cyclic approach, while trip question #2 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. Therefore, trip question #2 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; this is illustrated in the screenshots of trip question #2 provided in the Appendix.

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 Figure 7, 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.

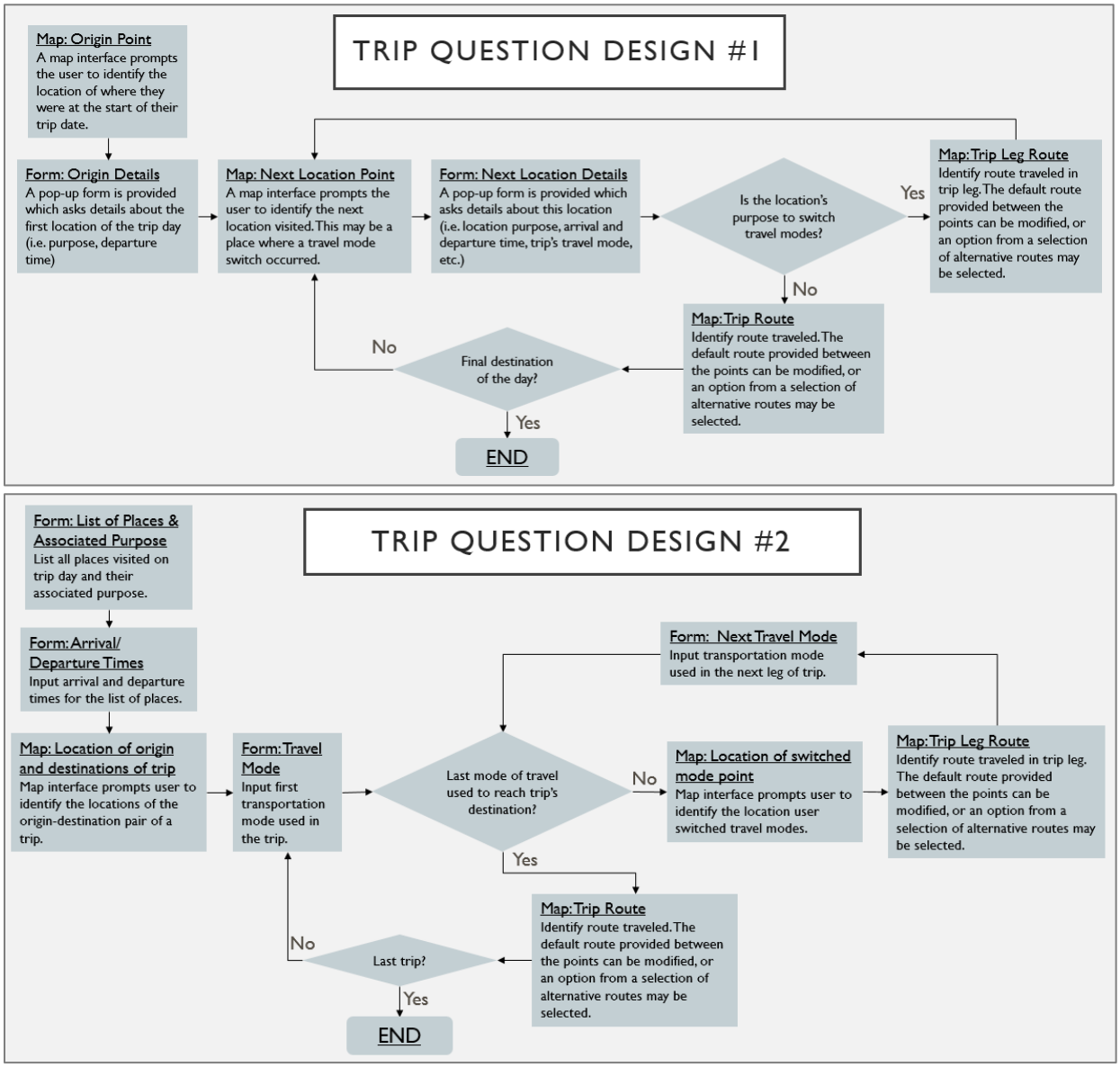

FIGURE 6. SIMPLIFIED STRUCTURE AND FLOW OF TRIP QUESTIONS #1 & #2 DESIGNS

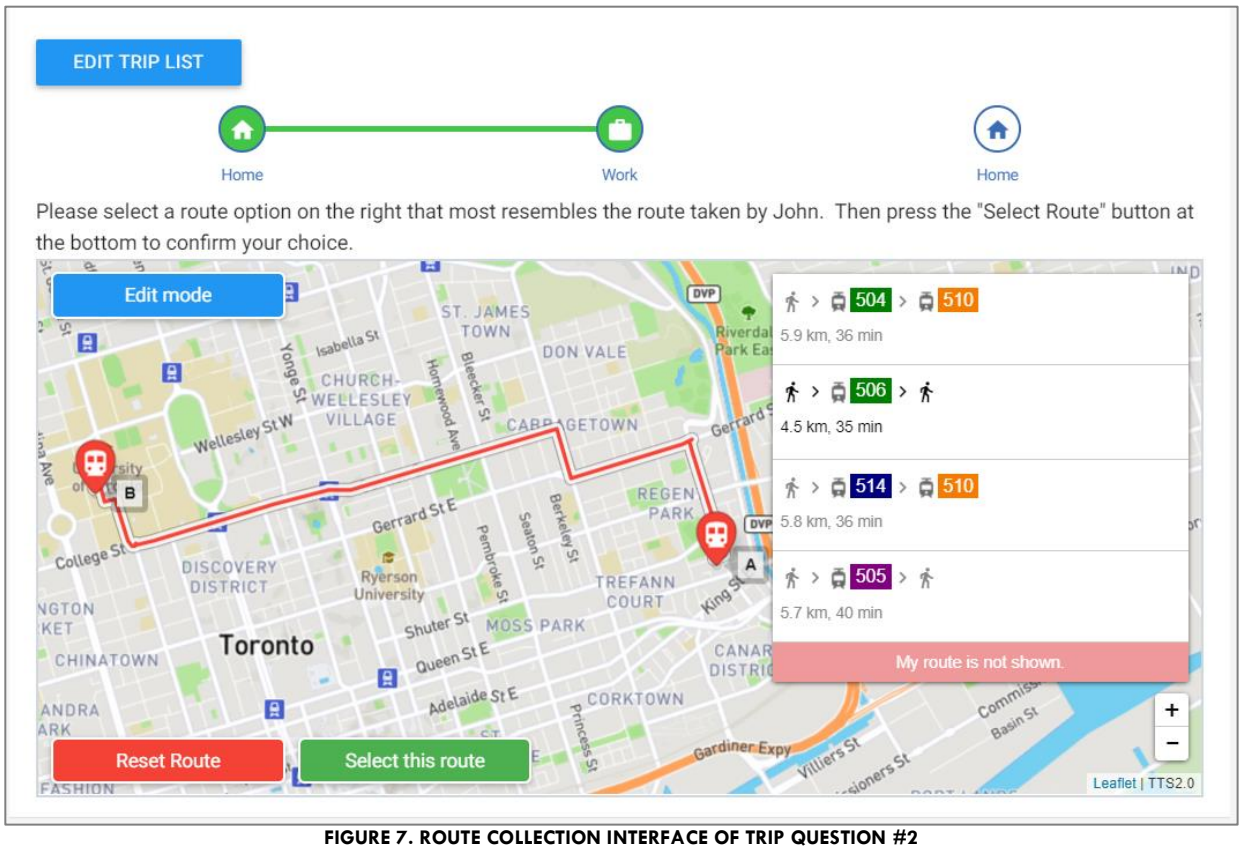

FIGURE 7. ROUTE COLLECTION INTERFACE OF TRIP QUESTION #2

3.3.2 Current Trip Question Design (Trip Question #3)

Focus group studies conducted on the first two trip questions designs revealed several usability issues in the designs; refer to Section 3.3.3 for details. Therefore, a third design (trip question #3) was created to attempt to address many of the issues with the prior two designs. Trip question #3 featured two key sections: a timeline to collect the sequence of locations visited, and a trip sequence question that links the locations in the timeline to form trips.

As shown in Figure 8, the timeline first prompts the respondent to enter the first and last location they visited on their trip day. Tool-tips, such as those pointing towards the blue buttons at the two ends of the timeline in Figure 8, are provided throughout the entire question. These tool-tips help guide the respondents step-by-step through the question.

Clicking on the blue button to add a location on the timeline reveals a menu of previously entered locations such as shown in Figure 9. Selecting one of the locations in the menu reveals a light-boxed overlay over the timeline prompting the respondent to enter details of the location such as its purpose and departure times (Figure 11). If the respondent chooses to add a new location that is not displayed in the menu, the survey displays an overlay similar to Figure 11where additional information about the location is collected.

Since respondents frequently forget to report their final return home trip, the user is whether they returned home at the end of their trip day (Figure 12). The respondent is only prompted if they select a location other than home as their final location.

Once the start and end locations of the timeline are entered, the survey prompts the respondent to add intermediate locations (Figure 13). The addition of intermediate locations to the timeline

functions in a similar fashion to adding the first and last locations on the timeline. Repetition and consistency are key to lessen the learning curve and burden on the respondent.

Once the timeline is complete, such as the one shown in Figure 14, the respondent can scroll down the survey page to the trip sequence question (Figure 15). The trip sequence question takes the locations from the timeline to construct a sequence of trips. Each trip is separated by tabs and under each tab, the travel mode and trip route information are collected for the corresponding trip. Similar to the timeline question, the trip sequence question also features tool tips to help teach and guide the respondent on how to use the question's interface. These tool tips only display for the first trip tab to avoid them becoming bothersome for respondents to see them repeatedly for each of their trips. However, if the respondent gets confused at any point of the trip sequence question, a help button on the top right corner of the question presents the most relevant tool-tip.

As shown in Figure 15, the question prompts the user to select the first mode used for the first trip. The mode categories are displayed as icons. Clicking on an icon reveals a menu of modes under the corresponding category. This nested design helps to minimize the clutter of mode response options displayed to the respondent. After a mode is selected, route alternatives, pulled from Google Direction's API, display on the left panel (Figure 16). Similar to Google Map's interface, respondents can select a route alternative, which is displayed on the map to the right. The question also allows respondents to report multi-modal trips through the "Add next travel mode" button on the left panel. As shown in Figure 17, this prompts the respondent to identify the location where they switched modes on the map. An example of a multi-modal trip entered in trip question #3 is shown in Figure 18. Once one trip is complete, tool-tips prompt respondents to click on the next tab to enter the mode and route information for their next trip. The trip-sequence question is complete once all tabs have trip information entered, visually indicated using checkmarks.

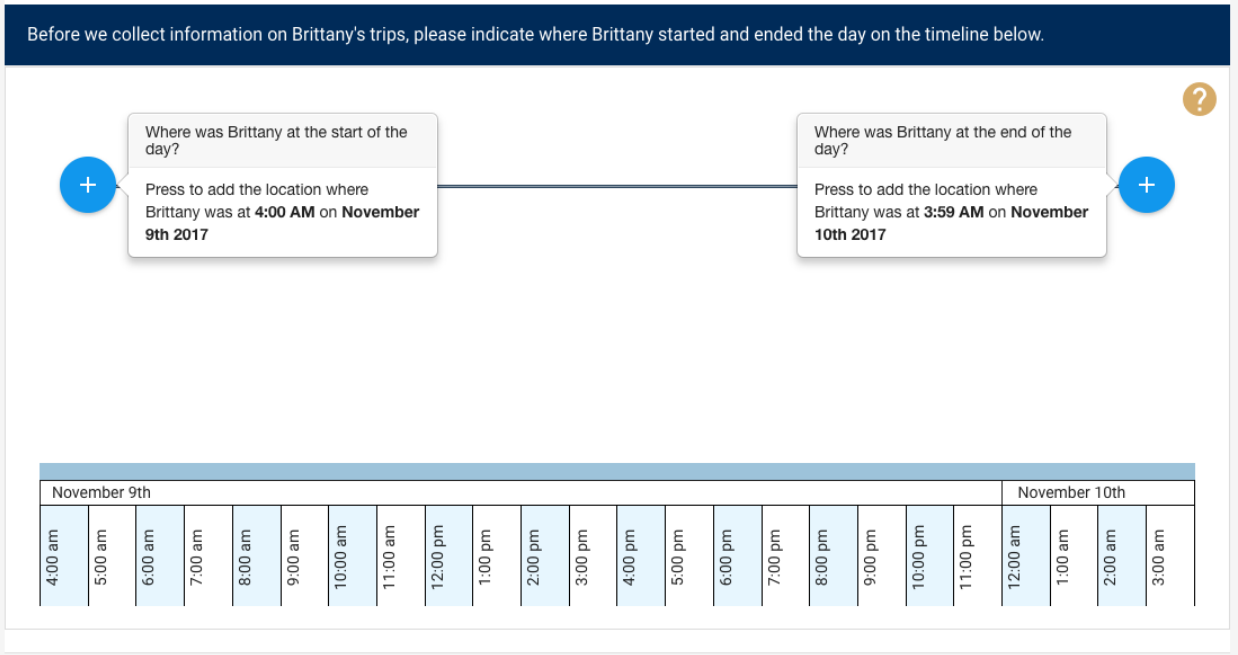

FIGURE 8. TRIP QUESTION #3 – INITIAL TIMELINE INTERFACE

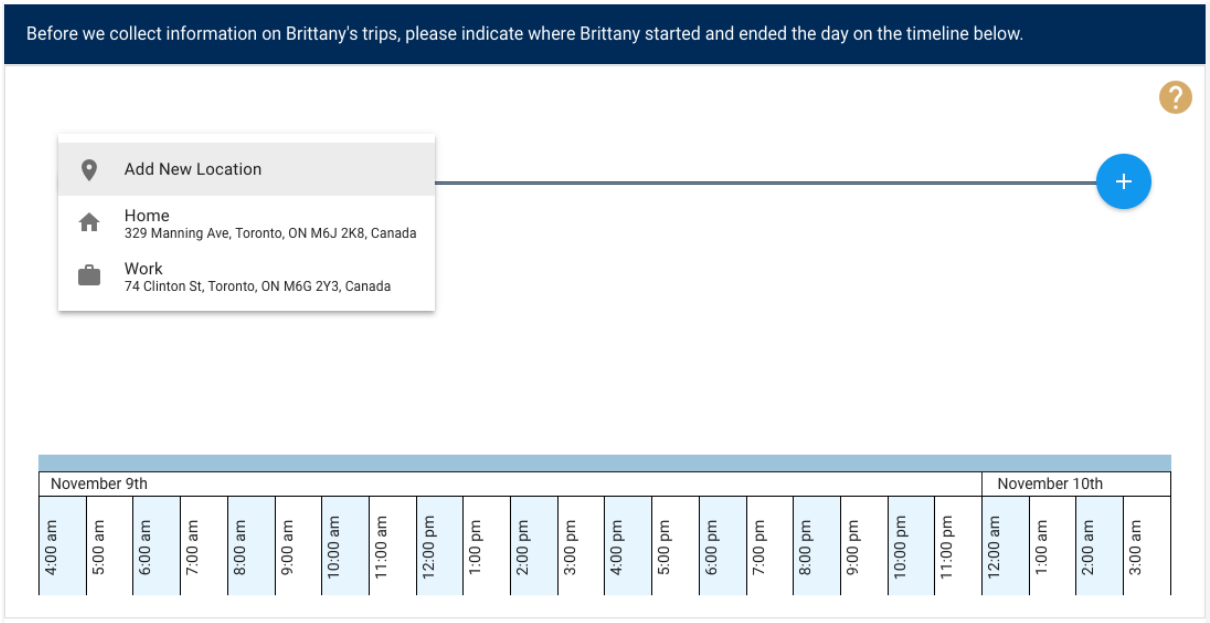

FIGURE 9. TRIP QUESTION #3 - TIMELINE DROP-DOWN MENU OF PIPED LOCATIONS

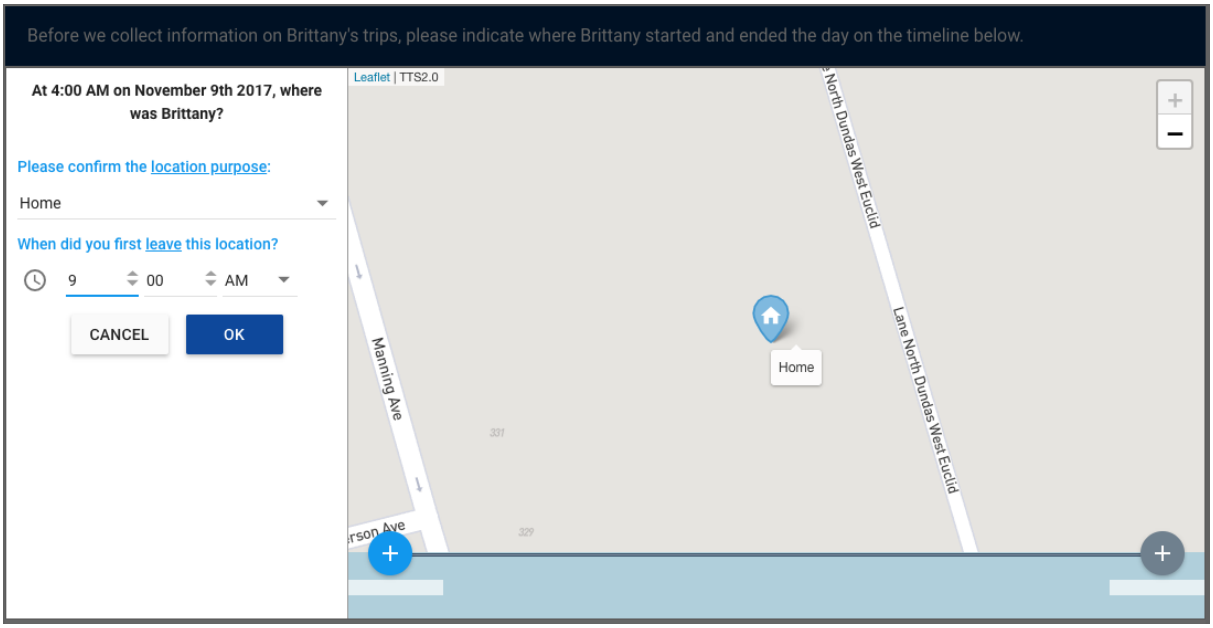

FIGURE 10. TRIP QUESTION #3 - TIMELINE DROP-DOWN MENU OF PIPED LOCATIONS

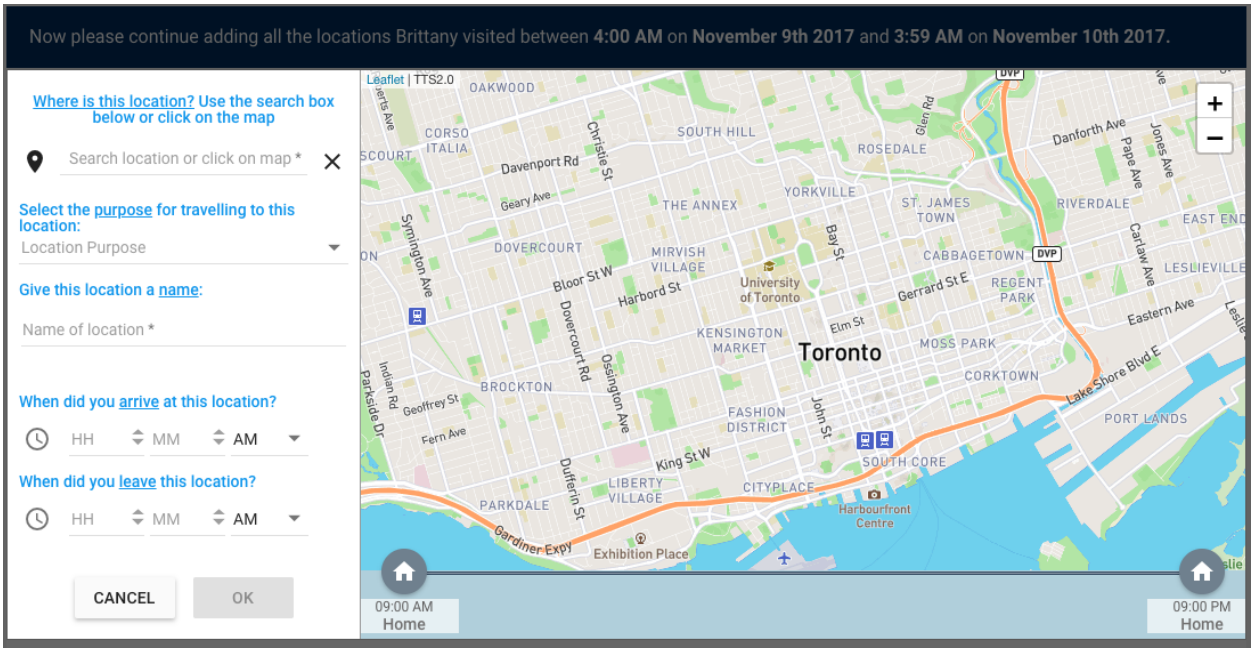

FIGURE 11. TRIP QUESTION #3 - TIMELINE POP-UP FORM FOR NEW LOCATION VISITED

FIGURE 12. TRIP QUESTION#3 - TIMELINE CHECK FOR HOME AT END OF THE DAY

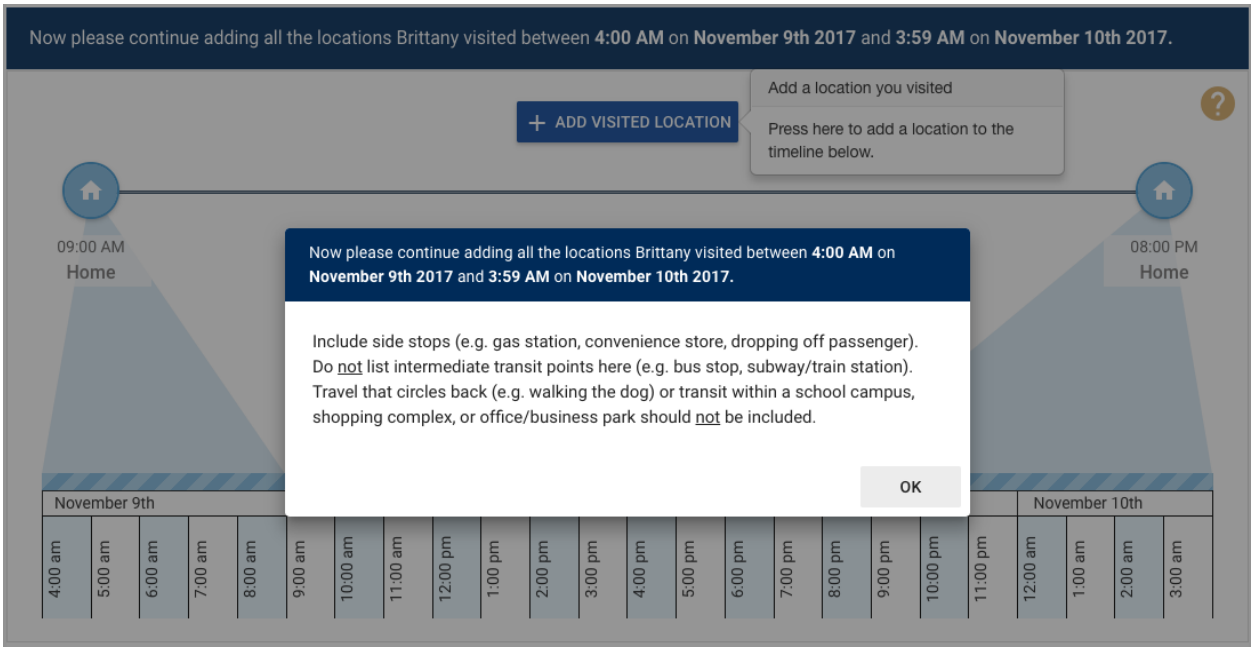

FIGURE 13. TRIP QUESTION #3 - TIMELINE PROMPT FOR INTERMEDIATE LOCATIONS

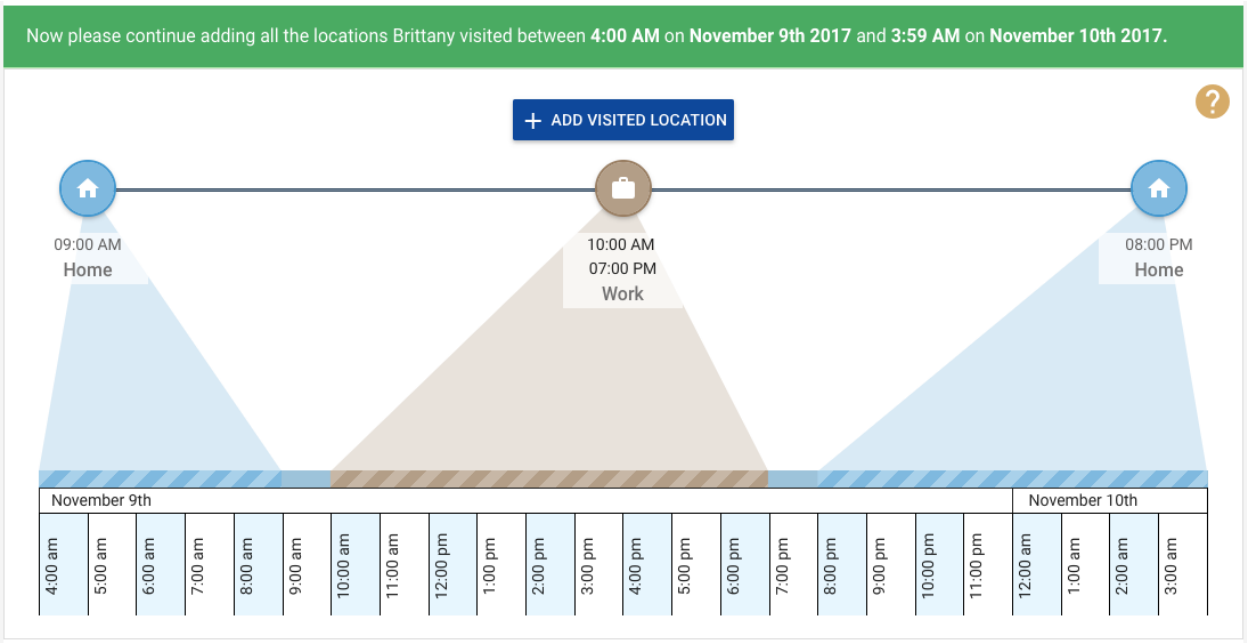

FIGURE 14. TRIP QUESTION #3 - EXAMPLE OF A COMPLETE TIMELINE

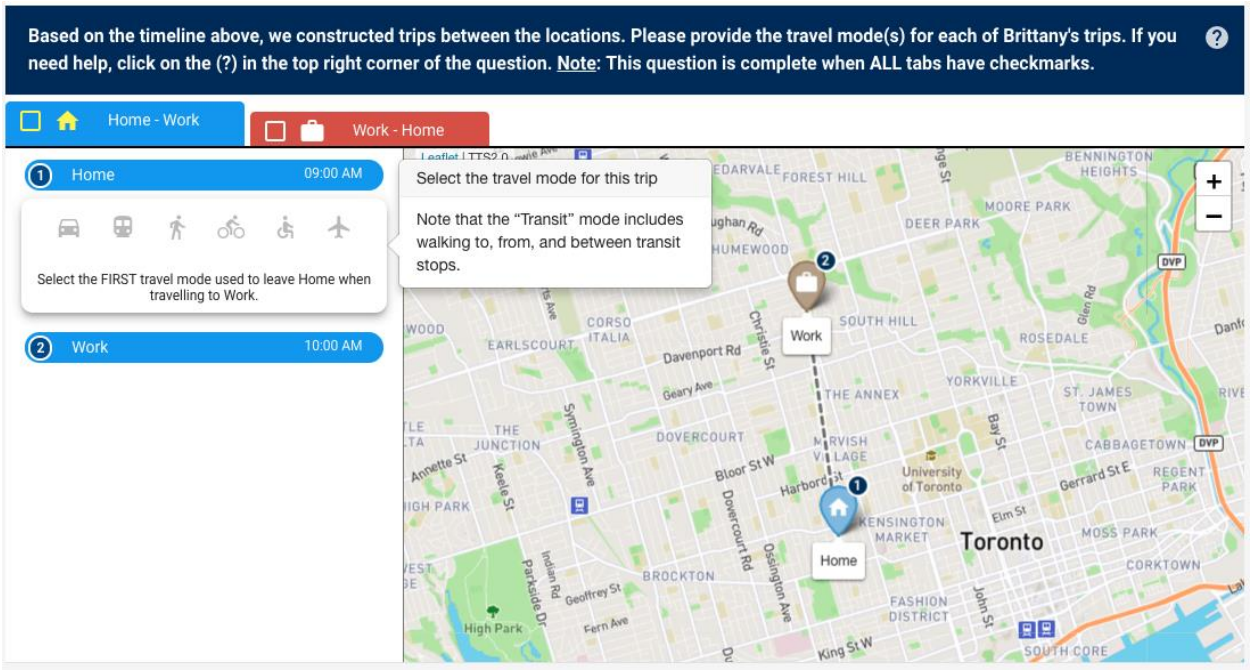

FIGURE 15. TRIP QUESTION #3 – INITIAL TRIP SEQUENCE QUESTION INTERFACE

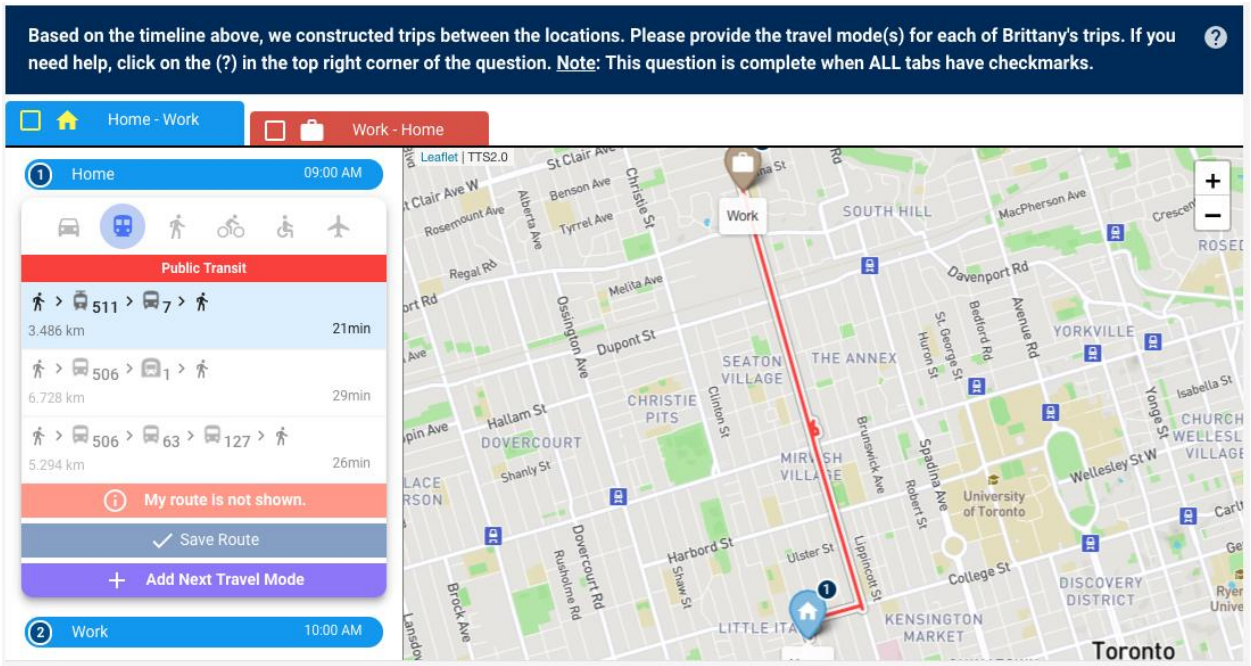

FIGURE 16. TRIP QUESTION #3 - TRIP ROUTE COLLECTION

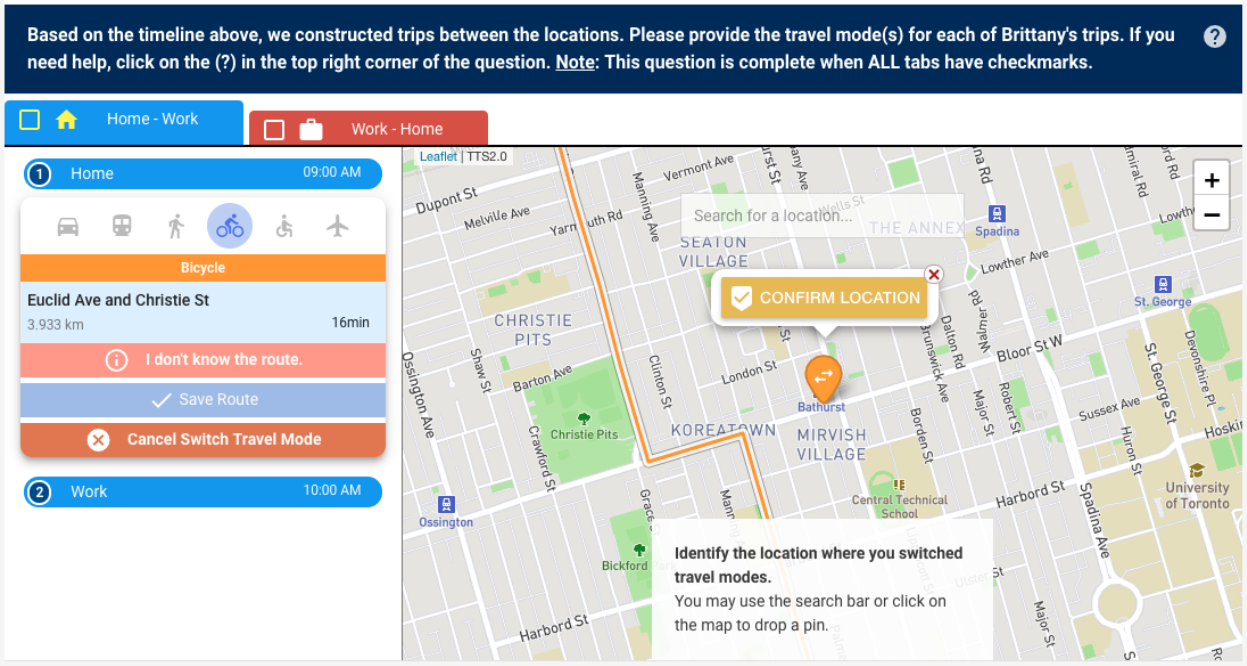

FIGURE 17. TRIP QUESTION #3 - PROMPT FOR A SWITCH MODE LOCATION FOR MULTI-MODAL TRIPS

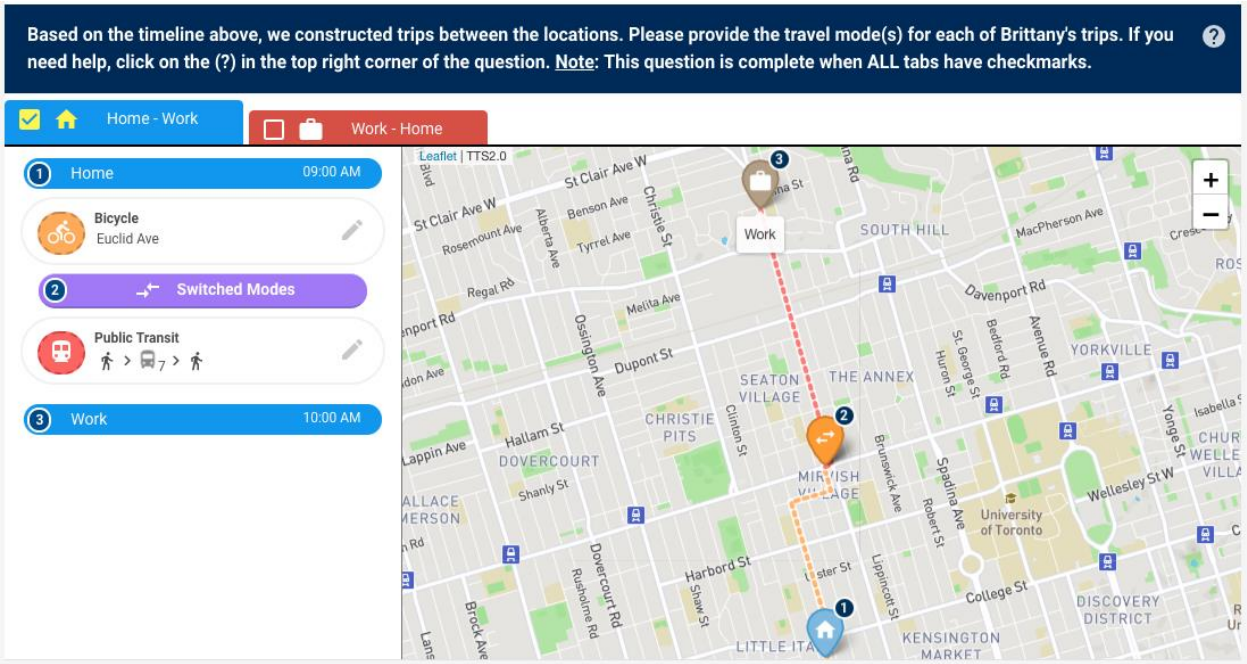

FIGURE 18. TRIP QUESTION #3 - EXAMPLE OF A MULTI-MODAL TRIP ROUTE ENTRY

It is apparent that the trip question #3 design works best on large screen devices but would be overwhelming for smaller-screened devices. Therefore, the question was programmed to be responsive to screen size. Instead of shrinking the trip question to fit, a separate mobile design of the question is rendered, as shown in Figure 19. The interface is simplified by removing the wedges from the timeline and separating the trip route tabs into pages.

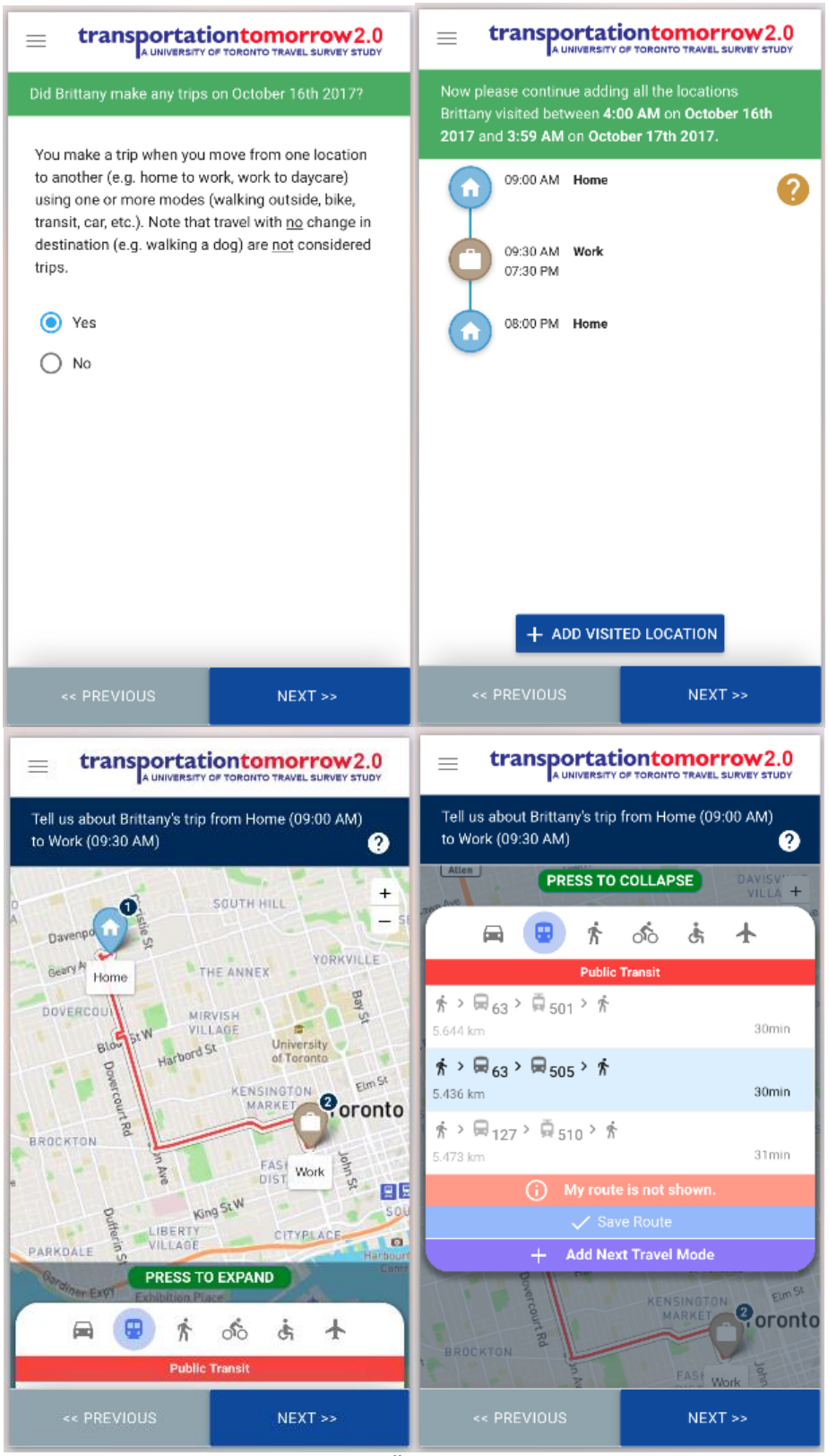

FIGURE 19. TRIP QUESTION #3 - MOBILE RESPONSIVE DESIGN

The combination of the timeline and trip-sequence tab design allows respondents to easily scroll up the survey page, add or remove a location from their timeline without losing the mode and route information they entered for unrelated trips. Separating the trip question in this fashion is a much more forgiving design than trip question #1 and #2. The previous designs made it difficult for respondents to edit their trips without losing a significant portion of information they have already entered. However, through further usability testing, the current design of trip question #3 still faces several usability issues; Section 3.3.4 highlights these key usability issues discovered in a mouse tracking study.

3.3.3 Focus Groups

To gather feedback on the first two trip question designs (trip question #1 and #2), two focus groups were conducted in June 2017. The first focus group comprised of graduate students at the University of Toronto, while the 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. It was apparent that the older participants had trouble with the interface and took much longer to complete both trip questions. On the other hand, the younger group of participants completed the questions rather quickly and had no or few complaints about the 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 trouble adjusting the routes on the map to match the routes they took as several small routes and alleyways 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 trip question design #2 was most favored by focus group participants, it was used in the summer field tests. Feedback on the design of the trip question was collected at the end of the 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 for the trip question because once a step was completed the window of the trip question would transit to the next step.

3.3.4 Mouse Tracking Usability Study

Trip question #3 was piloted during the fall field tests in late November 2018. During the fall field tests, additional short surveys with trip question #3 were distributed to prior summer field test respondents who volunteered to help with further usability testing. These short surveys collected general demographic information of the respondents, such as their gender and age, as well as a

recording of their mouse movements during the trip question. Mouse movements were tracked using Inspectlet (https://www.inspectlet.com/), an online tool for web session recordings. Inspectlet allows users to record the mouse movements, scrolls, clicks and key presses on a website. These recordings simulate the interactions of the user with the survey interface, which is very similar to the screen recording method used in the focus groups. Sensitive information, such as the respondent's home address entered in the survey, was configured to be ignored by Inpectlet.

In addition to analyzing the usability of and user interactions with the design of trip question #3, the study also investigated the burden associated with collecting route information. Therefore, two versions of the usability survey were distributed; one survey collected only transit routes, like the current TTS design, and the other collected all trip routes. The demographics of the respondents of the two surveys are summarized in Table 1. It is apparent that the simplified trip question, where only transit routes were collected, achieved a higher completion rate at 72% compared to a 64% completion rate for the survey that collected all route information. The age distribution of respondents, on the other hand, are relatively similar between the two surveys. It is, however, interesting to note that the age of respondents who completed the survey are skewed slightly younger than those that did not complete the survey. In terms of the respondents' gender, men are slightly more likely to complete the simplified trip question.

TABLE 1. RESPONDENT DEMOGRAPHICS AND DEVICE USAGE IN MOUSE TRACKING USABILITY TEST

	TRIP QUESTION #3 USABILITY SURVEY (ALL ROUTES)			TRIP QUESTION #3 USABILITY SURVEY (TRANSIT ROUTES ONLY)		
	All surveys	Complete surveys	Incomplete surveys	All surveys	Complete surveys	Incomplete surveys
Survey Count	108 (100%)	69 (64%)	39 (36%)	109 (100%)	78 (72%)	31 (28%)
RESPONDENT'S AGE (YEARS)						
Mean	54	53	56	54	53	56
Standard Dev.	16	16	17	16	15	16
Maximum	86	86	85	86	86	80
Minimum	24	24	29	17	17	30
RESPONDENT'S GENDER						
Male	53 (49%)	36 (52%)	17 (44%)	62 (57%)	45 (58%)	17 (55%)
Female	55 (51%)	33 (48%)	22 (56%)	47 (43%)	33 (42%)	14 (45%)
DEVICE USED						
Desktop	74 (100%)	50 (68%)	24 (32%)	68 (100%)	50 (74%)	24 (26%)
Tablet	23 (100%)	12 (52%)	11 (48%)	26 (100%)	15 (58%)	11 (42%)
Mobile	11 (100%)	7 (64%)	4 (36%)	15 (100%)	13 (87%)	4 (13%)

As shown in Table 1 above, it is overwhelmingly apparent that majority of the respondents tend to take their survey on a desktop. However, the completion rate on a tablet is noticeably less compared to the other devices. Unlike for mobile, a separate tablet design was not created for trip question #3; thus, the survey on a tablet displays as a scaled-down version of the desktop design. It may be possible that the design on smaller tablet screens compromised the usability and

in-turn the completion rate of the surveys. On the other hand, the completion rate on mobile is rather comparable to the completion rate on the desktop, in fact, mobile has a significantly higher completion rate than desktop for the simplified survey. This goes to show that it is important to have responsive designs to cater to different screen sizes.

To further investigate the reasons for the survey drop-offs, the respondents' point of drop-off is tallied against the device used. A summary of the results is presented in Table 2. The results reveal that approximately 66% of the drop-offs occur in the timeline section of trip question #3. Interestingly, the majority of the drop-off at the timeline section is in the early steps where respondents are asked to identify their first and last locations. This issue is significantly pronounced in the mobile design as all mobile drop-off occurs at the timeline. Therefore, this indicates that significant improvement is needed for the timeline design.

TABLE 2. TRIP QUESTION #3 POINT OF DROP-OFF BY DEVICE USED

	TRIP QUESTION #3 USABILITY SURVEY (ALL ROUTES)			TRIP QUESTION #3 USABILITY SURVEY (TRANSIT ROUTES ONLY)		
POINT OF DROP-OFF:	Timeline (first/ last locations)	Timeline (intermediate locations)	Trip sequence (routes)	Timeline (first/last locations)	Timeline (intermediate locations)	Trip sequence (routes)
DESKTOP	44%	6%	50%	40%	20%	40%
TABLET	33%	33%	33%	50%	0%	50%
MOBILE	71%	29%	0%	80%	20%	0%
ALL DEVICES:	50%	14%	36%	50%	18%	32%

A review of the Inspectlet recordings reveals that 20% of mobile users turned their mobile to landscape every time they had to type the arrival/departure times into the pop-up form. The repetitive turning off the phone to type information may increase respondent's fatigue; thus, it is important to minimize the typing required for the next iteration of the design.

A thorough review of Inspectlet recordings of incomplete surveys was conducted to identify the reasons for the drop-off rates. As shown in Table 3, the reasons are categorized into two categories: confusion/frustration, and fatigue. The analysis reveals that the majority of the respondents that drop-off the timeline did not show signs of confusion or frustration. Therefore, it is assumed that respondent fatigue caused the respondents the drop-off. This is understandable given that there are several steps required to complete the timeline which respondents may anticipate as a cumbersome process. However, the drop-offs that occurred at the trip route sequence appear to be due more so to confusion and frustration than fatigue. A review of the recordings reveals that 13% of the desktop users who did not complete the survey were having trouble with the trip sequence's tab design. Clicking on the tabs to proceed to the next trip is not obvious to desktop users although tool-tips were in-place to guide the respondents to the next tab. The mobile design does not have tabs, which may explain why none of the mobile users dropped off at the trip sequence section of the question.

Other issues observed at the trip sequence section include trouble with adding waypoints to routes, jumping to the trip sequence section before completing the timeline, as well as some confusion with the switch mode function. For the survey that only collected transit routes, 8.5% of respondents that reached the trip sequence section used the switch mode function to report multi-modal trips. However, for the survey that collected all trip routes, only 5.5% of respondents that reached the trip sequence section of question used the switch mode function. All reported multi-modal trips had two or three mode switches, except for one respondent who reported a total of six walk-transit

mode switches because they did not realize that the transit mode included walking to, from, and between transit stops.

TABLE 3. IDENTIFYING REASONS FOR DROP-OFF IN MOUSE TRACKING USABILITY TEST

	TRIP QUESTION #3 USABILITY SURVEY (ALL ROUTES)			TRIP QUESTION #3 USABILITY SURVEY (TRANSIT ROUTES ONLY)		
POINT OF DROP-OFF:	Timeline (first/ last locations)	Timeline (intermediate locations)	Trip sequence (routes)	Timeline (first/last locations)	Timeline (intermediate locations)	Trip sequence (routes)
CONFUSION/ FRUSTRATION	7%	0%	70%	0%	25%	57%
FATIGUE	93%	100%	30%	100%	75%	43%

A feature added to the timeline is the ability to insert nested episodes, such as the lunch episode within the work episode example shown in Figure 20 below. This was added to minimize the number of steps to edit the timeline if a respondent forgets to add short trips in their timeline. Unfortunately, only one instance of a nested episode was observed in the usability study. A careful review of this particular Inspectlet recording reveals that the respondent added a nested episode by accident. This confused the respondent and they reported it as a technical error with the survey. Therefore, this feature should be removed in the next iteration of the design.

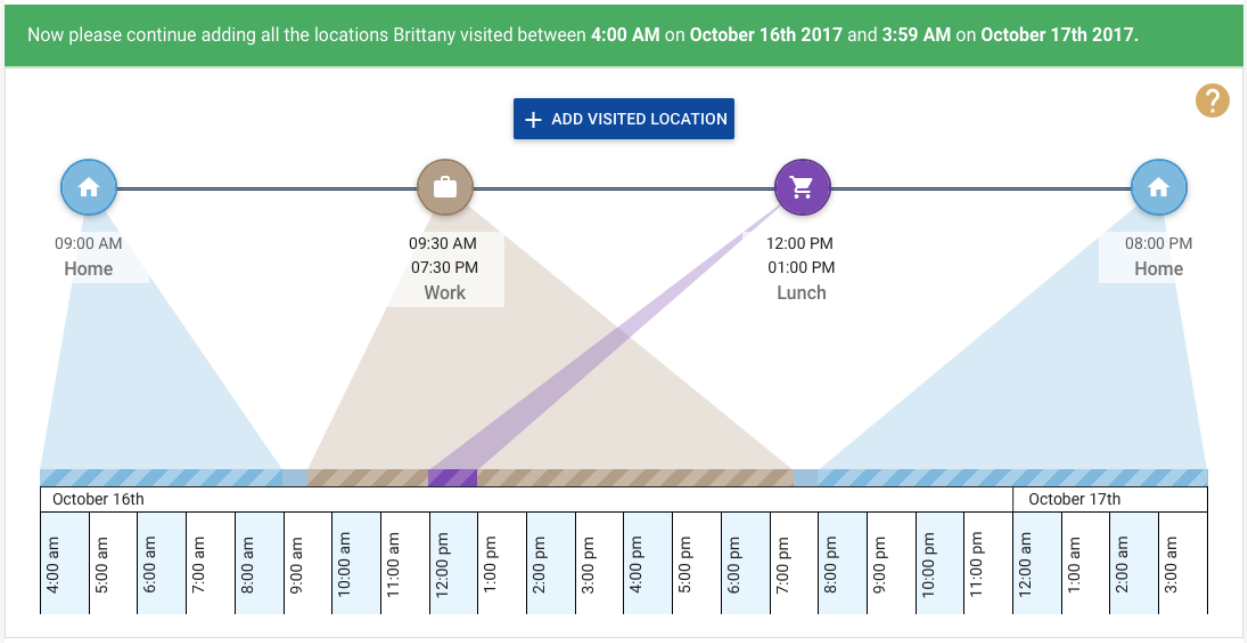

FIGURE 20. TRIP QUESTION #3 - EXAMPLE OF NESTED EPISODES IN TIMELINE

3.3.5 Respondents' Feedback and Suggestions

At the end of each field test survey, respondents were asked to share feedback and critical criticism of the trip question design. During the summer field tests, which is discussed further detail in Section 4.2, trip question #2 was piloted. The following are several notable comments and suggestions provided by respondents regarding the design of trip question #2:

- Areas of difficulty:
  - Adding and moving waypoints is difficult.
  - Respondents do not like being repetitively asked if they returned home at the end of every trip entered.
  - Cannot go back to edit trips without losing information previously entered.
  - Initial confusion when asked where they were at 4 am.
  - Cumbersome to add trips if a lot of trips were made and/or for a large household.
  - The question does not allow respondents to enter the same arrival time and departure time for a trip; this is problematic for short trips and drop-offs.
  - Whether to enter long distance trips and/or out-of-town trips is not clear.
  - The trip question at times seemed too repetitive.
  - The difficulty with completing the survey on mobile devices.
  - Not a very interesting survey.
  - It was not clear why certain questions are asked and how they help with transportation planning.
  - Entering arrival and departure times is time-consuming, especially since they are difficult to recall.
- Design features respondents liked:
  - Respondents appreciate the summary of their trips shown at the end of the question.
  - The alternative routes from Google Directions API help to reduce burden.
  - The question bar turning green/red is a good indication to the respondent when a question is complete or incomplete.
  - The progress bar of the trip segments at the top of the question helps respondents to keep track of which trip they were answering at the time.
  - The interactive map makes the question more engaging.
  - Some respondents like the repetitiveness of the trip question when entering routes because after the first few trip entries, they found they could enter their trip information faster as they could anticipate the next steps.
  - Questions and instructions are short and direct.
- Recommendations to improve the trip question design:
  - Make the trip question into multiple pages so it feels as though the respondent is progressing in the survey. At times they felt they were stuck on the trip question for a long time.
  - Would like a drag and drop feature to reorder locations visited.
  - Would like some open-ended, opinion-based questions on their view of transportation in their city.
  - Entering common places visited at the beginning of the survey instead of having to re-enter them into the trip question.
  - Simplified questions and tasks; too many instructions on the screen at once.
  - Some would prefer just to type and/or record a voice response to describe their routes instead of using the map interface.
  - Add the ability to draw on the maps instead of adding waypoints.
  - Would like to copy trips between household members to reduce burden.

Similarly, the fall field tests piloted trip question #3 and respondents were asked for feedback and suggestions at the end of their survey. The following are several notable comments and suggestions regarding trip question #3:

- Areas of difficulty:
  - Asking for the first and then the last location of the day is confusing and awkward.
  - Cumbersome design and question require a lot of mouse-clicking.
  - Some difficulty with completing the survey on mobile.
  - Clicking on tabs to proceed to next trip is not initially obvious. Perhaps each trip should be on separate pages.
  - Needed to confirm route selection by clicking on "Save Route" button is not initially obvious.
  - Calculated routes do not take into consideration rush hour travel times. The travel times shown do not always correctly reflect the actual travel time, especially trips during rush hour.
  - Entering multi-modal trips causes some initial confusion.
  - The survey is very time-consuming.
  - The design is a little too crowded. Some are overwhelmed by the number of buttons and features available on the page.
- Design features respondents liked:
  - Entering arrival/departure times is a little confusing, but the visual display on the timeline was helpful.
  - The graphics and the timeline feature make the survey engaging.
  - Respondents appreciate the mobile-responsive design.
- Recommendations to improve the design:
  - Preferred to be asked for trips in chronological order.
  - The tool tips are sometimes distracting, and it was not clear how to close them. Guidance and/or a tutorial could have been given upfront first.
  - Would like an easier, more user-friendly way to enter in arrival/departure times. A respondent recommends using a clock interface.
  - Many respondents would like to provide travel time.
  - Provide a completed timeline example for reference. A visual is better than reading a lengthy description of a trip. There was the uncertainty of what constitutes as a trip; therefore, more examples of a trip should be provided.
  - Would like to copy trips between household members to reduce burden.

In the mouse-tracking study, respondents were asked to compare the designs of trip question #2 and trip question #3 since they used both in the summer field test and the mouse-tracking study. The results are summarized in Figure 21, where trip question #2 is denoted as the "old design" and trip question #3 is the "new" design. It is evident that trip question #3 is seen as an improvement to trip question #2. Surprisingly, over 20% of respondents do not remember trip question #2 although they took the survey three months prior.

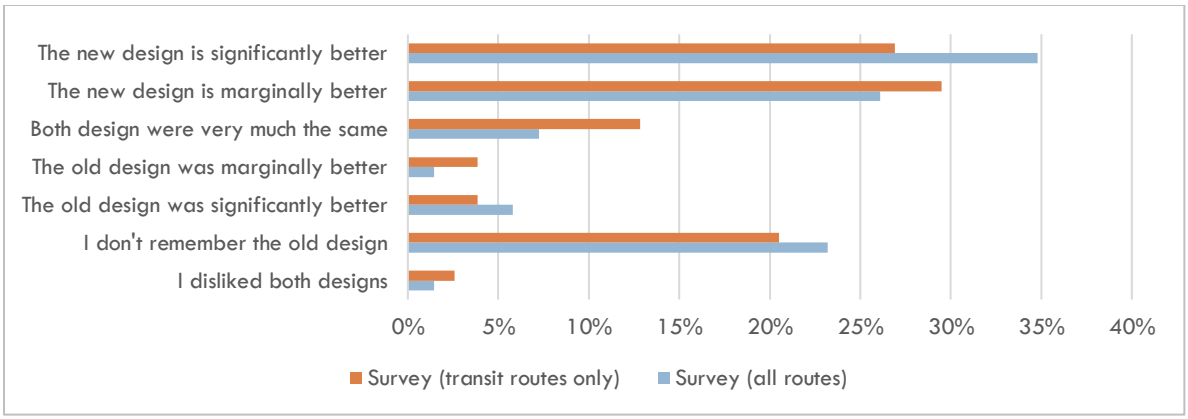

FIGURE 21. RESPONDENT'S IMPRESSION OF TRIP QUESTION #2 VS TRIP QUESTION #3

3.3.6 Final Design Recommendations

Throughout the iterative process of developing and testing trip question designs, many valuable lessons were learned. The following are some key, overall lessons learned:

- Respondents appreciate short, simple instructions guiding them through the question.
- Since users often remember short trips mid-way through their survey, a very forgiving design is needed.
- Separating the trip question into multiple pages confuses some users because they lose track of which trip they are answering for. However, page separation is needed as collecting all the trip information on a single page will result in an overwhelming and crowded interface. Therefore, if a multi-page design is implemented, a breadcrumb trail design is recommended so respondents can keep track of their progress in the trip diary.
- Minimize repetitive typing-to clicking-to typing tasks.
- Responsive web design is needed to cater to a range of screen sizes and improve usability.
- Asking respondents to adjust waypoints of their routes is a difficult task. Many respondents inaccurately drop waypoints while too zoomed out of the map, or try routes (particularly small walking and biking paths) that are not currently not mapped into Google Maps API.
- A graphically pleasing design that provides respondents feedback after every task motivates respondents to complete the survey.
- Typically older respondents experience more difficulty and response burden on a web-based survey.

It is obvious that trip question #3 stands as the best current design out of the three designs tested to date. However, there is still room for improvement based on the usability studies. Plans to develop the next trip question design iterations are currently underway. Based on the usability findings, the following are some recommended areas of improvement that are being explored:

- Simplifying the timeline design into several smaller steps/pages. This reduces the amount of information asked at a time and helps to declutter the page.
- Reduce the amount of information asked in the timeline; for example, only ask for departure time like in the TTS, instead of asking for both arrival and departure times.
- Create a more engaging timeline interface where elements can be dragged and reordered.
- Remove the ability to add nested episodes.
- Reconfigure the tab design used in the trip sequence question to a paged design.
- Add the ability to allow copying of trips between household members.

4 FIELD TESTS

Household travel surveys designed in the TRAISI web tool underwent field testing in the summer and fall of 2017. The primary objectives of the field tests were to test the usability of the web-survey designs and experiment with survey administration methods to improve data quality and reduce response burden. The design of both field tests and their results are discussed in this section of the report.

The summer field test 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 was to investigate if any of these methods have a significant impact on the completeness of the data and the burden on respondents.

Following the summer field test, significant changes were made to the trip question to address key usability concerns. Therefore, the fall field test was created to investigate the latest iteration of the trip question's design (i.e. trip question #3). These fall field test household travel surveys were distributed in late November 2017. In addition, to testing general usability issues, the field tests investigated the feasibility of collecting route information and experimented with providing respondents the option to complete their travel surveys through either a TRAISI web-survey or City-Logger's GPS app.

4.1 Description of Sample Frame and Survey Area

Field test 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. 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. For the summer field test, 7,700 households from the email list were sent email survey invitations. The fall field test contacted 10,000 households from the email list. The sampling process ensured that the two sets of the emails used for the field tests were random and did not overlap.

SELECT RESPONDENT DEMOGRAPHICS AND HOUSEHOLD STATISTICS OF THE TTS 2016, THE EMAIL FRAME, AND THE FIELD TESTS ARE PROVIDED IN

Table 4. The respondent's age and gender statistics include both self and proxy respondents who completed the survey. It is apparent that the average age of the email frame population is slightly younger than the entire TTS 2016 population. Although participants were drawn randomly from the email list for the field tests, it appears that household sizes with fewer members and older respondents were more likely to complete the summer field test compared to the fall field test. This discrepancy may be attributed to the differences in survey design of the two field tests.

TABLE 4. DEMOGRAPHIC AND HOUSEHOLD CHARACTERISTICS OF THE TTS 2016, EMAIL FRAME, AND FIELD TESTS

	TTS 2016	EMAIL FRAME	SUMMER FIELD TEST	FALL FIELD TEST
HOUSEHOLD SIZE (PERSONS)				
Mean	2.43	2.43	2.07	2.40
Standard Dev.	1.31	1.27	1.10	1.20
Maximum	12	11	8	7
Minimum	1	1	1	1
RESPONDENT'S AGE (YEARS)				
Mean	44.34	40.03	44.43	41.08
Standard Dev.	23.31	21.50	21.00	15.59
Maximum	99	99	91	88
Minimum	0	0	0	0
RESPONDENT'S GENDER (%)				
Male	48%	47%	50%	49%
Female	52%	53%	50%	51%

4.2 Summer Field Tests

For the summer field tests, two household travel surveys were created in TRAISI:

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. It should be noted that trip question design #2 was used in the survey.

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 opened and started 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 (AIA)

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

4.2.4 Results

The overall response rates of the two surveys are presented in Table 5. 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 5. DESCRIPTIVE STATISTICS OF SUMMER 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 the household's email were not sent sub-surveys. At the time of the field test, TRAISI 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 TRAISI, 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 6, the completion rates 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 6. DESCRIPTIVE STATISTICS OF SUB-SURVEY RESPONDENTS IN SUMMER FIELD TESTS

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 7. DESCRIPTIVE STATISTICS OF SUMMER FIELD TEST 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 7, 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 8, AND THE ANOVA RESULTS ARE PRESENTED IN

TABLE 9. A 95% CONFIDENCE LEVEL WAS ADOPTED FOR THE ANOVA ANALYSIS. AS SHOWN IN

Table 9, 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 8, 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 8. DESCRIPTIVE STATISTICS OF ANOVA VARIABLES FOR SUMMER FIELD TEST

Categories	Variables	Trip Rate [trips/day]			Trip Question Response Time [min]			Avg. 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

	11-18	88	0.91	2.43	88	5.06	81.04	5.56
(C)	**19 - 29**	142	2.04	3.85	139	6.17	49.64	3.03
Respondent's	**30 - 39**	201	2.72	4.73	190	9.66	94.42	3.55
age	**40-49**	230	2.35	3.94	222	8.49	89.87	3.61
[years]	**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 9. THREE-FACTOR ANOVA ANALYSIS FOR SUMMER FIELD TEST

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			

4.2.5 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 a 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 TRAISI 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.

4.3 Fall 2017 Field Tests

For the fall field tests, two household travel surveys using variations of trip question #3 were created in TRAISI:

1) Survey 1: Household travel survey where routes are collected for all trip routes; and
2) Survey 2: Household travel survey where only transit routes are collected – same as the TTS.

A total of 5000 households from the TTS 2016 email lists were sent Survey 1 and another 5000 households were sent Survey 2. These survey email invitations were distributed between November 11-17th, 2017. To remain relatively consistent with the 2016 TTS procedure, only weekday trips were collected, and the prompted recall method was employed.

In an attempt to increase response rates, two reminder emails were sent to respondents who did not start the survey; the first reminder was sent four days following the initial survey email invitation and the second reminder was sent four days following the first reminder email. Survey questions were the same across both surveys and were largely based on the 2016 TTS questionnaire.

In addition to testing the feasibility of collecting additional route information in the TTS, the field test also experimented with providing respondents the option to complete the web survey or

download a smartphone app (City Logger) to track their trips. Only email invitations to Survey 1 provided the additional option of the smartphone app. Survey 2 simply asked respondents to complete a web survey.

4.3.1 Results

The overall response rates of the two surveys are presented in Table 10 below. Compared to the summer field test that had an average response rate of 15%, the fall field test fared better with a 22% response rate. The increase in response rate is likely attributed to the two reminder emails sent to the fall field test participants. The completion rates between the two surveys are relatively comparable, as the completion rates for Survey 1 and Survey 2 are 54% and 55% respectively.

Interestingly in the joint TRAISI and CityLogger invitation for Survey 1, it is estimated that approximately 40% of respondents chose to download the CityLogger app and the remaining 60% of respondents chose the TRAISI web survey. Comparative analysis of the TRAISI web-survey respondents and the CityLogger respondents' demographics are provided in a separate report.

TABLE 10. DESCRIPTIVE STATISTICS OF FALL FIELD TEST RESPONSE RATES

	SURVEY 1 (ALL ROUTES)		SURVEY 2 (ONLY TRANSIT ROUTES)		TOTALS	
Total email invitations sent	5000	100%	5000	100%	10000	100%
Households chose CityLogger app	550 (estimate)	11%	N/A	N/A	N/A	N/A
Households started web-survey	813	16%	1382	28%	2195	22%
Households completed survey	439	9%	767	15%	1206	12%
Total complete trip diaries through the **WEB**	827	N/A	1629	N/A	2456	N/A

TABLE 11. DESCRIPTIVE STATISTICS OF FALL FIELD TEST RESPONDENT AND HOUSEHOLD

HOUSEHOLD SIZE [PERSONS]					
SURVEY	**Survey Status**	**Mean**	**Std. Dev.**	**Max.**	**Min.**
SURVEY 1 (ALL ROUTES)	Complete	2.07	1.10	7	1
	Incomplete	2.24	1.17	6	1
	All (Complete & Incomplete)	2.14	1.13	7	1
SURVEY 2 (ONLY TRANSIT ROUTES)	Complete	2.01	1.08	6	1
	Incomplete	2.27	1.20	8	1
	All (Complete & Incomplete)	2.11	1.14	8	1
MAIN RESPONDENT'S AGE [YEARS]					
SURVEY	**Survey Status**	**Mean**	**Std. Dev.**	**Max.**	**Min.**
SURVEY 1 (ALL ROUTES)	Complete	47.00	14.29	83	19
	Incomplete	52.53	15.57	94	17
	All (Complete & Incomplete)	49.21	15.05	94	17
SURVEY 2	Complete	48.53	14.00	88	21
	Incomplete	54.09	14.21	94	19

(ONLY TRANSIT ROUTES)	All (Complete & Incomplete)	50.82	14.35	94	19

MAIN RESPONDENT'S GENDER RATIO

SURVEY	VARIABLE	MALE	FEMALE
SURVEY 1 (ALL ROUTES)	Complete	48%	52%
	Incomplete	48%	52%
	All (Complete & Incomplete)	48%	52%
SURVEY 2 (ONLY TRANSIT ROUTES)	Complete	52%	48%
	Incomplete	54%	46%
	All (Complete & Incomplete)	53%	47%

As shown in Table 11, the respondent and household characteristics are relatively similar between the two surveys; however, a large difference is observed between completed and incomplete surveys. It is apparent that larger households tend to drop-out of the survey as the average household size for complete and incomplete surveys is approximately 2.04 and 2.25 people respectively. Figure 22 provides a visual comparison of the complete and incomplete surveys, and there is an obvious right-skew towards larger households for incomplete surveys. Furthermore, the results reveal that older respondents tend to drop-out of the survey. As shown in Figure 23, incomplete surveys also have obvious right-skew towards older respondents.

It is important to note that majority of the drop-off occurs at the trip question section of the survey; a detailed breakdown of the drop-off rates at each page of the survey is provided in Table 18 in Section 5.1. Given the finding that most of the survey drop-off occurs among larger households and older respondents, it is evident that the trip question must undergo further design iterations to accommodate older respondents and reduce burden for larger households. Similar conclusions are drawn from the usability studies discussed in Section 3.3.

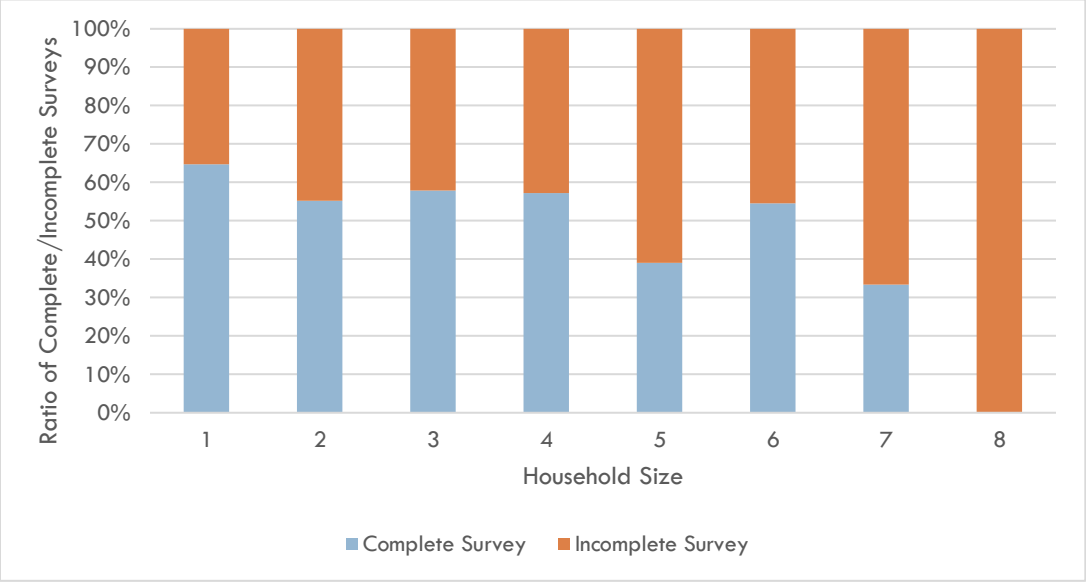

FIGURE 22. FALL FIELD TEST SURVEY COMPLETION BY HOUSEHOLD SIZE

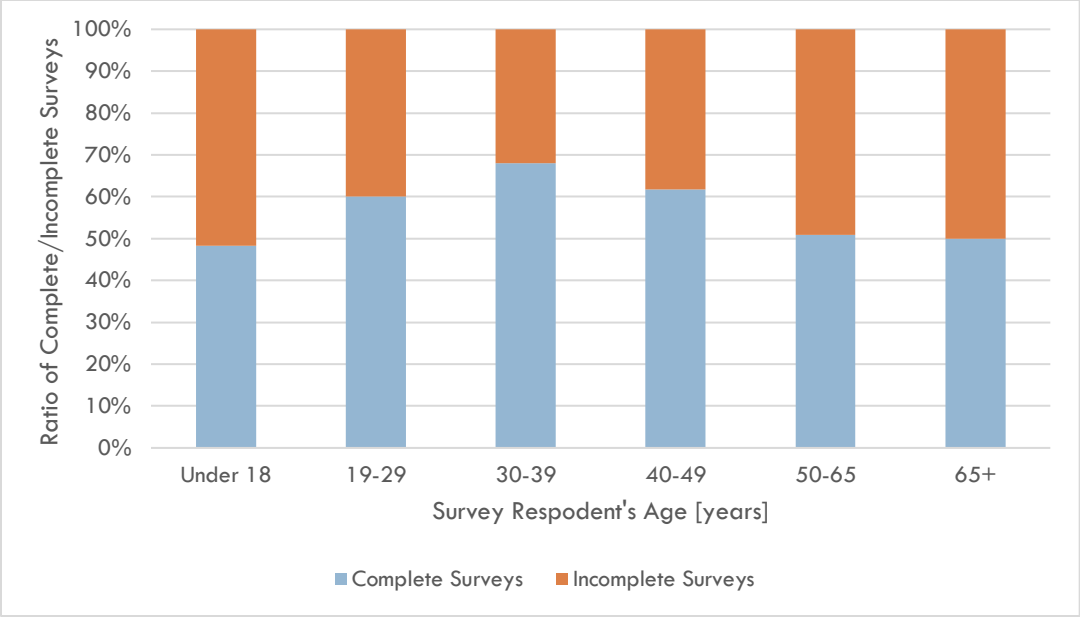

FIGURE 23. FALL FIELD TEST SURVEY COMPLETION BY MAIN RESPONDENT'S AGE

To investigate the performance of trip question #3's adaptive designs, the device used by the survey respondents is analyzed. Table 12 and Table 13 summarizes the share of devices used in the complete and incomplete surveys, respectively. The percent distribution of devices used in complete and incomplete surveys are reasonably comparable to the completion rates based on the device used ranged from 56% to 61%. Given only a maximum 5% difference in completion rate across the devices, it can be said that the type of device used to answer the survey did not have a significant influence on the survey completion rate. However, the results of the usability tests discussed in Section 3.3.4 somewhat contradicts this finding as it was found that the completion rates for tablet respondents were appreciably worse while the mobile respondents had higher completion rates. The additional length and burden of the field test surveys may have caused respondents to a drop-off in the earlier sections of the survey before the trip question. The length of the field test survey may have been more pronounced for mobile users since each question on the survey was separated into individual mobile screen pages, as opposed to the scrolling design seen on tablet and desktop surveys.

Respondents who did not complete their survey were less likely to use multiple devices. Over 81% of respondents used a single device during their survey and over 74% of these single device respondents used a desktop. Those that use more than one device tend to start on mobile and then switch to a desktop. Therefore, the mobile design of the survey is not as user-friendly as the desktop design. The mobile design that collects all trip routes used in Survey 1 is observed to have the most number of mobile to desktop switches. This finding is anticipated given that entering routes and manipulating way-points on a small mobile screen is much more difficult than on desktop. Since Survey #2 only collected transit routes and did not allow respondents to edit the routes waypoints, it is inherently more user-friendly on mobile; thus, the percentage of surveys completed over tablet and mobile is approximately 16% more in Survey #2 than Survey #1.

TABLE 12. DEVICES USED IN COMPLETED FALL FIELD TEST SURVEYS

Households who used only one device for survey

		Survey 1 (All Routes)		Survey 2 (Only Transit Routes)	
		Count	%	Count	%
Device Used:	DESKTOP	352	90%	549	74%
	TABLET	28	7%	119	16%
	MOBILE	10	3%	73	10%
Households who used more than one device for survey					
		Survey 1 (All Routes)		Survey 2 (Only Transit Routes)	
		Count	%	Count	%
First Device Used:	DESKTOP	0	0%	1	4%
	TABLET	0	0%	0	0%
	MOBILE	73	100%	26	96%
Last Device Used:	DESKTOP	73	100%	26	96%
	TABLET	0	0%	0	0%
	MOBILE	0	0%	1	4%

TABLE 13. DEVICES USED IN IN-COMPLETE FALL FIELD TEST SURVEYS

Households who used only one device for survey					
		Survey 1 (All Routes)		Survey 2 (Only Transit Routes)	
		Count	%	Count	%
Device Used:	DESKTOP	279	92%	443	74%
	TABLET	18	6%	96	16%
	MOBILE	7	2%	56	9%
Households who used more than one device for survey					
		Survey 1 (All Routes)		Survey 2 (Only Transit Routes)	
		Count	%	Count	%
First Device Used:	DESKTOP	0	0%	3	16%
	TABLET	0	0%	0	0%
	MOBILE	0	0%	16	84%
Last Device Used:	DESKTOP	0	0%	16	84%
	TABLET	0	0%	0	0%
	MOBILE	0	0%	3	16%

Given Survey 2's simplified trip question, it was anticipated that respondents would find it easier to log multimodal trips. As shown in Table 14 below, approximately two times more multi-modal trips are reported in Survey 2 than in Survey 1; however, it is important to note that the share of multi-modal trips collected is relatively small. Note that transit trips with walk access and egress are not considered a multi-modal trip in Table 14. The primary purpose of the mode share summary is to identify the portion of trips where respondents use the switch mode function in the two surveys. Google directions API provides walking routes to, from, and between transit stops and thus respondents reporting typical transit-walk trips did not need to use the switch mode function.

Therefore, it can be said that respondents are twice as likely to use the switch mode function given the simplified trip question.

More than 50% of trips collected in the field test were auto driver trips. A fair number of passenger, transit, and walking trips were also collected. The mode shares are relatively comparable between the two surveys except for a slight difference in the auto driver and auto passenger mode share percentages. It appears that Survey #1 collected more passenger trips than Survey #2. There is no logical explanation for this discrepancy, though it may be a result of different days' survey invitations were sent for each survey. For example, the field test was still active during Black Friday (November 24th, 2017) and reminders for Survey #1 were emailed out on Monday, November 27th. If participants started their survey on Monday, November 27th, they were asked to report last Friday's trips. Trips reported for Black Friday could have inflated the number of passenger trips observed in Survey 1.

Also shown in Table 14, the percentage of the type of trips by purpose is relatively similar between the two surveys except that more home-based-work trips are reported in Survey 2 and more home-based-discretionary trips are reported in Survey 1. Again, there is no logical explanation for this discrepancy apart from the one previously stated. Home-based-discretionary trips could have been inflated in Survey 1due to shopping trips made on Black Friday.

TABLE 14. FALL FIELD TEST REPORTED TRIPS BY MODE AND PURPOSE

		SURVEY 1 (ALL ROUTES)	SURVEY 2 (ONLY TRANSIT ROUTES)
Trip Mode	Driving	50%	56%
	Passenger	13%	9%
	Transit	14%	13%
	Walking	17%	14%
	Biking	4%	3%
	Other modes	1%	1%
	Multi-modal trips	2%	4%
Trip Purpose	Home-Based-Work	25%	32%
	Home-Based-School	7%	8%
	Home-Based-Discretionary	39%	33%
	Non-Home-Based	29%	27%

To investigate the effects of trip question #3 design on the completeness of the trip data and burden on respondents, a three-factor unbalanced ANOVA analysis was performed on the following variables:

- Independent variables:
  - (A) Route collection: Survey 1 (all routes), Survey 2 (only transit routes)
  - (B) Respondent's age: 11-18, 19-29, 30-39, 40-49, 50-65, 65+
  - (C) The last device used: desktop, tablet/mobile
- Dependent variables: respondent's trip rate [trips/day], respondent's trip question response time [minutes]

It is assumed that completeness of trip data and respondent burden are indirectly measured by respondent trip rates and trip question response times, respectively. Note that the ANOVA analysis excludes surveys completed in multiple sessions as it is difficult to determine the actual time a respondent spent on the survey.

Descriptive statistics of the variables are presented in Table 15, and the ANOVA results are presented in Table 16. A 95% confidence level was adopted for the ANOVA analysis. As shown in Table 16, none of the factors have a statistically significant direct effect on respondent's trip rates. However, the joint interaction effects of all three factors and the joint effect of route collection and last device used have statistically significant impacts on respondents' trip rates. This reveals that certain combinations of these factors can influence the trips reported by a respondent. All direct and interaction effects of the factors, except for route collection, are shown to have statistically significant impacts on the trip response times. Therefore, it is evident that asking for additional route information does not significantly decrease trip rates or increase response burden. However, response burden experienced is related to the respondent's age and the device they use to answer the survey.

As shown in Table 15, the trip rates are relatively comparable between Survey 1 and Survey 2. However, as anticipated, response times are slightly longer in Survey 1 as it asks for more route information. Similar to the findings in the summer field tests, the average response time per trip appears to increase with age. Longer response times can indicate greater burden; thus, it is understandable why older respondents tend to drop out of the survey, as shown previously in Figure 23. Interestingly, surveys done on tablet/mobile appear to have shorter response time per trip compared to desktop. This rather unintuitive finding may be the result of Survey 2 having greater share of tablet/mobile completed surveys than Survey 1.

TABLE 15. DESCRIPTIVE STATISTICS OF ANOVA VARIABLES FOR FALL FIELD TEST

		Trip Rate [trips/day]			Trip Question Response Time [min]			Avg. response time per trip
Categories	Variables	**Count**	**Mean**	**Var.**	**Count**	**Mean**	**Var.**	[min/trip]
(A) Route collection	Survey 1 (all routes)	417	2.92	2.12	417	8.47	0.85	4.00
	Survey 2 (only transit routes)	916	2.99	2.80	916	8.04	0.76	2.87
(B) Respondent's age [years]	11-18	88	2.64	1.31	88	3.05	0.01	2.33
	19 - 29	170	2.81	1.90	170	5.32	0.34	2.80
	30 - 39	365	3.08	3.04	365	7.64	0.62	2.51
	40-49	275	3.12	2.75	275	8.82	0.70	3.21
	50-65	335	2.95	2.69	335	10.12	1.00	3.76
	65+	100	2.74	2.23	100	11.19	1.34	5.02
(C) Last Device Used	Desktop	1073	2.96	2.56	1073	8.28	0.80	3.23
	Tablet/ Mobile	260	2.98	2.69	260	7.73	0.70	2.87

TABLE 16. THREE-FACTOR ANOVA ANALYSIS FOR SUMMER FIELD TEST

ANOVA: TRIP RATE				Alpha	0.05	
	SS	*df*	*MS*	*F*	*p-value*	*sig*
(A) Survey	0.98	1	0.98	0.39	0.53	no
(B) Respondent's Age	16.27	5	3.25	1.29	0.26	no
(C) Last Device Used	0.11	1	0.11	0.04	0.84	no

(A) x (B)	7.95	5	1.59	0.63	0.68	no
(A) x (C)	69.28	1	69.28	27.54	0.00	yes
(B) x (C)	7.93	5	1.59	0.63	0.68	no
(A) x (B) x (C)	47.24	5	9.45	3.76	0.00	yes
Within	3292.66	1309	2.52			
Total	3442.41	1332	2.58			

ANOVA: TRIP QUESTION RESPONSE TIME				Alpha	0.05	
	SS	*df*	*MS*	*F*	*p-value*	*sig*
(A) Survey	0.01	1	0.01	1.02	0.31	no
(B) Respondent's Age	1.14	5	0.23	22.14	0.00	yes
(C) Last Device Used	0.05	1	0.05	4.45	0.04	yes
(A) x (B)	0.64	5	0.13	12.37	0.00	yes
(A) x (C)	0.05	1	0.05	4.86	0.03	yes
(B) x (C)	0.47	5	0.09	9.07	0.00	yes
(A) x (B) x (C)	1.60	5	0.32	31.07	0.00	yes
Within	13.47	1309	0.01			
Total	17.42	1332	0.01			

4.3.2 Discussion

The fall field test survey results reveal that asking for additional route information, beyond the transit route information traditionally asked in TTS, does not significantly add to the survey burden or significantly decrease respondent's trip rates. However, it is found that respondents are twice as likely to report multi-modal trips when given the simplified trip question compared to a trip question that asks for all trip routes details. Therefore, although the route collection variation in trip question #3's design may not significantly reduce the number of trips reported by a respondent, it may compromise the quality and level of detail of data collected such as the reporting of multi-modal trips.

Furthermore, provided trip question #3's current design, asking only for transit routes and not allowing respondents to add waypoints to their routes results in a better, mobile-friendly design. Fewer mobile survey respondents will drop-out of the survey or will need to switch to a desktop. Therefore, when designing a household travel survey, the survey designer may need to consider collecting less detailed route information for mobile survey respondents.

It is evident that a large majority of respondents (over 80%) tend to take the survey on a desktop. Even with a large screen, respondents still appear to have issues with the trip question as nearly all the survey drop-off occurs at the trip question. Therefore, further testing and design iterations are needed to improve the trip question design. Household size and the age of the main respondents are contributing factors to the survey drop-off rates. Older respondents and larger households appear to experience more response burden when completing the survey, and thus are more likely to leave the survey.

5 COMPARISON OF 2016 TTS AND TRAISI WEB SURVEY

The field tests were designed to maintain as many elements of the 2016 TTS questionnaire while testing new methods and features. Given the similarity in elements between the field test survey and the 2016 TTS, various aspects can be compared and discussed. Unfortunately, statistical comparison of the field test and the 2016 TTS is infeasible provided the various biases introduced by significant differences in the sample frame, and survey design/administration. However, an overall comparison helps to highlight key findings and remaining issues to investigate.

5.1 Survey Abandonment

The summer and fall field test surveys have approximate completion rates of 61% and 55% respectively. Table 17 and Table 18 summarizes the survey retention rate and completion rate at each survey page of summer and fall field tests, respectively. It is important to note that Table 17 reports completion rates for only the prompted recall survey as it is the most comparable to the fall field test and the 2016 TTS design. An analysis of the 2016 TTS partial responses reveals that the 2016 TTS web-survey achieved a 76% completion rate. The significant difference in completion rates between the surveys is attributed to various factors such as the 2016 TTS having official Ministry of Transportation (MTO) issued letters. Also, it is important to note that the email list population used in the field test had completed a similar survey just a year prior which may have played a role in the response rates. Furthermore, Malatest, the market research firm hired to execute the 2016 TTS, had call centres make up to five telephone calls to households who abandoned their surveys to provide technical assistance. Though the fall field tests sent reminder emails to those who did not start their survey, no contact was made to encourage respondents who started but abandoned their survey. With Malatest's strategy to revive abandoned surveys, 5,488 of surveys completed online were initially started online and then completed over the phone. Therefore, this goes to show the importance of CATI support to increase completion rates (Malatest, 2017).

Malatest speculates that many cases of abandoned surveys were due to fatigue, as they received several complaints that the survey was too long and cumbersome (Malatest, 2017). Similarly, complaints about the survey length and cumbersome design were also received during the field tests. As discussed in Section 4.3.1, larger households and older respondents tend to take longer to enter their trip information and, thus, experience greater fatigue and drop-out rates. The 2016 TTS also found that the representation of larger households in the final dataset was much lower than that of the general population (Malatest, 2017).

As shown in Table 17 and Table 18, a large majority of the survey drop-off occurs at the trip-diary collection stage of the field test surveys. An analysis of the 2016 TTS also reveals that the majority (59%) of its drop-off occurs at the trip diary collection web-survey pages as well. The remaining drop-off occurs at the survey introduction (23%), and at the demographics section (18%) of the survey. The field tests experiences around a 10% drop-off rate at the demographic section of the survey. However, it is evident that the trip question portion of the survey attributes to the majority of the survey drop-offs. The next section of the report discusses the trip question performance and its issues in further detail.

TABLE 17. SUMMER FIELD TEST COMPLETION RATES BREAKDOWN (PROMPTED-RECALL SURVEY)

Survey Page	Question ID	Hhld Count	Retention rate	Completion Rate
0	Started Survey:	541	100.0%	100.0%
1	home_address	538	99.4%	99.4%
	dwell_type			
	n_vehicles			
	hhld_income			
2	veh_type	conditional page		
	veh_year			
	fuel_type			
3	hhld_pers	491	91.3%	90.8%
4	sex	490	99.8%	90.6%
	age			
5	emp_stat	485	99.0%	89.6%
	student_status			
6	occupation	484	99.8%	89.5%
	work_address			
	school_address			
7	driver_lic	484	100.0%	89.5%
	trans_pass			
	free_park			
8	Trip (trip question #2)	331	68.4%	61.2%
	trip_proxy			
9	Confusion	330	99.7%	61.0%
	Impression			
	Liked_features			
	Recommendations			
	Smartphone			
	tech_issue			
10	Dissatisfied_TripTest	305	92.4%	56.4%
	Satisfied_TripTest			

TABLE 18. FALL FIELD TEST COMPLETION RATES BREAKDOWN

Survey Page	Question ID	Survey 1 (All Routes)			Survey 2 (Only Transit Routes)		
		Hhld Count	Retention rate	Completion Rate	Hhld Count	Retention rate	Completion Rate
0	Started Survey:	813	100.0%	100.0%	1382	100.0%	100.0%
1	home_address	808	99.4%	99.4%	1369	99.1%	99.1%
	dwell_type						
	n_vehicles						
2	Household_alt	777	96.2%	95.6%	1307	95.5%	94.6%
3	age	775	99.7%	95.3%	1304	99.8%	94.4%
	sex						
4	student_status	770	99.4%	94.7%	1299	99.6%	94.0%
	emp_stat						
5	occupation	756	98.2%	93.0%	1270	97.8%	91.9%
	school_address						
	work_address						
6	trans_pass	754	99.7%	92.7%	1268	99.8%	91.8%
	driver_lic						
	free_park						
7	Trips (trip question #3)	440	58.4%	54.1%	769	60.6%	55.6%
	trip_proxy						
8	hhld_income	439	99.8%	54.0%	767	99.7%	55.5%
	Confusion						
	tech_issue						
	Impression						
	Liked_features						
	Recommendations						

5.2 Trip Question Performance

Although trip question #3 was designed to address the issues discovered with trip question #2, trip question #3, used in the fall field test, experienced an approximately 5% greater drop-off rate than the summer field test which used trip question #2. Judging from the mouse-tracking study (Section 3.3.4) and respondent's feedback (Section 3.3.5), the design of the timeline portion may be causing the higher drop-off rates. The timeline may be asking for too much information at once which overwhelms the respondent. With trip question #2, the respondent is asked to simply list the places they visited in chronological order and then on a separate page they are asked to enter their arrival and departure times. In trip question #3 list of places visited, arrival and departure time, as well as the location of the places, are all asked in the timeline. Therefore, as suggested in Section 3.3.5, elements from trip question #2 should be borrowed to improve the next trip question design iteration.

Usability test results, as discussed previously in Section 3.3, reveals that respondents generally prefer trip question #3 over trip question #2 but there are still major usability improvements to be made. Malatest also realizes very similar usability improvements needed for their 2016 TTS web-based trip question such as the need to copy trips between household members, and the ability to allow participants to easily edit their trip diary. The summer field tests concluded with the same findings and, thus, trip question #3 was designed to improve the flexibility of editing trips. However, due to programming constraints, copying trips between household members is to be explored in the next trip question design iteration.

Malatest noticed that providing simple definitions of the types of trips to report over the web survey was a challenge as trips defined by the scope of the TTS is rather limited (i.e. exclusion of recreational bicycling and walking trips, round-trips, work-related trips, etc.) (Malatest, 2017). The field test surveys also faced this issue with many respondents did not attempt to read the more expansive trip definition provided. Although the field test surveys did not instruct respondents to exclude reporting recreational bicycling and walking trips, Malatest found this exclusion caused many complaints and could have been a driver of survey abandonment (Malatest, 2017). Interestingly, this exclusion has been the standard in TTS as it is thought to reduce response burden. Perhaps with a well-designed trip question, the added burden of reporting recreational biking and walking trips may be minimal. However, it should be noted that collecting detailed biking and walking trip routes may not currently be feasible. Numerous field test respondents found it difficult to report the routes taken on the interactive map as many off-street cycling routes, alleys, and paths through buildings are not returned by the Google Maps API.

5.3 TTS Questionnaire Design

Further complaints and survey abandonment were observed in the 2016 TTS due to the questions asked in the survey. In addition to being displeased about the trip definition, as discussed in Section 5.2, some respondents discontinued the survey because they did not understand why the survey was collecting certain 'sensitive' demographic information (Malatest, 2017). The field tests also found some respondents questioning why certain questions were asked and how it helps with transportation planning. With a better understanding of the purpose of the questionnaire and its importance, motivation to complete the survey may be sustained.

Malatest noted that many respondents complained about the pertinence of the household income question in the survey. Interestingly, an analysis of the 2016 TTS reveals that less than 1% of respondents left the survey when it came to the household income question, which was asked at the end of the survey. Placing sensitive information, such as income, at the end of surveys has been a strategy used by many regional travel surveys. It is thought that once a respondent reaches the end of the survey, they are less skeptical about sharing this information as they have already committed to the survey. The field test experimented with the placement of the income question at the beginning and end of the survey and arrived at the same conclusion. As shown in Table 17, the income question was placed on the first page of the questionnaire for the summer field test. The drop-off rate experienced between the first and second pages is approximately 10%. However, in the fall field test, the income question is placed on the last page of the questionnaire. As shown in Table 18, the drop-off rate between the same two pages is now approximately 5%. Notably, the drop-offs at the last page of the survey with the income question are nearly negligible. Therefore, this implies that having the income question at the beginning of a survey could result in a 5% increase in drop-offs.

In addition to experimenting with the placement of the household income question, the field test also experimented with adding additional questions and response options. In the summer field test, additional questions about the household vehicles (i.e. vehicle type, year, fuel type) were added

as these are very common questions in many other household travel surveys. No significant survey drop-offs result from the addition of these questions. Furthermore, the fall field test experimented with adding additional travel mode options, as various respondents complained that the current TTS mode option list is limited. A total of fourteen travel mode options were provided, which included a few additional modes such as wheelchair, paratransit, and flight. Displaying all the options, however, in a radio button list is poor survey design practice, as the long list of options may overwhelm respondents and introduce biases. As a result, an icon-based accordion design, as shown in Figure 24, is used to categorize the mode options and display a subset of relevant options to the respondent. This design proved successful as no issues are detected with the mode selection in the usability tests. Therefore, for future TTS web-survey questions with many response options, a similar accordion design should be considered.

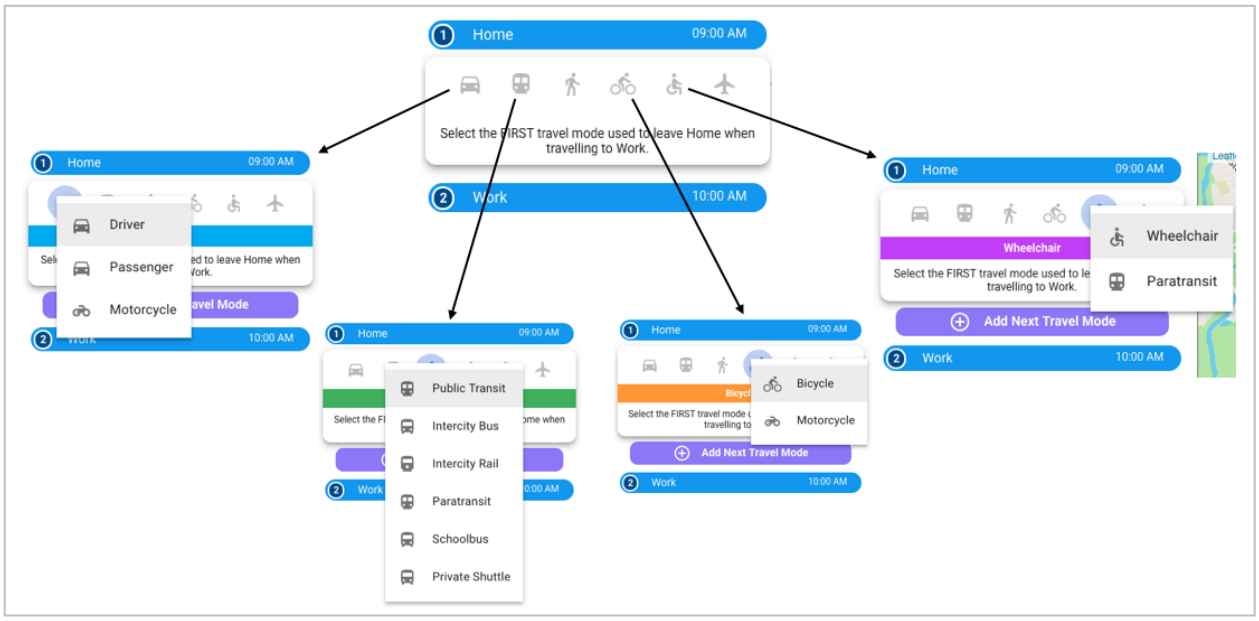

FIGURE 24. TRIP QUESTION #3 - MODE SELECTION ACCORDION DESIGN

OTHER TTS QUESTIONS THAT RECEIVE NUMEROUS COMPLAINTS ARE THE LIMITED OCCUPATION AND TRIP PURPOSE CATEGORIES. RESPONDENTS THOUGHT THE RESPONSE OPTIONS ARE TOO AGGREGATE AND NOT REPRESENTATIVE OF THEIR OCCUPATION AND/OR TRAVEL. ALTHOUGH THE PURPOSE OF PROVIDING FEW RESPONSE OPTIONS IS TO REDUCE RESPONSE BURDEN, IN THESE CASES THE LIMITED OPTIONS CAUSE RESPONDENTS CONFUSION AND DISSATISFACTION. FURTHERMORE, FROM A TRANSPORT MODELLING STANDPOINT, THIS HIGH LEVEL OF AGGREGATION DOES NOT HELP TO CAPTURE THE EXPLANATORY EFFECTS OF THESE VARIABLES IN MODELS. FOR EXAMPLE, IN THE 2016 TTS, 15% OF THE TRIPS REPORT AN "OTHER" PURPOSE WHICH IS A RELATIVELY LARGE SHARE OF TRIPS COMPARED TO TRIPS MADE BY OTHER MODES AS SHOWN IN

Table 19. This catch-all category "other" does not provide much information and, thus, compromises the explanatory power of a transport model. Therefore, the TTS questionnaire should reconsider the response categories for these questions.

TABLE 19. 2016 TTS TRIPS BY PURPOSE

Trip Destination Purposes	% of Trips
Daycare	1%
Facilitate passenger	6%
Home	42%
Market/Shop	10%
Other	15%
School	5%
Work	20%
Total:	100%

6 CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

This report 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 (TRAISI), along with statistical analysis of field tests examining various survey methods. The field tests experimented with trip route collection through an interactive map interface and voluntary self and proxy reporting methods through a custom survey feature (household question). In addition, the report 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 the respondent burden is analyzed through an 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.

Various usability studies conducted on several iterations of the trip question design reveal some usability issues and considerations to be focussed on for future iterations of the platform. It is found that older respondents and larger household are more likely to leave the survey when it came to the trip question. Although a large majority of respondents typically complete the survey over a desktop, a responsive design is needed to address usability issues due to smaller screen sizes on mobile and tablets. Usability concerns and survey abandonment is particularly pronounced in small screen devices when respondents are asked to input their trip routes in the interactive map. Waypoints are difficult to place and small walk/bike ways, in particular, are not mapped into the Google Maps API. However, an ANOVA analysis of the field test results reveal that asking for trip routes, beyond just the transit routes asked in the TTS, does not significantly add to the survey burden or significantly decrease respondent's trip rates. Overall, collecting trip route information through a web-survey is a feasible option, although inputting routes of walk and bike trips should be omitted as it increases respondent frustration.

Based on the usability and field test findings, it is evident that additional improvements are needed for the current trip question in TRAISI, such as simplifying the timeline design and allowing respondents to copy trips between household members. Other remaining work includes re-evaluating the current TTS questionnaire as various issues, such as the limited occupation and trip purpose options, were apparent in the 2016 TTS and field tests.

7 ACKNOWLEDGMENTS

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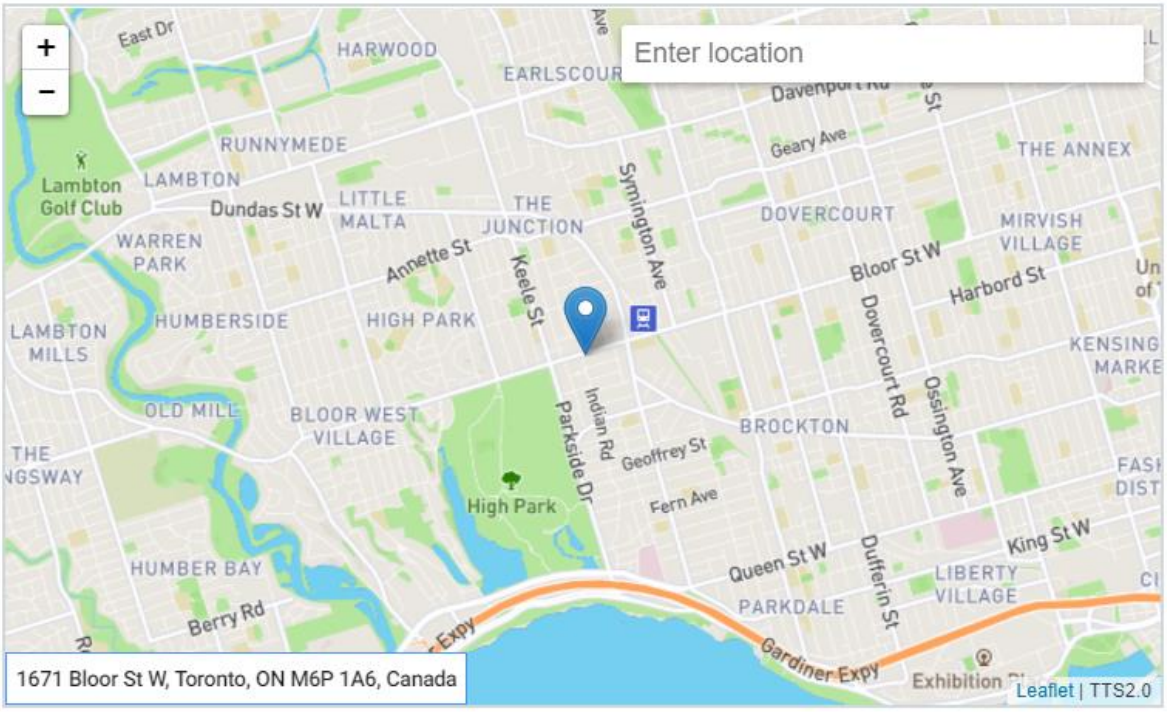
APPENDIX – SAMPLE QUESTIONNAIRE

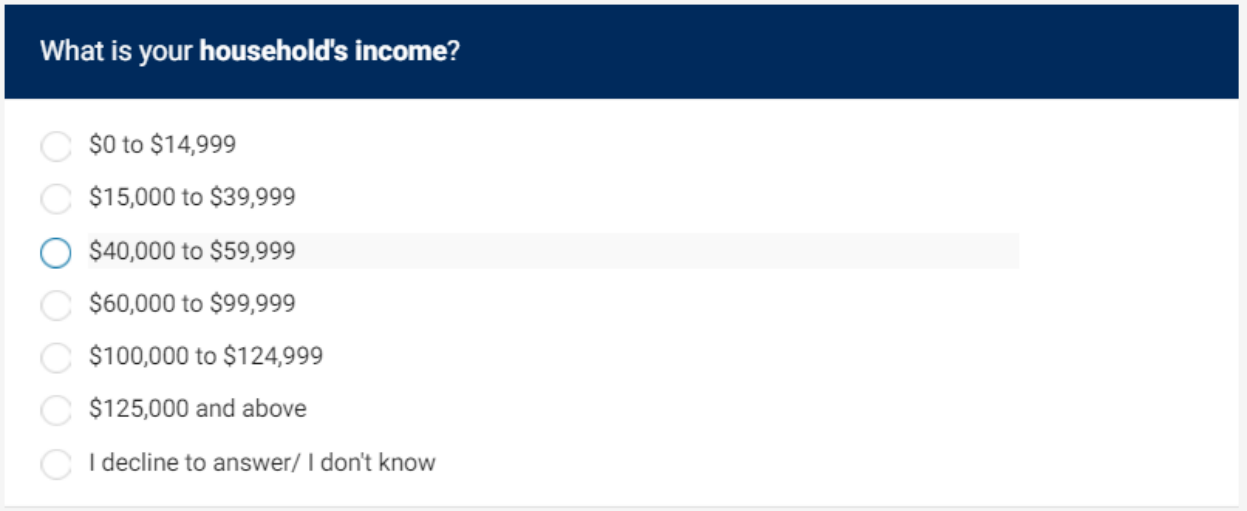
Page 1: Household

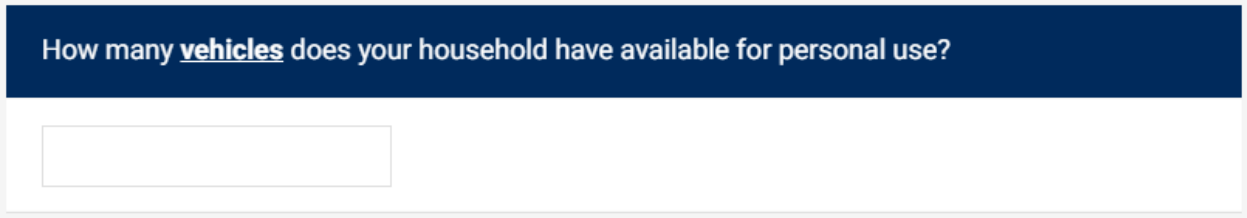
Please identify the **current address of your household** by dropping a pin on the map and/or using the search function below.



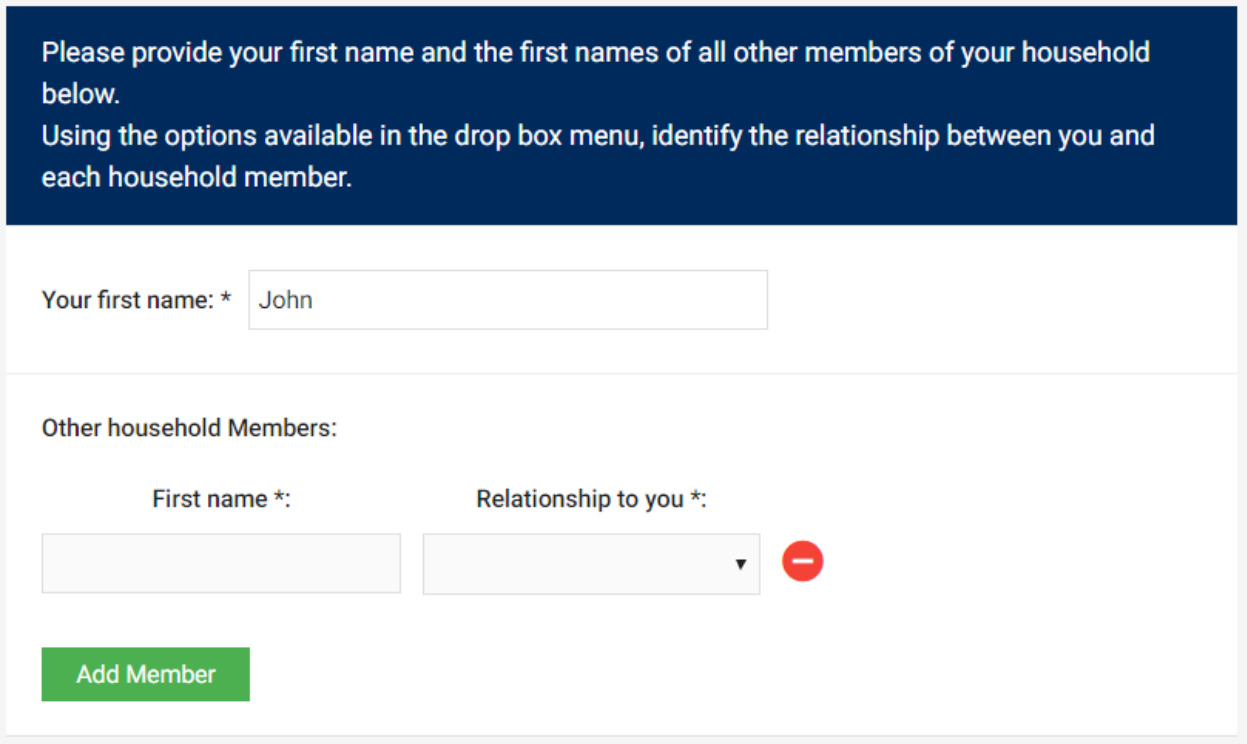
Please select the **dwelling type** of your household.

- ○ House
- ○ Apartment
- ○ Townhouse
- ○ Other
- ○ I don't know



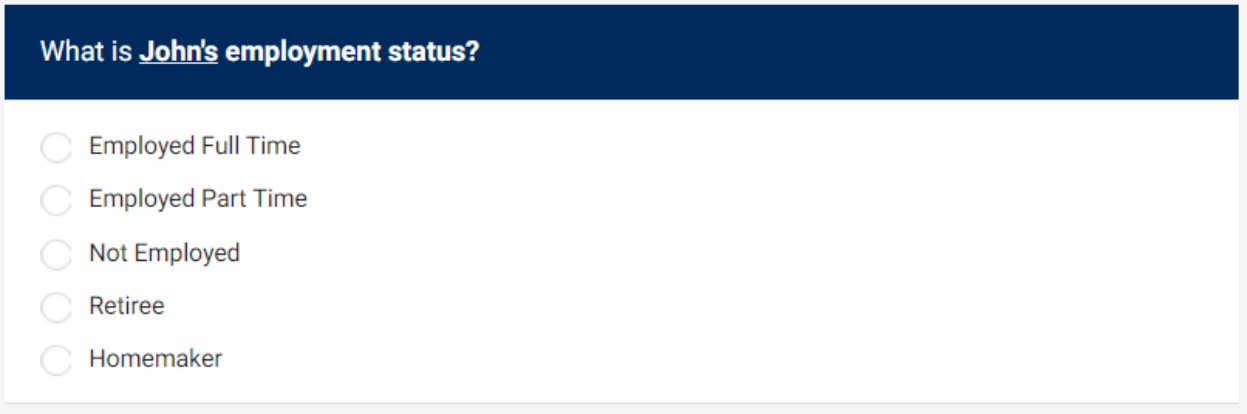


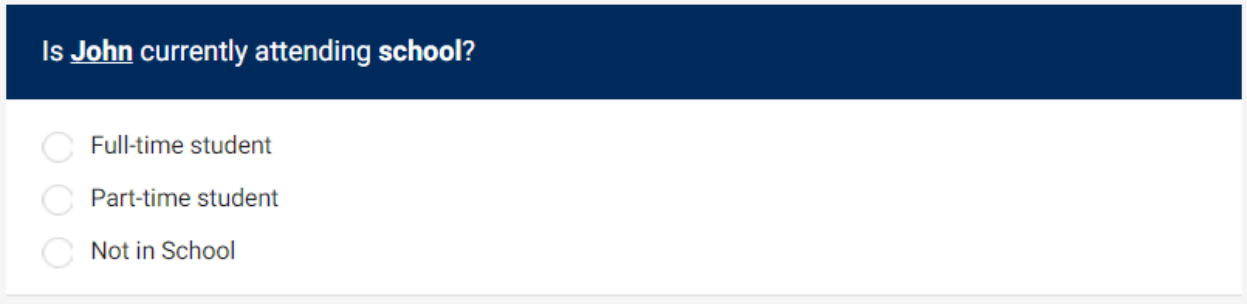
Page 2: Members



Page 3: Demographics

Page 4: Employment





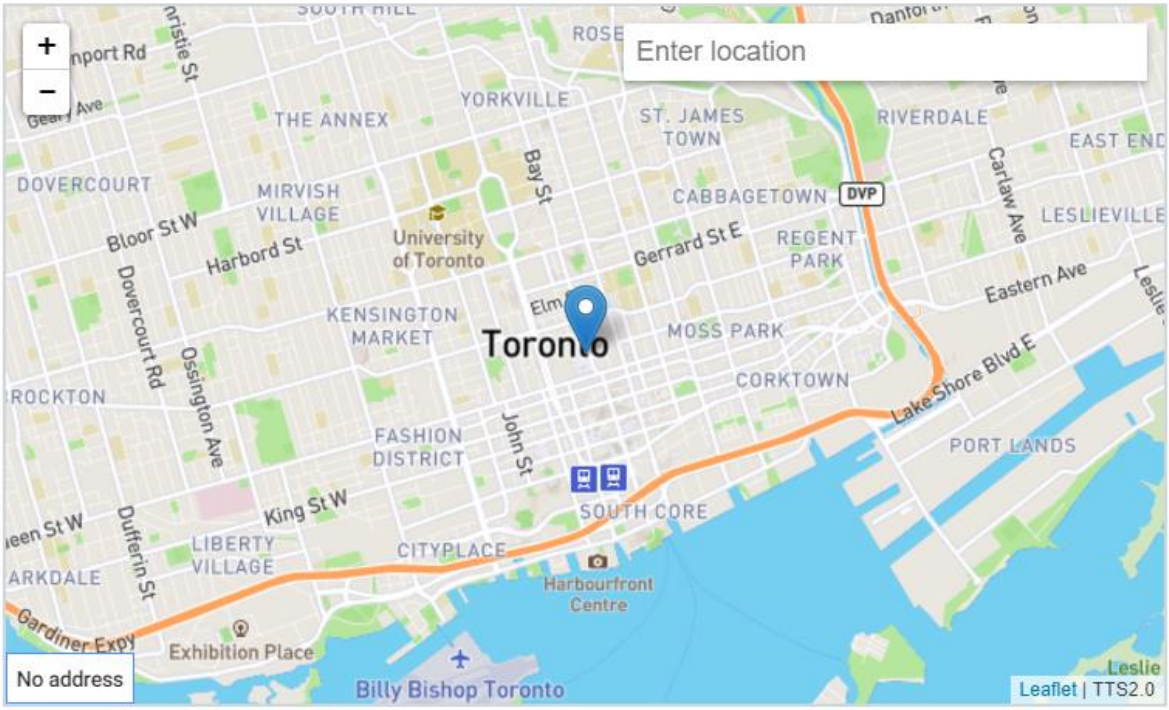
Page 5: Employment

What is the field of John's occupation?

- ○ General Office / Clerical
- ○ Manufacturing / Construction / Trades
- ○ Professional / Management / Technical
- ○ Retail Sales and Services

Please identify the location of John usual place of work by selecting one of the options.

- ○ Work from home
- ○ No usual place of work
- ○ Usual place of work which is shown in the map below



Page 6: Transportation

Is there **free parking at John's place of work?**

- Yes
- No

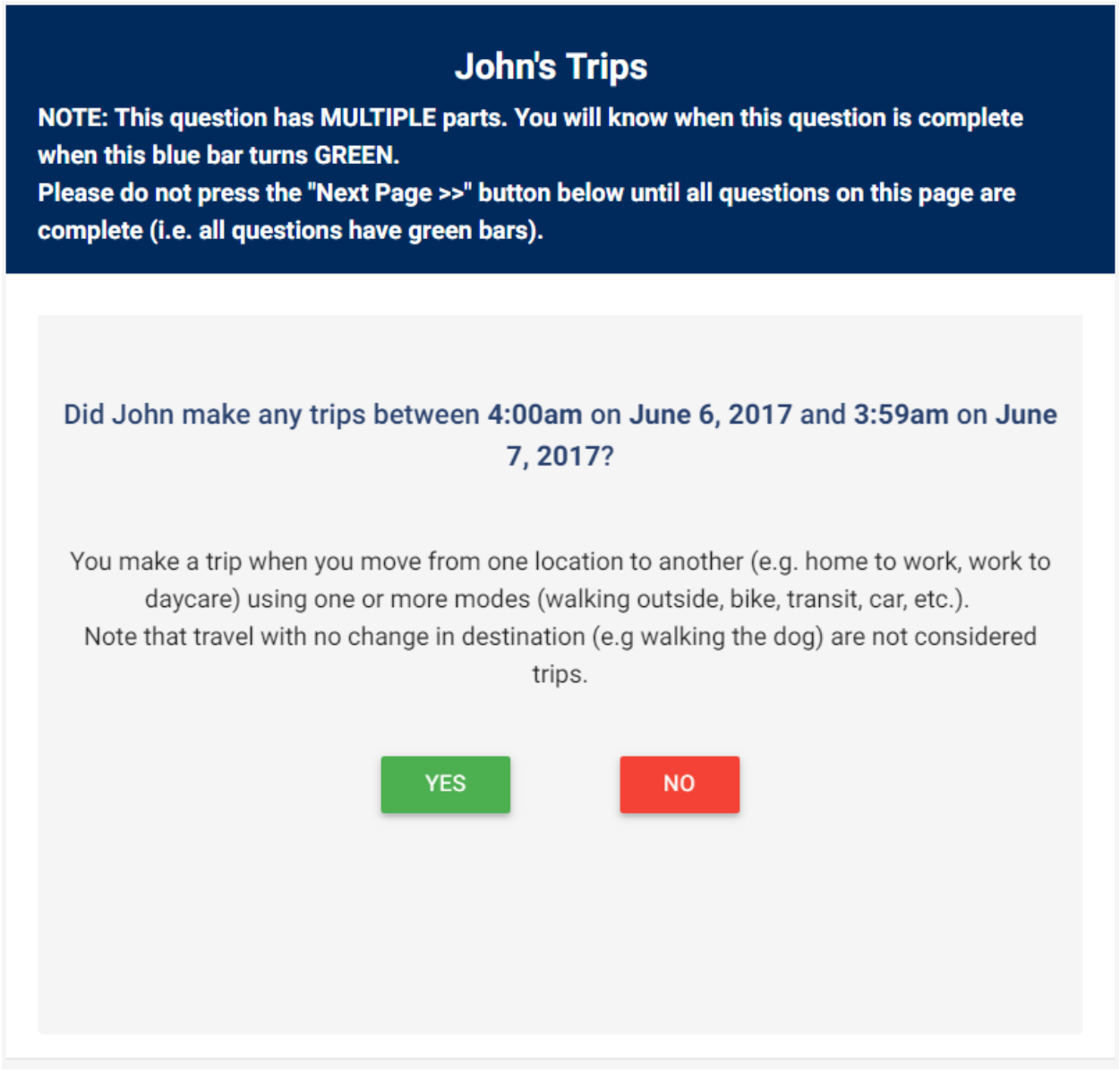
What **transit pass** does **John** own?

- GO Transit Pass
- Metropass
- Combination or Dual Pass
- Other Agency Pass
- Do not own transit pass

Does **John** possess a valid **driver's license**?

- Yes
- No

Page 7: Trips
Trip Question #2 Design (Summer Field Tests):



Please list all the places John went between 4:00am on June 6, 2017 and 3:59am on June 7, 2017. Chronological order must be respected.

Note: Include side-stops (e.g. gas station, convenience store, dropping off passenger). Do not list intermediate transit points (e.g. bus stop, subway station) as they will be handled on the next screen. Travel that circles back (e.g walking the dog) or travel within a business/office park, a school campus, or a shopping complex should not be included.

John's day began at	**Home**	↓
Then John went to	**Work**	↑ ×

3 Where did John go after **work**?

- ○ Home
- ○ Work
- ○ School
- ○ Other

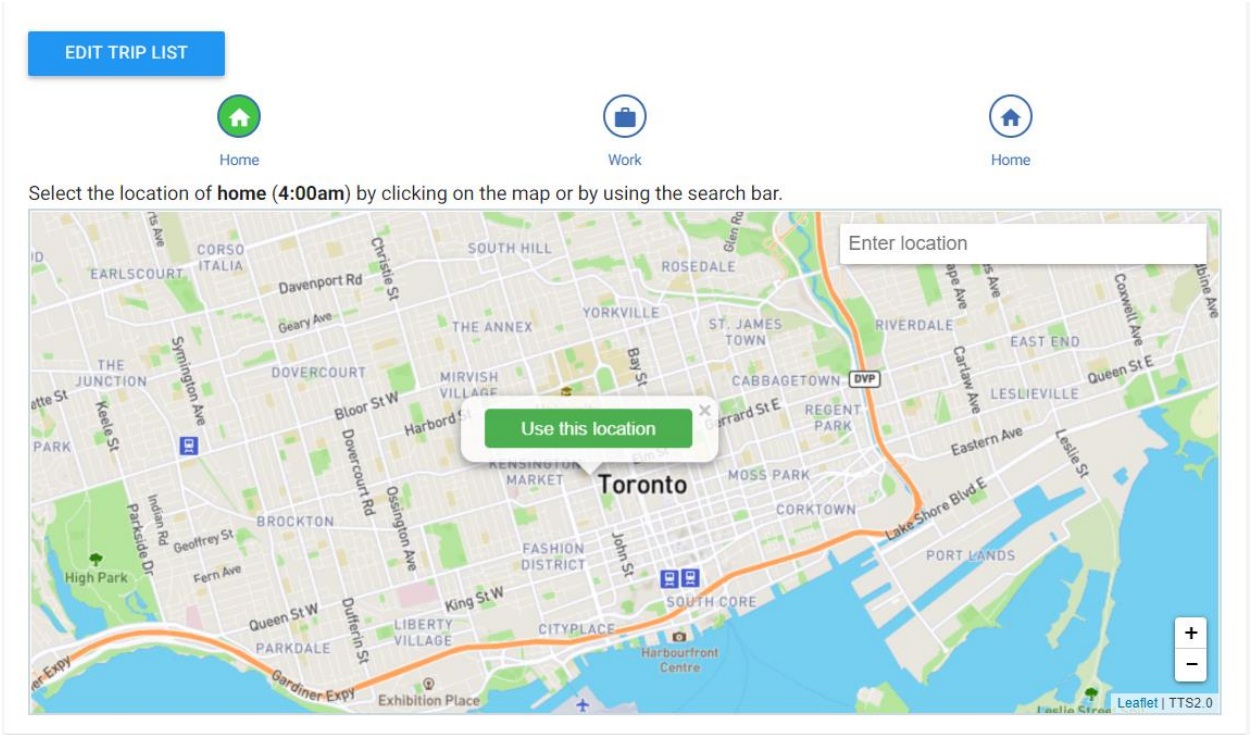
Add next location | No more trips

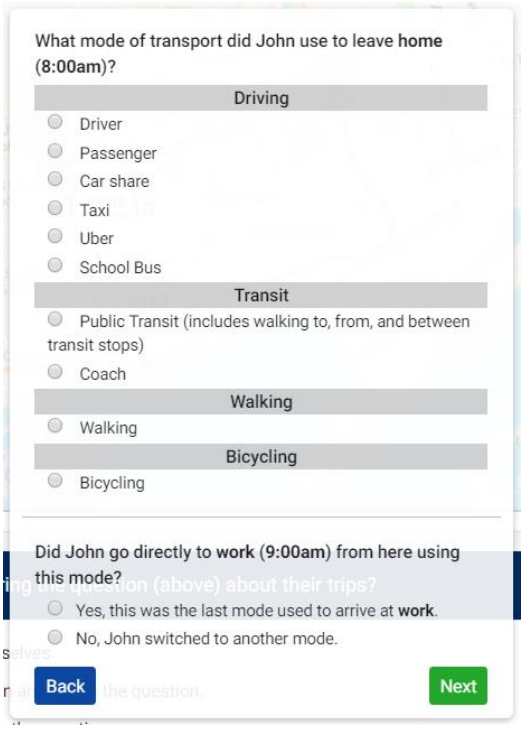
John did not make any trips.

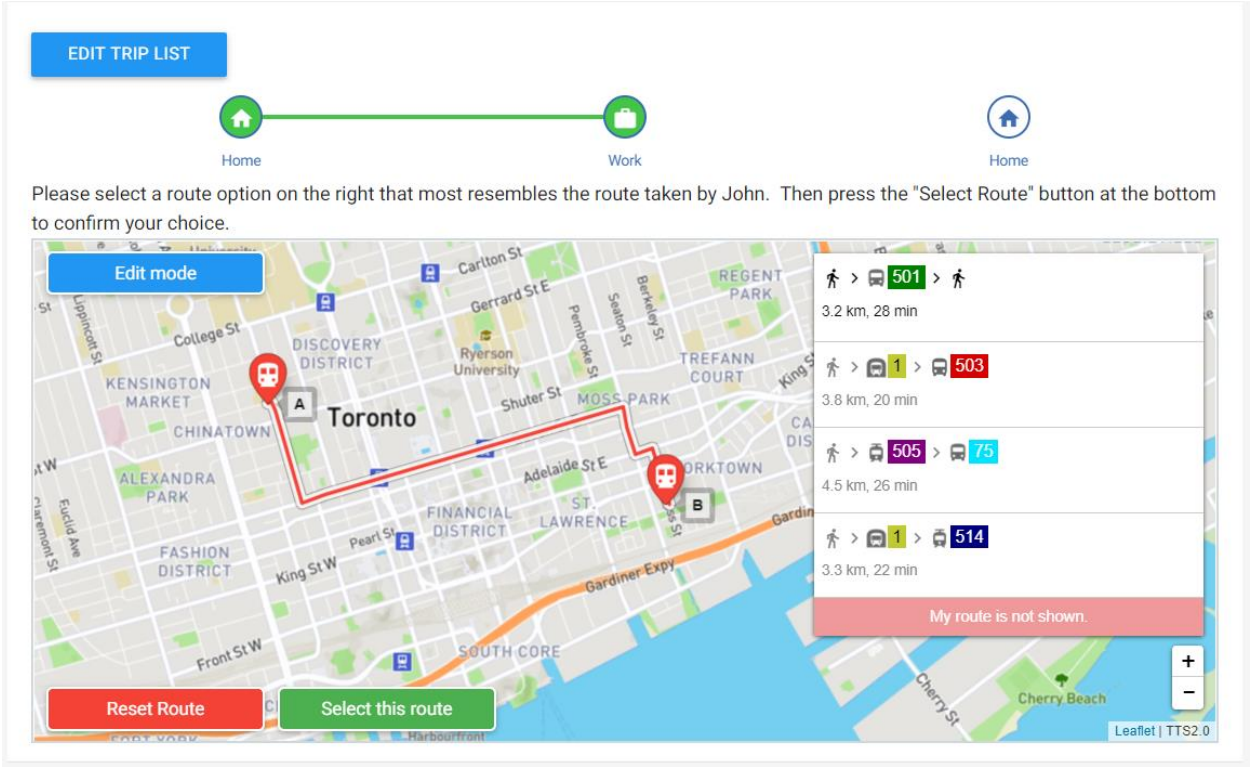
Please provide the arrival and departure times of each place John went to on trip day.

Location	Arrival time	Departure time
Home		00
Work	00	00
Home	00	

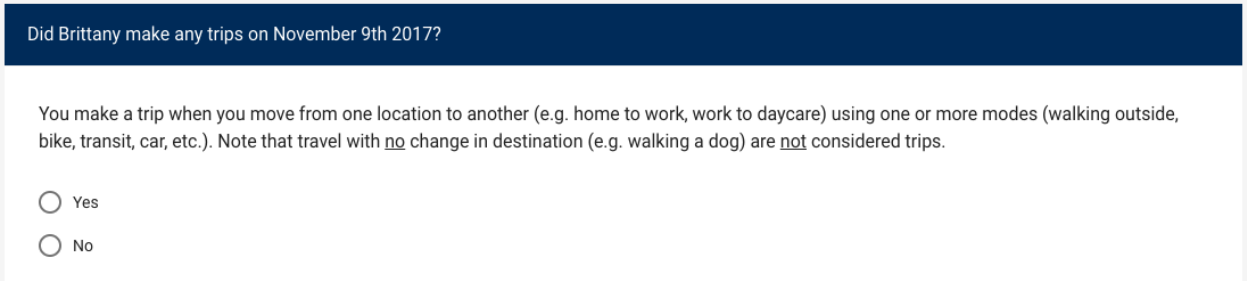
BACK | NEXT

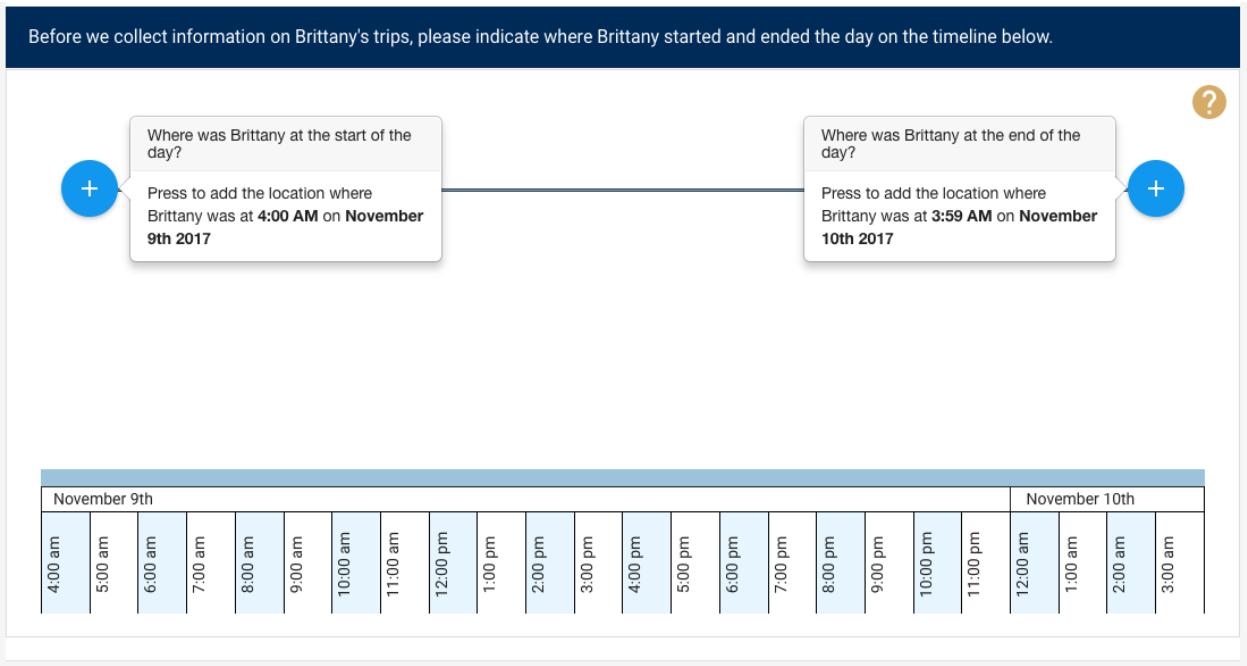

EDIT TRIP LIST
Home
Work
Home
Select the location of **home** (**4:00am**) by clicking on the map or by using the search bar.
Enter location
Use this location
Toronto
Leaflet | TTS2.0

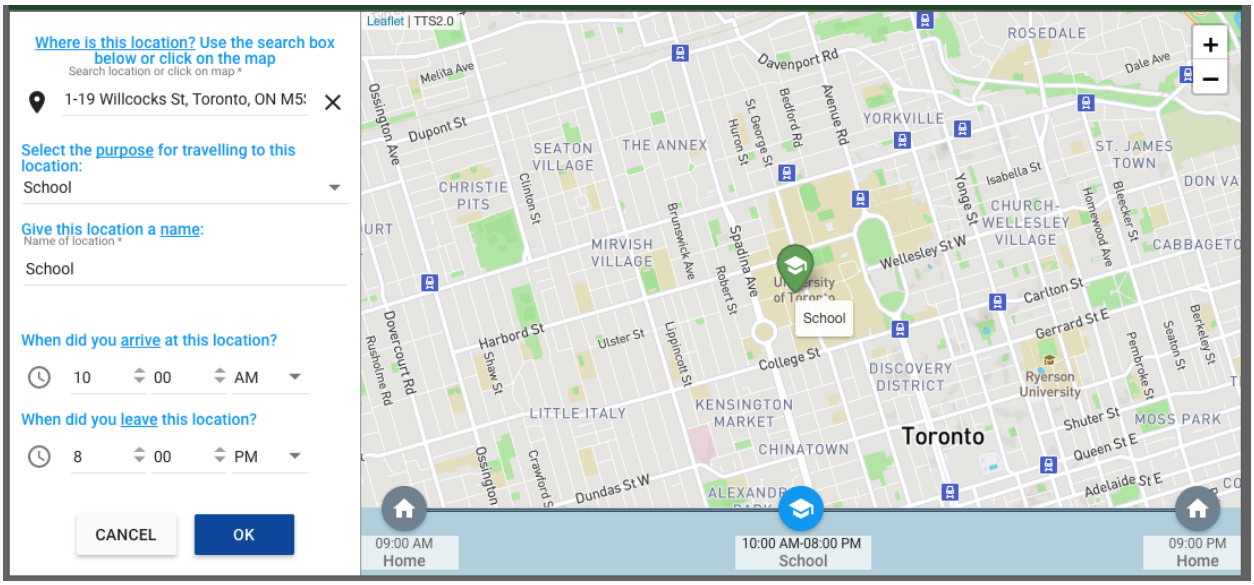

What mode of transport did John use to leave **home** (**8:00am**)?
Driving
Driver
Passenger
Car share
Taxi
Uber
School Bus
Transit
Public Transit (includes walking to, from, and between transit stops)
Coach
Walking
Walking
Bicycling
Bicycling
Did John go directly to **work** (**9:00am**) from here using this mode?
Yes, this was the last mode used to arrive at **work**.
No, John switched to another mode.
Back
Next

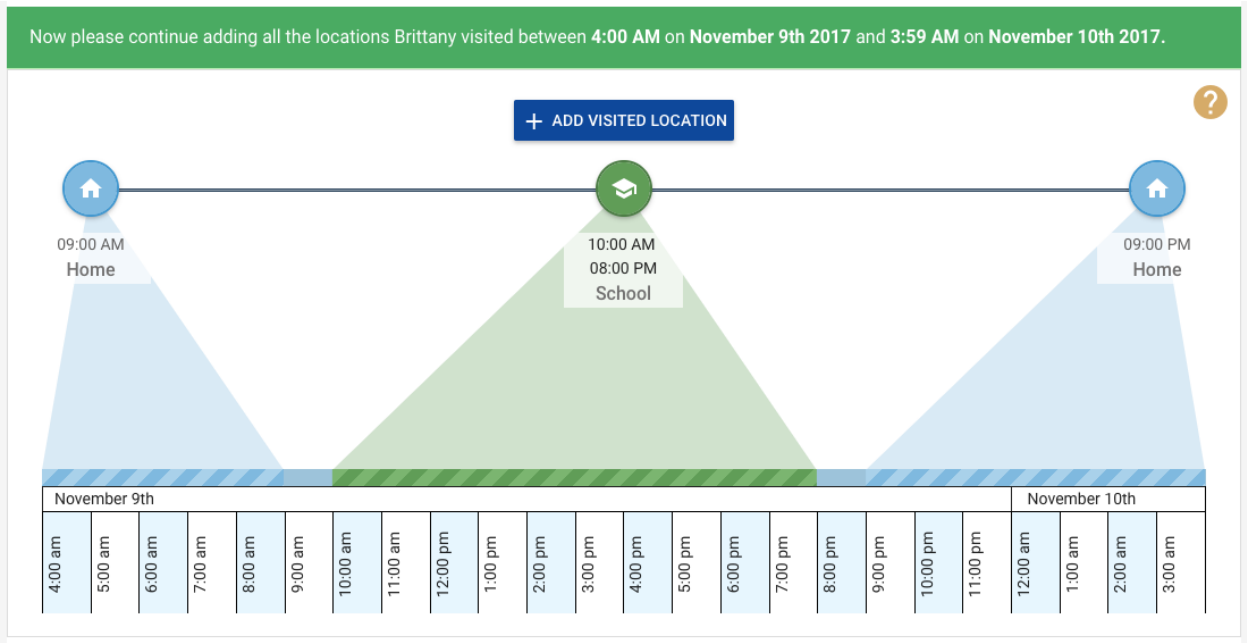

EDIT TRIP LIST
Home
Work
Home
Please select a route option on the right that most resembles the route taken by John. Then press the "Select Route" button at the bottom to confirm your choice.
Edit mode
Toronto
A
B
501
3.2 km, 28 min
1
503
3.8 km, 20 min
505
75
4.5 km, 26 min
1
514
3.3 km, 22 min
My route is not shown.
Reset Route
Select this route
Leaflet | TTS2.0

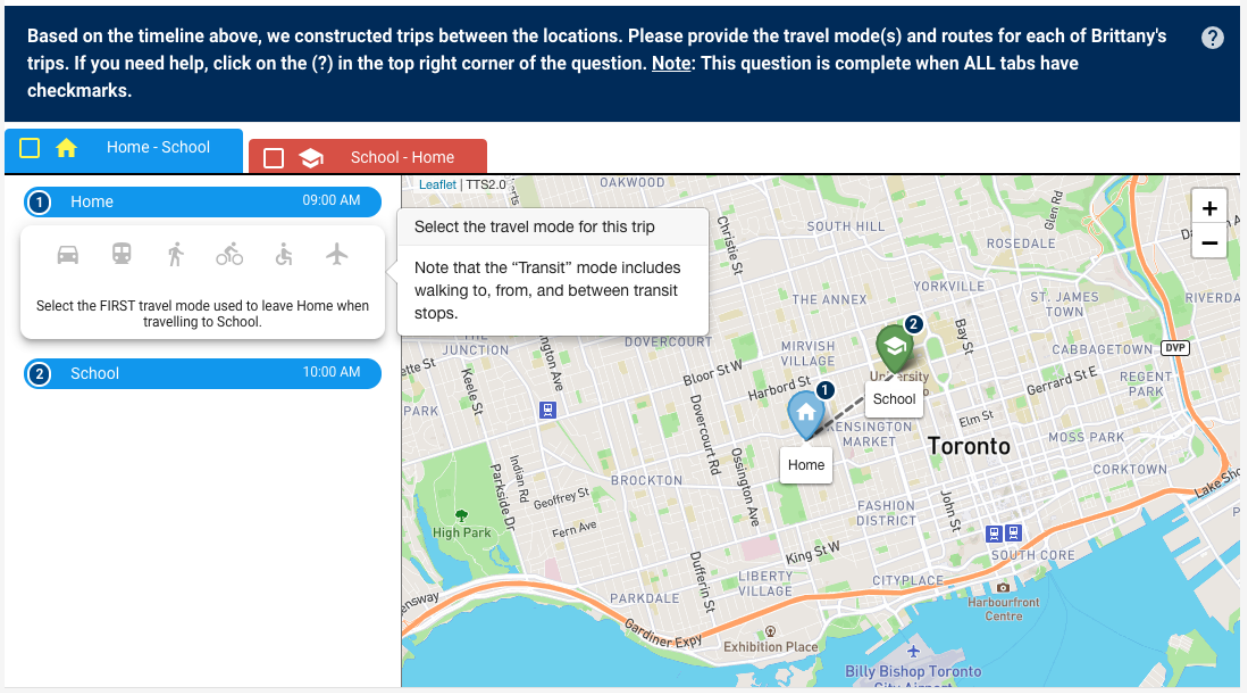
Trip Question #3 Design (Fall Field Tests):

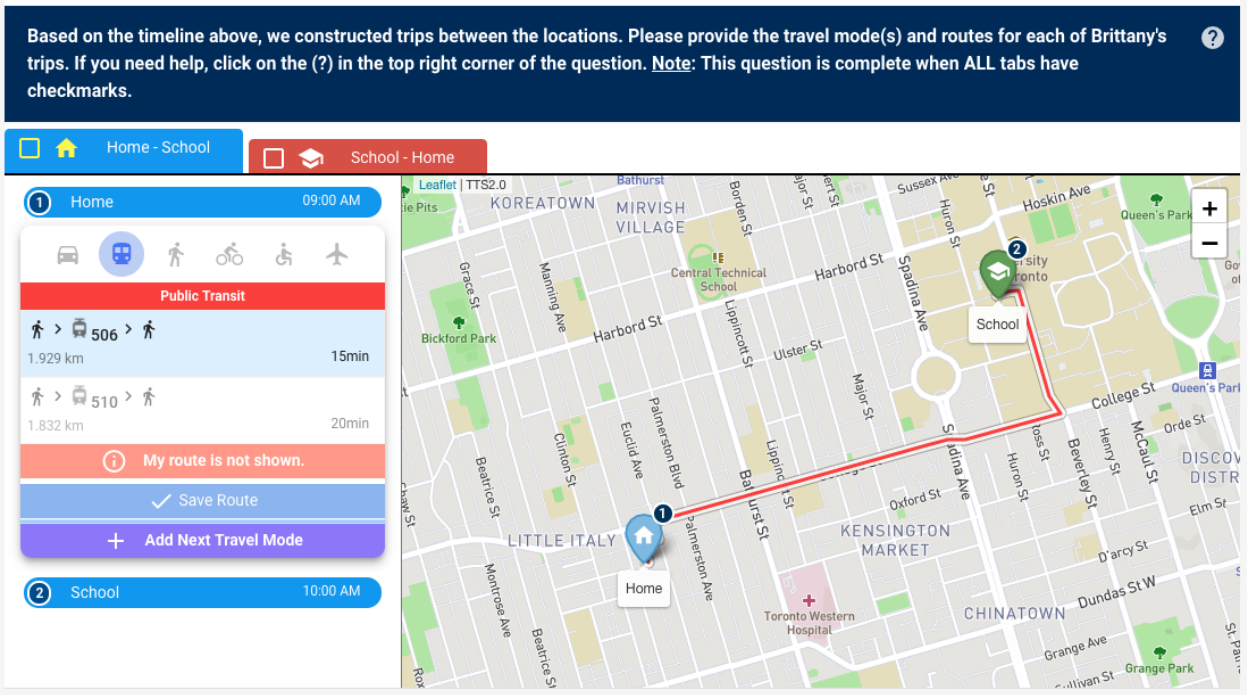





Where is this location? Use the search box below or click on the map
Search location or click on map *
1-19 Willcocks St, Toronto, ON M5
Select the purpose for travelling to this location:
School
Give this location a name:
Name of location *
School
When did you arrive at this location?
10 00 AM
When did you leave this location?
8 00 PM
CANCEL
OK
Leaflet | TTS2.0
ROSEDALE
Davenport Rd
Dale Ave
Melita Ave
Ossington Ave
Dupont St
SEATON VILLAGE
THE ANNEX
Huron St
St. George St
Bedford Rd
Avenue Rd
YORKVILLE
ST. JAMES TOWN
CHRISTIE PITS
Clinton St
Isabella St
Yonge St
CHURCH-WELLESLEY VILLAGE
Homewood Ave
Bleecker St
DON VA
MIRVISH VILLAGE
Brunswick Ave
Spadina Ave
Robert St
Wellesley St W
CABBAGETO
School
Carlton St
Gerrard St E
Harbord St
Ulster St
Lippincott St
College St
DISCOVERY DISTRICT
Ryerson University
Berkeley St
Seaton St
Pembroke St
Dovercourt Rd
Rusholme Rd
Shaw St
LITTLE ITALY
KENSINGTON MARKET
Shuter St
MOSS PARK
Toronto
CHINATOWN
Queen St E
Ossington
Crawford St
Dundas St W
Adelaide St E
09:00 AM
Home
10:00 AM-08:00 PM
School
09:00 PM
Home


Now please continue adding all the locations Brittany visited between 4:00 AM on November 9th 2017 and 3:59 AM on November 10th 2017.
ADD VISITED LOCATION
09:00 AM
Home
10:00 AM
08:00 PM
School
09:00 PM
Home
November 9th
November 10th
4:00 am
5:00 am
6:00 am
7:00 am
8:00 am
9:00 am
10:00 am
11:00 am
12:00 pm
1:00 pm
2:00 pm
3:00 pm
4:00 pm
5:00 pm
6:00 pm
7:00 pm
8:00 pm
9:00 pm
10:00 pm
11:00 pm
12:00 am
1:00 am
2:00 am
3:00 am


Based on the timeline above, we constructed trips between the locations. Please provide the travel mode(s) and routes for each of Brittany's trips. If you need help, click on the (?) in the top right corner of the question. Note: This question is complete when ALL tabs have checkmarks.
Home - School
School - Home
1 Home 09:00 AM
Select the FIRST travel mode used to leave Home when travelling to School.
2 School 10:00 AM
Select the travel mode for this trip
Note that the "Transit" mode includes walking to, from, and between transit stops.
Leaflet | TTS2.0
OAKWOOD
SOUTH HILL
ROSEDALE
THE ANNEX
YORKVILLE
ST. JAMES TOWN
RIVERDA
JUNCTION
DOVERCOURT
MIRVISH VILLAGE
CABBAGETOWN
DVP
REGENT PARK
KENSINGTON MARKET
Toronto
MOSS PARK
CORKTOWN
BROCKTON
FASHION DISTRICT
SOUTH CORE
CITYPLACE
LIBERTY VILLAGE
PARKDALE
High Park
Harbourfront Centre
Exhibition Place
Billy Bishop Toronto
School
Home
Harbord St
Bloor St W
King St W
Gardiner Expy


Based on the timeline above, we constructed trips between the locations. Please provide the travel mode(s) and routes for each of Brittany's trips. If you need help, click on the (?) in the top right corner of the question. Note: This question is complete when ALL tabs have checkmarks.
Home - School
School - Home
1 Home 09:00 AM
Public Transit
506
1.929 km
15min
510
1.832 km
20min
My route is not shown.
Save Route
Add Next Travel Mode
2 School 10:00 AM
Leaflet | TTS2.0
KOREATOWN
MIRVISH VILLAGE
Central Technical School
Bickford Park
Queen's Park
LITTLE ITALY
KENSINGTON MARKET
CHINATOWN
Toronto Western Hospital
Grange Park
School
Home
Harbord St
College St
Dundas St W
Spadina Ave
Bathurst