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Mobility on Demand (MOD) Sandbox Demonstration: Tri-County Metropolitan Transportation District of Oregon (TriMet) OpenTripPlanner (OTP) Shared-Use Mobility

Evaluation Report

JULY 2020

FTA Report No. 0170
Federal Transit Administration

PREPARED BY

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U.S. Department of Transportation
Federal Transit Administration

COVER PHOTO

Courtesy of TriMet

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liter	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

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13. ABSTRACT

This report evaluates the TriMet OpenTripPlanner (OTP) project, part of the Federal Transit Administration (FTA) MOD Sandbox Program. The TriMet OTP project was designed to enhance the existing TriMet trip planner to include shared-use mobility (SUM) options, real-time information on transit vehicle arrivals, pedestrian routing in consideration of sidewalks, and other interface enhancements. The evaluation explored the technical function of the TriMet OTP, including geocoding, routing, and data veracity. It also evaluated user response to the TriMet OTP through a survey and an unscripted test of its trip planning and routing capabilities. Finally, expert (stakeholder/project partner) interviews with project participants were conducted to assess lessons learned from the project operation. Overall, the results found that the TriMet OTP was an enhancement over the existing TriMet trip planner and provided some features that were superior to other leading trip planners. The results of the evaluation supported the hypotheses that the design interfaces were improved, the shared mobility and real-time information was useful, and the new design would facilitate better access and egress to transit. Some challenges were uncovered with respect to the capacity of the Pelias geocoder to handle misspellings or unusual inputs relative to other geocoders. The pedestrian routing also displayed a few limitations but performed well overall. Most hypotheses in this evaluation were supported, and, overall, the project was found to perform very well.

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ABSTRACT

This report evaluates the TriMet OpenTripPlanner (OTP) project, part of the Federal Transit Administration (FTA) MOD Sandbox Program. The TriMet OTP project was designed to enhance the existing TriMet trip planner to include shared-use mobility (SUM) options, real-time information on transit vehicle arrivals, pedestrian routing in consideration of sidewalks, and other interface enhancements. The evaluation explored the technical function of the TriMet OTP, including geocoding, routing, and data veracity. It also evaluated user response to the TriMet OTP through a survey and an unscripted test of its trip planning and routing capabilities. Finally, expert (stakeholder/project partner) interviews with project participants were conducted to assess lessons learned from the project operation. Overall, the results found that the TriMet OTP was an enhancement over the existing TriMet trip planner and provided some features that were superior to other leading trip planners. The results of the evaluation supported the hypotheses that the design interfaces were improved, the shared mobility and real-time information was useful, and the new design would facilitate better access and egress to transit. Some challenges were uncovered with respect to the capacity of the Pelias geocoder to handle misspellings or unusual inputs relative to other geocoders. The pedestrian routing also displayed a few limitations but performed well overall. Most hypotheses in this evaluation were supported, and, overall, the project was found to perform very well.

EXECUTIVE SUMMARY

The Federal Transit Administration (FTA) is leading an initiative, the MOD Sandbox Program, to explore how public transit agencies could incorporate new technologies that complement and support the traditional functions of public transit. A project in the program was the TriMet OpenTripPlanner (OTP) for Shared-Use Mobility. The TriMet OTP, initially released by TriMet (Portland, Oregon) in 2009, was the first trip planner to allow for multiple modes to be considered in one trip and had an initial focus on incorporating biking and walking networks into trip plans with transit. The TriMet MOD Sandbox project built upon the core of OTP to incorporate shared-use mobility (SUM) options.

The TriMet OTP MOD Sandbox Demonstration project aimed to create a complete open platform for the integration of transit and SUM options on a responsive web and mobile platform. The project advanced the development of two core data frameworks upon which future initiatives could build:

- Extending the OTP to support the integration of transit trip planning with SUM modes and real-time transit information.
- Implement a fully-functional and comprehensive open geocoder, built off the existing Pelias geocoder, a service that transforms location names, streets, or addresses into latitude and longitude coordinates. The objective of building this geocoder was to advance a non-proprietary system for geocoding that could lower the costs for implementing a trip planning system.

This report presents the results of the independent evaluation (IE) of TriMet's beta OpenTripPlanner Shared-Use Mobility application (hereafter referred to as OTP). The TriMet OTP was one of 11 MOD Sandbox Demonstration projects partially funded by FTA. The IE was sponsored by the U.S. Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) and FTA. The evaluation was guided by 11 hypotheses to explore the technical performance of the OTP and the user response to several design and interface features. The approach and outcome from evaluating each hypothesis are summarized in the following sections.

Hypothesis 1: The matching of addresses and other points of interests (POIs) for transit users in Pelias is comparable to other leading geocoders.

A core functionality of any trip planner is the capacity to correctly geocode inputs by the user. The project used the Pelias geocoder because it was open source and had been demonstrated as capable in previous applications. To compare the Pelias geocoder to others, the IE team worked with two sets of addresses, one that included about 2,000 addresses and was supplied by the TriMet project team and another that also included about 2,000 addresses and was generated by the IE team, drawing from Portland property records. These addresses were geocoded using Pelias, Google Earth, ArcGIS, and Mapbox.The evaluation assessed how many Pelias-geocoded addresses were within 200 feet of the addresses geocoded by the other geocoders. Results were mixed; Pelias performed very well with the IE-generated data set but showed some accuracy limitations with the TriMet-supplied test dataset. The findings mostly supported Hypothesis 1.

Hypothesis 2: The accuracy of the geocoding results from Pelias with regard to point locations is comparable to other leading geocoders.

The analysis of Hypothesis 1 evaluated comparability; for example, two geocoders could be wrong in the same way on a given point, but still could be comparable in terms of performance if the geocoded points were within proximity of each other. Hypothesis 2 looked more at the accuracy of the geocoder, which was evaluated using polygons provided by TriMet defining the location (or area) of a given address. If a geocoded point fell within the polygon, the geocode was considered correct; if the point fell outside the polygon, the geocode was considered incorrect. Results showed that the Pelias-geocoded points in the data tested were less effective than Google Earth, Mapbox, or ArcGIS. The reasons may stem from a more limited ability of Pelias to handle inputs that are misspelled or transposed streets. These limitations suggest that Hypothesis 2 was only partially supported.

Hypothesis 3: Trips planned using OTP will show faster travel times with SUM incorporated, as compared to leading trip planners without SUM.

A key objective of the TriMet MOD Sandbox project was to incorporate shared mobility options into existing trip planning options. Hypothesis 3 sought to evaluate whether the incorporation of those options would lead to faster travel times being provided to users. This was evaluated by randomly drawing origin and destination pairs from the IE team's address dataset and then running them through the TriMet trip planner, which had SUM options, and Google Maps, which had transit options. Results showed that the SUM options tested for the trips were, on average, faster than the same trip when planned by using public transit only. The results supported Hypothesis 3.

Hypothesis 4: The resulting itineraries and choices will be valid.

The IE team conducted a survey in collaboration with TriMet of the TriMet Riders Club.[4] Selected members were asked about their use of trip planners and their travel patterns, household characteristics, and demographics. The survey

[1]The TriMet Riders Club is a group of TriMet riders who volunteer to serve as beta testers for future transit in Portland. TriMet communicates with members about changes to transit and solicit feedback, and members receive tips on how to commute efficiently and receive discounts for local businesses and organizations. For more information, see https://trimet.org/club/index.htm.

also asked users to test the TriMet OTP, during which they were asked to plan a trip using the trip planner. The origin, destination, and other parameters of the trip plan or "planned trip" were defined by the respondent, who was then asked a series of questions about the output. Results of questions assessing validity suggested that most respondents considered the output to be correct. On a scale of 1 (Very Poor) to 10 (Excellent), about 70% rated the results very highly (ratings of 8–10). This and other findings supported Hypothesis 4, that the trip planner could produce valid results through live unscripted tests.

Hypothesis 5: When routing pedestrians, OTP favors streets with sidewalks and lower environmental stress (e.g., lower speed limits and traffic volume).

The evaluation explored the capacity of the TriMet OTP to consider the presence of sidewalks as part of pedestrian routing. The test evaluated whether the pedestrian routes from the TriMet OTP were safer and made greater use of sidewalks relative to a leading trip planner for pedestrian trips using 30 origins/destinations. These trips were planned and manually assessed for correctness, use of sidewalks, and routing on low-speed or pedestrian-friendly streets. The analysis found good performance with respect to correctly routing pedestrians in ways that increased pedestrian use of sidewalks or presented them with safe low-speed residential streets. The TriMet OTP and Google Maps sometimes produced the same results. Overall, the analysis supported Hypothesis 5.

Hypothesis 6: Sidewalk presence/absence information is available for all streets in the TriMet trip planner region.

An objective of the TriMet OTP project was to produce updated sidewalk presence and absence information that would be used to enhance walking trip planning. The sidewalk data updated by TriMet was supplied to the IE team, which assessed the accuracy of the information by drawing a random sample of 300 street segments from the dataset and using streetscape photos (e.g., Google Street View) to assess whether the sidewalk data appeared as depicted in the data. The evaluation found the sample to be highly accurate, at 96%. Incorrect observations reported no sidewalks when sidewalks did exist, and inaccuracies did not report sidewalks in locations where no sidewalks existed. The analysis supported Hypothesis 6.

Hypothesis 7: The project improves the accessibility of information for SUM options relative to prevailing options.

The survey of the TriMet Riders Club asked about the accessibility of information for SUM options and its impact on trip planning. About 60% of respondents felt that having access to SUM options in the TriMet OTP would increase their mobility, about 41% rated the information as very useful (ratings of 8–10), and about 70% considered the shared mobility information in the OTP to be improved over the existing (non-beta) trip planner. Survey results suggested that the SUM options were useful to a majority of respondents, but a sizeable minority (20–40%) rated the information as not very important or not an improvement. Overall, the findings supported Hypothesis 7.

Hypothesis 8: The usability and design of the web-based OTP interface is considered improved by testing respondents in the population.

The evaluation explored the degree to which the TriMet OTP improved design and usability. The survey of the TriMet Riders Club asked about perceptions of the user interface design and its key attributes. Generally, responses indicated high ratings for the interface design, with the majority (56%) rating it 8 or higher; only 11% rated it 1–4. More than 80% of respondents considered the updated interface to be an improvement over the existing TriMet trip planner. The findings of the analysis supported Hypothesis 8.

Hypothesis 9: The real-time information provided by the OTP interface will provide improved information that is considered useful to the user.

The TriMet OTP contains real-time trip information on the arrival of transit vehicles at specific stops, with data updating every minute. The survey asked about the perceived usefulness of real-time information in trip planning; respondents found it to be very useful, with more than 75% rating it 8–10. The findings generally supported Hypothesis 9.

Hypothesis 10: Users report that the OTP improves their ability to overcome first-mile/last-mile challenges.

The survey evaluated whether respondents felt that the trip planner improved their ability to overcome first/last-mile challenges in the Portland metropolitan area. Respondents already considered their ability to access and egress public transit to be good; when asked about the ability of the TriMet OTP to improve their access and egress, about 70% felt that it would at least slightly improve it, and about 64% believed it would at least slightly improve their ability to make multimodal trips. Overall, the findings supported Hypothesis 10.

Hypothesis 11: The process of deploying the project will produce lessons learned and recommendations for future research, development and deployment.

The IE team conducted stakeholder interviews with project team members to document lessons learned from the project experience. Overall, Portland stakeholders described the MOD Sandbox project as an enabler for unifying public transit agencies around data standards and data-sharing expectations and felt that it gave the region "collective bargaining power" to negotiate with national mobility service providers. During the pilot, TriMet learned the importance of building relationships and trust with project partners and encouraged other MOD sites to build long-term partnerships.

Table ES-1

Summary of Findings

Hypothesis	Status	Key Finding
1. The matching of addresses and other POIs for transit users in Pelias is comparable to other leading geocoders.	Mostly supported	The analysis geocoded points and their relative proximity to each other and determined that Pelias performed comparably with the TriMet test suite and very well with the IE test suite.
2. The accuracy of the geocoding results from Pelias with regard to point locations is comparable to other leading geocoders.	Partially supported	The analysis of geocoded points evaluated whether they fell within the polygons defining the test address. The Pelias geocoder matched about half the points, and other geocoders matched about 60% of the points.
3. Trips planned using OTP will show faster travel times with SUM incorporated, as compared to leading trip planners without SUM.	Supported	The travel times of trips with and without the SUM options showed that the OTP showed faster travel times relative to trip planners without this information.
4. The resulting itineraries and choices will be valid.	Supported	A survey of beta testers showed that at least 90% of respondents felt that the trip planner located their origin and destination correctly.
5. When routing pedestrians, OTP favors streets with sidewalks and lower environmental stress (e.g., lower speed limits and traffic volume).	Supported	A manual review of 30 walkable trips found that the weighting scheme of the OTP directed users to lower-stress walking environments.
6. Sidewalk presence/absence information is available for all streets in the TriMet trip planner region.	Supported	A visual review of 300 random road segments found that sidewalk information was highly accurate.
7. The project improves the accessibility of information for SUM options relative to prevailing options.	Supported	Survey responses of beta testers suggested that the project improved their accessibility to shared mobility options.
8. The usability and design of the web-based OTP interface is considered improved by testing respondents in the population.	Supported	Survey respondents generally gave high ratings to the usability and design interface.
9. The real-time information provided by the OTP interface will provide improved information that is considered useful to the user.	Supported	The real-time information in the OTP functioned well and as specified and was cited as very useful to most survey respondents.
10. Users report that the OTP improves their ability to overcome first-mile/ last-mile challenges.	Supported	Survey respondents reported that the OTP was able to improve their ability to get to and from public transit and make multimodal trips.
11. The process of deploying the project will produce lessons learned and recommendations for future research, development, and deployment.	Supported	The project produced several lessons learned and successes that may enable wider use of open-source trip-planning applications.

SECTION

1

Introduction

Overview of MOD Sandbox Demonstrations

The Federal Transit Administration (FTA)'s Mobility on Demand (MOD) effort developed around a vision of a multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature. FTA selected 11 MOD Sandbox Demonstration projects that are testing solutions that advance the MOD vision. In partnership with public transportation agencies, the MOD Sandbox is demonstrating the potential for new innovations to support and enhance public transportation services by allowing agencies to explore partnerships, develop new business models, integrate transit and MOD solutions, and investigate new, enabling technical capabilities.

Evaluation of each project's benefits and impacts will guide the future implementation of innovations throughout the U.S. Broadly, MOD Sandbox projects take several approaches, including the development of new or improved trip planners, integration of new mobility services with traditional public transit functions, and implementation of new integrated payment and incentive structures for travel using public transit. Several Sandbox projects focus on improving first/last-mile access to public transportation through collaboration with private sector operators, including bikesharing, carsharing, ridesourcing/Transportation Network Companies (TNCs), and other shared mobility operators.

Table 1-1 provides a summary of all projects in the MOD Sandbox Program.

Table 1-1

Overview of MOD Sandbox Projects

Region	Project	Description
Chicago	Incorporation of Bikesharing Company Divvy	Releases updated version of Chicago Transit Authority's (CTA) existing trip planning app. New version incorporates Divvy, a bikesharing service, and allows users to reserve and pay for bikes within the app.
Dallas	Integration of Shared-Ride Services into GoPass Ticketing Application	Releases updated version of Dallas Area Rapid Transit's (DART) existing trip planning app. Updated version incorporates shared-ride services to provide first/last-mile connections to public transit stations and allows users to pay for services within the app.
Los Angeles and Puget Sound	Two-Region Mobility on Demand	Establishes partnership between Via and LA Metro. Via provides first/last-mile connections for passengers going to or leaving from transit stations. There is a companion project in Seattle, WA.
Phoenix	Smart Phone Mobility Platform	Releases updated version of Valley Metro's existing trip planning app. New version updates trip planning features and enables payments.
Pinellas County (Florida)	Paratransit Mobility on Demand	Improves paratransit service by combining services from taxi, ridesourcing/TNCs, and traditional paratransit companies.
Portland	Open Trip Planner Share Use Mobility	Releases updated version of TriMet's existing multimodal app. New version provides more sophisticated functionality and features, including options for shared mobility.
San Francisco Bay Area	Bay Area Fair Value Commuting (Palo Alto)	Reduces SOV use within Bay Area through commuter trip reduction software, a multimodal app, workplace parking rebates, and first/last-mile connections in areas with poor access to public transit.
	Integrated Carpool to Transit (BART System)	Establishes partnership between Scoop and BART. Scoop matches carpoolers and facilitates carpooling trips for passengers going to or leaving from BART stations with guaranteed parking.
Tacoma	Limited Access Connections	Establishes partnerships between local ridesourcing companies/TNCs and Pierce Transit. Ridesourcing companies provide first/last-mile connections to public transit stations and park-and-ride lots with guaranteed rides home.
Tucson	Adaptive Mobility with Reliability and Efficiency	Built integrated data platform that incorporates ridesourcing/TNC and carpooling services to support first/last-mile connections and reduce congestion.
Vermont	Statewide Transit Trip Planner	Releases new multimodal app for VTrans that employs fixed and flexible (non-fixed) transportation modes to route trips in cities and rural areas.

An independent evaluation (IE) is required by Federal Public Transportation Law (49 U.S.C. § 5312(e)(4)) for demonstration projects receiving FTA Public Transportation Innovation funding. The IE for the MOD Sandbox Demonstration projects is sponsored by the USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO) and FTA.

This report focuses on the evaluation of the MOD project with the TriMet public transit system implemented in the Portland, Oregon, metropolitan area. The project, OpenTripPlanner (OTP) Shared-Use Mobility, aimed to deliver an open source trip planning platform for Portland. Evaluation of the project involved exploring a number of hypotheses surrounding the project's ability to build a trip planner that could effectively geocode addresses, incorporate shared-use mobility (SUM) options into travel options, provide valid choices, appropriately route pedestrians in consideration of known sidewalk infrastructure, and achieve related objectives.

Evaluation Framework

For each of the 11 MOD Sandbox projects, the IE team developed an evaluation framework in coordination with the project team. The framework is a project-specific logic model that contains the following entries:

1. **MOD Sandbox Project** – denotes the specific MOD Sandbox project.
2. **Project Goals** – denotes each project goal for the specific MOD Sandbox project and captures what each MOD Sandbox project is trying to achieve.
3. **Evaluation Hypothesis** – denotes each evaluation hypothesis for the specific MOD Sandbox project. The evaluation hypotheses flow from the project-specific goals.
4. **Performance Metric** – denotes the performance metrics used to measure impact in line with the evaluation hypotheses for the specific MOD Sandbox project.
5. **Data Types and Sources** – denotes each data source used for the identified performance metrics.
6. **Method of Evaluation** – denotes the quantitative and qualitative evaluation methods us

SECTION 2

TriMet MOD Sandbox

Project Summary

Created in 1969, the Tri-County Metropolitan Transportation District of Oregon (TriMet) is a special district of the State of Oregon governed by a seven-member Board appointed by the Governor. TriMet serves a population of approximately 1.8 million in 533 square miles of the urban portion of the three-county Portland metropolitan area and provides a full range of services through 5 light rail lines (MAX), 84 bus routes, and a commuter rail line (Westside Express Service, WES). According to the 2018 Annual Agency Profile in the National Transit Database (NTD), TriMet's bus ridership was 56.7 million and its light rail ridership was nearly 39 million. TriMet also provides a door-to-door paratransit service (LIFT) for qualified persons with mobility challenges who are unable to ride on TriMet's fixed-route services. TriMet's LIFT service is supported by 258 LIFT buses, 15 vans, and 52 taxis. These services are fully ADA-compliant, with most of TriMet's buses and light rail vehicles featuring step-free, low-floor boarding. TriMet also provides operating support for the Portland Streetcar line.

The OpenTripPlanner (OTP), initially released as an open source project by TriMet in 2009, was the first to introduce multiple modes in one trip with the original focus on incorporating biking and walking networks with public transit. Adoption of OTP has been strong, with implementation in dozens of cities and countries worldwide. For the MOD Sandbox Demonstration project, TriMet built upon the core of the OTP to incorporate shared-use mobility (SUM) options.

TriMet's OTP SUM project aimed to create a complete open platform for the integration of public transit and SUM options. The open data, software, and user interface, responsive on both web and mobile platforms, aimed to help TriMet customers make informed decisions about their mobility choices, including the critical first and last miles of public transit trips for which a bus or train alone could not always provide full access for an end-to-end trip.

TriMet's MOD Sandbox Demonstration project included the development and expansion of two core data frameworks for current and future collaboration upon which OTP initiatives can be built:

- Extension of the OTP code base to support the integration of public transit trip planning with SUM modes such as bikeshare and TNCs and updated real-time public transit information.
- Implementation of a fully-functional and comprehensive open geocoder built off the existing Pelias geocoder. Geocoding (address locating) is a primary requirement for trip planning; a non-proprietary and non-restrictive option

for address locating would substantially lower the barrier to entry for many public transit systems to offer trip planning and can achieve significant cost savings for public transit agencies, government agencies, and the public.

In addition to core elements of the foundation frameworks, the project also included:

- Development of a comprehensive web-based user interface that allows users to make intermodal trip plans, including SUM and demand-responsive service.
- Improvements to base-map data so the OTP can support enhanced pedestrian accessibility information and improvements to regional address data that make location search and geocoding more effective and user-friendly.

TriMet's key partners for the project are Conveyal, IBI Group, Cleared For Takeoff, Moovel, and Oregon Metro; other contributing partners include AC Transit, Los Angeles Metro, Vermont Agency of Transportation, Santa Clara Valley Transportation Authority, Regional Transit District of Denver, City of Portland, car2go (ShareNow), Lyft, Uber, Motivate, Trillium Transit, Cambridge Systematics, Fehr and Peers, and the USF Center for Urban Transportation Research.

Project Timeline

The main milestones for the TriMet OTP SUM (hereafter referred to as OTP) project were as follows:

- **January 18, 2017** – TriMet OTP Shared-Use Mobility Kickoff Workshop
- **January 20, 2017** – Phase I start
- **Quarter 1, 2017** – Milestone 1: Itinerary-based trip planning
- **Quarter 2, 2017** – Milestone 2: Geocoding, bikeshare support, profile-based trip planning
- **Quarter 3, 2017** – Milestone 3: Real-time integration, advanced transit mapping
- **Quarter 4, 2017** – Milestone 4: Pedestrian routing, stop and route viewers
- **Quarter 2, 2018** – Milestone 5: Shared-use mobility, extended user interface functionality
- **April 18, 2018** – TriMet OTP SUM integration design workshop; project Phase II start
- **May–August 2018** – Test Version 1 and field demonstration star
- **October 2018** – Heuristic Study 1 and subsequent development enhancements
- **November 2018** – Heuristic Study 2
- **December 2018** – IE online survey
- **January 20, 2019** – Project close

TriMet collected relevant data for this MOD demonstration between August 2018 and January 2019. Subsequent testing of the trip-planner related to the functional hypotheses of the evaluation occurred in Spring and Summer 2019.

SECTION

3

Evaluation Approach, Planning, and Execution

The evaluation of the MOD Sandbox project was guided by an evaluation plan developed at the outset of the project. The evaluation plan was built primarily off a logic model constructed by the IE team and had five basic components:

1. **Project Goals** – The stated goals of the project; project goals were defined from the proposal, project summary, and discussion with project team members.
2. **Evaluation Hypothesis** – Each project had a corresponding hypothesis, a statement that could be answered with "Yes" or "No" that was related to measuring the achievement of the associated project goal.
3. Performance Metric – Described the measurement that was proposed to be used to evaluate the hypothesis.
4. **Data Sources** – Data sources that followed the performance metric and described the data type and source necessary to compute or evaluate the performance metric.
5. **Method of Evaluation** – Defined how the hypothesis would be evaluated; with the logic model, this was very general, declaring whether the evaluation would be completed via survey analysis, activity data analysis, time series analysis, or other method.

The logic model was effectively a table, with one row containing five cells, each populated with the components described above. The content of the logic model was populated in advance of project implementation, where knowledge of the project trajectory and exact data collected were uncertain. The first four components of the logic model constructed for the evaluation of the logic model constructed for the evaluation of the TriMet project are presented in Table 3-1.

The quantitative and qualitative evaluation methods used in the TriMet IE included the following:

- System testing of the geocoders and trip planners
- Data verification
- Survey analysis
- Summary of expert (stakeholder/project partner) interviews

Table 3-1

Evaluation Hypotheses, Performance Metrics, and Data Sources for TriMet Sandbox Project

Evaluation Hypothesis	Performance Metric	Data Elements	Data Sources
1. The matching of addresses and other POIs for transit users in Pelias is comparable to other leading geocoders.	Difference between number of addresses and POIs correctly matched in Pelias and number of addresses and POIs correctly matched from other leading geocoders	Geocoding test results [test address/POI ID.	Geocoding test results
2. The accuracy of the geocoding results from Pelias with regards to point locations are comparable to other leading geocoders.	Difference between number of accurate address locations from Pelias and number of accurate address locations from other leading geocoders.	Geocoding test results [test address ID; zone ID; binary test score (1 = inside test polygon, 0 = outside test polygon); distance from centroid (ft)]	Geocoding test results
3. Trips planned using OTP will show faster travel times with SUM incorporated, as compared to leading trip planners without SUM.	Difference in trip times of test trips from OTP and other leading trip planners on the market.	OTP time and cost comparison results [trip ID, origin, destination, departure time, estimated arrival time, trip cost] with single-mode and SUM-OTPs	OTP time and cost comparison results
4. The resulting itineraries and choices will be valid.	Survey response to questions probing reliability of planned trips.	Survey questions	OTP user survey
5. When routing pedestrians, OTP favors streets with sidewalks and lower environmental stress (e.g., lower speed limits and traffic volume).	Number of sample trips where new OTP can be configured to take a slightly longer but safer walking route rather than the shortest route.	Elements from new version of OTP: trip ID, origin, destination, walking time, walking distance, walkability index	Walkability trip testing results
6. Sidewalk presence/absence information is available for all streets in the TriMet trip planner region.	Number of random samples where the OTP back-end contains correct sidewalk information, verified through Mapillary and Bing street-level imagery.	Sidewalk test elements: link ID, sidewalk presence in OTP back-end, sidewalk presence in Google Street View	Sidewalk test results
7. The project improves the accessibility of information for SUM options relative to prevailing options.	Survey response to questions probing perception of utility of SUM options in OTP.	Survey questions	OTP user survey
8. The usability and design of the web-based OTP interface is considered improved by testing respondents in the population.	Survey response to questions probing perception of usability and design of web-based OTP interface.	Survey questions	OTP user survey
9. The real-time information provided by the OTP interface will provide improved information that is considered useful to the user.	Survey response to questions probing perception of utility of real-time information presented by the updated OTP.	Survey questions	OTP user survey
10. Users report that the OTP improves their ability to overcome first-mile/last-mile challenges.	Survey response to questions probing perception of first-mile/last-mile information in OTP.	Survey questions	OTP user survey
11. The process of deploying the project will produce lessons learned and recommendations for future research, development and deployment.	Lessons learned and recommendations	Stakeholder inputs	Stakeholder interviews

The content of the logic model was translated into a data collection plan, which was incorporated into a broader evaluation plan. The evaluation plan contained further details on the proposed data structures and analytical approaches to address each hypothesis. The evaluation plan was reviewed by project stakeholders and finalized at the inception of the project. The project team then executed the project, working with the IE team to collect and transfer data at key junctures.

Data Collected

A variety of datasets was used to conduct the evaluation. TriMet and the IE team collaborated on survey development and deployment. TriMet supplied addresses to conduct tests on the geocoder, and additional addresses were internally generated by the IE team. The remainder of the project components to be evaluated could be accessed and tested independently. The available datasets included the following:

- **Survey Data** – A survey of TriMet trip users from the TriMet Riders Club was launched in December 2018. This survey was designed to ask questions about trip planning habits and asked respondents to test the new trip planner and provide feedback. A total of 187 survey responses were received. An incentive of $50 in one-day adult transit passes was provided by TriMet to those who completed the survey.
- **Address Data** – Much of the evaluation involved testing the performance of the new trip planner relative to the performance of other existing trip planners and geocoders. TriMet provided a set of addresses to test geocoding accuracy, and the IE team tested its own set of addresses from Portland property records.
- **Sidewalk Data** – Sidewalk infrastructure data were collected to evaluate whether the trip planner routed pedestrians to use this infrastructure, even if it meant not taking the shortest path.
- **Expert Interview Data** – The IE team conducted interviews in August 2019 with experts who were directly connected to the project team and had deep knowledge of the project that covered lessons learned, challenges and barriers, and key institutional findings.

These datasets were applied to evaluate the hypotheses defined in the evaluation plan.

SECTION

4

Evaluation Results

This section explores the defines hypotheses and addresses the questions they posit using the data available.

Hypothesis 1: The matching of addresses and other POIs for transit users in Pelias is comparable to other leading geocoders.

Performance Metric	Key Finding
Difference between number of addresses and POIs correctly matched in Pelias and number of addresses and POIs correctly matched from other leading geocoders.	The analysis geocoded points and their relative proximity to each other and found that Pelias performed comparably with the TriMet test suite and very well with the IE test suite.

The TriMet IE placed heavy emphasis on testing the functionality of the user interface and supporting components. Because the project had a strong development focus, testing the capabilities of the system to perform its stated goals was a primary objective.

A principal hypothesis of the evaluation was to ascertain whether the performance of core underlying functionality, such geocoding and address-matching capabilities, were comparable to and competitive with other accessible geocoders. Fundamentally, this involved the evaluation of performance with respect to address matching.

To evaluate the accuracy of the Pelias geocoder as incorporated into the TriMet application, TriMet provided the IE team with a test suite of 2,020 addresses (note that this was 2,020 actual addresses, not the coincidental year of the report's publication). Those addresses were entered into the Pelias and other geocoders to ascertain the difference in their output. The other geocoders used for comparison included ArcGIS (through the World Geocoding Service), Google Earth, and Mapbox. Each address was entered, and the corresponding geocode output was compared to the geocode output of the Pelias geocoder—e.g., 1234 ABC Street was translated into a GPS latitude and longitude by each geocoder; the comparison was of these GPS outputs.

The performance metric for evaluating this hypothesis was the difference between number of addresses and POIs correctly matched in Pelias and those correctly matched from other leading geocoders. A challenge with this metric was defining what constituted a "correctly matched" address. It was not expected that the Pelias geocode outputs would produce an exact match with other geocoders, and there is no universal standard on what precise GPS coordinates should be associated with any given address.

To address this ambiguity, the analysis used the redundancy of nearness of several geocoder outputs to verify a given point. If multiple geocoders produced points that were mutually near or within a defined margin, then the point was considered to be verified as a function of mutual agreement. Although the leading geocoder coordinates generally fell within close distance of the Pelias test suite, they very rarely corresponded to the exact coordinates of the Pelias geocode. A radial tolerance parameter of 200 feet was chosen to define agreement vs. disagreement for a given point. Many single-family houses are much smaller than this radius and fit well within a 400-foot diameter, but a smaller radius was needed because the geocoding of large properties (such as commercial developments) introduced considerable variability into points that were otherwise correct. That is, Google Earth and ArcGIS both could correctly translate an address to coordinates for a shopping mall, and the distance between those points would exceed the length and width of most single-family houses. In addition to testing the addresses provided by TriMet, the IE team randomly selected its own batch of 2,000 addresses from Portland OpenData's address database. These additional random addresses were similarly evaluated within the Pelias geocoder against the same leading geocoders and the same tolerance parameters.

First, the 2,020 addresses from the TriMet dataset were geocoded, and the corresponding geocodes from the test suite provided by the TriMet team were tested against the ArcGIS, Google Earth, and Mapbox geocoders with the 200 feet tolerance parameter. Individually, the addresses geocoded by Pelias were within 200 feet of 62% of the ArcGIS-geocoded points, 60% of the Google Earth-geocoded points, and 60% of the Mapbox-geocoded points. The distribution of distances from the Pelias-geocoded points are shown in Figure 4-1. Note not all data labels add to these percentages due to rounding.

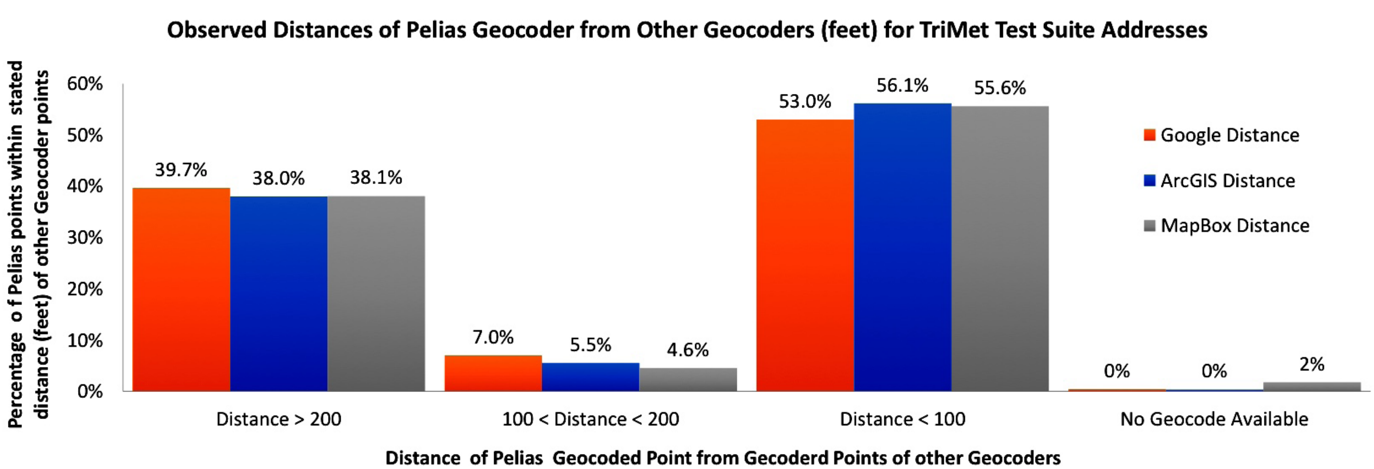


Figure 4-1

Evaluation of TriMet test suite geocodes and addresses compared to ArcGIS, Google Earth, and Mapbox

Figure 4-1 shows the individual comparisons of Pelias with each geocoder separately. The combined comparisons, for which Pelias disagreed and the other geocoders agreed, is also useful. For example, 1,367 (68%) of Pelias-geocoded observations agreed with at least one other geocoder, 1,258 (62%) agreed with at least two other geocoders, and 1,047 (52%) agreed with all three geocoded points. The lack of agreement does not necessarily mean that Pelias is wrong. In some cases, the incorrect geocoding can be by the other geocoder, hence the need for a redundancy of comparison. However, Pelias was more likely to be incorrect when it did not agree with any of the other geocoders and the other geocoders agreed. This comparison was made as well, where the distance between the geocoded points in ArcGIS, Google Earth, and Mapbox was calculated. In cases in which these were within 200 feet of each other and Pelias was not within 200 feet of either, Pelias was considered more likely to be inaccurate. For 170 points (8%), none of geocoders agreed with each other; for the remaining 483 (24%), Pelias did not agree within any of the geocoders, whereas at least one of the other three geocoders agreed with another. In such cases, more than one of the platforms was wrong or Pelias was incorrect. For 280 (14%) points, the three other geocoders agreed with each other (within 200 feet), but Pelias was in disagreement. A random audit of these points confirmed that Pelias was incorrect in cases in which the other three geocoders were in agreement. For comparison, 86 (4%) points had Google Earth in disagreement with the other three geocoders.

As noted in Figure 4-1, the geocoder producing the disagreed result changed depending on the address. The data suggest that 53–56% of points were in close agreement within 100 feet of the Pelias geocode. Primarily, geocodes fell outside of this tolerance parameter as a result of three factors:

- Sizeable area associated with an address
- Ambiguity of addresses
- Failure to match address or general error

Figures 4-2 and 4-3 show examples of the first two factors. Figure 4-2 shows the distance discrepancies that can occur when geocoding a large property such as a shopping mall. Both points correctly identify the property, but the ArcGIS point (green) geocode is in the Clackamas Town Center to the left, whereas the Pelias (yellow) geocode is at the center, leaving it well outside the target parameter of 200 feet radius of the ArcGIS point. Such an error would be significantly inaccurate on a residential street but still technically correct for a large property. Figure 4-3 shows the case of a vague address for which the street number is not identified. In such cases, there is ambiguity as to where to assign the latitude and longitude of the location.

Figure 4-2

Example of large building geocoding error

Figure 4-3

Example of vague address geocoding – ArcGIS (blue dot) vs. TriMet (green dot)

In addition to the 2,020 points provided by TriMet, the IE team randomly selected 2,000 additional addresses randomly drawn from the Portland-Metro address directory to further evaluate the Pelias geocoder. Using the online version of Pelias provided by TriMet for the Portland-Metro area, these addresses were run through the Pelias, ArcGIS, Google Earth, and Mapbox geocoders. Figure 4-4 shows the distribution of distances the points from these geocoders were found to be from the Pelias geocoder.

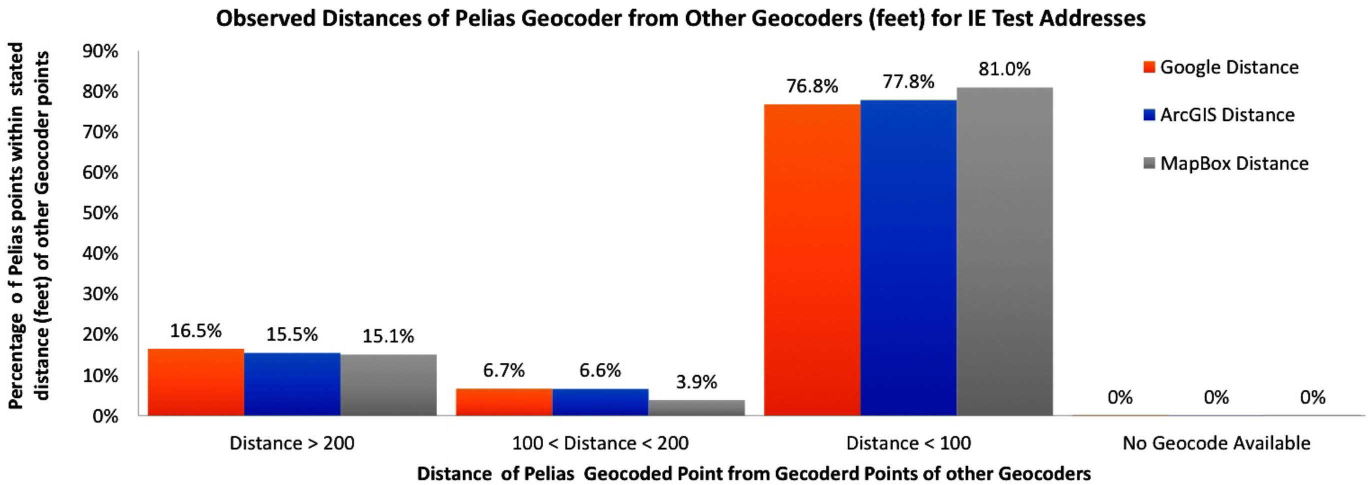


Figure 4-4

Comparison of geocoding distances for Pelias, Google Earth, ArcGIS, and Mapbox

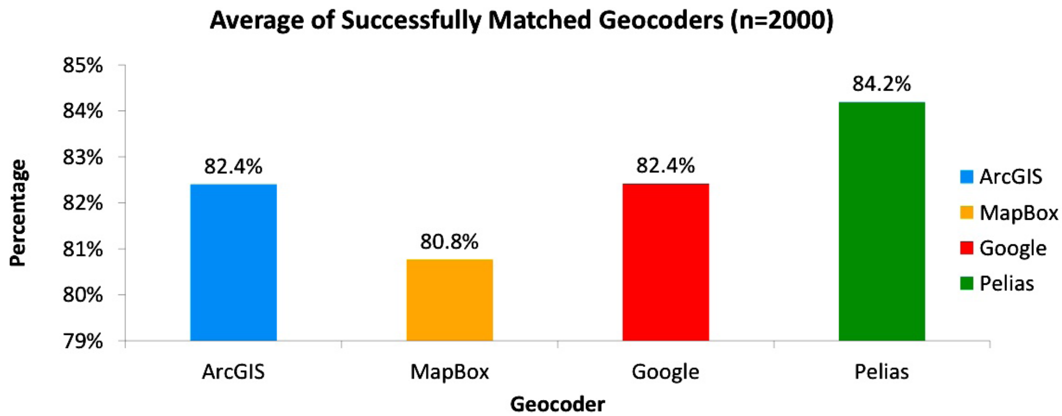
The Pelias geocoder performed better with the IE-selected addresses. Within 200 feet, it agreed with 83% of Google Earth points, 84% of ArcGIS points, and 84% of Mapbox points. As with the test suite, the Pelias geocoder agreed with different geocoders for different points. It agreed with at least one other geocoder for 1,882 (94%) points, with two other geocoders for 1,731 (87%) points, and with all three geocoders for 1,423 (71%) points. There was no agreement among any geocoders for 40 (2%) points, whereas for 78 (4%) points, the Pelias geocoder did not agree with any other geocoder, but at least two agreed (with 200 feet of each other) on the location of a given point. This does not confirm that Pelias was incorrect, as the other coders could be collectively wrong, but such points would be more likely candidates for the inaccuracy of Pelias given the agreement of the other geocoders. Only 18 points (1%) in this dataset were mutually agreed upon by the three geocoders and were not within 200 feet of the Pelias coordinates for the point. By comparison, 70 (3.5%) points showed Google Earth in disagreement with the other three geocoders. By this measure, Pelias was more comparable to the other geocoders than Google Earth for the IE test dataset.

This higher accuracy with the IE test addresses may be because the TriMet test suite contained some addresses that were selected based on user submissions, such as the Clackamas Town Center, as well as other entry types that were designed to challenge the Pelias geocoder, and many were large buildings. In the IE test data set, addresses were randomly selected from a property database, which meant that more residential units were selected rather than large buildings, so the large building error encountered in the TriMet test was not experienced to the same degree.

How the different geocoders compared to each other was evaluated. Each geocoder exhibited a relative nearness to the results of the other geocoders—that is, when comparison of the Pelias geocoder was extended across all three geocoders, results show that, collectively, a similar percentage of points was found within the 200-foot range with each. The results are shown in Figure 4-5.

Figure 4-5

Cross-comparison of matching across geocoders using IE random addresses



The data in Figure 4-5 show that, on average, nearly 81% of the addresses geocoded by Mapbox were within 200 feet of the points geocoded by the other three geocoders. This cross-comparison shows a very comparable measure of relative agreement; the Pelias geocoder had the highest percentage of addresses in agreement with the other geocoders. Findings from the analysis of the TriMet test suite suggest the need for a review of Pelias for some more challenging entries it may face. However, the IE test suite notably found that that the Pelias geocoder performed very well with respect to comparability with results. In the IE-generated set of test cases, Pelias geocoded addresses in ways that were highly comparable to the other geocoders. Collectively, these results suggest that Hypothesis 1 is mostly-supported, that the address matching of the Pelias geocoder is comparable to other leading geocoders.

Hypothesis 2: The accuracy of the geocoding results from Pelias with regard to point locations are comparable to other leading geocoders.

Performance Metric	Key Finding
Difference between number of accurate address locations from Pelias and number of accurate address locations from other leading geocoders.	Analysis of geocoded points evaluated whether they fell within the polygons defining the test address. The Pelias geocoder matched about half the points; other geocoders matched about 60% of the points.

Hypothesis 1 evaluated the comparability of the Pelias geocoder with three leading geocoders for accessibility with address queries. Evaluation of Hypothesis 2 was slightly different—it looked at the accuracy of the Pelias geocoder relative to the other geocoders for a given set of addresses for which the location was defined. The accuracy test followed from the test data applied in Hypothesis 1. Accuracy in geocoding can become subjective at a certain resolution. As shown in Figure 4-2, two points can be some distance apart and still be accurate in representing the location. This distance can be considerable for large properties, but the tolerance is less for smaller properties such as single-family homes.

To evaluate the accuracy of Pelias geocoding, the project team supplied the IE team with a series of polygons that defined the area covered by each address. If a point from a geocoded address was anywhere inside the polygon, the result was considered accurate; if the point fell outside the polygon, it was considered inaccurate. The polygon test was conducted only for data supplied to the IE team from the project team, as the IE team did not have the resources to generate its own polygons for the self-generated data selected randomly from property values.

The test was conducted on the 2,020 addresses supplied by the project team and included location names (when relevant) in addition to addresses. The geocoded points were assigned to polygons through a spatial join. The analysis also evaluated the nearness of geocoded points that did not fall within their associated polygon to allow a review of the distribution of nearness across the geocoders for the same test suite dataset. The resulting accuracy of this analysis is presented in Table 4-1.

Table 4-1

Summary of Successful Matches to Unique Addresses

Nearness Category	Count of Addresses				Percentage of Addresses			
	Pelias	*Google Earth*	*Mapbox*	*ArcGIS*	*Pelias*	*Google Earth*	*Mapbox*	*ArcGIS*
Within polygon	984	1244	1219	1221	49%	62%	60%	60%
0–100 ft away	223	250	221	350	11%	12%	11%	17%
100–200 ft away	91	105	98	139	5%	5%	5%	7%
200–300 ft away	52	52	43	36	3%	3%	2%	2%
300–400 ft away	22	28	33	39	1%	1%	2%	2%
400–500 ft away	27	20	13	29	1%	1%	1%	1%
More than 500 ft away	621	321	393	206	31%	16%	19%	10%

The results show the number of uniquely-defined addresses that were properly geocoded that fell within the polygon and the distribution of points that fell within some distance from the polygon assigned to the point. The percentages represent geocodes within the polygon and the distribution of distance for which points fell outside the polygon for all addresses in the test suite dataset (2,020). This provides a comparison of accuracy across the geocoders for this dataset. The Google Earth geocoder was found to be most accurate, at 62% for all addresses. The ArcGIS geocoder was the second most accurate, followed by Mapbox and Pelias.

The test was also run without facility names, only addresses. In this test, Mapbox's performance improved to the level of ArcGIS and Google Earth, but the accuracy of Pelias remained the same, lower than the other geocoders. Figure 4-6 shows an example of geocoded points that fell within and outside the defined polygons for the given location. The left image shows a case in which all geocoded points fell within the polygon; the right image shows a case in which one of the geocoders fell outside the polygon. Note the variance in all points that is inherent with geocoding.

Figure 4-6

Examples of polygon geocoding

Although all geocoders exhibited limitations to their accuracy, the analysis found that the accuracy of the Pelias geocoder was more limited when compared to the other geocoders in this test and was the least accurate geocoder in the test suite. The difference was large enough that the Pelias geocoder was not comparable or equivalent in accuracy to Google Earth, ArcGIS, or Mapbox. These limitations may exist because of challenges Pelias may face with respect to handling inaccurate user submissions (such as misspellings) relative to the other geocoders. Collectively, the results suggest a partially-supported finding for Hypothesis 2.

Hypothesis 3: Trips planned using OTP will show faster travel times with Shared Use Mobility (SUM) incorporated, as compared to leading trip planners without SUM.

Performance Metric	Key Finding
Difference in trip times of test trips from OTP and other leading trip planners on the market.	Travel times of trips with and without SUM options showed that the OTP showed faster travel times relative to trip planners without this information.

Hypothesis 3 was that the OTP would show faster travel times using SUM compared to the travel times shown in conventional trip planners that did not incorporate SUM options. The OTP had several shared mobility options available at the time of the evaluation, such as car-sharing and bike-sharing, among others. These options included car2go, Park & Ride (can be used to connect to carpooling, vanpooling, or public transit), Biketown (station-based bikesharing), and e-scooter (dockless e-scooter systems). To evaluate this hypothesis, 2,000 trips were generated by randomly pairing the 2,000 addresses generated by the IE team to evaluate Hypothesis 1. These trips were run through the OTP and Google Maps, which was chosen because of its status as a leading trip planner and because it does not yet incorporate SUM-based options in Portland.

For each option available in the trip planners, the reported trip time was collected for each trip pair. The performance metric was the trip times and their comparative average across all computable pairs. Because the trips were randomly generated, some of the 2,000 trip pairs were not computable by the trip planners, often because the origin/destination fell outside public transit coverage, which would result in the projected walking distance exceeding the maximum distance allowed by the trip planner. The failure to plan a trip was mode-specific; for example, sometimes a trip using car2go was not possible according to the OTP, but trips using other modes were. Only trips that were successfully planned by both TriMet and Google Maps services were considered for analysis in the final sample size.

For three of the four shared mobility modes—car2Go, Biketown, and e-scooter—the OTP averaged a lower projected trip time than the Google Maps, with differences of -8.3, -6.4, and -6.0 minutes, respectively; Park & Ride had a difference of a little over 11 minutes. A t-test was computed for the differences of the mean for each shared mobility option, and the results are presented in Table 4-2. The differences in the means were found to be significant for each mobility option at a 99% confidence level. Analysis results generally confirm Hypothesis 3, that the travel times for SUM-incorporated trips were found to be shorter than conventionally-planned trips using a comparable leading trip planner. This was not the case with the Park & Ride option, but it was considered to be a function of the option itself, not of the trip planner. The OTP showed that the incorporation of shared mobility options into the planner can consistently reveal faster trip times than the options provided by more conventional transit trip planning applications.

Table 4-2

Summary of Trip Time Comparison

Modes	Count	Average	Standard Deviation	Median	T-test p-value
car2go (one-way carsharing)	n = 1173	-8.3	13.8	-6.3	0.00
Park & Ride	n = 1323	11.9	20.6	10.2	0.00
Biketown (bikesharing)	n = 1456	-6.4	11.6	-5.0	0.00
e-scooter	n = 1456	-6.2	11.9	-5.0	0.00

Hypothesis 4: The resulting itineraries and choices will be valid.

Performance Metric	Key Finding
Survey response to questions probing reliability of planned trips.	A survey of beta testers showed that at least 90% of respondents felt that the trip planner located their origin and destination correctly.

Hypothesis 4 sought to evaluate whether the itineraries and choices provided to users would be considered valid and correct. To address this hypothesis, the IE team deployed a test user survey that asked several questions to evaluate the degree to which respondents considered the output received from the trip planner to be valid.

The survey was designed to evaluate the trip planning needs of respondents and their relative satisfaction with existing trip planning resources. It also facilitated on-the-spot testing of the TriMet OTP. The survey design allowed respondents to access the OTP in a new window while leaving the survey open, use the trip planner, and return to continue the survey. Respondents were asked to enter a trip origin and destination of their choice into the OTP, after which they received options and reported on those options. The parameters entered were communicated via a URL back to the survey or direct responses if URL communication was not easy (as with a smart phone). The survey sample was drawn from the TriMet Riders Club; those interested in receiving notifications about TriMet or providing input into the service could sign up to be a member. This provides TriMet with a group of transit users who are willing to offer input and feedback on services, including trip planners. Survey respondents were recruited from this list, and 187 surveys were completed. Respondents received an incentive of 10 one-day adult TriMet transit passes ($50 value).

Because respondents could choose their own trips to plan, they were in the best position to report on the validity of the OTP output. Responses to survey questions provided insight into the relative validity as perceived by the respondents on the trip they planned using the OTP.

Figures 4-7 through 4-10 are graphs that provide context regarding the travel and household structure of the survey respondents, including household size, vehicle ownership, and relationships within the household. The questions served to inform the context of subsequent questions; for example, a question about sharing expenses vs. income was asked because households in roommate situations often share expenses but do not share vehicles or other assets, whereas households sharing income make other decisions jointly and share assets (such as vehicles).

Figure 4-10 shows that the respondent base includes a fairly high share of households (or individuals) without a car (35%). The distributions suggest that most respondents lived in households with more than one person and at least one vehicle; however, a substantial share (25%) lived as individuals. About 80% of the households surveyed had no more than one car.

Figure 4-7

Number of people living in current household of respondent

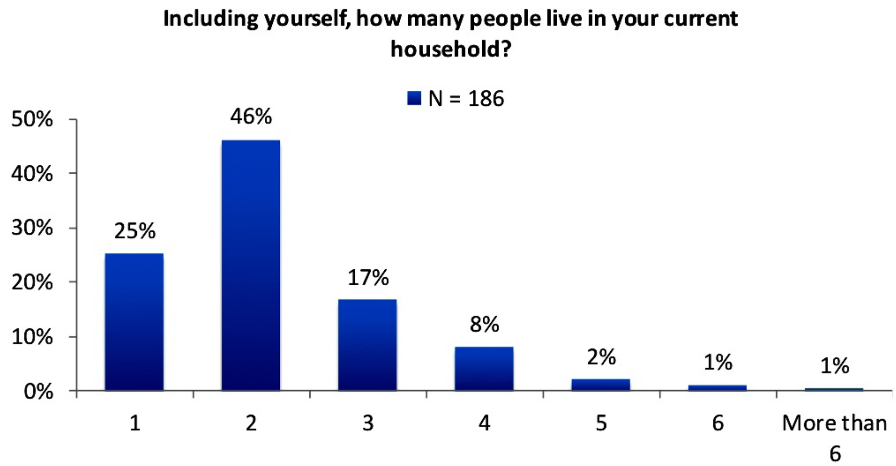


Figure 4-8

Description of people in current household of respondent

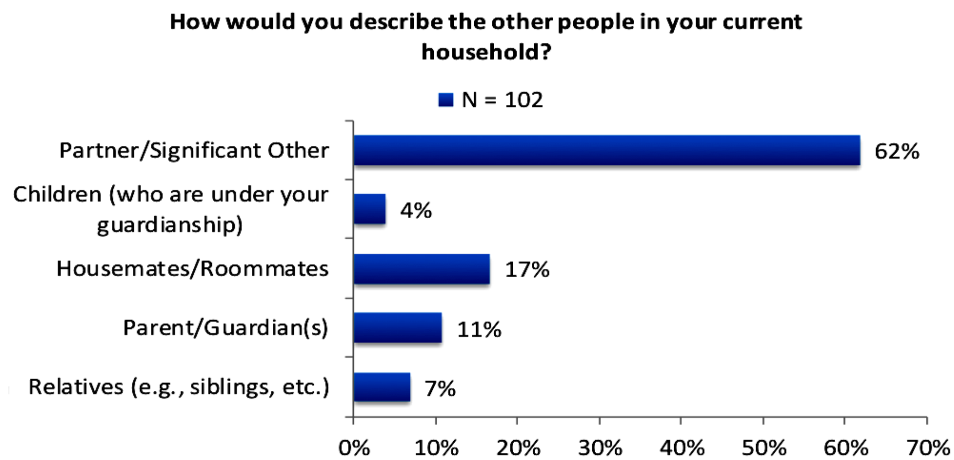


Figure 4-9

Financial relationship with people living in current household of respondent

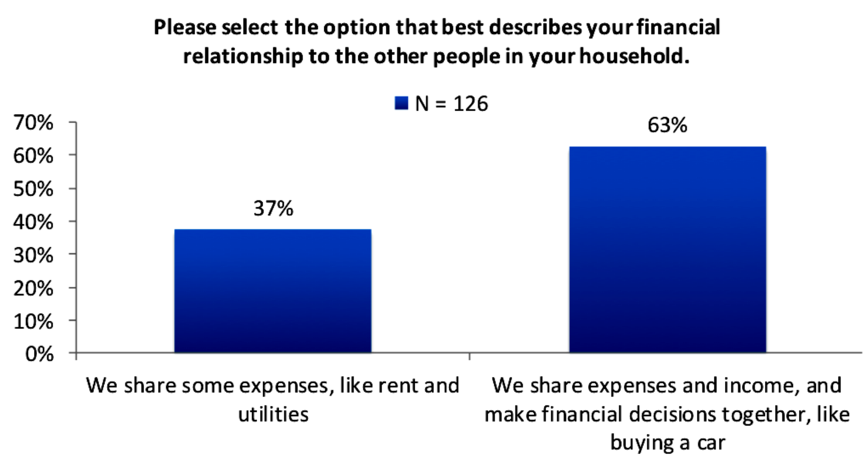


Figure 4-10

Number of vehicles currently owned/ leased by respondent household

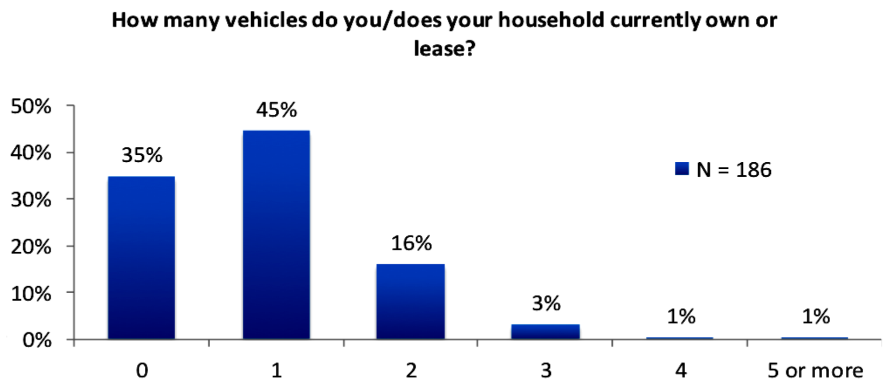


Figure 4-11 shows the distribution of mileage driven using these household vehicles, indicating that the sample population generally drove less than the average Portland household, with more than 50% of the sample living in households that drove 7,000 miles or less.

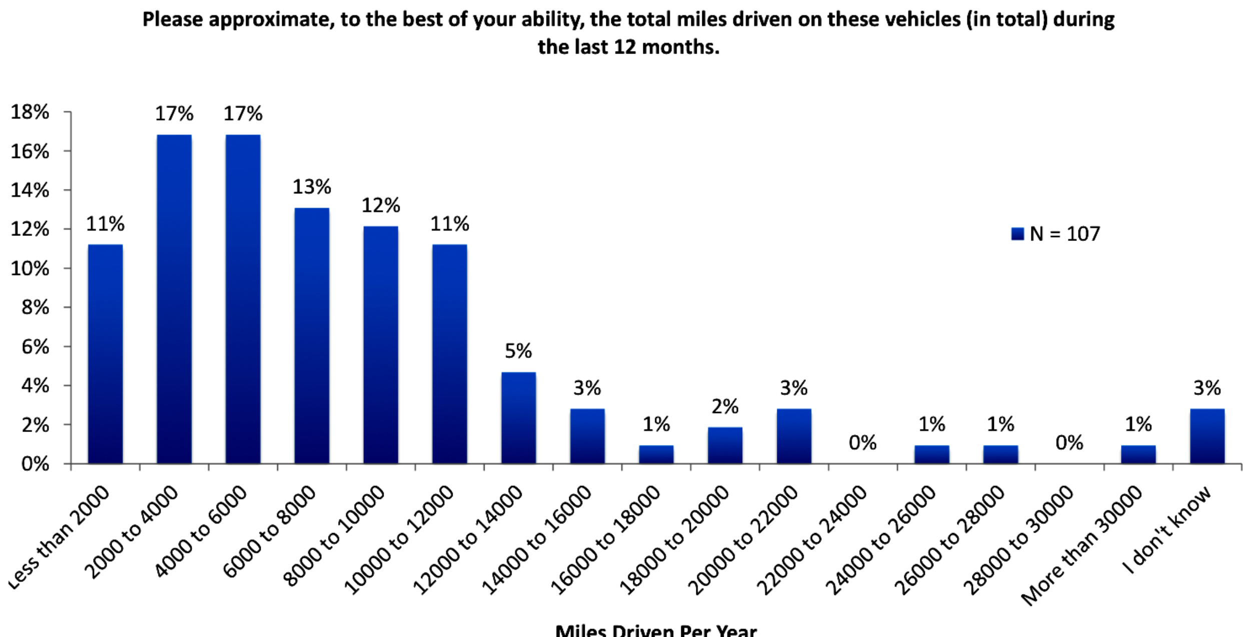


Figure 4-11

Mileage driven on household vehicles

Figure 4-12 shows the modes used by respondents, indicating that, perhaps as expected, they were very familiar with public transit—97% had used the bus, 96% had used the MAX, and 67% had used the streetcar. All percentages exceeded the share that reported driving alone in the last 12 months (59%).

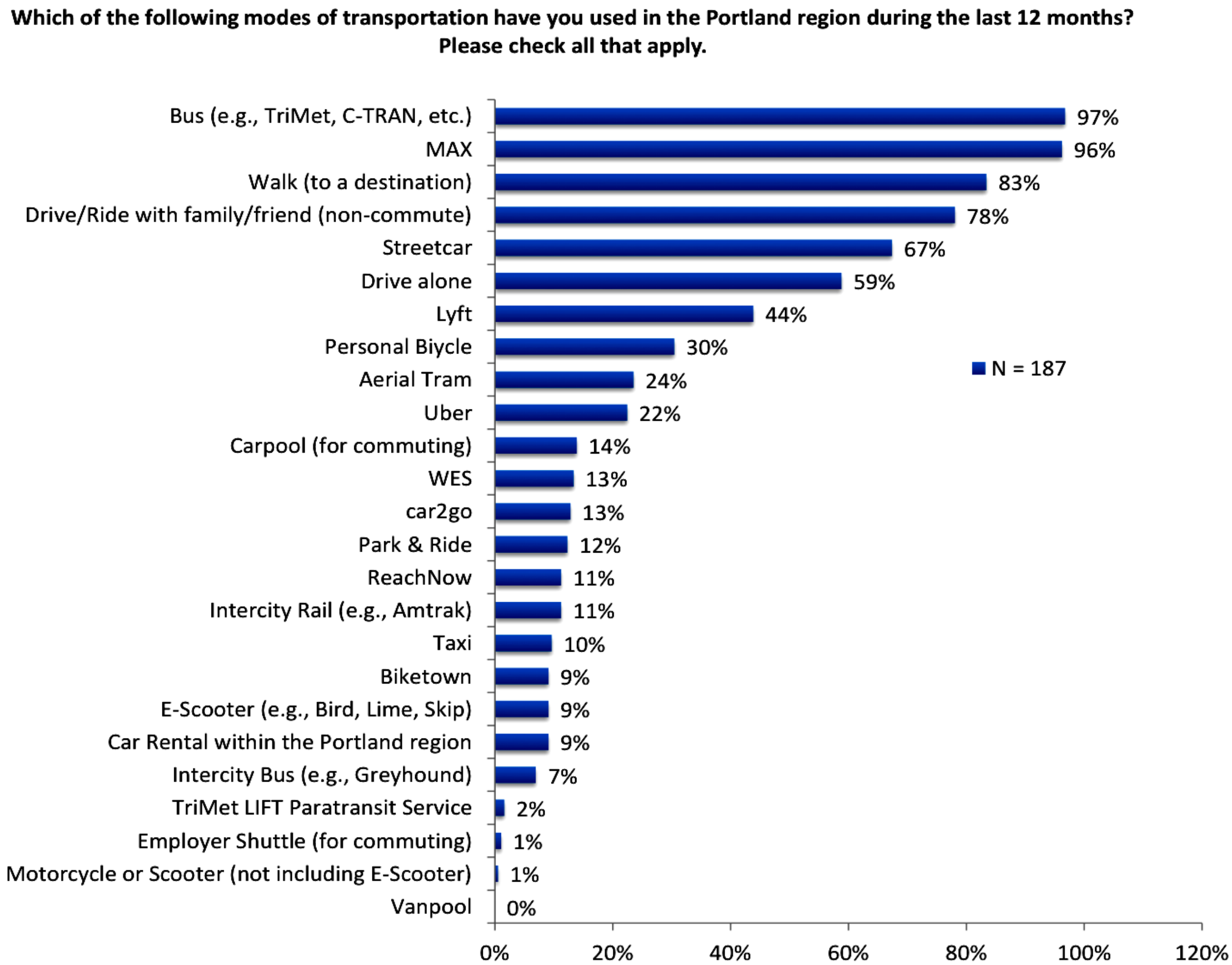


Figure 4-12

Modes used by respondents in last 12 months

Figure 4-13 shows the trip planners used by respondents, indicating that the existing TriMet trip planner (the previous one, not the one tested), was relatively well used among the sample population. The second most popular trip planner was Google Maps; Transit App and PDX Bus were in distant third and fourth places.

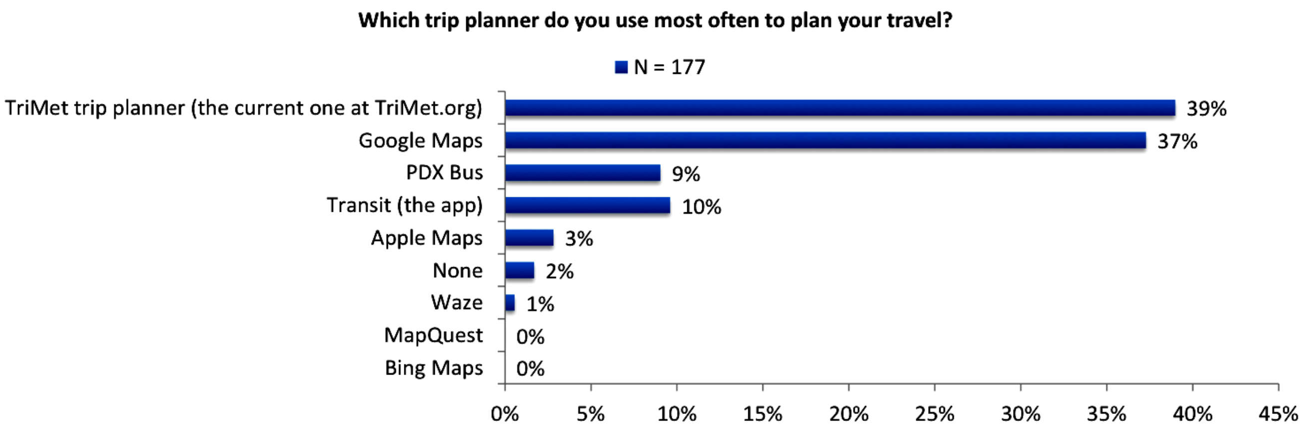


Figure 4-13

Trip planners used by respondents

Respondents could access the trip planner in several ways. The most common was via computer (64%); 32% used a smart phone, and 4% used a tablet.

Figure 4-14 shows how respondents entered their location into the tested trip planner; most used the "Current Location" feature, automatically taking the location from the instrument used to take the survey. The second most common was an exact address entry, followed by cross-street entries.

Figure 4-14

Method of entry for origin

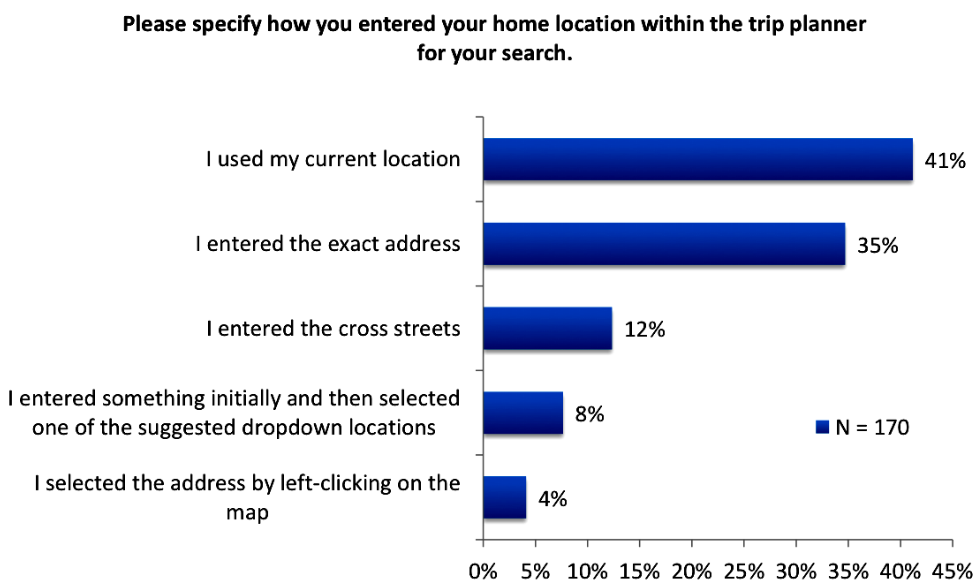
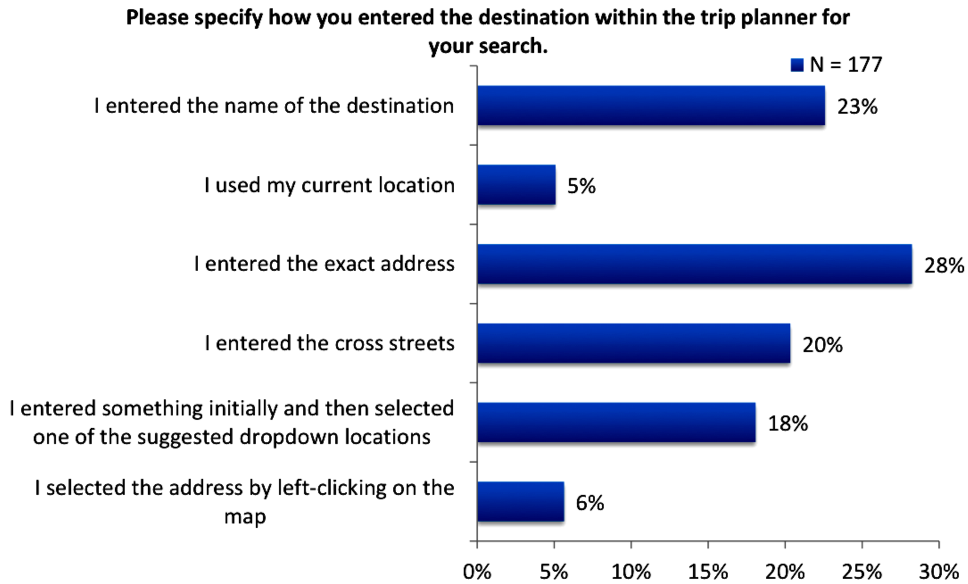


Figure 4-15 shows how respondents entered their destination information. Most entered their exact address, following by entering the name of destination, by entering cross streets, and by using the drop-down menu of suggested options. Respondents also could select their destination (or their origin) by left-clicking on a map. The least common destination selection methods was use of their current location.

Figure 4-15

Method of entry for destination



Based on respondent input, the survey asked about the correctness of output from the OTP to assess validity. Figure 4-16 shows respondent assessments of origin and destination correctness on a Likert scale (strongly agree to strongly disagree). In total, 91% of respondents reported that the OTP located their origin correctly, and only 9% reported that it was not located correctly; 90% of respondents reported that the OTP located their destination correctly, and only 10% reported that it was not located correctly. This suggests that the trip planner was broadly returning valid results for respondents.

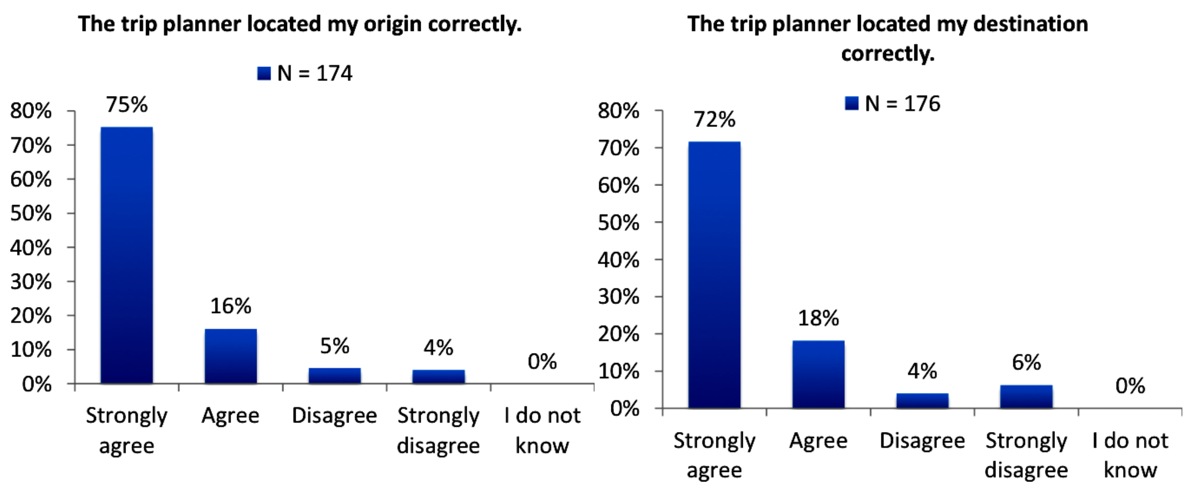
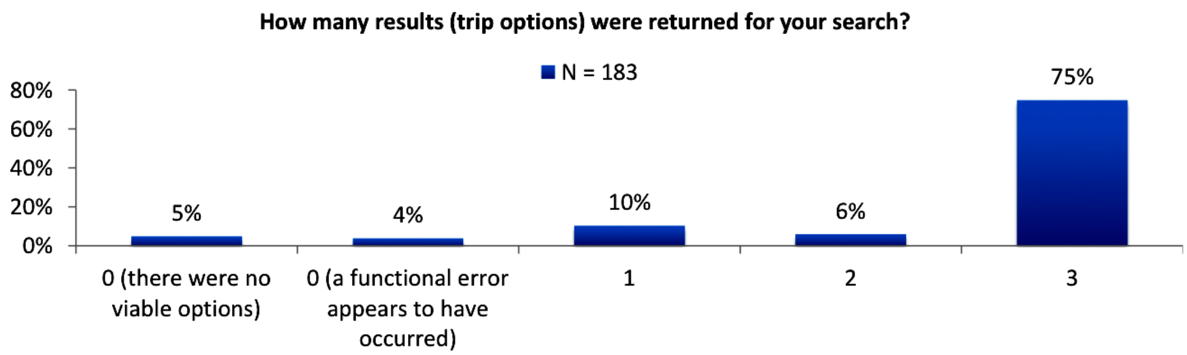


Figure 4-16

Reported correctness of results

Figure 4-17 shows the number of trip options received by respondents. Most (75%) received the maximum three responses, and 16% received one or two; 9% reported no options received, and only 4% reported a functional error. Overall, 49% thought the suggested "Best Bet" trip option was best for them, and 41% reported that options 2 or 3 or all were correct and satisfactory. Only 10% stated that no results returned to them were correct or satisfactory or that they did not know enough to respond.



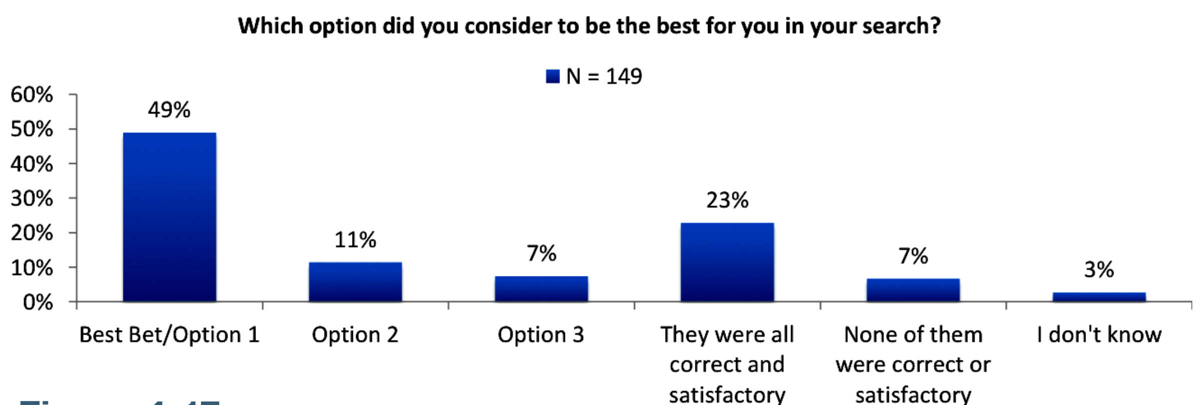


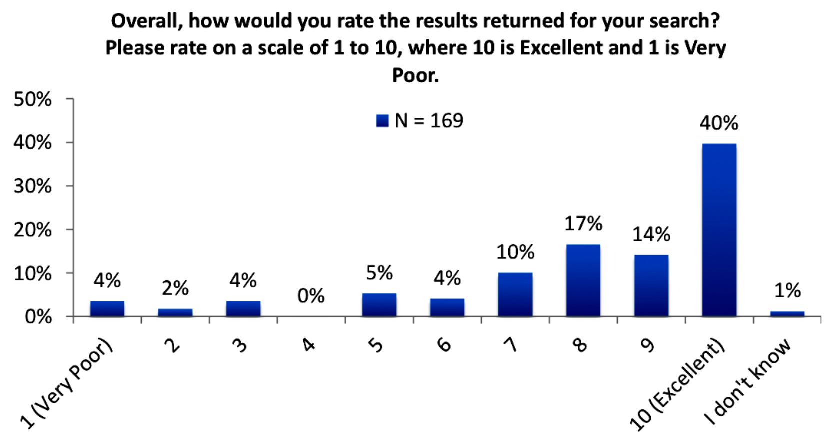
Figure 4-17

Results count and performance

Figure 4-18 shows the distribution of how respondents rated the results returned for their search. Overall, 71% rated the results as high (rating of 8, 9, or 10), and 10% rated the results as poor (rating of 1, 2, or 3).

Figure 4-18

Rating of search results returned



Overall, the results of the survey analysis found that most (at least 90%) test respondents found that the OTP returned valid results. The mid-survey test of the OTP did not provide origins and destinations for the respondents to use; they were free to plan a trip of their choice, thus exposing the process to possible user error. About 10% of respondents reported having trouble, either with no options were returned or as a user error indicated. Despite this result, the OTP performed very well in the user test, which contained a high degree of user freedom, and the results returned were deemed correct and acceptable by most respondents. Given these findings, the IE research team considers Hypothesis 4, that the resulting itineraries and choices will be valid, to be confirmed.

Hypothesis 5: When routing pedestrians, OTP favors streets with sidewalks and lower environmental stress (e.g., lower speed limits and traffic volume).

Performance Metric	Key Finding
Number of sample trips where new OTP can be configured to take a slightly longer but safer walking route rather than the shortest route.	A manual review of 30 walkable trips found that the weighting scheme of the OTP directed users to lower-stress walking environments.

Evaluation of the OTP explored its capacity to consider the presence of sidewalks as part of its routing algorithm for pedestrian trips. A key objective for the new TriMet trip planner was to provide a safe, user-friendly experience for pedestrians by promoting sidewalk routing. Analysis of Hypothesis 5 verified the existence and accuracy of sidewalk tags in the TriMet region through OpenStreetMaps. This analysis builds on evaluating the OTP's ability to use that data for appropriate routing decisions.

To conduct its routing for trip planning, the OTP uses a series of weighting factors that collectively determine the route that will be recommended to the user. The weights are assigned to street links, which are multiplied by distance. The routing algorithm solves the shortest distance based on the weights times the distance. The weights applied to the OTP during this evaluation (which are subject to change) are shown in Table 4-3.

Table 4-3

Pedestrian Link Weights of OTP

Type1	Key1	Value1	Combined Rule Operator	Type2	Key2	Value2	Factor
equal	footway	sidewalk	none				1.1
equal	highway	service	none				1.2
absent	name		none				1.2
equal	highway	trunk	none				1.2
equal	highway	trunk_link	none				1.2
equal	highway	primary	none				1.2
equal	highway	primary_link	none				1.2
equal	highway	secondary	none				1.1
equal	highway	secondary_link	none				1.1
equal	highway	tertiary	none				1.1
equal	highway	tertiary_link	none				1.1
greater	lanes	4	none				1.1
equal	sidewalk	both	none				0.8
equal	sidewalk	left	none				0.9
equal	sidewalk	right	none				0.9
equal	surface	unpaved	none				1.4

A pedestrian trip will consider these weights in providing travel options to the user. A street with sidewalks on both sides will reduce the weighted distance of the route, whereas streets that have faster traffic have higher weights and will increase the weighted distance of the route.

The weighting factors suggest that the OTP favors sidewalks and streets with lower environmental stress. Testing the effectiveness of the routing in practice is challenging because several factors in the route are considered simultaneously. The OTP may weight certain links to be of higher environmental stress, but, in practice, it still may recommend the route if it is significantly shorter than a lower-stress route that is considerably longer.

To test Hypothesis 5, a total of 30 origin/destination trips were selected by the IE team to evaluate whether the OTP was providing routes that were relatively low-stress compared to available alternatives. The same trips were routed using Google Maps to evaluate an alternative provided by an outside trip planner. The assessment was based on whether the OTP-recommended route had sidewalks and overall speed-based pedestrian stress levels. The area surrounding the origin was explored and, if possible, a destination point was chosen with two possible routes—one without sidewalks and a slightly longer route with sidewalks. This occurred when residential areas (which typically did not have sidewalks) and commercial zones (which typically had sidewalks) were adjacent. Trips were intentionally selected to be short (< 1 mile) to simplify the route and remove the bus option from the calculation. Environmental stresses such as speed limit and volume were the same for most routes, as trips were short and generally were planned through residential streets. Therefore, the primary metric for trip success was whether the OTP planned route was at an equivalent lower pedestrian stress level relative to the route recommended by Google Maps. This measure was ultimately qualitative. Some recommended routes contained sidewalks and others did not. The OTP could recommend routes that did not have sidewalks over those that did if the street speed or other factors suggested that it was a lower-stress walk. Table 4-4 shows the origin/destination pairs that were evaluated.

When considering the presence of sidewalks, traffic speed, and overall pedestrian stress level, the results found that the TriMet OTP generally had good performance with respect to correctly routing pedestrians in ways that improved or expanded their use of sidewalks or provided a lower stress level relative to a more direct route. In many cases, TriMet OTP and Google Maps produced equivalent results; for some trips, the OTP conveyed a walking route that was improved relative to Google Maps. In one case, the OTP recommended a route that was slightly higher-stress than the alternative presented by Google Earth, but the difference between the two routes was minimal. Previous reviews of OTP routes found some illogical routes, but these were corrected by the time a second review was conducted. Based on the assessment, analysis of this hypothesis concluded that the TriMet OTP was successfully providing routes that would favor sidewalks and/or lower-stress environments for pedestrian routing. The results were not significantly different from routes presented by alternative trip planners, but they clearly considered street-level stress factors that would impact the pedestrian experience.

Table 4-4

Tested Origin/Destination Pairs for OTP Pedestrian Routing

Origin Address	Destination Address
All Saints Episcopal Church, 4033 SE Woodstock Blvd, Portland, OR 97202	Bi-Mart Membership Discount Stores, 4315 SE Woodstock Blvd, Portland, OR 97206
14520 NE San Rafael St, Portland, OR 97230	NE Sacramento & 148th, Portland, OR 97230
6920 SE 52nd Ave, Portland	6801 SE 60th Ave, Portland
5916 NE Going St, Portland, OR	5401 NE Prescott St, Portland, OR
3822 SE Tenino St, Portland, OR 97202	3704 SE Lexington St, Portland, OR 97202
8205 SW 24th Ave, Portland	8122 SW 31st Ave, Portland, OR 97219
6955 N Smith St, Portland, OR 97203	6956 N Columbia Way, Portland, OR 97203
Chai Thai, 14035 SE Stark St, Portland, OR 97233	14149 SE Taylor St, Portland, OR 97233
10927 SW 37th Ave, Portland, OR 97219	Jackson Middle School, 10625 SW 35th Ave, Portland, OR 97219
Starbucks, 7737 SW Capitol Hwy, Portland, OR 97219	SW 35th & Canby, Portland, OR 97219
Crossroads Food Bank, 2407 NE 102nd Ave, Portland, OR 97220	2115 NE 105th Ave, Portland, OR 97220
NE 82nd & Wygant, Portland, OR 97220	Portland Fire & Rescue Station 12, 8645 NE Sandy Blvd, Portland, OR 97220
6230 SE 46th Ave, Portland, OR 97206	Back to Eden Bakery Food Cart, 4804 SE Woodstock Blvd, Portland, OR 97202
Lu Don Apartments, 8415 SE Bush St, Portland, OR 97266	Meineke Car Care Center, 3635 SE 82nd Ave, Portland, OR 97266
2504 NE Alberta St, Portland, OR 97211	4803 NE 26th Ave, Portland, OR 97211
SW Vermont & 34th, Portland, OR 97219	3569 SW Dakota St, Portland, OR 97221
A Gifted Hands Chiropractic, 12019 SE Powell Blvd, Portland, OR 97266	SE Division & 119th, Portland, OR 97266
14805 SE 148th Ave, Portland, OR 97233	14947 SE Mill St, Portland, OR 97233
Rose City Park Elementary School, 2334 NE 57th Ave, Portland, OR 97213	Rice School, Portland, OR 97213
15111 Southeast Start Street	15141 SE Yamhill
6541 SE Stark St, Portland, OR 97215	6611 SE Scott Dr, Portland, OR 97215
SW Spring Garden & 14th, Portland, OR 97219	1637 SW Carson St, Portland, OR 97219
SW Vermont & 30th, Portland, OR 97239	3111 SW California St, Portland, OR 97219
13413 SE Division St, Portland, OR 97236	13335 SE Powell Blvd, Portland, OR 97236
10405 Southeast Boise St	4435 SE 107th Ave
13805 Northeast Sandy Blvd	13521 NE Whitaker
3955 SE 112th Ave, Portland, OR 97266	4109 SE 114th Ave, Portland, OR 97266
Human Services Oregon Department, 4744 N Interstate Ave, Portland, OR 97217	2006 N Wygant St, Portland, OR 97217
4709 SE 61st Ave, Portland, OR 97206	4508 SE 60th Ave, Portland, OR 97206
12019 NE Sacramento St, Portland, OR 97220	11725 NE Brazee St, Portland, OR 97220

Hypothesis 6: Sidewalk presence/absence information is available for all streets in the TriMet trip planner region.

Performance Metric	Key Finding
Number of random samples where the OTP back-end contains correct sidewalk information, verified through Mapillary and Bing street-level imagery.	Visual review of 300 random road segments found that sidewalk information was highly accurate.

One of the technical hypotheses in the evaluation was to determine whether the OTP contained information on whether sidewalks were present or were present for specific street links. The purpose of this hypothesis was to support evaluation of the hypothesis that the OTP would adjust routing for pedestrian trips to better account for pedestrian safety. TriMet supplied a count of street segments and linear miles that were tagged during the project.

A complete verification of the correctness of all sidewalk locations across the Portland metropolitan region would require manual verification at the street level. Because TriMet's sidewalk data were unique, there was no independent data source with which to compare it. Furthermore, visually corroborating the sidewalk data via physical inspection would be problematic given the resources of the IE team. To address these challenges, the IE team drew a random sample of 300 street segments from TriMet data containing information on whether there were sidewalks and indicating if the sidewalk was on the "right," "left," or "both." The first two fields were context-dependent on the direction being faced, but generally indicated a sidewalk on one side and not the other. A sample of these data is shown in Table 4-5, which contains a selection of the data drawn for testing.

Through the OpenStreetMap in-browser editor, the accuracy of the sidewalk tags (left, right or both sides of the street) was evaluated using a combination of Mapillary and Bing Street View (mapping services that provide street views of roads in cities) to explore the road segment. Bing Street View was used to visually evaluate the presence of each of the 300 segments randomly sampled. Of the 300 segments, only 13 had incorrect tags; 6 of those 13 needed to have sidewalk tags added, 5 needed to be upgraded to "both" (from either "right" or "left"), and 2 needed to be downgraded from "both" to "left" or "right."

Table 4-5

Sample of Sidewalk Data Tested

full_id	osm_id	osm_type	highway	maxspeed	sidewalk
w118642893	118642893	Way	residential	20 mph	right
w5520441	5520441	way	residential	20 mph	left
w134955104	134955104	way	secondary	25 mph	both
w119415804	119415804	way	residential	20 mph	no
w220548947	220548947	way	residential	20 mph	both
w5535813	5535813	way	tertiary	20 mph	both
w124788560	124788560	way	secondary	30 mph	right
w45673629	45673629	way	secondary	35 mph	both
w5531377	5531377	way	residential	20 mph	both
w603948908	603948908	way	tertiary	25 mph	both
w604404141	604404141	way	primary	30 mph	both
w190656352	190656352	way	tertiary	25 mph	left
w586135817	586135817	way	residential	20 mph	both

The accuracy rating (96%) suggests that the roadways in the TriMet region generally have accurate and reliable tags. Notably, 11 of the inaccuracies in this analysis found that sidewalk data needed only to be upgraded to either show sidewalks where none were indicated or needed to indicate that sidewalks were on both sides of the street instead of one. No cases were found in which sidewalks were reported in the data but not actually present. The data confirmed Hypothesis 6, that the TriMet OTP contained accurate sidewalk information.

Hypothesis 7: The project improves the accessibility of information for SUM options relative to the prevailing options.

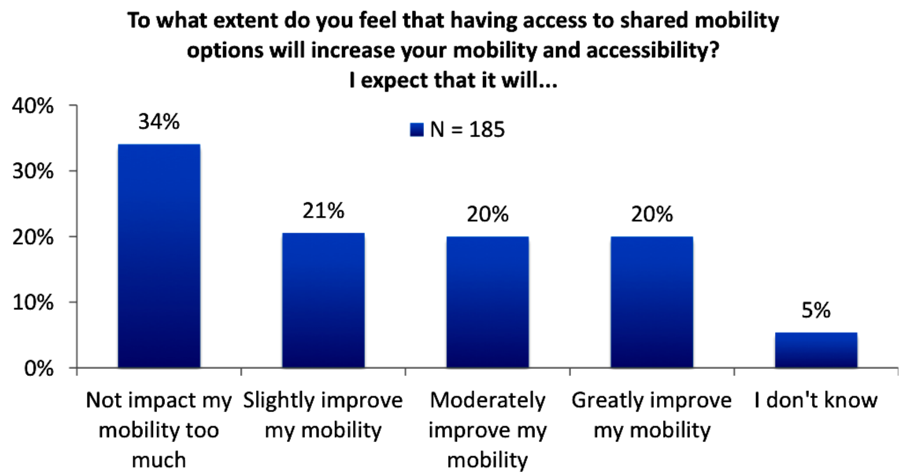
Performance Metric	Key Finding
Survey response to questions probing perception of utility of SUM options in OTP.	Survey responses of beta testers suggested that the project improved their accessibility to shared mobility options.

The survey sought to evaluate the degree to which the TriMet OTP improved the accessibility of information for SUM options. The OTP is unique in that it can incorporate shared mobility options into the trip routing delivered to the user. The functionality of this feature is self-evident in the use of the system. Exploring this hypothesis was done through a user survey.

Figure 4-19 shows the distribution of responses to the question exploring the degree to which respondents felt having access to shared mobility would increase their mobility and accessibility. This question evaluated the degree to which respondents expected that information about shared mobility within the OTP would be useful to them.

Figure 4-19

Shared mobility options and mobility and accessibility



In total, 40% believed the options would moderately or greatly improve their mobility and 55% believed it would have no impact or would only slightly improve mobility; only 5% did not know if it would make a difference.

Figure 4-20 shows responses to a slightly different question, which asked for a comparison of the performance of the existing TriMet trip planner with the beta version tested in this survey as it relates to delivering information on shared mobility. The results show that respondents considered the OTP to be improved in this regard. About 16% reported not having the appropriate context for comparison, and 18% reported no noticeable improvement. The remaining two-thirds of respondents reported noticing at least some improvement in their ability to plan with shared mobility compared to the previous trip planner.

Figure 4-21 shows the reported usefulness of having access to shared mobility in the OTP, indicating that 25% did not feel access to such information would be very useful (ratings of 1–4); 41% rated the utility of information as very useful (ratings of 8, 9, 10), and the remaining respondents considered such information to be moderately or occasionally useful (ratings of 5, 6, and 7).

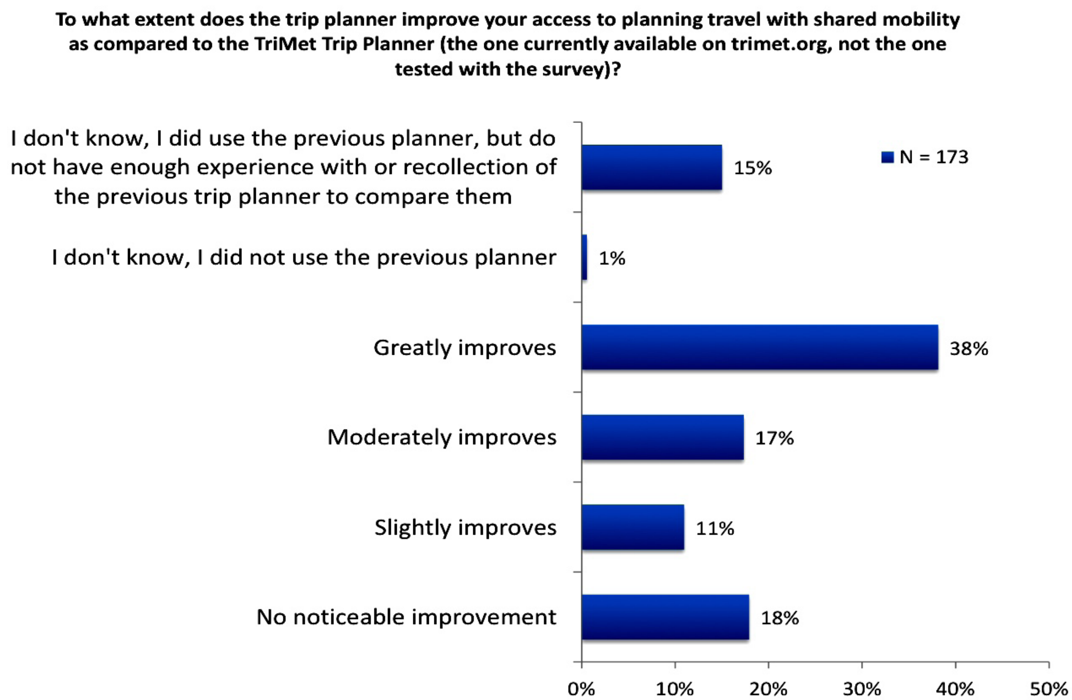


Figure 4-20

Trip planning access with shared mobility options

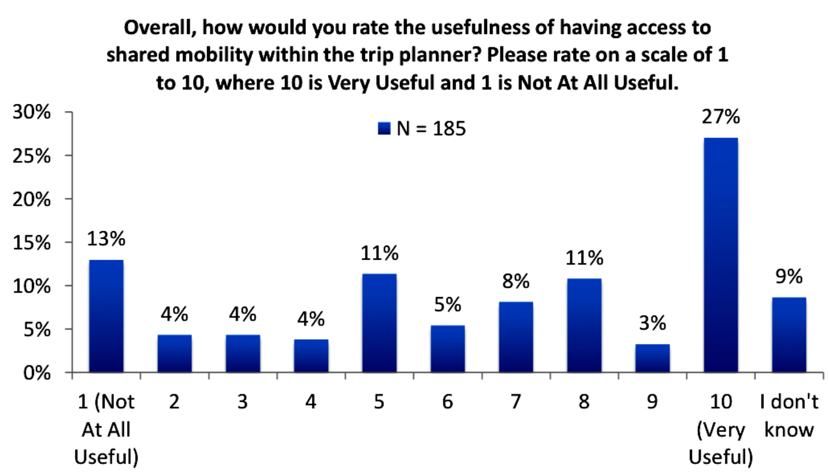


Figure 4-21

Usefulness of having access to shared mobility

Not all respondents considered the shared mobility information to be useful or an improvement, but most reported that the OTP delivered information on shared mobility better than what was previously available and that the information would be useful. Taken together, these findings generally confirm Hypothesis 7.

Hypothesis 8: The usability and design of the web-based OTP interface is considered improved by testing respondents in the population.

Performance Metric	Key Finding
Survey response to questions probing perception of usability and design of web-based OTP interface.	Respondents to the survey generally gave high ratings to the usability and design interface.

The evaluation sought to explore the degree to which the new TriMet trip planner was an improvement in the context of design and usability. A series of questions explored the perception of the user interface design in terms of navigation, functionality, and results display.

Figures 4-22 and 4-23 show the general user assessment of the OTP design interface and ratings of its perceived improvement over the existing TriMet trip planner. Generally, the new system was rated higher than the existing TriMet trip planner for interface design, with 56% of respondents rating it 8 or higher, 11% rating it 1–4, and 28% rating it 5–7. A total of 39% stated that it greatly improved their ability to plan for trips, 31% stated that it was a moderate improvement, and 10% reported no noticeable improvement. Note that respondents who reported not using the previous TriMet trip planner were not asked this question.

Figure 4-22

Overall rating of OTP user interface design

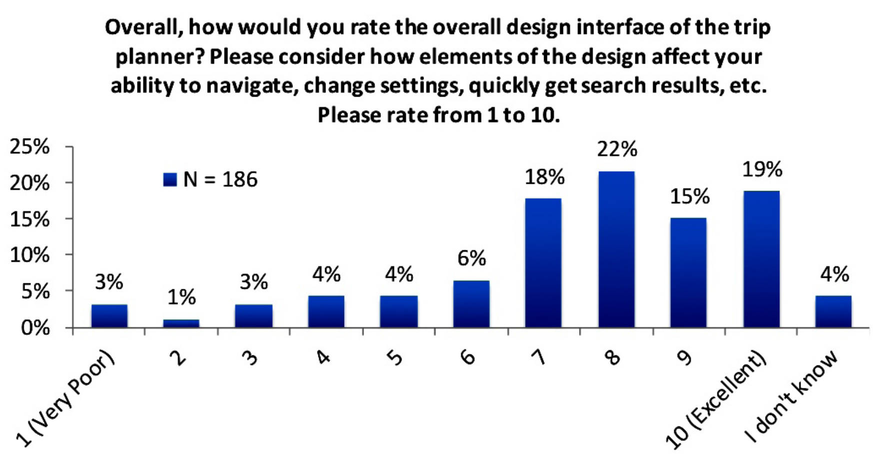


Figure 4-23

Overall rating of OTP user interface design compared to existing TriMet planner

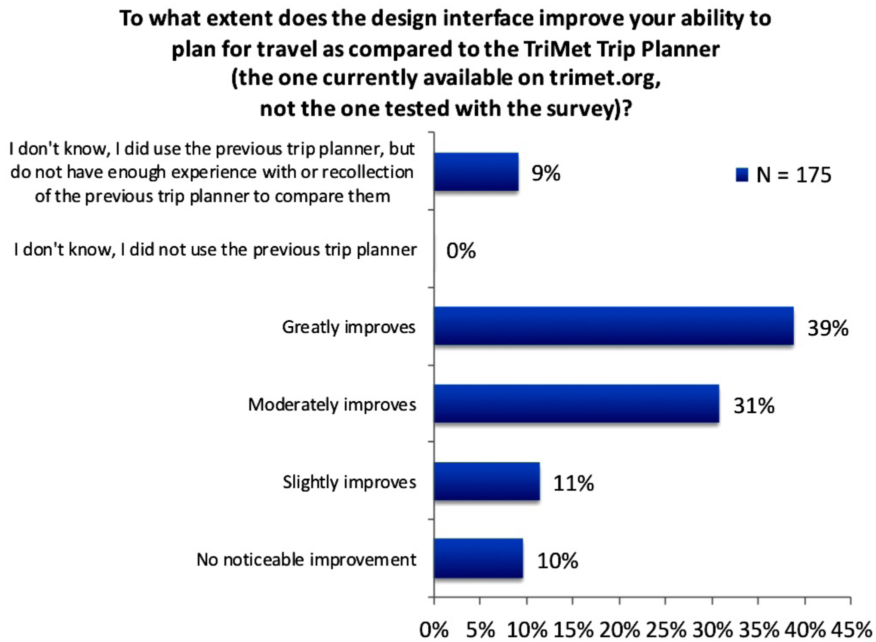
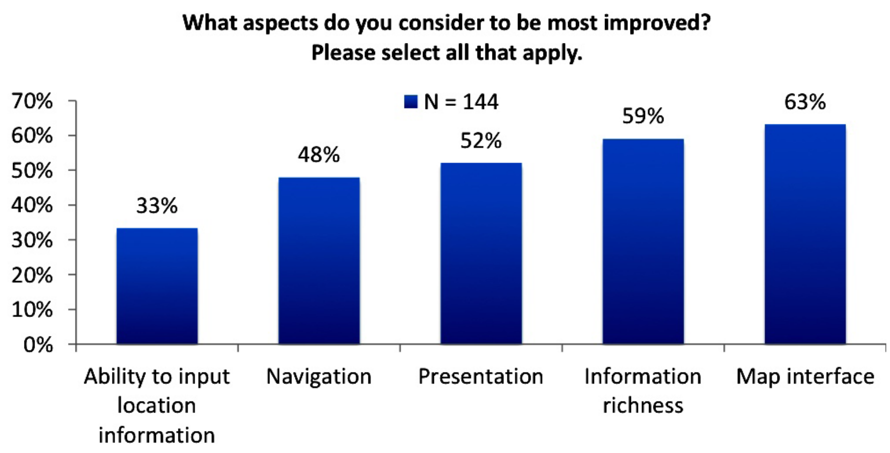


Figure 4-24 further probed respondents regarding the qualities of the design interface they considered to be most improved. This question was asked only of respondents who perceived some design improvement, and they could select all responses that applied. Results show that, overall, most respondents considered the map interface to be the most improved, followed by information richness and presentation.

Figure 4-24

Relative improvement of usability



Overall, the results of the evaluation found that a majority of respondents considered the OTP to be a considerable improvement over the existing TriMet trip planner. The degree of perceived improvement varied across respondents, but about 80% of respondents who could compare the two trip planners felt that the OTP had an improved design interface for trip planning. These findings generally confirm Hypothesis 8.

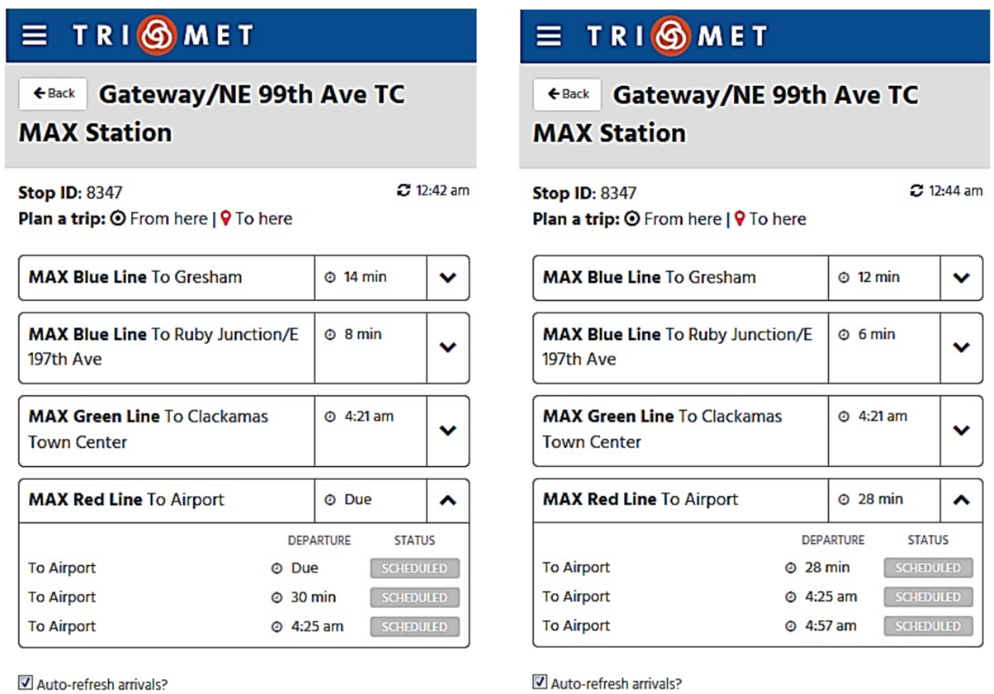
Hypothesis 9: The real-time information provided by the OTP interface will provide improved information that is considered useful to the user.

Performance Metric	Key Finding
Survey response to questions probing perception of utility of real-time information presented by the updated OTP.	The real-time information on the OTP functioned well and as specified. The real-time information was reported to be very useful to most survey respondents.

The evaluation assessed the degree to which the real-time information in the OTP interface such as arrival of public transit vehicles to specific stops was considered useful. An example of the real-time information provided in the OTP is shown in Figure 4-25. This information is conveyed for a single stop, where the lines connecting to the stop each have the next arrival time. Users can click on a particular line to see the future planned arrivals of the selected line. The data updates every minute.

Figure 4-25

Examples of OTP real-time interface



Figures 4-26 and 4-27 show responses to two questions that evaluated the perceived usefulness of real-time information in trip planning and clearly show that users considered it to be very useful. In total, 76% of respondents rated the utility of the real-time information at the top of the scale, between 8 and 10. When asked the degree to which the OTP real-time information improved trip planning over the existing trip planner, 53% reported that it greatly improved it, 18% reported that it moderately improved it, and 11% reported that it only slightly improved it; only 7% reported no noticeable improvement. The findings confirm Hypothesis 9, that the real-time information provided by the OTP was useful and an improvement over the existing trip planner capabilities.

Figure 4-26

Usefulness of real-time information in OTP

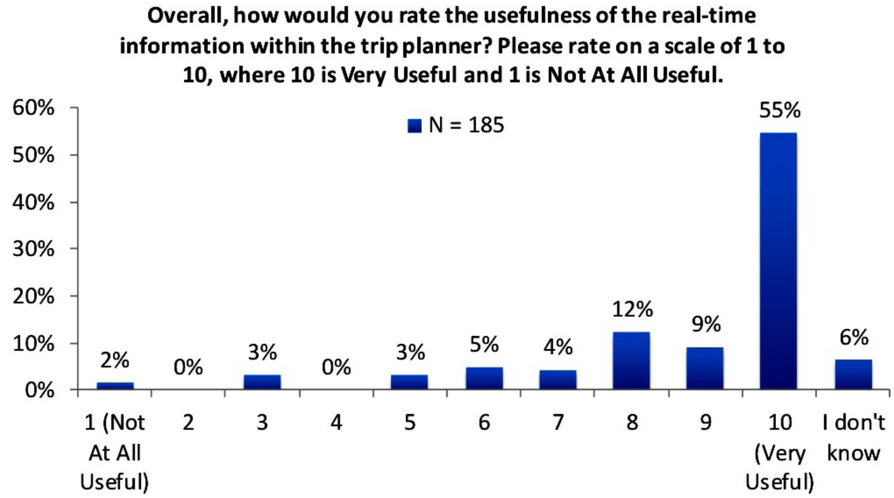
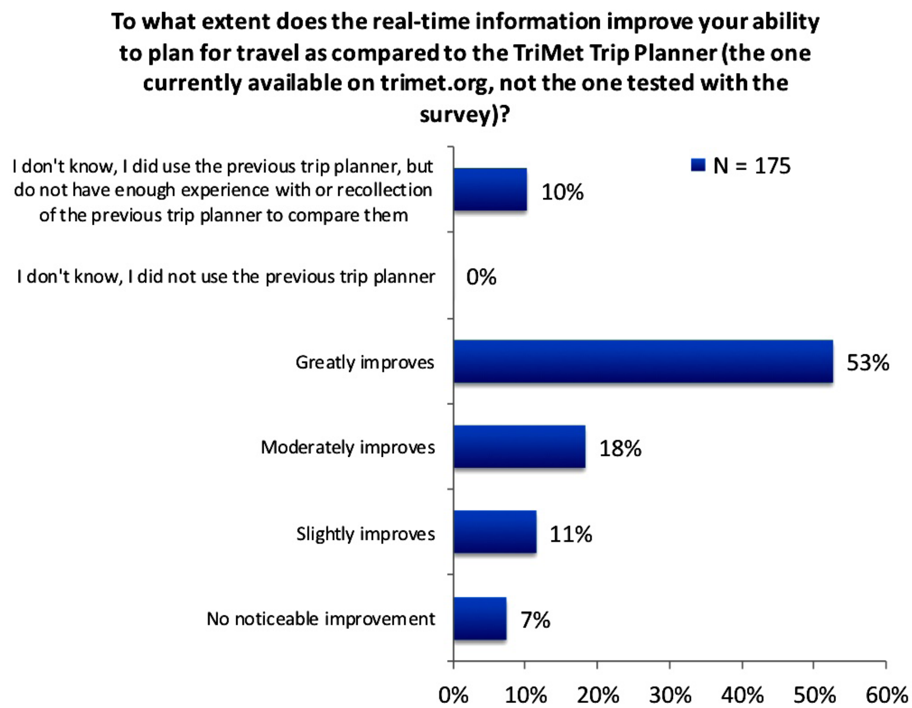


Figure 4-27

Ability of OTP real-time information to improve planning for travel compared to existing trip planner



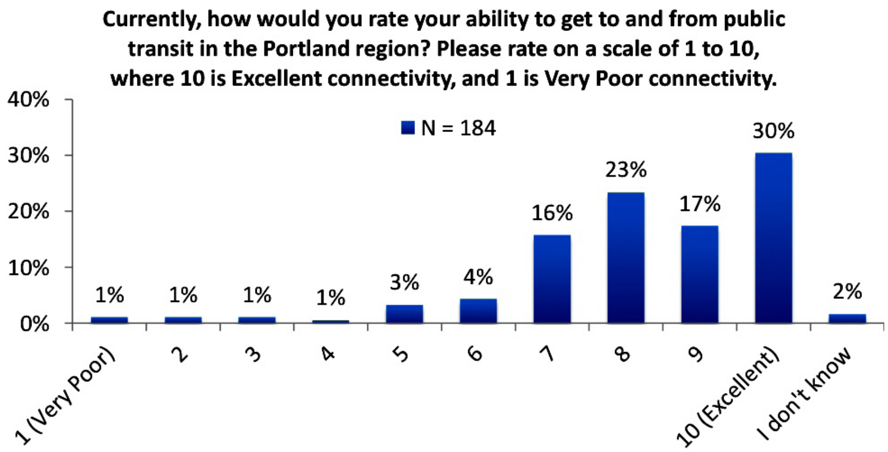
Hypothesis 10: Users report that the OTP improves their ability to overcome first-mile/last-mile challenges.

Performance Metric	Key Finding
Survey response to questions probing perception of first-mile/last-mile information in OTP.	Survey respondents reported that the trip planner was able to improve their ability to get to and from public transit and make multimodal trips.

The final survey hypothesis sought to evaluate whether the OTP improved the ability of users to overcome first-mile/last-mile challenges in Portland. Several questions were asked to evaluate the degree to which respondents felt that the trip planner improved their getting to and from public transit and their ability to make multimodal trips. Figure 4-28 shows that most respondents in Portland already considered their ability to access and egress public transit to be good, with 70% rating it between 8 and 10.

Figure 4-28

Ability to get to and from public transit in Portland region



Figures 4-29 and 4-30 show the degree to which respondents perceived the OTP to be able to improve their ability to access and egress public transit in the Portland region and to conduct multimodal trips. The distributions show that a large majority of respondents felt that the OTP would yield some improvement to both. Approximately 30% felt that the OTP would greatly improve these capabilities. Forty-four percent (44%) noted that it would enable at least a slight improvement in their ability to access or egress public transit, and 32% noted that it would enable at least a slight improvement to conducting multimodal trips. Twenty-three percent (23%) felt that it would offer no noticeable improvement in their ability to access or egress public transit, and 20% felt there would be no noticeable improvement to conducting multimodal trips.

Figure 4-29

Ability of OTP to improve access and egress to public transit in Portland region

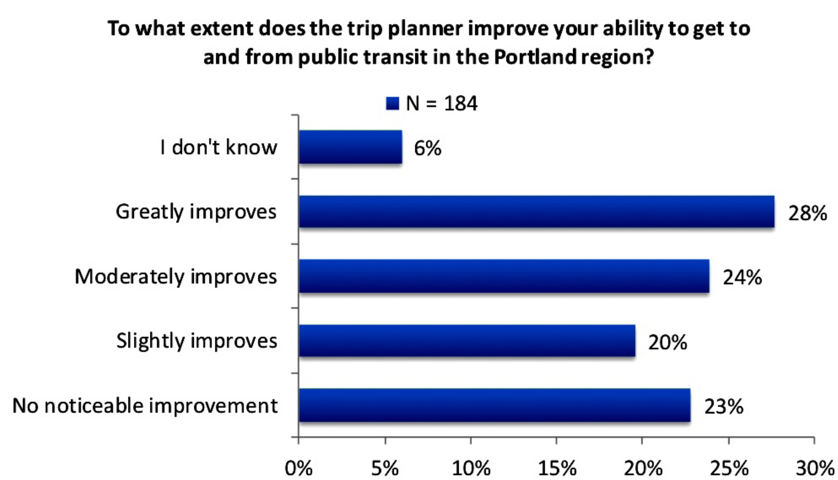
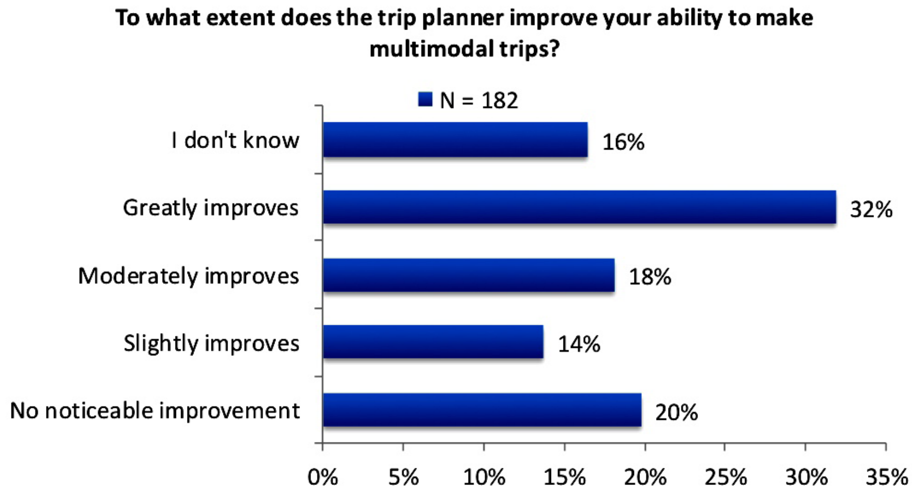


Figure 4-30

Ability of OTP to improve making multimodal trips



Finally, Figure 4-31 shows the responses to an anticipated mode shift as a result of using the TriMet OTP. Because respondents were testing the OTP rather than actively using it, the responses reflect an expectation of mode shift rather than an actual mode shift. The results show that the mode with the greatest potential gain in usage was public transit alone. Other modes, such as walk only, Lyft + transit, Park & Ride, and bike + transit, are well represented with respect to increased use relative to decreased use. The question was included to assess whether the information provided might cause shifts in behavior, either towards or away from public transit, given the new information about other options. Most respondents did not expect a significant decline in their use of modes as a result of the OTP; the mode with the greatest expected decline was walk only, likely from the substitution of the greater use of transit.

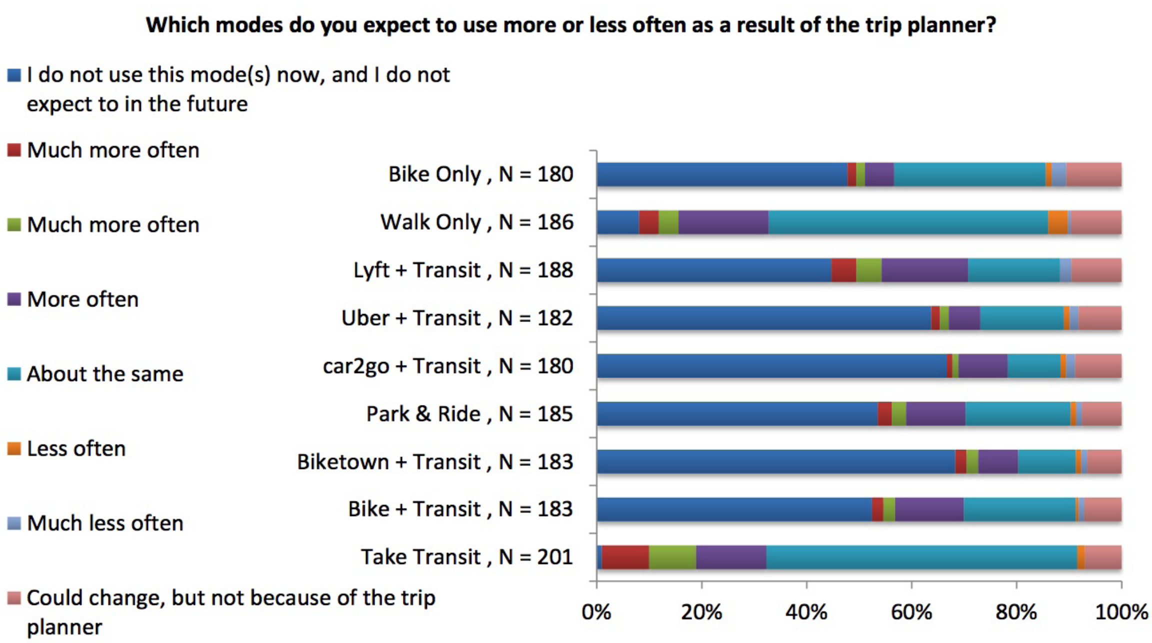


Figure 4-31

Anticipated mode shift from use of OTP

Broadly, these findings suggest a confirmation of Hypothesis 10, that the TriMet OTP would improve respondent ability to access and egress public transit.

Hypothesis 11: The process of deploying the project will produce lessons learned and recommendations for future research and deployment.

Performance Metric	Key Finding
Lessons learned and recommendations	The project produced a number of lessons learned and successes that may enable wider use of open source trip-planning applications.

The evaluation team interviewed members of the TriMet project team to better understand challenges, barriers, successes, and broader lessons learned from the implementation of the project. The next section is a synthesis of those interviews and the findings related to Hypothesis 11.

SECTION

5

Lessons Learned from Program Partners

The evaluation team interviewed members of the TriMet project team to better understand challenges, barriers, successes, and broader lessons learned from the implementation of the project.

Background

TriMet's trip planner is an open-source, multimodal trip planning system collaboratively built by a team of developers from across the world, coordinated by TriMet and OpenPlans and initially funded through the Oregon Metro 2009–2011 Regional Travel Options Grant. For TriMet, an open-source trip planner was an attractive option because of lower development costs, increased control over data sets, and independence from vendors that wanted to charge large fees for software licenses and map updates. However, prior to TriMet's trip-planner initiative (and, to some extent, today), many public agencies were unfamiliar with how to implement the open-source trip planner. Beginning in the early 2010s, TriMet began considering investments to enhance its trip planning system. These discussions emerged for three key reasons:

- TriMet's original text-based trip planner was a proprietary transit trip planner that provided planned itineraries with limited walking instructions. Similarly, many proprietary trip planning tools such as Google Maps emphasize single mode trip planning. For these reasons, TriMet began to envision a multimodal trip planner that could allow travelers to plan and compare journeys using multiple public and private transportation modes.
- TriMet hoped to update its geocoder, which had become a common cause of customer complaints, as it required a patchwork of fixes and became increasingly unstable. Geocoding, a primary requirement for trip planning, translates an address or place name into spatial coordinates that can be understood by routing software. Geocoders are often the cause of navigational errors and typically constitute the largest number of consumer complaints with trip planning apps and websites.
- The growth of TNCs and their potential competition with public transportation was beginning to raise concerns in the agency, which led TriMet to increasingly discuss creating a Mobility as a Service (MaaS) platform with integrated trip planning, ticketing, and bundled service options.

The MOD Sandbox Program was a driving force for TriMet to convene interested parties to collaborate on an open-source, multimodal trip planning system that would not only meet TriMet's increasing needs but potentially could be a viable alternative for other public transit agencies through the open-source platform. TriMet's MOD Sandbox project consisted of four main goals:

1. **OpenTripPlanner (OTP)** – Extending the code to incorporate shared mobility, real-time information, and enhanced accessibility.
2. **Pelias Geocoder** – Extending the functionality for government agencies and improving match rates and accuracy of location.
3. **OpenStreetMap and OpenAddresses** – Improving data to support new features and enhancing existing features for comprehensive trip planning and geocoding.
4. **Integrated Payment Plan** – Developing a future "one click payment"feature in the application. (This goal was not part of the implementation evaluated in this report but remained part of future plans with the trip planner.)

Planning Process

To accomplish these goals, TriMet initiated a robust planning process that included hiring a consultant, Moovel (rebranded as YourNow through a joint venture between Daimler and BMW), to help the agency conduct upfront research, simplify its fare catalog (e.g., zone-based, time-based, discount programs, free vs. paid transfers, and regional connectivity with other public transit providers), and develop a white paper on how to achieve integrated mobility solutions. The white paper became an important stage in the process to align stakeholders (which grew to 60+ over the course of the project), solicit feedback from partners on the current state and future direction of the mobility market, and establish structures for regional compatibility (e.g., a common fare payment language). The white paper also helped lay the groundwork for future phases of OTP implementation.

One of the key successes with TriMet's OTP project was strong communication among project partners. The project held regular conference calls, coordinated using online project management (e.g., Slack, Trello, etc.), and held multiple in-person meetings and working group sessions at critical phases of the project. Generally, stakeholders said that these check-in calls and in-person meetings were critical to establishing a clear timeline of deliverables and aligning the interests of all stakeholders and keeping the project on track.

The planning calls and workshops also fostered strong discussions about how to visually represent certain trip planning concepts visually, such as the following:

- Visual language and symbology for:
  - Connections between demand-responsive services connecting to fixed-route service

  – Depicting demand-responsive services (e.g., is it a route line? how is the line's geography determined? is it an arch from the origin to the destination?)
- Customer expectations for pick-up location markers (e.g., icons of people, vehicles, etc.)

As such, the development of the OTP fostered a constructive dialogue not only about approaches to "visual language" but also how to standardize this language across the OTP platform, including the TriMet and VTrans projects. Although stakeholders from both projects noted the importance of big points of coordination, they also acknowledged that there could have been more routine interactions between the projects (e.g., quarterly coordination meetings).

Working with TNCs

TriMet received a non-binding letter of commitment from both Lyft and Uber, indicating that it initially wanted historical data for analysis. However, TriMet realized quickly that such a broad data request was not likely to happen and instead narrowed the scope and amended the open application programming interface (API) to make it easier to come to agreement with the TNCs on data privacy, security, restrictions, and legal agreements. Early in the process, the TNCs became concerned about comparing the availability and cost of their services with one another on the OTP. TriMet needed to obtain an amendment to the standard data use agreement to use the API with both Lyft and Uber; however, they could not be shown on the same screen for a side-by-side comparison. The OTP ultimately continued with Uber only. Anecdotal evidence suggests that, in practice, consumers are already comparing Lyft and Uber to one another on different screens, in different windows or apps, or on different devices. Lyft opted not to continue at the conclusion of the MOD Sandbox grant. As of February 2020, Uber continues to participate in the OTP.

According to stakeholders, the MOD Sandbox Program became the impetus for a driving voice to bring diverse public agency interests together to approach the private sector with a unified trip planning and data standard. As such, Portland stakeholders describe the MOD Sandbox Program as a critical enabler for unifying public agencies around a single voice for data standards and data-sharing expectations. There was a strong feeling among Portland stakeholders that this gave the region "collective bargaining power" to negotiate with national mobility service providers. During the pilot, TriMet learned the importance of building relationships and trust with project partners and encouraged other MOD sites to build long-term partnerships.

Testing and Refinement

TriMet had a robust process for testing the OTP. During initial design, mock-ups allowed a variety of project stakeholders to comment on design choices.

TriMet conducted extensive internal and external testing with various partners (Metro, Portland's MPO; the City of Portland; and others) that worked well for the agency. Once the prototype was deployed in early 2018, additional design refinements were made in response to heuristic testing and feedback from users participating in beta testing.

The TriMet team also developed a script specifically to test how successfully the geocoders matched each address. Additionally, TriMet contracted with PlusQA to bring in five professional testers with a variety of travel preferences and habits as part of a heuristic evaluation. Each was given a list of typical trip planning tasks to walk through and report on their findings and impressions. These early testing efforts culminated in a group of TriMet customers recruited through TriMet's Riders Club to beta-test the prototype application. In total, 250 beta testers were selected from 377 who applied using a qualifying questionnaire.

Finally, as part of the evaluation process, TriMet surveyors performed in-depth, one-on-one field shadowing interviews to assess the public transit/TNC integration in practice using the OTP. Test trips were taken throughout the TriMet service area from January 3–14, 2019, on weekdays and Saturdays at various times of day. Participants tested the new trip planner application, completed trips using TriMet and Uber or Lyft, and provided feedback about the OTP shared-mobility functionality by completing a survey. In total, 11 test trips were successfully completed.

Respondents provided feedback about their user experience, the intuitiveness of the user interface, and what they liked and disliked about the application. Two key challenges were identified. First, the original plan was to test the TNC wheelchair-accessible vehicle function in the OTP. It was able plan a trip that combined TNCs and public transit but was unable to plan the same trip after the wheelchair-accessible option was selected; respondents continued to enter various destinations with the same outcome. It was later determined that this was not a problem with the application but was due to the very limited supply of wheelchair-accessible TNC vehicles in the Portland metropolitan region. Second, prior to each interview, surveyors planned multiple future trips with destinations that successfully combined Uber and public transit.

Because future trips were based on public transit schedules and did not account for real-time vehicle availability (of both public transit and TNC vehicles), it was difficult to replicate these exact trips during the testing interview if testers were attempting to plan a trip further into the future. As the surveyors were planning these trips several hours in advance of field work, it is not surprising that some changed; TNC vehicle locations can make a major difference in the OTP's results. However, as future trips were based on schedules and/or anticipated vehicle availability, it was not always possible to replicate the exact pre-planned trip during the testing interview (for example, a TNC vehicle may not have been in the area at the time of the actual test trip).

Equity and Accessibility

The project intended to enhance equity and accessibility in three core areas:

- **Improvements in ADA pedestrian routing** – A core goal of the OTP was to incorporate additional information such as the presence/absence of sidewalks to improve trip planning for people with disabilities and older adults. Although TriMet was able to include sidewalk information in trip planning, it had hoped for (but was unable to obtain) more accurate curb-level data, which would have required much field work and been cost prohibitive for the agency.
- **Trip planning for people requiring wheelchair-accessible TNC vehicles** – Initially, TriMet allowed people with disabilities to plan a trip that included a wheelchair-accessible TNC vehicle. Portland requires TNCs operating in the city to offer this service; however, as noted above, when the agency conducted a field test with test users (including a person with disabilities), it was determined that wheelchair-accessible TNC vehicles were unavailable during testing. TriMet learned that although the City requires accessible TNC vehicles, that does not necessarily result in accessible vehicle availability. TriMet decided to remove the feature because it believed it would be inappropriate to allow a user to plan a trip with an accessible TNC connection if that connection was unreliable for users.
- **Unbanked and under-banked households** – The project team worked with Moovel (responsible for conducting the integrated payment plan) to develop strategies for making future integrated payment functionality accessible to people without access to a bank or credit or debit card accounts.

Grant Administration

Portland stakeholders indicated that they probably would not have pursued OTP feature enhancements had it not been for the MOD Sandbox Program, noting that no funds would have been available because developing apps is inherently an expensive endeavor that can cost public agencies upwards of $2,000,000 in capital expenditures and an additional $500,000 annually to maintain the app (based on cost estimates for developing and maintaining other public sector transportation apps). Additionally, Portland stakeholders noted that the MOD Sandbox Program offered notable benefits by allowing TriMet to name partners and proceed with the procurement process without a request for proposals.

OTP stakeholders also noted that they did not believe a full year for demonstrations and evaluations was needed, noting a preference for more planning time at the beginning and less time for demonstrations and evaluations (e.g., 18 months and 6 months, respectively). OTP stakeholders acknowledged that this could be, in part, due to the software engineering-intensive nature of OTP development. A key recommendation for future FTA grant programs is to allow flexible timelines to accommodate very different types of demonstrations.

SECTION 6

Conclusions

The results of the evaluation found that the TriMet OTP achieved many of its stated objectives. The IE team tested and evaluated the accuracy of the Pelias geocoder, which drives the OTP's core functionality. The TriMet project team provided the IE team with a test suite of about 2,000 addresses, which were added to an internally-generated dataset of 2,000 addresses drawn from Portland property records; these data were used to evaluate the address accuracy of the Pelias geocoder to determine if its performance was comparable to other leading geocoders such as Google Earth, Mapbox, and ArcGIS based on the criterion that Pelias-geocoded addresses fell within 200 feet of points identified by geocoding. It was generally found that the performance of Pelias was comparable to that of the other geocoders; on average, about 84% of the Pelias-geocoded addresses fell within 200 feet of the geocoded addresses by the other geocoders. However, when the accuracy of the Pelias geocoder was assessed using a polygon dataset, it was found that Pelias did not perform as well as Google Earth, Mapbox, and ArcGIS. In this test, each address in the polygon dataset was geocoded in the test suite. The addresses were more commonly geocoded to fall within the polygon when using Google Earth, Mapbox, and ArcGIS, whereas the Pelias geocoder exhibited a lower success rate. This test included location names; when names were not included, Pelias accuracy was lower than Google Earth and ArcGIS but Mapbox accuracy improved.

The IE team evaluated the travel times projected by the TriMet OTP with SUM options compared to conventional trip planners without these options. Random trip pairs using the addresses drawn from the property records database were evaluated, and results found that shared mobility options (except Park & Ride) generally projected lower travel times than those in conventional trip planners.

The IE team conducted a survey with members of the TriMet Riders Club, who tested the OTP during the survey, to test several hypotheses regarding the OTP's validity and usefulness. Respondents were asked to plan their own trips as part of the test and generally found that the trip planner produced valid results. The survey was also used to evaluate the degree to which the design interface was an improvement over the existing TriMet trip planner. Respondents scored the design interface favorably, noting several improvements with respect to the map interface, information richness, and general presentation. The survey also evaluated the degree to which offering SUM options was useful to respondents. About 60% reported that having such options in the OTP would at least slightly improve their mobility, and 20% said it would greatly improve their mobility. The survey evaluated whether the real-time information delivered by the TriMet OTP would be useful; respondents generally reported that it would be very useful, and a majority stated it would greatly improve their ability to plan for trips compared to the existing TriMet trip planner. Users also reported that they believed the OTP would improve their ability to access and egress public transit and to make multimodal trips. Overall, the respondents testing the TriMet OTP reacted favorably to its design and utility.

The IE team also tested sidewalk data in the TriMet OTP to evaluate its accuracy. It was found that the TriMet OTP sidewalk data was highly accurate and reflective of actual infrastructure, which was inspected using Google and Bing Street View applications. The evaluation also inspected the routing of walk trips using the TriMet OTP and compared them with Google Maps and the existing TriMet trip planner. Some issues were identified with the routing algorithms of the TriMet OTP and Google Maps in terms of choosing the safest pedestrian route or providing routes that were logical; sometimes the TriMet OTP performed better, but other times it performed worse than Google Maps. The IE team could not conclude that walk routing of the TriMet OTP was an unequivocal improvement over Google Maps when conducting its test.

Overall, the TriMet OTP was well received by survey respondents as a design and functional improvement over the existing TriMet trip planner. Respondents found many of its features to be useful, particularly for increasing their access to and from public transit. Survey respondents indicated that they would likely use public transit more as a result of these improvements.

Findings from the expert (stakeholder/project partner) interviews suggest that the project was essential for bringing parties together to advance the developments achieved during this project; however, technical challenges with respect to geocoding and routing remain. The Pelias geocoder performed well and, within a margin of 200 feet, is comparable to leading geocoders Google Earth, Mapbox, and ArcGIS. With respect to accuracy on the supplied test dataset, Pelias struggled to perform as well as the other three geocoders and may need some refinement in taking inputs in different forms and appropriately geocoding them.

Despite those challenges, the evaluation found that the TriMet OTP is generally well-designed and performed well for a test group, suggesting that with refinements, the system will make a substantive contribution to trip planning capabilities.

APPENDIX

A

Additional Survey Results

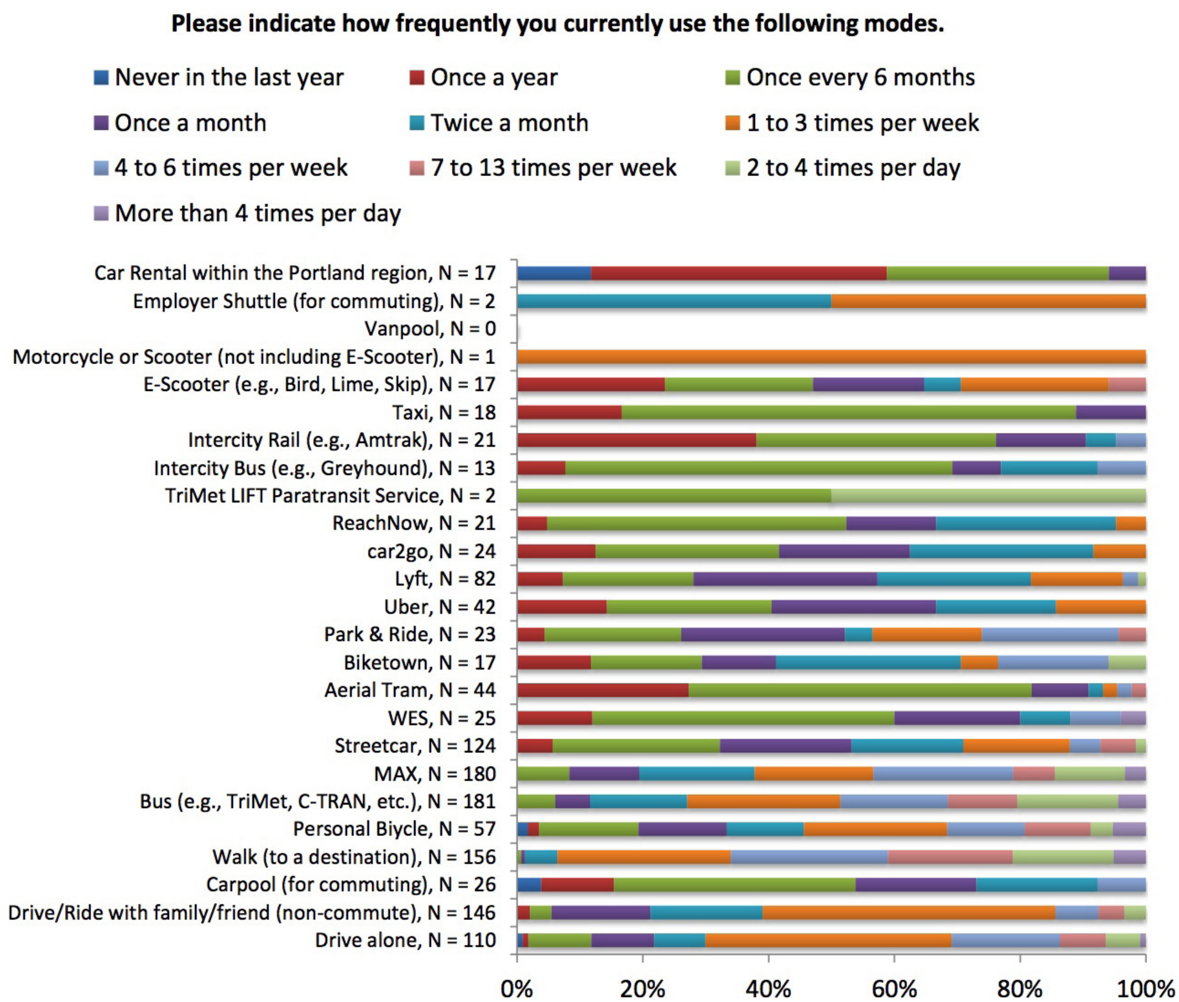


Figure A-1

Frequency of mode use

Figure A-2

Transit modes selected in search

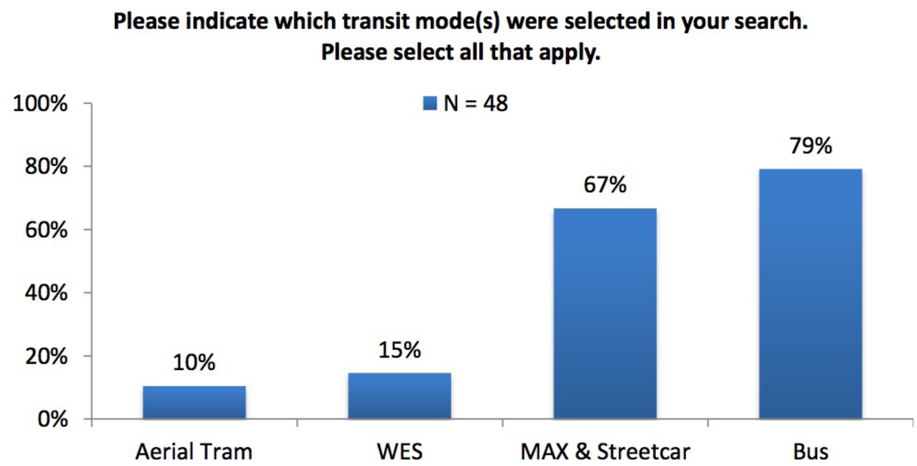


Figure A-3

Changes made to default settings

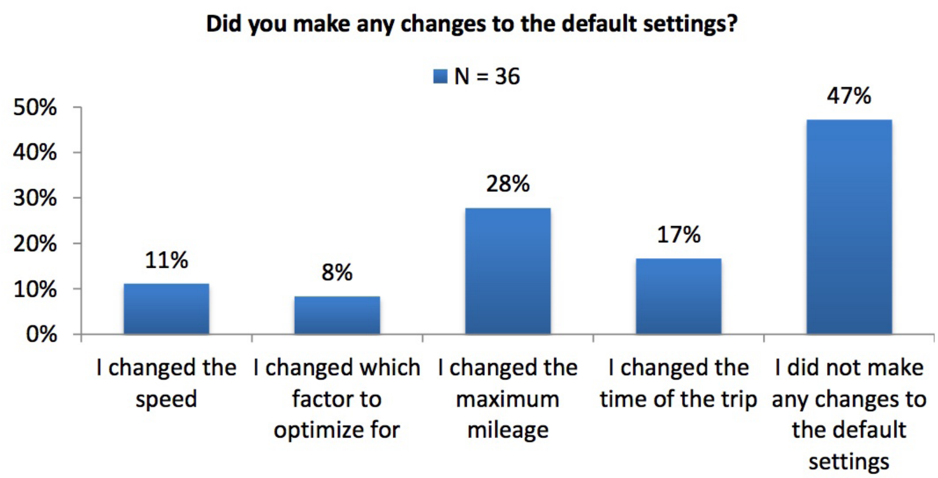


Figure A-4

Maximum walking radius set

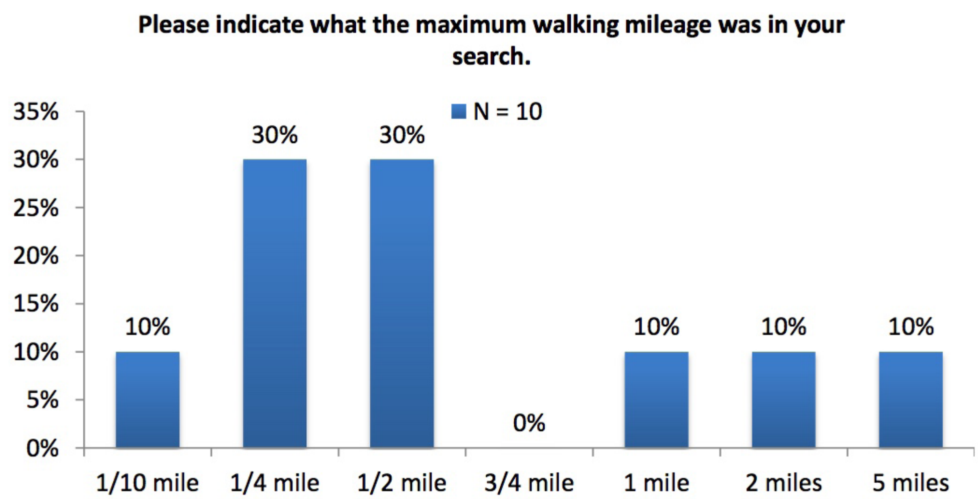


Figure A-5

Method of trip time change

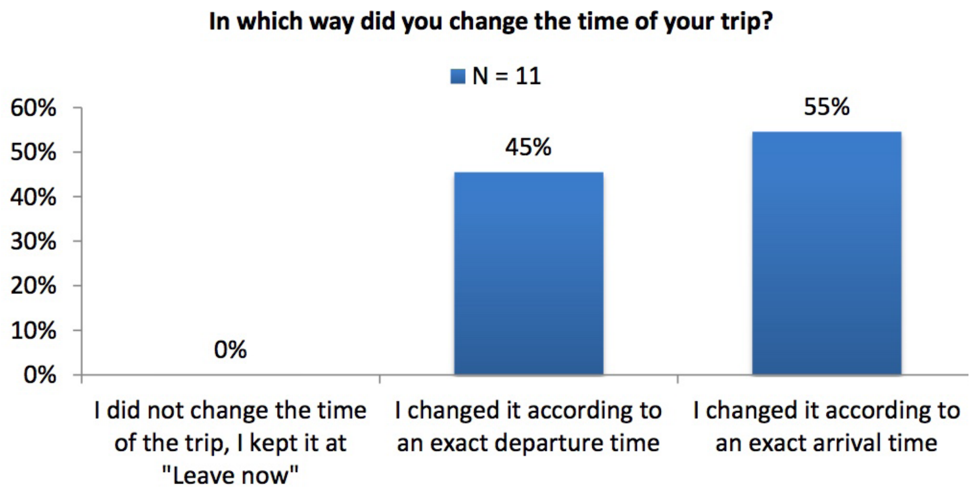


Figure A-6

Satisfaction with results of search

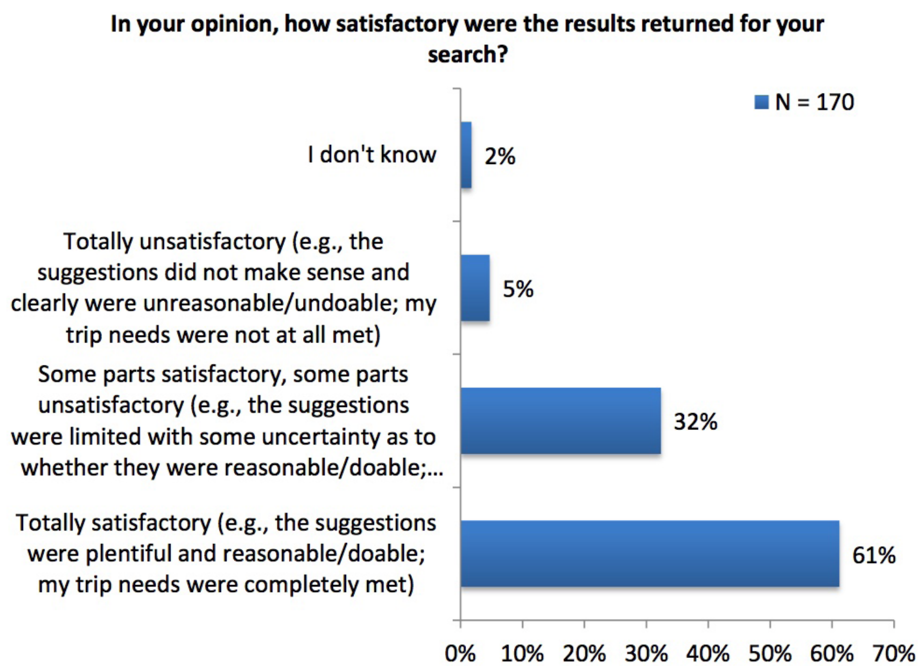


Figure A-7

Use of previous TriMet trip planner

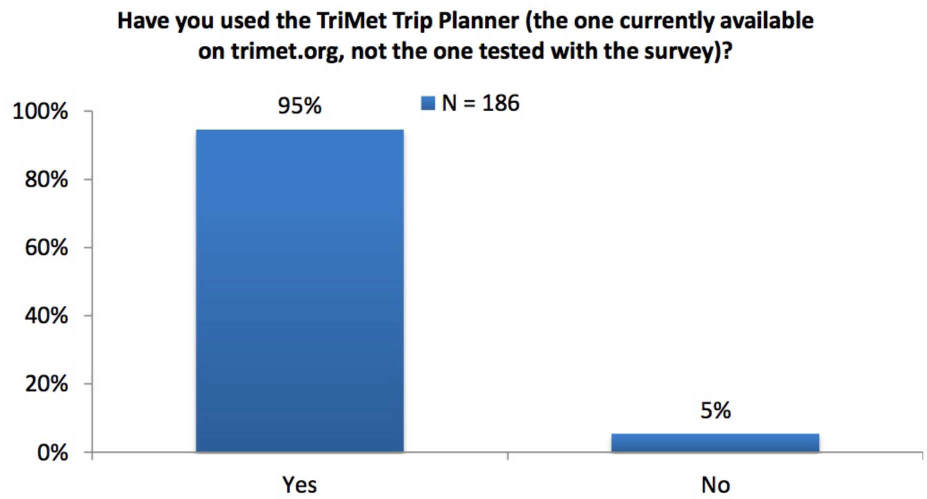


Figure A-8

Frequency of use of previous TriMet trip planner

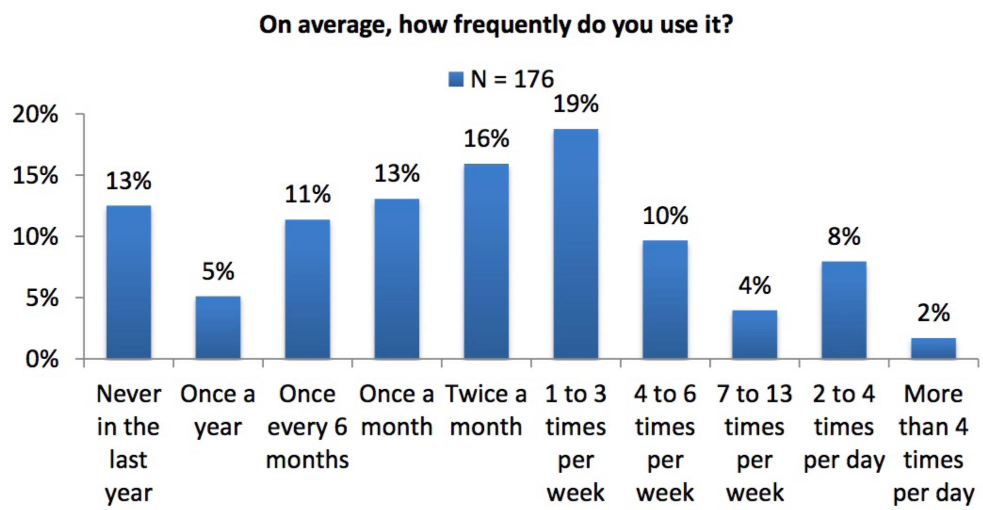


Figure A-9

Rating of map functionality with TriMet OTP

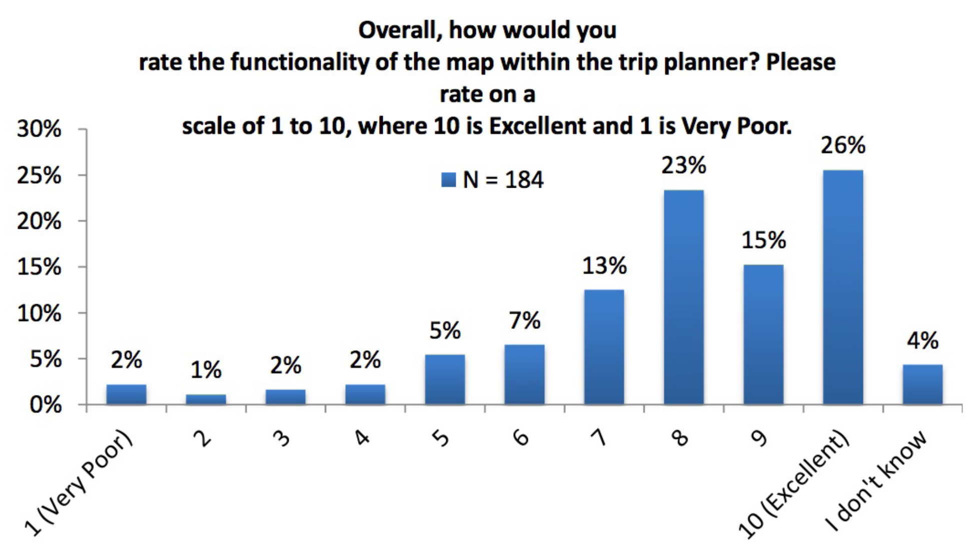


Figure A-10

Survey respondent gender

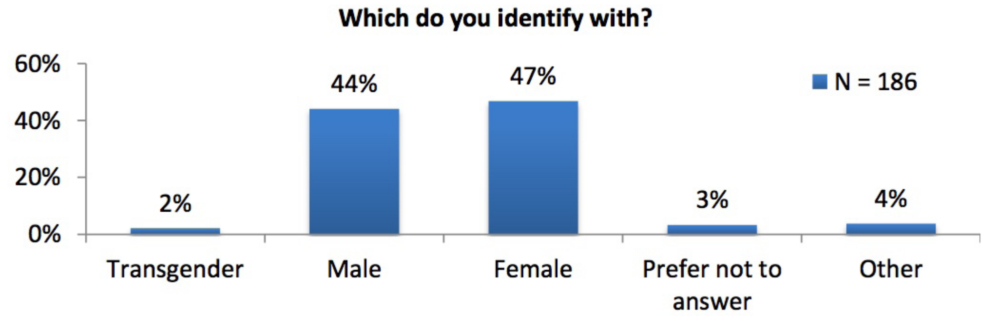


Figure A-11

Use of wheelchair by survey respondents

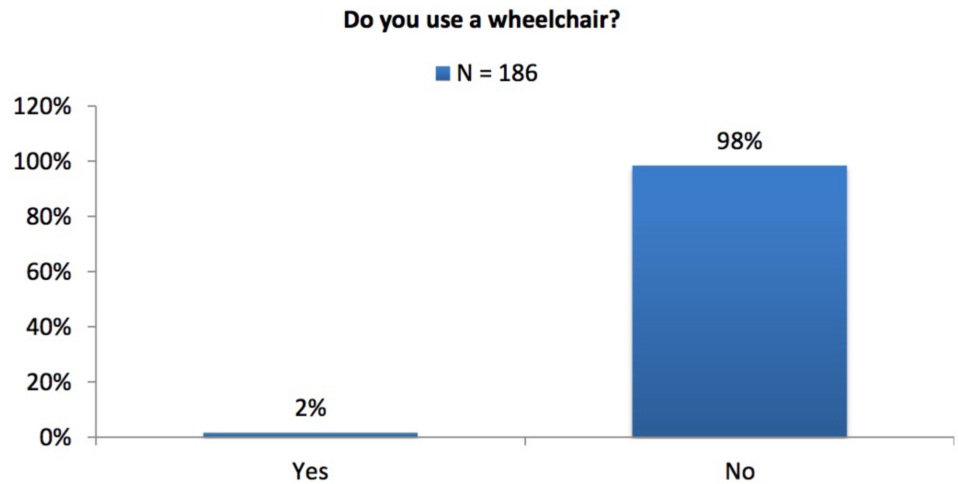


Figure A-12

Survey respondents requiring specialized accommodations for transportation

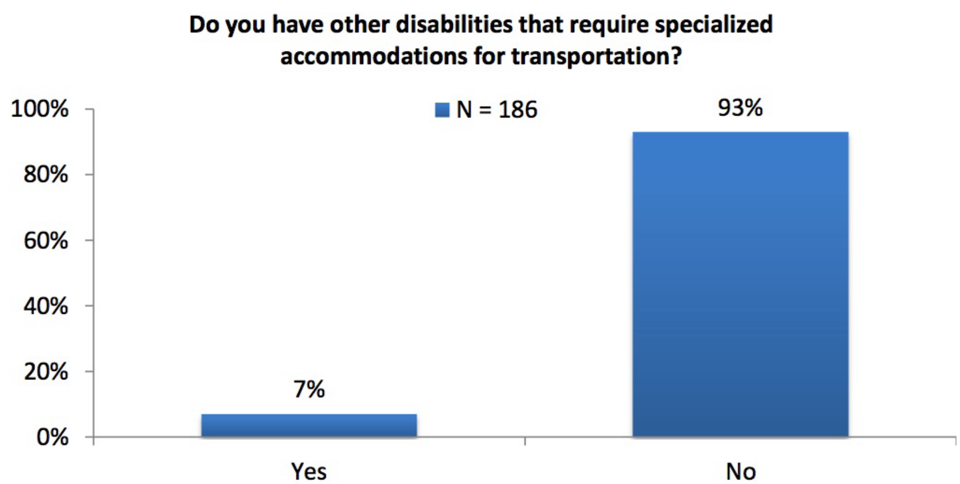


Figure A-13

Survey respondents requiring ADA-compliant vehicles and infrastructure for transportation

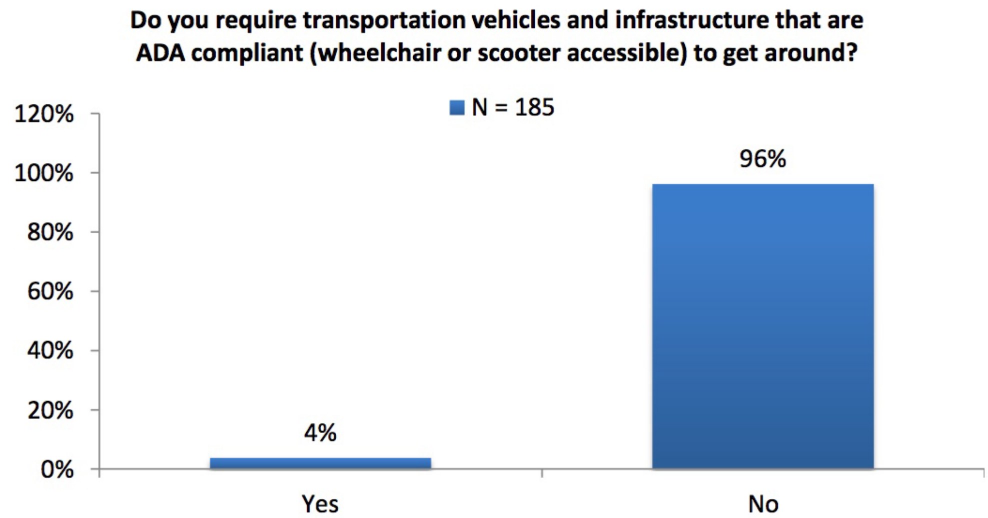


Figure A-14

Education level of survey respondents

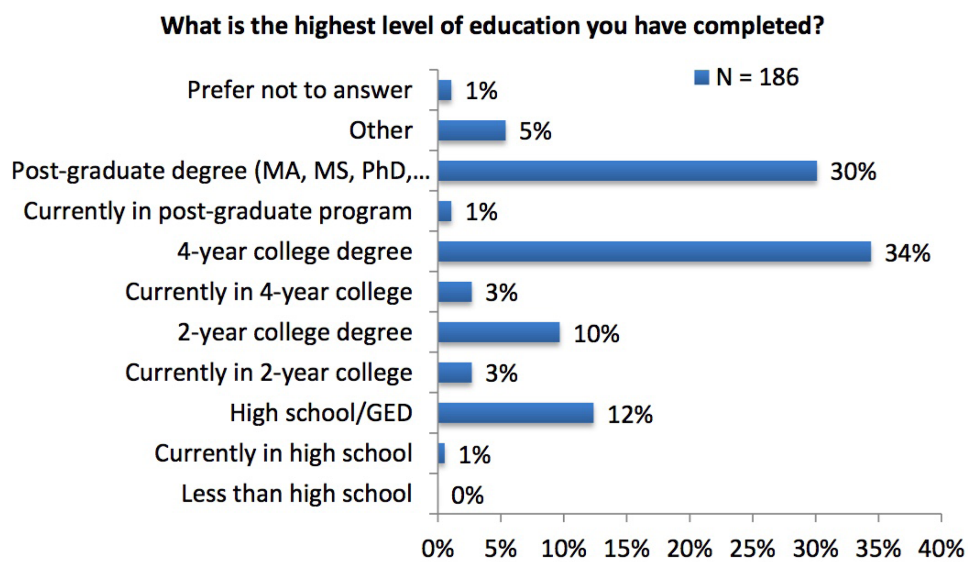


Figure A-15

Race or ethnicity of survey respondents

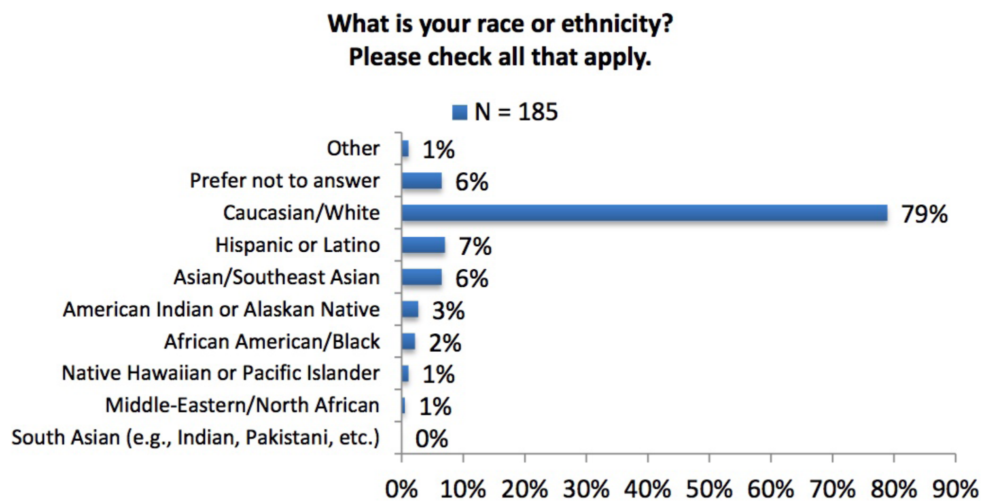


Figure A-16

Housing type of survey respondents

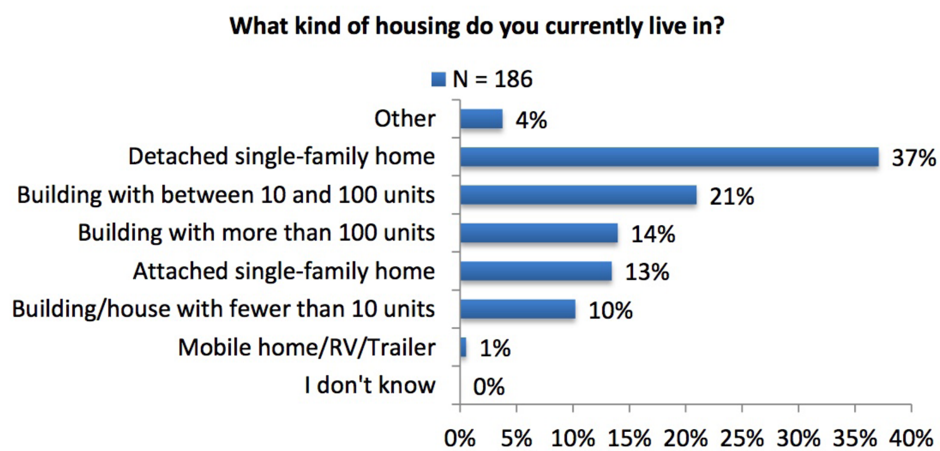
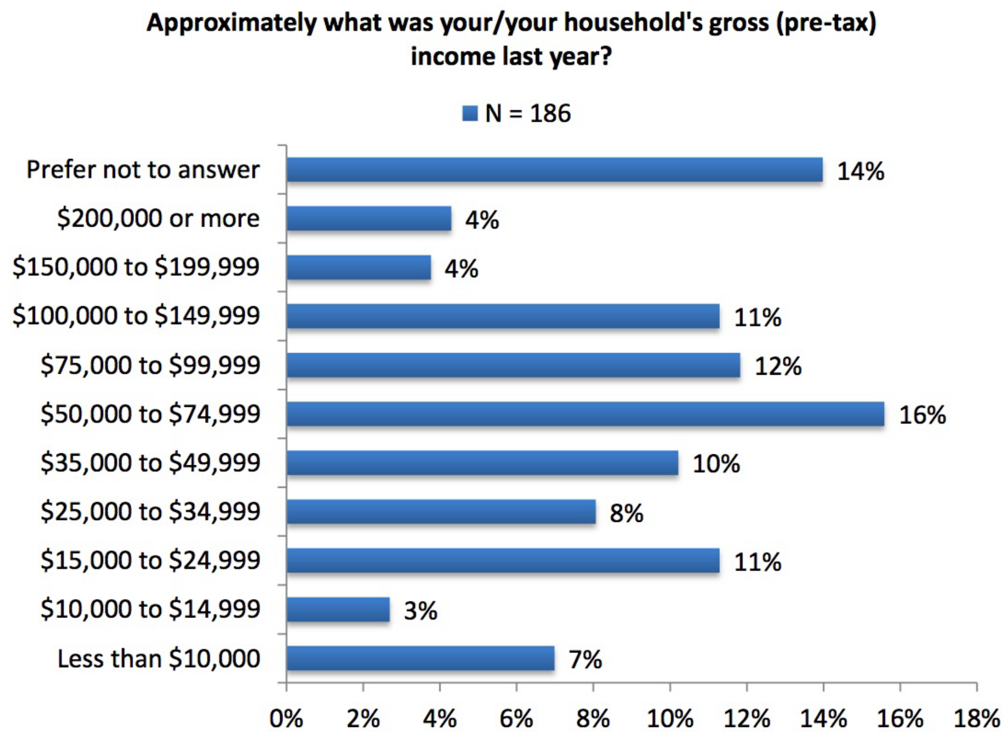


Figure A-17

Income distribution of survey respondents



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