FTA RESEARCH

FEDERAL TRANSIT ADMINISTRATION

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

Final Report

JUNE 2021

FTA Report No. 0197

PREPARED BY
TriMet
IBI Group

U.S. Department of Transportation
Federal Transit Administration

COVER PHOTO

Courtesy of TriMet

DISCLAIMER

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

Final Report

JUNE 2021

FTA Report No. 0197

PREPARED BY

Tri-County Metropolitan Transportation District of Oregon (TriMet)
1800 SW 1st Avenue, #300
Portland OR 97201

IBI Group
801 2nd Avenue, Suite 1000
Seattle, WA 98104

AVAILABLE ONLINE

https://www.transit.dot.gov/about/research-innovation

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	liters	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)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE June 2021	2. REPORT TYPE Final	3. DATES COVERED January 2017-September 2019

4. TITLE AND SUBTITLE Mobility on Demand (MOD) Sandbox Demonstration: Tri-County Metropolitan Transportation District of Oregon (TriMet) OpenTripPlanner (OTP) Shared-Use Mobility, Final Report	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Bibiana McHugh (TriMet), Madeline Steele (TriMet), Myleen Richardson (TriMet), Jonathan Campbell (IBI Group)	5d. PROGRAM NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSE(ES) Tri-County Metropolitan Transportation District of Oregon (TriMet) 1800 SW 1st Avenue, #300 Portland, OR 97201 IBI Group 801 2nd Avenue, Suite 1000 Seattle, WA 98104	8. PERFORMING ORGANIZATION REPORT NUMBER FTA Report No. 0197
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Transit Administration Office of Research, Demonstration and Innovation 1200 New Jersey Avenue, SE, Washington, DC 20590	10. SPONSOR/MONITOR'S ACRONYM(S) FTA 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12 . DISTRIBUTION/AVAILABILITY STATEMENT
Available from: National Technical Information Service (NTIS), Springfield, VA 22161; (703) 605-6000, Fax (703) 605-6900, email [orders@ntis.gov]; Distribution Code TRI-30

13. SUPPLEMENTARY NOTES [www.transit.dot.gov/about/research-innovation] [https://www.transit.dot.gov/about/research-innovation] [https://doi.org/10.21949/1520683] Suggested citation: Federal Transit Administration. Mobility on Demand (MOD) Sandbox Demonstration: Tri-County Metropolitan Transportation District of Oregon (TriMet) OpenTripPlanner (OTP) Shared-Use Mobility, Final Report.Washington, D.C.: United States Department of Transportation, 2020. https://doi.org/10.21949/1520683

14. ABSTRACT
This report documents the TriMet OpenTripPlanner (OTP) project, part of the Federal Transit Administration (FTA) Mobility on Demand (MOD) Sandbox Program, providing details of a project that makes major strides toward the plan-book-pay function and helps pave the way with open source software so other agencies also can implement these functions. 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 or data enhancements. This project significantly improves transit trip planning by including more modes and enhancing mapping, geocoding, and spatial data, accomplished using open source software, which minimizes up-front cost and delay for other systems to start their own multimodal trip planner. It also provided strategic planning that answers critical questions for future implementation of paying for the multimodal trip. The project had four main goals: 1) for the OpenTripPlanner (OTP), extend code to incorporate shared-use mobility (SUM) modes, real-time information, and enhanced accessibility narrative, 2) for the Pelias geocoder, extend functionality for government agencies and improve match rate and accuracy of locations, 3) for OpenStreetMap and OpenAddresses, improve data to support new and enhance existing features for comprehensive trip planning and geocoding, and 4) develop an Integrated Payment Plan for a future one-click payment feature by using existing software and data and leveraging open source software, open data, and open standards to facilitate widespread adoption and easy replicability for other transit agencies. TriMet partnered with five transit agencies to ensure that project requirements were inclusive and comprehensive.

15. SUBJECT TERMS
Trip planning, OTP, MOD Sandbox, mobility on demand, TriMet, Pelias, geocoding, OpenStreetMap, OpenAddresses, shared use mobility

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified	Unlimited	308	19b. TELEPHONE NUMBER

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Acknowledgments

This project was a collaborative effort by private and public entities working together to solve problems with highly-creative solutions. TriMet would like to acknowledge all who contributed to the successful completion of the project, which lays the groundwork for future cooperative initiatives.

This project would not have been possible without the opportunity and support provided by the visionary team responsible for the MOD Sandbox Grant, including the FTA Office of Mobility Innovation, notably Vincent Valdez, Murat Omay, Nazy Sobhi, Christina Gikakis, Gwo-wei Torng, and Steven Mortensen. A special note of appreciation to Murat Omay, TriMet's FTA Project Manager, for his guidance, encouragement, and support.

TriMet acknowledges core Project Management team members Bibiana McHugh, Jon Campbell, Madeline Steele, and Ritesh Warade and additional contributors Cassadi Willey, Ginger Shank, Meredith Rider, and Myleen Richardson.

TriMet also wants to gratefully acknowledge the following outstanding contributors:

- **Key Project Partners:**
  - **IBI Group** – Project Management and Coordination
    Ritesh Warade, Jon Campbell
  - **Conveyal LLC** – Application Development and Design Team
    David Emory, Andrew Byrd, Evan Siroky, Kate Chanba, Landon Reed
  - **Pelias Geocoder Development Team**
    Julian Simioni, Peter Johnson, Alyssa Wright, Diana Shkolnikov, Randy Meech
  - **Oregon Metro** – Regional Address Improvements
    Caleb Winter, Luis Murillo, Robb Kirkman, Steve Erickson, Tom Marshall
  - **moovel North America** – Integrated Payment White Paper
    Courtney Longfellow, Toshi Forrest
  - **Center for Urban Transportation Research, University of South Florida** –Open Source Transit Software White Paper
    Sean Barbeau, Steven Polzin
  - **Fehr & Peers** – Pelias Geocoder External Assessment Marshall Ballard
- **Project Partners:**
  AC Transit, BART, City of Portland, LA Metro, Portland Streetcar, RTD, VTA, VTrans
- **Data Providers:**
  BIKETOWN, car2go, Lyft, Uber, Zipcar

- **Active Contributing Participants:**
  Booz Allen Hamilton, Cambridge Systematics, Clevor Consulting Group, Connective DX, DKS Associates, Full Path Transit Technology, Interline Technologies, Lane Transit District, Mapzen, ODOT, PLUS QA, ReachNow, Ride Connection, Samsung, Shared-Use Mobility Center, Trillium Transit, UC Berkeley Transportation Sustainability Research Center

Appreciation is also extended to TriMet MOD Sandbox Team members Anna Couzens, Carl Green Jr., Brett Hamilton, Jonathan Hendryx, Nathan Jones, Tom Lin, Tim McHugh, Meshawn Muchow, Myleen Richardson, Meredith Rider, George Roth, Rhyan Schaub, Ginger Shank, Noel Torres, Dave Whipple, Cassadi Willey, John Zimmerman and, notably, Frank Purcell, lead TriMet application developer.

TriMet would also like to thank the independent evaluation team, especially Elliot Martin and Mikaela Hoffman-Stapleton, for quickly preparing a high-level summary of online beta testing results for inclusion in this report.

Finally, special thanks to all the testers for contributing their invaluable feedback, which was used to make continuous improvements and refinements over the last two years.

Abstract

This report documents the TriMet OpenTripPlanner (OTP) project, part of the Federal Transit Administration (FTA) Mobility on Demand (MOD) Sandbox Program, providing details of a project that makes major strides toward the plan-book-pay function and helps pave the way with open source software so other agencies also can implement these functions. The 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 or data enhancements. This project significantly improves transit trip planning by including more modes and enhancing mapping, geocoding, and spatial data, accomplished using open source software, which minimizes up-front cost and delay for other systems to start their own multimodal trip planner. It also provided strategic planning that answers critical questions for future implementation of paying for a multimodal trip. The project had four main goals: 1) for the OpenTripPlanner (OTP), extend code to incorporate shared-use mobility (SUM) modes, real-time information, and enhanced accessibility narrative, 2) for the Pelias geocoder, extend functionality for government agencies and improve match rate and accuracy of locations, 3) for OpenStreetMap and OpenAddresses, improve data to support new and enhance existing features for comprehensive trip planning and geocoding, and 4) develop an Integrated Payment Plan for a future one-click payment feature by using existing software and data and leveraging open source software, open data, and open standards to facilitate widespread adoption and easy replicability for other transit agencies. TriMet partnered with five transit agencies to ensure that project requirements were inclusive and comprehensive.

EXECUTIVE SUMMARY

Private mobility services have changed personal transportation as we know it, but the integration of these modes with public transportation services can be revolutionary. Integrating these new mobility options with fixed-route transit can have a tremendous positive impact on the environment, sustainability, fluid seamless mobility, safety, and security and offer freedom from travel disabilities.

To achieve the vision of integrating mobility options, the US transit industry ultimately needs a technology platform that allows planning, booking, and paying for trips that involve as many travel modes as needed to make a convenient trip. Combining transit with a bikeshare or ridesourcing trip (e.g., Uber), for example, would meet the needs of more travelers than transit alone and would reduce the reliance on single-occupancy vehicles for transportation. This would require a robust software platform with a highly user-friendly interface. Using open source software solutions can provide that function in a form that could help keep costs down, maximize interoperability, and increase the resilience and longevity of the product. In 2009, TriMet took early steps toward this vision when it introduced a multimodal trip planner that included transit, biking, and walking and combinations of those modes.

This project significantly improves transit trip planning by including more modes and enhancing mapping, geocoding, and spatial data. This leap forward was accomplished using open source software, which will minimize the up-front cost and delay for other systems to start their own multimodal trip planner. It also provided strategic planning that answers critical questions for future implementation of paying for the multimodal trip. This report provides details of the TriMet project, which makes major strides toward the plan-book-pay function and helps pave the way with open source software so other agencies also can implement these functions.

TriMet was one of 11 recipients of the Federal Transit Administration's (FTA's) Mobility on Demand (MOD) 2017–2019 Sandbox grants, which are designed to encourage innovation, technology, and partnerships in the MOD space. TriMet's project proposal consisted of four main goals:

- **OpenTripPlanner (OTP)** – Extend code to incorporate shared-use mobility (SUM) modes, real-time information, and enhanced accessibility narrative.
- **Pelias geocoder** – Extend functionality for government agencies and improve match rate and accuracy of locations.
- **OpenStreetMap and OpenAddresses** – Improve data to support new and enhance existing features for comprehensive trip planning and geocoding.
- **Integrated Payment Plan** – develop for a future one-click payment feature in the application.

The approach was to achieve these goals by using existing software and data and leveraging open source software, open data, and open standards to facilitate widespread adoption and easy replicability for other transit agencies. Adoption of OTP has been strong, and TriMet has collaborated with agencies and private companies in multiple cities and countries to ensure that all improvements made to the OTP software will be available to and benefit all users. TriMet also partnered with five other transit agencies to ensure that project requirements were inclusive and comprehensive.

All four objectives were completed on time and within budget. The new OTP, TriMet's "Next Generation Trip Planner," now integrates transit with other shared-use modes in one complete door-to-door itinerary, with a robust geocoder and rich, open, up-to-date data for point of interest locations, sidewalk coverage, and more.

Key Lessons Learned

- Unlike automobiles, public transit alone cannot provide door-to-door service, and other modes, such as Transportation Network Companies (TNCs) such as Lyft and Uber, may not be affordable to everyone. Combining modes can reduce travel time from transit alone, solve the first/last mile problem, and offer more affordable trip options than ridesourced trips alone.
- The Pelias geocoder is now even more robust and much easier for agencies to implement and customize.
- Open application program interfaces (APIs) are critical to development of multimodal trip planners. It is appropriate, and may be necessary, for cities and other regulating agencies to require such APIs from private mobility providers as a condition of operation.
- The current OTP application provides partial book and pay functionality; after a trip is planned, customers can click "Book Ride" and their ridesourcing app will open with all needed details pre-entered, greatly decreasing the friction of multimodal booking.
- A Mobility as a Service (MaaS) platform is necessary to support multimodal plan-book-pay applications. This platform includes strategic plans and implementations considering a range of factors including big data, technology, and a Mobility Management Plan as part of a larger Smart Cities plan.
- Public-private partnerships need to be established.
- Policy and regulations need to be established and negotiated for access to private mobility provider data and open APIs.
- A requirement for the success of MaaS is for transit agencies to move from transit providers into the role of a regional Mobility Management Center, which requires a complete reconstruction of identity.

- Approaches that contributed to the success of this project include transparency (all project documentation made available on a shared drive), inclusiveness, public- private partnerships, communication tools, weekly meetings, kick-off workshop and prototype release workshop, and surveys, feedback, and analysis.
- The OTP Shared-Use Mobility (SUM) Team employed a multipronged, iterative testing strategy to enable continuous improvement of the applications. Key evaluation methods and projects included Regular, informal testing of application prototypes by the core team throughout the two-year project, which allowed for rapid enhancements and bug fixes
- Two heuristic usability studies
- An independent evaluation survey conducted by the UC Berkeley Transportation Sustainability Research Center
- Testing by external project partners and an expanded group of TriMet employees
- In depth one-on-one field shadowing

Feedback allowed the project team to make iterative improvements to the user interface design and core functionality.

The new trip planner was released as a public beta for continued testing and feedback in early 2019. In the future, the trip planner will be incorporated into the TriMet website's main page and customer tools. A strategy to expand the trip planner with an integrated payment system is planned for a future phase.

SECTION 1

Project Background

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

TriMet's OTP SUM project has created an open platform for the integration of transit and SUM options. The open data, software, and responsive user interface will help customers understand the available multimodal options to meet their mobility needs, including for the critical first and last miles of trips where a bus or train alone does not always directly serve their origin and/or destination.

This report documents the entire process of the OTP SUM project, covering the background and rationale for the effort, the project team and approach, application development for both OTP and the Pelias geocoder, testing and evaluation, lessons learned, and next steps.

History of OTP, Open Source Software, and Open Data

OTP is an open source, multimodal trip planning system collaboratively built by a team of developers from across the world and originally coordinated by TriMet and OpenPlans (a former civic technology advocacy organization). The OTP project was initially funded through an Oregon Metro 2009–2011 Regional Travel Options Grant.

TriMet's original text-based trip planner was a proprietary transit trip planner, providing transit trip itineraries with limited walking instructions; however, customers frequently requested the ability to plan multimodal trips, such as the ability to bike to transit. Similarly, many proprietary trip planning tools such as Google Maps focus primarily on single-mode trips. The ability to plan multimodal trips (a combination of transit, walking, and biking) and bring as much information as possible into one central location allowed commuters to make informed decisions about their transportation choices while encouraging sustainable modes and decreasing the number of drive-alone vehicle trips. Commercial off-the-shelf solutions were cost-prohibitive for TriMet and many US transit agencies, whereas open source, multimodal trip planners were relatively new to the market and lacked both a strong user and developer base and a sustainable support model.

TriMet convened 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 agencies. TriMet partnered with OpenPlans, a non-profit organization that specialized in open source software and civic projects, and several other developers to apply for an Oregon Metro Regional Travel Options grant in 2008 to begin work on an open source, multimodal trip planner, which came to be known as the OpenTripPlanner. From the outset, OpenPlans was responsible for leading the technical development of the project, facilitating a strong development community around the code, and providing a sustainable business model around the software to ensure maintenance and support options for agencies.

Overview of MOD Sandbox Program

The Federal Transit Administration's (FTA) MOD Sandbox Demonstration Program is an avenue through which integrated MOD concepts and solutions, supported by local partnerships, are demonstrated in real-world settings. In 2016, FTA identified and funded project teams to innovate, explore partnerships, develop new business models, integrate transit and MOD solutions, and investigate new, enabling technical capabilities such as integrated payment systems, decision support, and incentives for traveler choices.

The objectives of the MOD Sandbox Program are to:

- Enhance transit industry preparedness for MOD
- Assist the transit industry with developing the ability to integrate MOD practices with existing transit service
- Validate the technical and institutional feasibility of innovative MOD business models and document MOD best practices that may emerge from the demonstrations
- Measure the impacts of MOD on travelers and transportation systems
- Examine relevant public sector and federal requirements, regulations, and policies that may support or impede transit sector adoption of MOD

From 78 eligible applications, FTA selected 11 grant recipients and awarded a total of $8 million in funding. The OTP SUM project received $678,000 in funding, supported by $324,000 in in-kind contributions by key project partners.

Mobility on Demand (MOD) and Mobility as a Service (MaaS)

MOD and Mobility as a Service (MaaS) are two approaches to Mobility Management, concepts that seek to give people customized, reliable, and flexible transportation options by allowing them to plan, book, and pay for public and private multimodal transportation services using real-time information about travel options, time, and cost. Although they are related concepts, MOD and MaaS are two distinct aspects of the Mobility Management toolkit:

- **Mobility on Demand** refers to the goal of providing door-to-door transportation convenient to when people need to travel.
- **Mobility as a Service** refers to paying for a trip or set of trips that might include multiple modes and providers.

MOD and MaaS enable cities and their citizens to address congestion and environmental issues by increasing public transit adoption and car-sharing. At its core, MOD is a solution that puts the customer first, allowing them to craft their journey to their unique needs, priorities, and preferences.

Importance of Geocoding to Trip Planning

Geocoding, or address locating, is a primary requirement for trip planning, as it translates an address or place name into spatial coordinates that can be understood by routing software. Many geocoding options currently available to transit agencies, such as the Google Places API or the Esri geocoder, are expensive and have license limitations on use, which often are a roadblock to agencies hoping to implement OTP. To increase adoption of OTP, a geocoding option that meets the following characteristics is necessary:

- Free from fees and limitations
- Customizable
- Comprehensive and includes transit-specific landmarks such as transit centers and bus stops and the place names of businesses, civic institutions, and other locations that users expect a trip planner to understand after using proprietary tools such as Google Maps or Apple Maps

A non-proprietary and non-restrictive option for address locating will substantially lower the barrier to entry for many transit systems to offer a trip planning tool and can achieve significant cost savings for transit agencies, government agencies, and the public. TriMet's OTP SUM project set out to address this need and also to provide other important functions to improve TriMet's own multimodal trip planning and geocoding functionality and a tool that any other transit agency in the US (or the world) could use with relative ease.

SECTION 2

Project Overview

Project Scope

Goals, Strategy, and Objectives

Project goals were to improve OTP trip planning functionality to support MOD in an open source environment and to lay the groundwork for MaaS, as follows:

- Improve the open source, non-proprietary OTP platform by
  - incorporating SUM modes
  - optimizing trip plans based on real-time vehicle locations
  - enhancing the user interface
  - improving pedestrian routing
- Implement a fully-functional and comprehensive open geocoder built off the existing Pelias geocoder that includes implementation of a reference framework for government agencies to auto-feed their authoritative address data into a publicly-accessible geocoding service; this alternative can achieve significant cost savings for transit agencies any for any government agency, developers, and the public.
- Plan for future integrated payment function.

The project strategy was to leverage open source software, open data, and open standards to facilitate widespread adoption.

Objectives of the project were to:

- Allow users to get information about and compare transit trips in combination with SUM options in addition to the biking and walking options previously available in OTP.
- Provide users with a more accurate and robust matching of addresses and points of interest when using OTP.
- Improve the usability and design of the web-based OTP interface.
- Provide users with real-time information regarding their trip plans and optimize trips based on current vehicle locations.

Technical Approach

With a complex scope of work requiring a broad spectrum of expertise, the OTP SUM project team took a distributed approach to work on the project scope as follows:

- **TriMet and IBI Group** – Project management, development coordination, and outreach to other OTP and MOD Sandbox stakeholders
- **Conveyal** – Software development for OpenTripPlanner enhancements
- **Mapzen/Cleared for Takeoff** – Software development for Pelias geocoder
- **Fehr and Peers** – Testing and evaluation of Pelias geocoder
- **TriMet and Oregon Metro** – Data improvements to OpenStreetMap and Oregon Metro master address file
- **moovel** – Development of integrated payment plan

These distributed responsibilities mapped to project tasks and milestones, allowing for effective tracking and accountability. With key partners and other project stakeholders located across the US (and internationally), the project leveraged various coordination tools to facilitate open and frequent communication and coordination among project partners and stakeholders, including:

- **InVision** – User interface design collaboration and feedback
- **GoToMeeting** – Teleconferencing, webinars, and screen sharing
- **Trello** – Schedule, task, and milestone tracking
- **GitHub** – Code change management and issue tracking
- **Slack** – Weekly development team stand-up meetings, text-based team communication

Equity and Accessibility

The OTP SUM project team ensured that equity and accessibility were key considerations throughout the OTP SUM development, implementation, and testing process. With assistance from TriMet's Title VI and Equity Program Administrator and the Diversity and Transit Equity department, the OTP SUM team implemented the frameworks and policies used by TriMet to evaluate equity and accessibility considerations for the OTP SUM application. For additional information, see Appendix A, Equity and Accessibility Report.

Title VI

TriMet and the project team adhered to all rules and regulations provided through FTA Circular 4702.1B, as adopted through TriMet's 2016 Title VI Program Update, throughout OTP SUM development, implementation, and testing.

The new OTP front-end is a "mobile first" web application, not a native smartphone app. This means that its full functionality is available to all internet users, regardless of whether they access the tool from a smartphone, desktop computer, tablet, or other type of hardware. Thus, it does not exclude minority and low-income individuals who may not own a smartphone but who can access the internet in other ways. It also avoids the effort and cost of maintaining smartphone systems on multiple platforms.

For people who lack access to or comfort with the internet, the enhanced trip planning capabilities are available via TriMet's Rider Support Call Center. OTP SUM functionality is accessible to customers through the call center, which provides trip planning assistance seven days per week from 7:30 AM to 5:30 PM.

Although the scope of this phase of OTP SUM included only a plan for payment integration and not implementation of integrated payment, TriMet recognizes that some of its customers might not have access to bank accounts or credit card accounts to link to for payment of SUM trips. 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 linked bank or credit card accounts.

Environmental Justice

Although the scope of this phase of OTP SUM included only a plan for payment integration, not implementation of integrated payment, TriMet recognized that some of its customers might not have access to bank accounts or credit card accounts to link to payment for SUM trips. 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 linked bank or credit card accounts.

Accessibility

This project directly addressed some critical trip planning accessibility needs for persons with disabilities. A key component of enhancements made by to the core OTP routing engine allows for improved pedestrian routing by incorporating additional information from the OpenStreetMap (OSM) pedestrian network. With these back-end enhancements, pedestrians will be preferentially routed on streets with sidewalks, quieter streets, and streets that are paved. OTP will also be less likely to suggest trips that cut through parking lots, which can be dangerous and confusing, and it strongly penalizes high-speed roads that lack sidewalks. Thus, it helps support better trip planning for persons who use mobility devices. These settings are fully configurable and can be adapted by other agencies based on their local conditions and data availability.[1]

[1] For technical details about how this is implemented, see https://github.com/opentripplanner/OpenTripPlanner/blob/trimet-dev/docs/Pedestrian-Routing.md.

To take advantage of these new route settings, TriMet added sidewalk presence and absence information to almost all streets[2] in its seven-county region. This significant effort in improving both the sidewalk presence data in the street network and its use in OTP provides safer and more pleasant pedestrian routes and provides a model for replicating this work in other regions.

The combined efforts on this project improve trip planning for people with disabilities and the aging population who often depend on these flexible services. These data and back-end routing enhancements provide the basis for infusing this information into the OTP core engine so it can make optimal use for planning pedestrian trips. Further, with this capability included in the OTP core, derivative products such as Conveyal Analysis, a transit service planning tool that relies on the OTP routing engine to model the accessibility impacts of service planning scenarios, will have enhanced capabilities for equity analysis activities. In addition, the VTrans MOD Sandbox Project is expanding OTP to support demand-responsive transit service by consuming the GTFS-flex specification, which will allow it to create itineraries involving "flexible" public transit modes such as hail-and-ride and deviated-fixed services. The combined efforts of this project and the VTrans project will improve trip planning for people with disabilities and the aging population who often depend upon door-to-door mobility services such as demand-responsive transit service and ridesourcing providers.

The scope of the OTP SUM project was limited to allowing passengers to plan trips, with links to SUM provider apps for booking and payment. There is no direct provision or subsidy for the SUM segments of trips planned within OTP SUM; therefore, equivalent service requirements do not apply for the SUM segments of trips planned within OTP. Multiple efforts in the Portland region and elsewhere were aimed at increasing the accessibility of other modes, such as increasing the number of wheelchair-accessible vehicles (WAV) for ridesourcing providers.

[2] Sidewalk data were not added to freeways, service streets such as alleys, driveways, and parking aisles, or streets where dense vegetation made it impossible to confidently determine sidewalk presence or absence in aerial imagery.

Timeline and Milestones

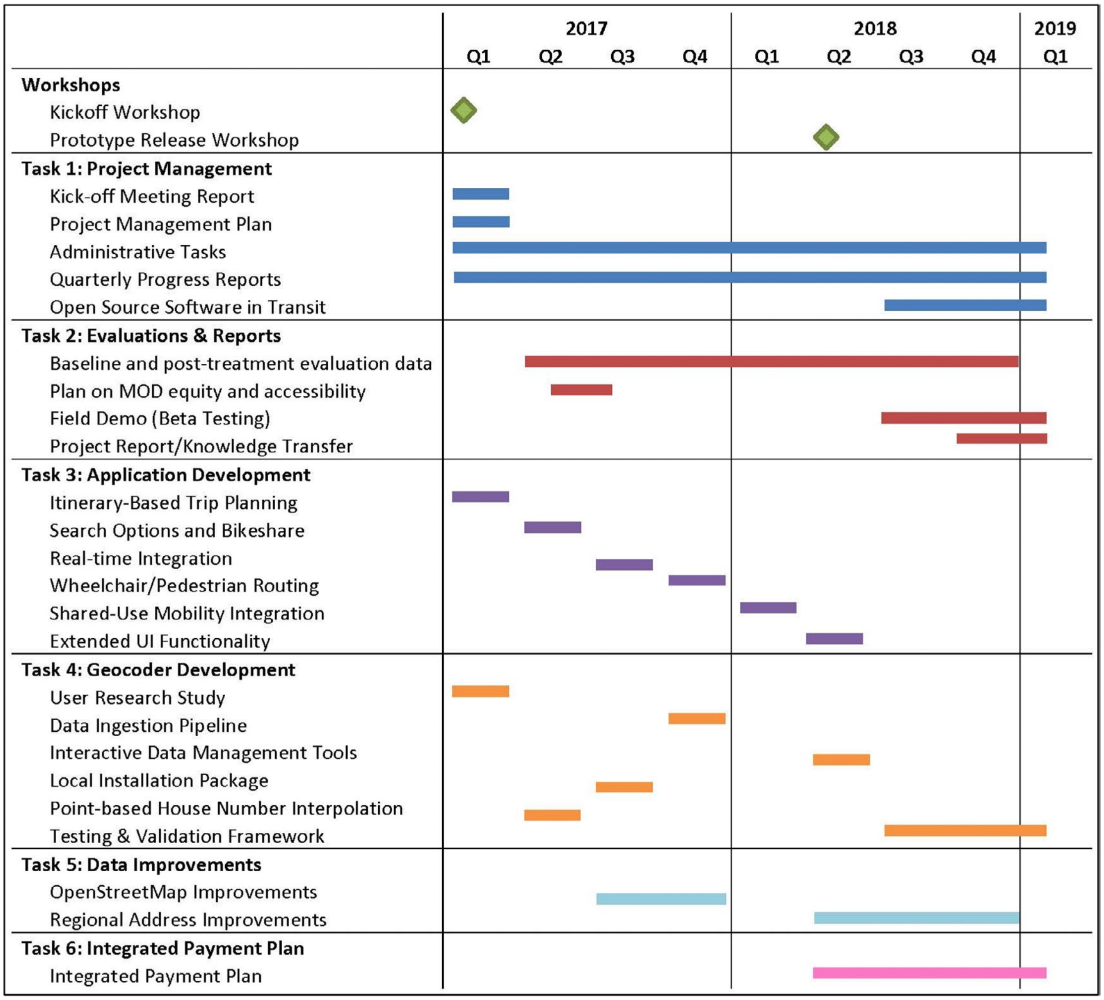


Figure 2-1 *Project timeline and milestones*

Budget

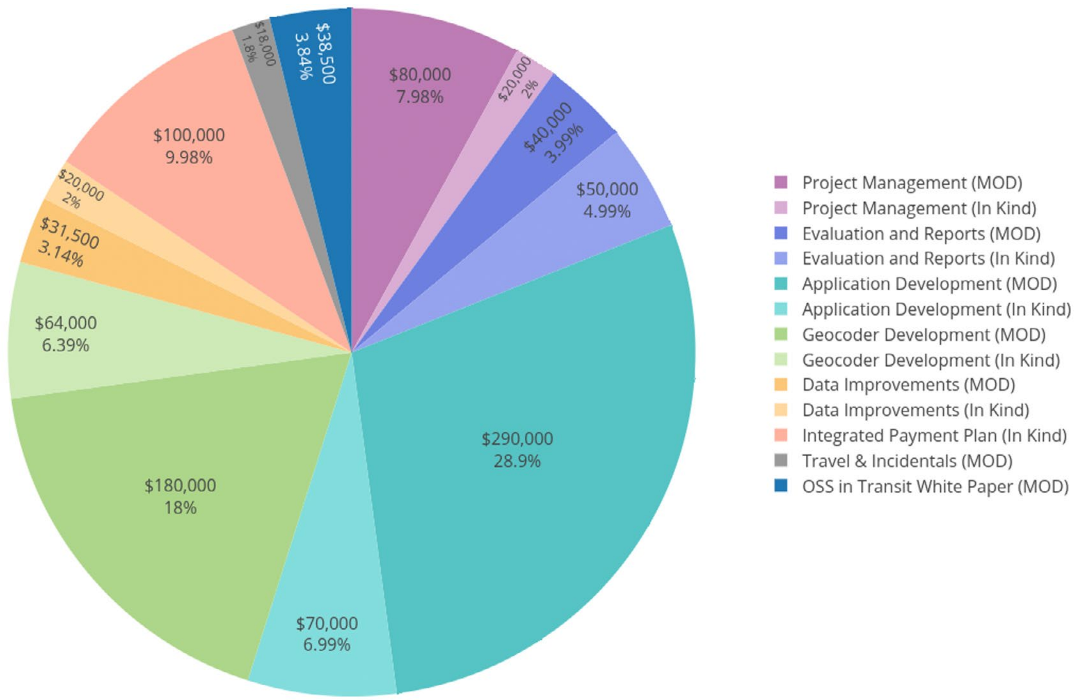


Figure 2-2 *Budget breakdown for OTP SUM project*

Table 2-1 *Budget Breakdown by Task*

Task #	Task	Budgeted MOD Sandbox Federal Amount ($)	MOD Sandbox Non-Federal Cost Share ($)	Total Budget ($)
1	Project Management (includes Open Source Software Transit Software White Paper)	$118,500	$20,000	$138,500
2	Evaluation and Reports (includes equity and accessibility, data collection and coordination with independent evaluator, knowledge transfer, field demonstration—beta testing of application, project report)	$40,000	$50,000	$90,000
3	Application Development	$290,000	$70,000	$360,000
4	Geocoder Development	$180,000	$64,000	$244,000
5	Data Improvements	$31,500	$20,000	$51,500
6	Integrated Payment Plan		$100,000	$100,000
	Travel & Incidentals	$18,000		$18,000
	Itemized Total	**$678,000**	**$324,000**	**$1,002,000**
	Cost Share Breakdown	68%	32%	

Team

Table 2-2 *OTP Project Team and Roles*

Organization	Organization Type	Role	Contact
TriMet	Public agency	Lead agency	Bibiana McHugh
IBI	For-profit entity	Project management	Ritesh Warade
Conveyal	For-profit entity	Application development	David Emory
Mapzen*	For-profit entity	Geocoder development	Diana Shkolnikov
Cleared for Takeoff**	For-profit entity	Geocoder development	Julian Simioni
Oregon Metro Data Resource Center	Metropolitan planning organization	Regional address data maintainer/provider	Robert Kirkman
moovel	For-profit entity	Integrated payment plan	Courtney Longfellow
Center for Urban Transportation Research (CUTR)	Academic institution	Open Source Transit Software white paper	Sean Barbeau
Fehr and Peers	For-profit entity	Geocoder testing	Marshall Ballard

** Mapzen led geocoder development from January 2017 to January 2018*
*** Cleared for Takeoff led geocoder development from February 2018 to January 2019*

Mapzen Closure and Transition to Cleared for Takeoff

One of the original key partners for the project, Mapzen, was a subsidiary of Samsung. In January 2018, Samsung announced the closure of Mapzen, terminating early the MOD Sandbox contract for work on the Pelias geocoder. The first year of working in coordination with the Mapzen team resulted in a more robust and flexible Pelias geocoder, with benefits that extend far beyond the OTP SUM project to a wide spectrum of Pelias users everywhere.

The Mapzen closure ultimately had no negative impact on the project. Almost immediately following the Mapzen closure, the majority of the Pelias technical team from Mapzen started a new company, Cleared for Takeoff, to continue to work on Pelias in the same capacity. Samsung generously waived all invoiced work up to the Mapzen closure, leaving the OTP SUM project with the full $200,000 originally budgeted to complete the work. As much of the work had already been done, it was possible to complete the original scope of work and add additional enhancements, based on priorities that had been identified during the project's first year, for $180,000. The remaining $20,000 was reallocated to produce a report on Open Source Software in Public Transit. This paper was prepared by the University of South Florida's Center for Urban Transportation Research (CUTR) and is included as Appendix B, Open Source Transit Software White Paper.

The TriMet MOD Sandbox Project was based on open source solutions, a strategy that proved particularly successful in this instance. As the Pelias geocoder is open source software with a significant global support community, worldwide use of, improvements to, and maintenance of Pelias is expected to flourish as an open source project.

Project Development and Stakeholder Engagement

Project Management

With team partners located in multiple cities on both coasts and internationally, project management included:

- Weekly scheduled meetings (Slack or webinars) to ensure continued communication
- Use of Trello for project management
- Use of GitHub for code change management
- Publicly-accessible repository of documents and presentations for project management
- Use of InVision for application interface development and review
- Continued updates to online project dashboard available to the public at trimet.org/mod to ensure transparency

For additional information, see Appendix C, Project Management Plan.

Workshops

Although the majority of project work was conducted remotely, two on-site workshops were held in Portland, Oregon, at major project milestones to allow for intensive collaboration by the project team and coordination and collaboration with other OTP and MOD Sandbox stakeholders.

Kickoff Workshop

On January 18–19, 2017, TriMet hosted a workshop to kick off the MOD Sandbox project that drew over 40 participants, including key project partners, other MOD Sandbox grantees, and OTP stakeholders. Foals and objective for this workshop follow.

- Goals
  - Establish a common vision for OpenTripPlanner incorporating the various OTP initiatives underway
  - Kick off and coordinate technical development for the project

- Objectives – participant common understanding of:
  - Their development objectives
  - What they need to do to meet TriMet technical requirements
  - How their tasks interface with other components of the project and broader OTP ecosystem

See Appendix D, Kickoff Workshop Report, for additional information.

Prototype Release Workshop

A second project workshop was held April 18–19, 2018, serving as a milestone as the project prototype was released and the team transitioned into testing and evaluation. The workshop was hosted by moovel, the key partner responsible for drafting an Integrated Payment Plan. The workshop acted as a kickoff for this task, allowing moovel to gather input from the broad spectrum of OTP stakeholders in attendance. Another primary focus for this workshop was coordination among OTP developers, including those working on OTP SUM and the VTrans OTP-flex projects, around merging multiple streams of OTP development back into the master OTP code base. This coordination helped ensure that all future users of OTP would be able to benefit from the enhancements developed for both the OTP SUM and OTP-flex projects. This is a highly important part of open source software, in which improvements made by one group benefit all users of the software. Planning and coordination during this workshop laid the groundwork for the upcoming testing and evaluation phase of the OTP SUM project.

SECTION
3

OpenTripPlanner Enhancement

Application development consisted of enhancements to TriMet's existing OTP-based multimodal trip planner, including both the underlying multimodal routing engine and the user-facing web interface. In addition to the development milestones described below, additional minor enhancements to OTP were completed by Conveyal under a support contract with TriMet. Although these enhancements were not part of the MOD Sandbox scope, they were included in the beta release used for testing under the MOD Sandbox project. For additional descriptions of all OTP development completed during the duration of the MOD Sandbox project, see documentation on the OTP GitHub repository.

Objectives

Routing capabilities were extended to reflect ongoing trends in traveler behavior and open data availability. Enhancements include the ability to incorporate SUM services into multimodal trip planning (for example, use of a ridesourcing service such as Uber or Lyft to access transit). Advances in the quality and availability of real-time transit data were also incorporated, with enhancements to the routing engine's ability to consume real-time data and modify trip plans accordingly. Other improvements include support for the General Bikeshare Feed Specification (GBFS) and enhanced pedestrian routing.

In addition to the enhanced routing capabilities, a comprehensive new web-based user interface (UI) was developed. The new UI incorporates aspects from existing OTP front-end projects, including TriMet's existing interactive trip planner, and the otp.js library. The new UI was written using modern web development practices and frameworks, including the React framework and Redux architecture, which emphasizes modularity and reusability of components in a variety of contexts; the intention was to build a library that not only serves as the foundation for a comprehensive new OTP UI but also serves as a resource for developers working on complementary projects.

Milestones

- Initial design and itinerary-based trip planning
- Geocoding, bikeshare support, profile-based trip planning
- Real-time integration, advanced transit mapping
- Wheelchair/pedestrian routing, stop and route viewers
- Shared-use mobility, extended UI functionality

Strategy

- **Milestone 1: Initial Design and Itinerary-Based Trip Planning**
  - *UI/UX Design* – High-level UI/UX concepts for new OTP front-end framework, detailed UI mock-ups for Milestone 1 development tasks, and preliminary mock-ups for Milestone 2 tasks
  - *Itinerary Search Components* – Library of modular user interface components for itinerary-based search; initial search options to include date and time of travel, depart vs. arrive, and mode(s) of travel (transit, walking, bicycling, etc.)
  - *Narrative Display Components* – Narrative display of itinerary results, including turn-by-turn directions for walking, bicycling, and driving segments
  - *Base Map Components* – Base map with support for multiple user-selectable base layers and ability to specify start/end location via click/tap on map
  - *Itinerary Map Overlay* – Graphical display of itinerary results on map
- **Milestone 2: Geocoding, Bikeshare Support, Profile-Based Trip Planning**
  - *UI/UX Design* – Refinement of designs of Milestone 2 tasks; preliminary mock-ups for Milestone 3 tasks
  - *Geocoding Integration* – Ability to specify start/end location via address search, powered by Pelias geocoder
  - *GBFS Import* – Back-end enhancements to support import and processing of GBFS data
  - *Bikeshare Search/Display* – Addition of bikeshare as searchable/displayable travel mode
  - *Bikeshare Overlay* – Graphical display of available bikeshare stations and floating bikes on map
  - *Profile-based Trip Planning* – Searching and narrative display of profile-based result, with ability to toggle between itinerary and profile search modes
  - *Extended Search Options* – Custom walk/bike speeds, maximum walk/bike ranges

Bikeshare Integration – In the case of BIKETOWN (Portland's bikeshare system), data for bike availability are available in the GBFS format, now an industry standard. The BIKETOWN system allows for bikes to be left either at designated stations within the service area or, for an additional fee (currently $1.00), bikes can be left elsewhere within the service area as long as they are locked to a public bike rack. These bikes are then shown as "floating bikes" in BIKETOWN's GBFS data feed. OTP SUM will plan trips that include pick up of a BIKETOWN bike from a station or a floating bike but it allows a BIKETOWN trip leg to end only at a designated station, as the GBFS data format does not include a service area polygon, so the OTP SUM routing engine cannot determine if a trip end point is a valid location to end a BIKETOWN trip at a public bike rack.

- **Milestone 3: Real-time Integration, Advanced Transit Mapping**
  - *UI/UX Design*– Refinement of designs of Milestone 3 tasks; preliminary mock-ups for Milestone 4 tasks
  - *Schematic Transit Mapping* – Visualization of trip plan in schematic/diagrammatic format similar to stylized transit maps, and ability to toggle between schematic and geographic views
  - *Display of Real-time Results* – Display and explanation of recommended trip options that were optimized considering real-time arrival predictions and vehicle locations; display of GTFS-RT alerts for affected service in itinerary results
  - *Stops Overlay* – Overlay of transit stops on map (derived from GTFS), with ability to select stop as start/end location
  - *Routes Overlay* – Overlay of labeled transit routes on map (auto-generated from GTFS)
- **Milestone 4: Wheelchair/Pedestrian Routing, Stop and Route Viewers**
  - *UI/UX Design* – Refinement of designs of Milestone 4 tasks; preliminary mock-ups for Milestone 5 tasks
  - *Stop Viewer* – Interactive display of real-time arrival predictions for routes serving a given stop, triggered by stop click on map or from itinerary
  - *Route Viewer* – Interactive display of routes with links to detailed schedule page
  - *Wheelchair/Pedestrian Routing* – Back-end development to support enhanced wheelchair/pedestrian routing
  - *Wheelchair/Pedestrian Narrative Display* – Enhanced narrative display of wheelchair/pedestrian accessibility

Pedestrian Routing – OTP SUM introduces extended functionality for weighting pedestrian routing based on OSM tags. This functionality can be used to favor or disfavor specific street edges in walk routing based on properties of the corresponding OSM ways, such as roadway type or the presence of sidewalks. At the heart of the pedestrian routing functionality is the “walk comfort” configuration, which defines a set of “rules” that map specific conditions based on a street or path’s attributes to “walk comfort” factors. The walk comfort factors are applied to a street segment when the routing engine is considering that segment for a pedestrian trip segment. A single rule specifies one or more "tests" that must be satisfied for the rule's weighting factor to be applied to a given street or path segment. The factor is a multiplier that is applied to the default segment weight (which itself is a combination of segment length and elevation-derived steepness, if applicable). Factors greater than 1.0 adjust the weight upward making the segment less attractive to routing, while factors less than 1.0 adjust the weight downward making it more attractive.

- **Milestone 5: Shared-use Mobility, Extended UI Functionality**
  - *UI/UX Design* – Refinement of designs of Milestone 5 tasks
  - *SUM Back-end Support* – Back-end enhancements to support import and processing of SUM data and routing using SUM trip segments
  - *SUM Narrative Display* – Addition of shared-use mobility vehicle as selectable mode and display of information specific to SUM segments (e.g., wait time for vehicle, trip cost) as applicable
  - *Extended Narrative Display* – Display of health and environmental impacts
  - *Elevation Profile* – Graphical display of topography for walking and biking segments (Note: The elevation profile functionality was developed as part of this project but was ultimately excluded from the beta release during design refinements.)
  - *Print/Share Tools* – Ability to view results in print-friendly format and ability to share results via hyperlink/email/social media
  - *Distance Measurement* – Interactive tool for measuring distance on map

Ridesourcing Provider Integration

Integration of data from the ridesourcing providers Uber and Lyft involved a more iterative process, largely driven by negotiations with the ridesourcing providers over what data would be provided and how their data would be shown in the application. Initially, the OTP SUM project team requested aggregated data, including rough estimates of ridesourcing wait times by time of day and location within the Portland region to optimize the trip planning algorithm. However, generating and storing these rough estimates would have been problematic, requiring custom development of new APIs and significant data logging within OTP.

After internal discussion, the OTP SUM project team decided to pursue an alternative approach to planning trips that have a ridesourcing segment. This new approach required use of only the ridesourcing provider's public API, simplifying the approval process for both the TriMet project and other future implementations of OTP SUM. This approach is also provider-agnostic, and other ridesourcing integration would only require development of a data loader to translate their API into the OTP data structure.

The OTP routing engine treats ridesourcing trips planned now are different from those planned for the future due to limitations of the ridesourcing public APIs. For trips planned to depart now, if a trip option begins with a ridesourcing segment, OTP will call the API with an origin only to get a wait time estimate to use in initial route evaluations. If a trip option ends with a ridesourcing segment, the routing engine will make the following key assumption: if the ridesourcing ride is not occurring very soon, the customer will have an opportunity to book it in advance. Thus, the routing engine will use the "scheduled trip" departure window as the basis for the wait time estimate for that ridesourcing trip segment. For trips planned for the future, the "scheduled trip" departure window will be used as the basis for wait time estimates for ridesourcing segments at either the start or end of the trip.

Under this approach, OTP will make one API call per trip planning search and two calls per recommended trip to the ridesourcing availability API when planning a transit trip itinerary including a ridesourcing segment. One call will be made prior to beginning the OTP routing search to determine current wait time at the user's start location. If the final itinerary includes a ridesourcing leg at the start of the trip (a ridesourcing "access" leg), a follow-up call will be made using the two endpoints of the access leg to determine the fare for the access leg. If the final itinerary includes a ridesourcing leg at the end of the trip (a ridesourcing "egress" leg), an additional call will be made with the endpoints of the egress leg to determine the fare and wait time of that leg. The wait time will be reported to users as the suggested lead time to book their ridesourcing trip prior to arriving at their final transit stop.

Extended UI Functionality

As noted, the OTP user interface was redesigned and rewritten using modern web design practices and frameworks, which emphasizes modularity and reusability of UI components in a variety of contexts. Design for these user interface modules took an iterative approach. During initial design, mock-ups using the InVision platform allowed a variety of project stakeholders to comment on design choices. Once the prototype was deployed in early 2018, additional design refinements were made in response to the heuristic testing and feedback from users participating in beta testing. Figures 3-1, 3-2, and 3-3 show the evolution of the user interface design, from initial mock-ups submitted as part of the grant proposal to the current design used for beta testing.

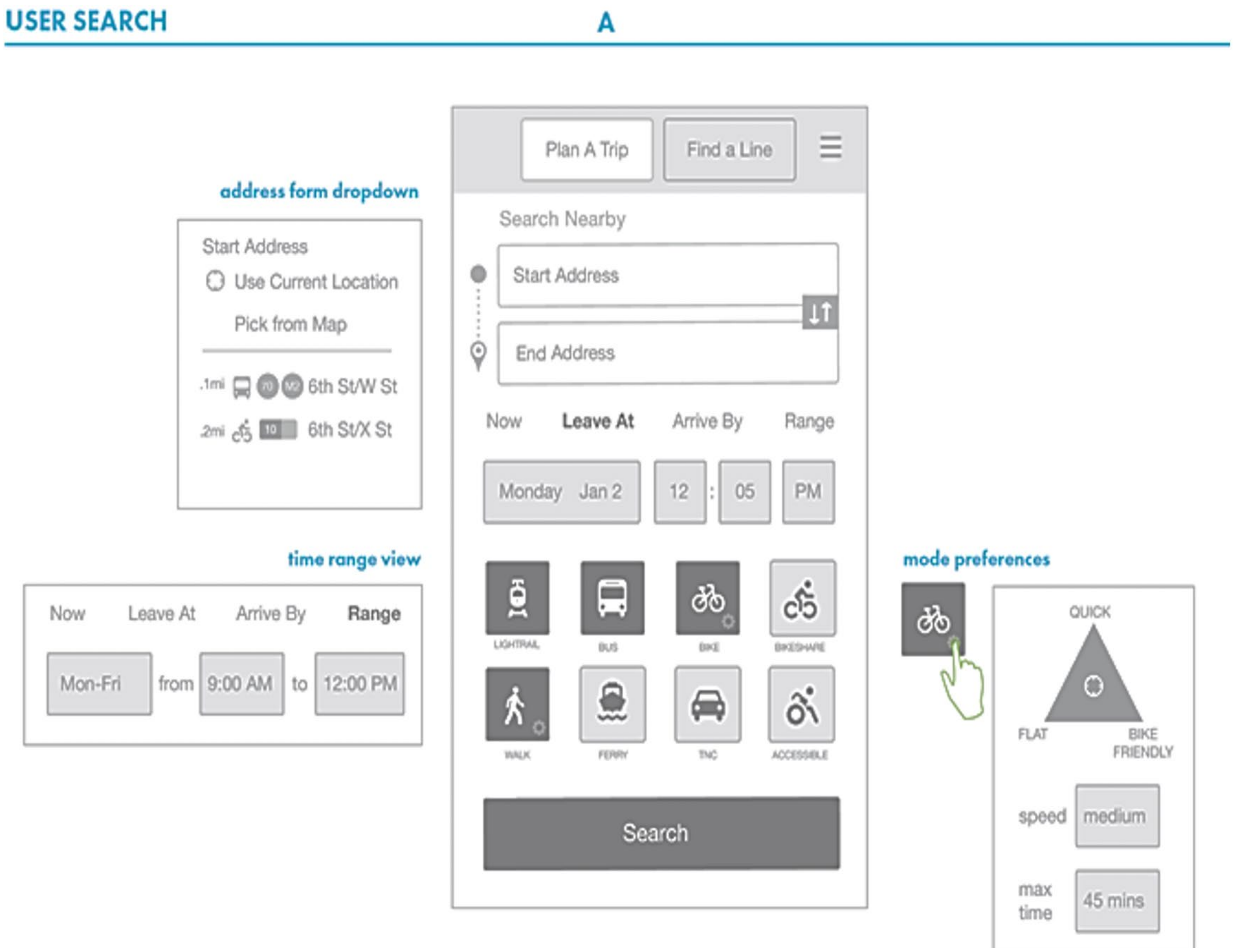


Figure 3-1 *UI mock-up from original project proposal*

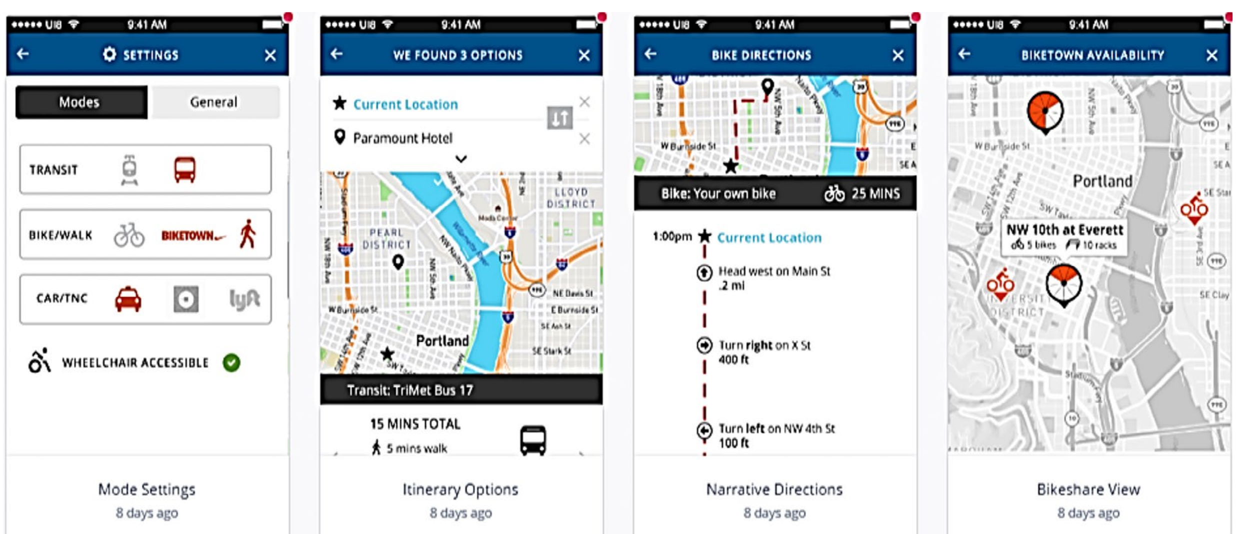


Figure 3-2 *UI mock-ups from prototype development, March 2017*

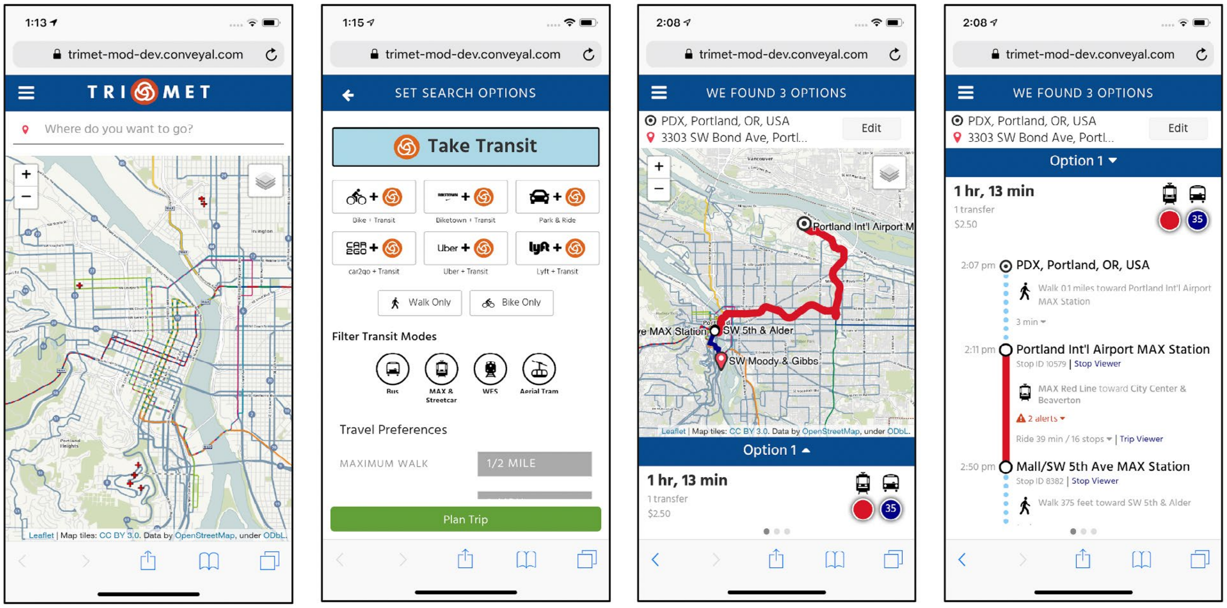


Figure 3-3 *UI screenshots of beta application, January 2019*

Outcome and Benchmark

The development milestones described above led up to the release of a functional prototype at the April 2018 workshop. Over the course of the development process, some originally-planned features or enhancements were dropped from the eventual prototype. Profile routing and a simplified, schematic display of trip options were dropped once it was determined that significant additional development beyond the scope of the project would be necessary to bring features from baseline functional to a polished state appropriate for use in the final product. In addition, the planned wheelchair routing enhancements needed to be dropped due to unforeseen limitations in the degree to which accessibility is tagged in OSM data.

Following the workshop, the prototype application continued to be updated to incorporate design feedback from the workshop and the testing and evaluation processes (described below), as well as additional enhancements that were outside the scope of this project and funded by TriMet's OTP support contract with Conveyal.

Benchmarking Multimodal Trip Planning

In most trip planning tools that incorporate both transit and SUM modes, the returned trip options are unimodal, so users must compare taking transit or an SUM mode for the entire trip. In this model, the user's consideration among modes will often be a question of time/cost trade-off, with the transit option being cheaper but slower and the SUM mode (such as a ridesourcing) quicker but more expensive. In addition, each of these single modes may not serve the user's origin or destination well; perhaps the origin location has a prohibitively long wait for a ridesourcing pick up or the destination is too far from a transit stop to make walking from that transit stop reasonable. The multimodal functionalities of OTP SUM address these issues. A trip including both a transit segment and a ridesourcing segment could be much faster than the transit-only trip but also much less expensive than a ridesourcing-only trip.

To test this hypothesis, trip plans were developed using 15 representative origin-destination combinations[3] (OD pair) that were chosen to broadly cover the TriMet service district. For each OD pair, trips were planned using OTP SUM for both transit-only and transit+ridesourcing. The ridesourcing APIs were used to produce ridesourcing-only trip plans for comparison purposes. For both transit+ridesourcing trips and ridesourcing-only trips, plans were made for both ridesourcing providers to yield a generalized average ridesourcing trip time. Table 3-1shows results of this benchmarking test.

Table 3-1 *Benchmark Multi nodal Trip Plans*

		MOD OTP Transit		Transit+TNC Average		Avg. TNC Alone	
Trip Origin	**Trip Destination**	**Total Time**	**Total Cost**	**Avg. Time**	**Avg. Cost**	**Avg. Time**	**Avg. Cost**
PCC Sylvania	Gabriel Park	28	$2.50	22	$8.50–$11.50	22	$15.84
Beaverton High School	Cedar Hills Crossing Shopping Center	23	$2.50	Could not plan trip		19	$13.06
Lewis & Clark College	Pioneer Courthouse Square	33	$2.50	34	$8.50–$11.50	42	$31.70
SW Edgewood & Huntington Ave	Oregon Zoo	25	$2.50	17	$8.50–$11.50	18	$21.12
Central Library	SW Nevada & SW Virginia	35	$2.50	25	$8.50–$11.50	18.5	$16.03
SW 25th & SW Luradel	Safeway, 8145 SW Barbur Blvd	33	$2.50	Could not plan trip		16.5	$11.87
OHSU	SW 10th & SW Harvey Milk St	18	$2.50	23	$8.50–$11.50	18.5	$16.08
Skidmore Fountain	Smith Memorial Student Union	15	$2.50	17	$2.50	14	$11.82
SW Gaines/SW Moody	Japanese Gardens	60	$2.50	Could not plan trip		23	$18.20
Taylor Dr & Carson Dr	PCC Sylvania	132	$2.50	81	$8.50–$12.50	48.5	$32.64
Lake Oswego Transit Center	Luscher Farm	36	$2.50	Could not plan trip		26.5	$15.26
Marylhurst University	SW 57th & SW Joshua St	112	$2.50	Could not plan trip		34.5	$21.48
SW 42nd & Galeburn St	Marylhurst University	46	$2.50	39	$8.50–$11.50	32	$25.41
SW Brookridge & SW 84th	Tualatin Hills Park	55	$2.50	27	$8.50–$12.50	21	$15.11
1050 SW Montgomery St (formerly RiverPlace Athletic Club)	SW 20th & W Burnside St	33	$2.50	34	$8.00–$11.00	19	$14.39

Notes: Trips planned to leave at 12:00 noon on Thursday, 1/31/2019. Origins/destinations for which transit+TNC trip returned "could not plan trip" are because could not meet routing engine. Requirement that at least 50% of trip's distance be transit segment of trip.

[3] These same 15 origin/destination pairs were used for benchmarking Transit+Bicycling and Transit+Walking multimodal trip plans during the original development of OTP. For more information, see https://trimet.org/mod/docs/OTP%20Final%20Report%20-%20Metro%202009-2011%20RTO%20Grant.pdf.

SECTION

4

Pelias Geocoder Enhancement

Introduction

Having a reliable and cost-effective geocoding solution is often a barrier to entry for transit agencies considering implementing OpenTripPlanner. At the start of this project, Mapzen's Pelias geocoder was already a robust, production-ready, open source geocoder, and the Mapzen team had capacity and interest in enhancing Pelias as part of the OTP SUM effort.

Application development for the Pelias geocoder for this project sought to enhance the existing Pelias geocoding engine and related tools to make it a viable option for agencies looking to implement OTP. For additional descriptions of all Pelias development completed during the duration of the MOD Sandbox project, see documentation on the Pelias GitHub repository.

Objectives

Although the Pelias geocoder was production-ready and had a growing user base at the onset of this project, new functionality and several enhancements were necessary to make it a viable option for use with OTP. These requirements formed the following development milestones:

- **Core Milestones:**
  - User research study
  - Interactive data management tools
  - Data ingestion pipeline
  - Local installation packages
  - Point-based address interpolation
  - Testing and validation frameworks
- **Additional Milestones:**[4]
  - Alias table functionality
  - Query and sorting improvements
  - Adoption of TriMet transit data loader

[4] These milestones were added to the Pelias geocoder enhancement scope when Cleared for Takeoff took over development responsibility as a result of Mapzen choosing to contribute as in-kind all work completed at the time of Mapzen's shutdown.

- Documentation improvements
- Support for OpenStreetMap (OSM) entrance tags
- Blacklists for problematic records

Strategy

User Research Study

Although Pelias already ingested OpenAddresses (OA) prior to the MOD project, significant work was done to make it easier for agencies to feed their address data into this system. Previously, the only way to add data to OA was through use of GitHub, which can be daunting for non-programmers.

A user research study was conducted by Mapzen to understand the needs of the transit agencies and local municipality administrations related to data management. The results of this study informed design decisions for development of the OA data management tools.

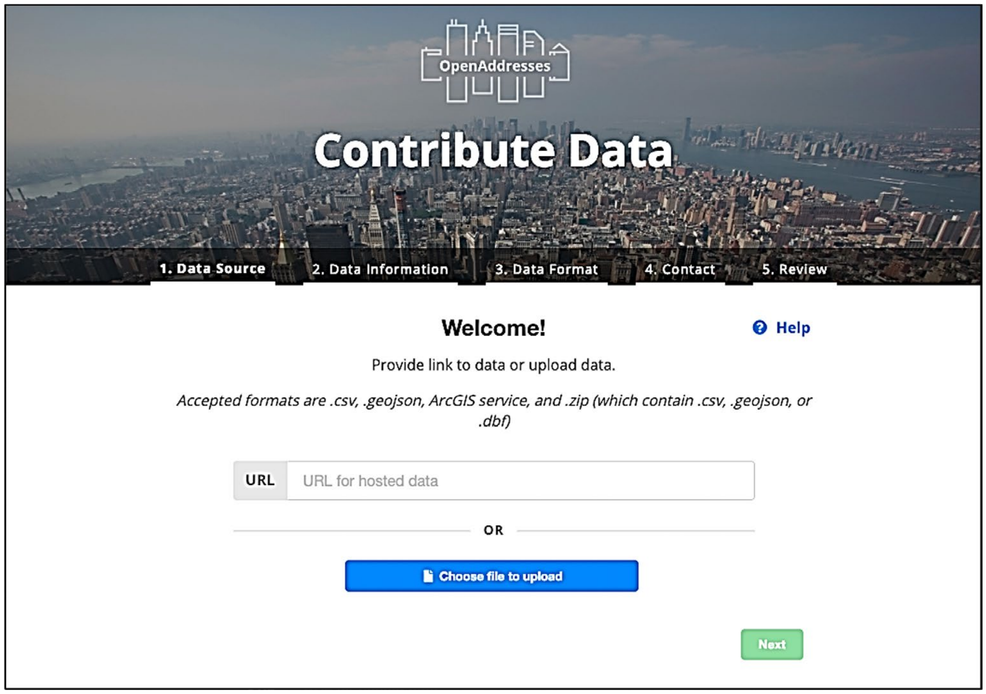
Interactive Data Management Tools

Pelias developers implemented a resilient, intuitive, and simple user experience for adding and maintaining data from a variety of sources to OpenAddresses. The final interface was based on the findings of the user research study and serves the following user needs:

- Allow users to add, maintain, and remove data sources with minimal to no assistance.
- Allow users to investigate revision history for each data source.
- Allow users to identify maintainers of existing data sources from local municipalities.
- Ability to view data from each data source in various forms, such as a map or table.

Figure 4-1

New home page for OA submit service



Data Ingestion Pipeline

Changes were made to the back-end OA data ingestion process to support the interactive user experience and the automated update cycle.

Local Installation Packages

Pelias developers created a simple setup system for agencies wanting to install a local instance of the search engine using only a subset of the available data sources. This system is key to ensuring replicability of the OTP SUM platform.

Point-based Address Interpolation

In addition to implementing the data ingestion and maintenance system, Pelias developers also contributed functionality to account for missing addresses and attempts to estimate their location by implementing a point-based address interpolation solution, which the search engine previously did not support. This functionality is necessary to fill gaps in the authoritative data published to OA by the agencies. It allows Pelias to return interpolated addresses without the presence of range data sources, such as U.S. Census TIGER shapefiles. Pelias combines known address points with street geometry to find probable location of missing addresses, even when address range information is not included in the streets.

Figure 4-2 *Visualization of Pelias interpolation algorithm*

Testing and Validation Frameworks

Pelias developers also created a thorough testing platform to allow users to ensure that their data are being searched correctly and that the results are formatted according to local postal service rules. This allows users to specify search queries that they regard as critical and/or representative for their instance of Pelias, and run these tests automatically each time the data are reloaded into Pelias to ensure quality.

Alias Table Functionality

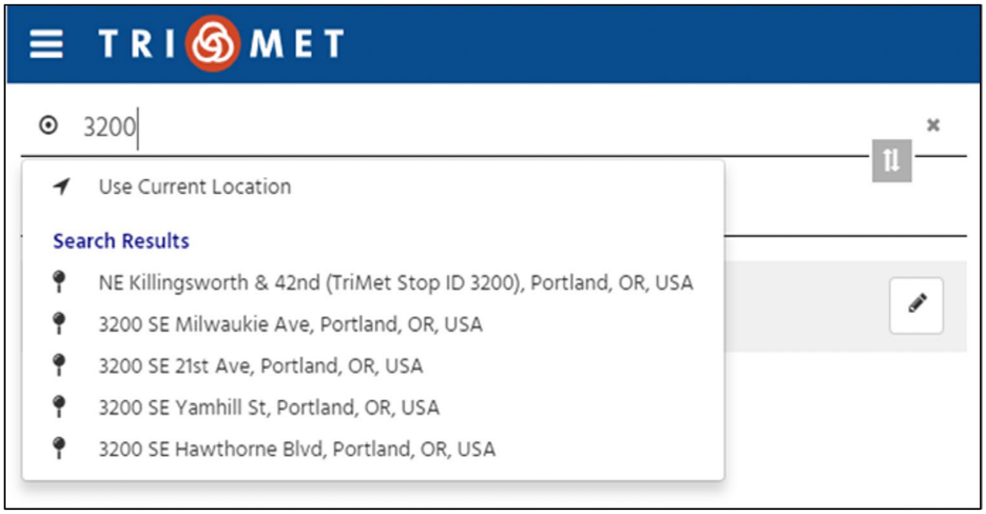
TriMet's customers and the TriMet Rider Support team often input abbreviations for major landmarks (e.g., TTO for Transit Ticket Office, PDX for Portland International Airport, etc.) and for some streets (e.g., TV Hwy for Tualatin Valley Highway, MLK for Martin Luther King Jr Boulevard). TriMet's pre-existing geocoder allowed for use of such aliases, which was identified as a key requirement for Pelias as well. It has now been incorporated into the code base, and other agencies will be able to supply their own alias tables when setting up their own instances of Pelias.

Query and Sorting Improvements

Pelias developers created a system that allows TriMet to favor certain types of data in the results. The TriMet team used this weighting system to ensure that transit Stop IDs are weighted above street addresses, so when a customer keys in a Stop ID it appears at the top of the list.

Figure 4-3

Example of TriMet Pelias favoring Stop ID over addresses in search results



In the first year of the project, TriMet developers prepared a tool for loading transit points of interest (POIs) from GTFS. The Pelias developers incorporated this code into the Pelias project to enable easier updating for TriMet, and replicability for other agencies.

Adoption of TriMet Transit Data Loader

In the first year of the project, TriMet developers prepared a tool for loading transit POIs from GTFS. Pelias developers incorporated this code into the Pelias project to enable easier updating for TriMet and replicability for other agencies.

Documentation Improvements

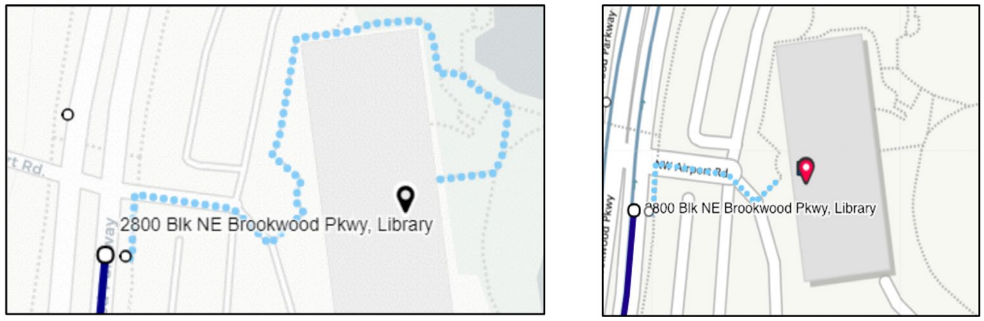
To support widespread adoption of Pelias, the team has updated and added to the project's documentation on GitHub.

Support for OpenStreetMap Entrance Tags

To improve pedestrian routing, the Pelias developers also added support for OSM entrance tags. Prior to this enhancement, Pelias would return the center of an OSM area, which could lead to poor directions. For example, if a rider planned a trip to the Brookwood Library in Hillsboro, Oregon, they were directed on a long walk to the back of the building rather than to the front door.

Figure 4-4

Geolocation entrance tags



Blacklists for Problematic Records

In some cases, the addition of an entrance tag was not sufficient to ensure correct routing to a location. For example, Portland International Airport, a major destination, is represented in OSM by a large polygon. The center of that polygon was on a runway and not suitable for trip planning, and the main entrance of the airport was inside the polygon, so the entrance tag solution would not work. As TriMet already has a point for the airport in its location data, the best solution was to remove the OSM version of the airport from TriMet's Pelias instance. The Pelias developers implemented this fix by creating support for "blacklists" of records, one for OSM and one for OA, that are deleted each time data are loaded into the geocoder. TriMet staff can add to these lists as needed; as with other Pelias enhancements, this can easily be implemented by other agencies.

Outcome and Benchmark

TriMet developed a geocoder testing data set to track the performance of the TriMet Pelias instance over time and relative to other geocoders. The team selected 2,000 location polygons that reflect the range of TriMet's geocoder needs. Polygons were used instead of points, because for many locations it is impossible to define a single correct point (e.g., the main entrance of a shopping mall might be an appropriate point, but its center point would also be correct). The polygons were modified and validated using JOSM and OpenStreetMap. The test suite included locations from five categories and subcategories (in parentheses):

- Points of Interest (top user submissions from log files, intersections, and landmarks)
- Business (eFare outlets, major employers, and FourSquare-validated businesses)
- Residential (OpenAddresses, addresses with leading zeros, and theoretical addresses)
- Transit (transit Stop IDs, rail stations, and park and ride locations)
- Anomaly (misspellings, locations with aliases)

Once the testing suite was validated, the TriMet team developed a script to determine how well a set of geocoders matched each address. The colors in Figures 4-5 and 4-6 indicate if a geocoder returned a point that was within the validated polygon or how far it was from the polygon if outside it. (*Note*: TriMet Pelias is second only to Google in terms of "inside validated polygon" accuracy. Google has not been tested since their restrictive new pricing model was introduced in July 2018. ArcGIS and OSM/Nominatim were last tested in October 2018 because of technical changes to their APIs since then.)

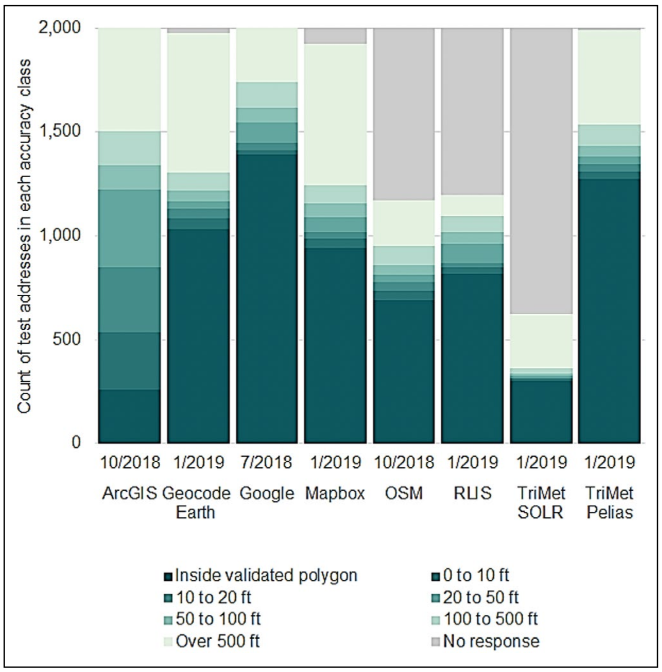


Figure 4-5

Comparison of most recent performance of geocoders with TriMet's geocoder test suite

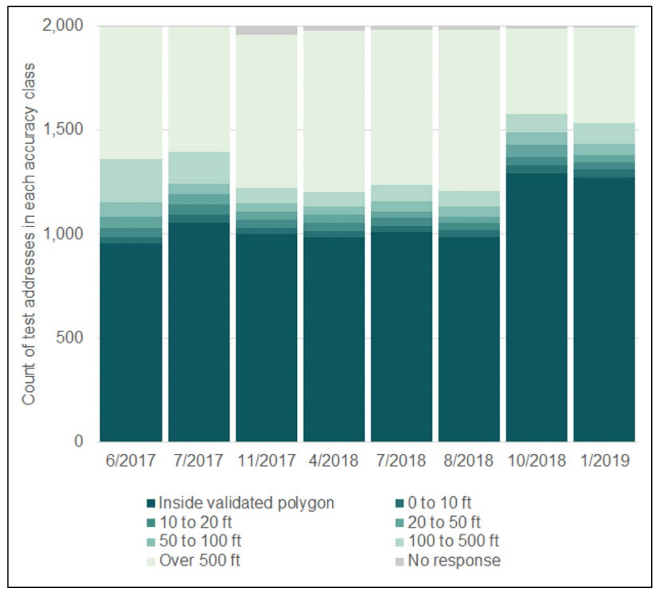


Figure 4-6

TriMet Pelias instance showing good performance

TriMet Pelias has shown good performance since first tested in June 2017 and major improvements in late 2018. A slight dip in performance in January 2019 relative to October 2018 was due to the team's decision to favor Stop IDs over other categories, such that a correct number (e.g., an intersection) might be coming in just behind the stop that most closely matched the intersection.

The Pelias system also was tested independently by Fehr & Peers to ensure that it is, in fact, repeatable. They used the newly-developed setup system to create their own instance and also used the new OA front-end to load authoritative data from their region into OA. Their findings are included as Appendix E, Pelias Geocoder External Assessment.

SECTION

5

Data Improvements

Master Address File Improvements

TriMet partnered with Oregon Metro, the Portland metropolitan area planning organization (MPO), to improve the region-wide address database that Metro compiles, the Master Address File (MAF). Metro's jurisdiction includes 23 cities and the unincorporated areas of Clackamas, Multnomah, and Washington counties, which voluntarily contribute a variety of data to Metro, including addresses. Metro aggregates these data sets and publishes them for general consumption on a quarterly basis. The TriMet-Metro project team evaluated the current state of the MAF, which is a key data source for TriMet's geocoder, and identified five areas of potential errors and where improvement would be needed:

- Duplicate addresses
- Geocoding issues
- Address points not within buildings
- Address prefix issues
- ZIP code issues

Strategy

The data used as the baseline was the August 2018 quarterly MAF. After identifying all potential issues in the MAF, the project team worked systematically through every area of improvement identified. Every issue was investigated, a solution was formulated, and all resulting addresses that needed to be improved were flagged and coded accordingly. At the end of this process, all flagged addresses were moved to a database to be shared with the address data maintainers. The project team also reviewed and flagged erroneous address points known to TriMet. TriMet maintains a list of erroneous addresses in its "patch list."

Outcome and Benchmark

Of 791,844 address points, 0.49% of address records were flagged for potential issues; an additional 3.75% (29,713) were found to need spatial adjustments because the address point locations did not intersect a building footprint. In total, 86.8% of the address records in the TriMet patch list were identified and tagged for correction. For details, see Appendix F, Regional Address Improvements Final Report.

As noted, the findings and supporting data were distributed to the address maintainers, which Metro requested they review the findings for their jurisdiction and update the source for inclusion in the MAF where appropriate. The deadline to implement and incorporate the improvements was set for the first quarterly publication of the 2019 cycle (February). It is important to note that Metro does not have authority over the MAF data contributors; it was expected that the improvements would be implemented gradually as the contributors adjusted their processes and production schedules.

OpenStreetMap Improvements

OpenStreetMap (OSM), often referred to as the "Wikipedia of Maps," is a free, editable, flexible, and detailed map of the world. TriMet has used it as the base map for its spatial applications, including OTP, since 2011, and staff regularly contribute to the project to help keep it up-to-date and to add data attributes that are relevant for routing. OTP was designed to consume OSM data and has been tailored to its data model and attributes. The Pelias geocoder also uses OSM, pulling names and coordinates for businesses, restaurants, parks, and other POIs from it, as well as using its street network in the smart address interpolation algorithm. As a part of the MOD project, the TriMet team made thousands of edits to OSM to further improve both trip planning and geocoding.

Several key objectives guided TriMet's OpenStreetMap work:

- Add data to support safer, more comfortable pedestrian routing. To take advantage of OTP's new ability to route pedestrians depending on street attributes, the team:
  - Added sidewalk presence or absence information to appropriate streets[5] in the seven-county region,[6] as there are plans to expand the coverage of TriMet's trip planner beyond the TriMet service district to include transportation providers across the whole seven county region.
  - Updated speed limit data in the region; many speed limits recently were decreased, and because OTP SUM avoids routing pedestrians on high-speed streets (especially when they lack sidewalks), it was important to update this data set.
- Improve point of interest discovery by name in Pelias.
  - As Pelias pulls restaurants, businesses, and other POIs from OSM, added many of these locations so TriMet riders can easily plan trips to/from more destinations using the OTM SUM application.

[5] Sidewalk data were not added to freeways, service streets such as alleys, driveways, and parking aisles or streets where dense vegetation made it impossible to confidently determine sidewalk presence or absence in aerial imagery.

[6] TriMet's seven-county area of interest includes Clark County in Washington, and Marion, Yamhill, Polk, Washington, Multnomah, and Clackamas counties in Oregon.

- Improve accuracy of pedestrian routing.
  - Added entrance tags to large buildings, parks, and other areas so the OTP SUM application could guide riders to the correct place. In some cases, OTP would incorrectly direct people to the back of a building; adding entrance tags resolved this issue.
  - Added service streets to enhance trip planning. Occasionally, when buildings were set too far back from the street, it could make it impossible to route to them. The team added parking lots and parking aisles to enable routing to such buildings.

Strategy

TriMet makes all updates to OSM individually instead of using an automated import process. This is the OSM community's preference because automated imports can lead to numerous data issues, such as duplicated features, conflicting line work, and spatial inaccuracies. TriMet also remains engaged with the local OSM community through meetups and seeks buy-in on any editing choices that may be controversial. Because of time and budget constraints, editing is done remotely and does not involve field work. Specific strategies for each of the above objectives are described below.

Add Data to Support Safer, More Comfortable Pedestrian Routing

Adding Sidewalk Presence/Absence Data

After consideration and discussion with the local OSM community, the TriMet team decided to add sidewalk tags to OSM centerlines (sidewalks-as-metadata) instead of adding a separate line representing each sidewalk (sidewalks-as-separate-ways). The sidewalks-as-metadata approach was favored for several reasons:

- It is much faster to add tags than new lines.
- Creating thousands of miles of new sidewalk lines would make it more difficult to maintain the data in the region.
- OTP would require significant changes to its core routing engine to take full advantage of the sidewalks-as-separate-ways data model.

The methods used for sidewalk tagging were as follows:

- Each appropriate street segment was given a sidewalk tag with a value of either "no," "right," "left," or "both" to indicate sidewalk presence or absence. (Street segments in OSM have a directionality, and the left/right values are in reference to that direction.)
- Work was completed using a powerful OSM editing application called JOSM, which has a sidewalk style to visually expose the sidewalk metadata.

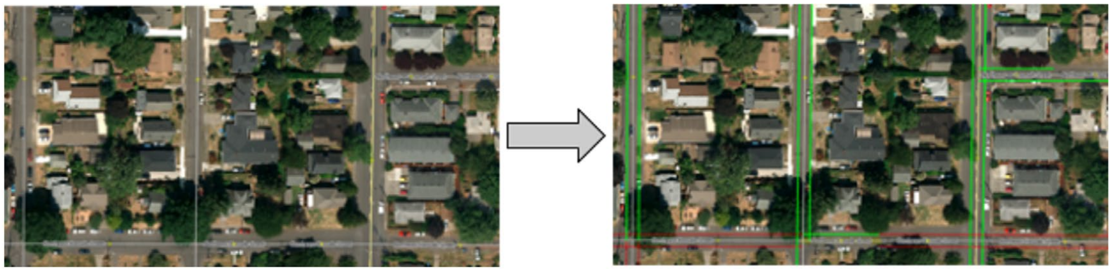


Figure 5-1 *OSM data over aerial imagery in JOSM - sidewalks style activated to visualize sidewalk tags (right)*

- Reference layers included:
  - Jurisdiction asset shapefiles representing sidewalk locations provided by Oregon Metro partners
  - Georeferenced aerial imagery collected each summer by the Regional Aerial Photo Consortium
  - Bing aerial imagery
  - Oregon Metro streets and trails data
  - Mapillary and Bing Streetside[7] imagery became available to OSM editors in 2018, after the bulk of sidewalk tagging had already been completed for the region, but it is now used for maintenance and newly constructed or altered streets.
- If a single street segment had inconsistent sidewalk presence along its length, it was cut into two ways where the sidewalk coverage changed.[8]
- Each team member would check out an area to prevent editing conflicts.
- Overpass Turbo (an interactive OSM querying tool) was used to quickly identify incorrectly or incompletely tagged areas.

Adding and Updating Speed Limit Data

In 2018, the City of Portland reduced the speed limit from 25 to 20 miles per hour on most of its residential streets. There have also been a number of speed limit reductions on arterials with high crash rates. To keep abreast of such changes and ensure that they are incorporated into OSM in a timely manner, the TriMet team monitored jurisdictional news and announcement feeds. Mapillary

[7] Unlike Google Street View, both Mapillary and Bing Streetside have licenses that allow OSM data to be created using their imagery. In early 2018, Mapillary paid drivers to collect imagery for the core urban areas in the Portland Metro region, making this a very current and useful data set.

[8] If only one lot on a segment has a sidewalk, the team did not bother to split the way to add a sidewalk because most of the block would obviously not be accessible by sidewalk. However, if a sidewalk was missing from just one lot, that could be a real issue for someone with poor mobility, so the street was split to show the gap in coverage.

was also helpful for this task, as they extract street signs automatically from their imagery and provide these signs as a reference layer in OSM editors.

Improve Point of Interest Discovery by Name in Pelias

Adding POIs

As noted, the Pelias geocoder pulls POIs from OSM, which already includes a large number of such locations; to make the data set even more robust, the TriMet team added hundreds of POIs and updated hundreds of others. Key data sources included:

- Business websites
- Mapillary imagery
- Bing Streetside imagery
- Food facility inspection lists from Multnomah and Clackamas counties

Improve Accuracy of Pedestrian Routing

To improve pedestrian routing, the TriMet team added entrance tags to some large buildings or areas; for example, for correct routing to/from the Oregon Zoo. Prior to adding an entrance tag to the zoo's main gate, OTP was sending customers to the center of the zoo, which is over a quarter of a mile from the closest light rail station/bus stop. If a customer had reduced the maximum walk distance to a quarter of a mile, the trip was impossible; however, now that the entrance of the zoo is used for routing, this is no longer an issue. To find other places in need of a similar fix, the team tested shopping malls, large stores, and parks and added tags as appropriate. The team also added parking aisles and service streets in places where a building is set far back from the street to improve routing. These areas were not possible to find in an automated way, so the preferred method was to toggle between the rendered OSM base map and an aerials layer, quickly scanning for parking lots that appeared as blank spaces on the OSM tiles.

Outcome and Benchmark

In the two-year period from January 1, 2017 through January 1, 2019, the TriMet team achieved the following:

- 8,602 total changesets were uploaded to OpenStreetMap:
  - 4,568 involved sidewalk data improvements
  - 1,021 were updates to or additions of speed limit tags
  - 979 created or updated POI information
  - 491 service streets created for more accurate routing at beginning and end of journeys

- 15 targeted additions of entrance tags for better geocoding at important destinations
- 1,528 miscellaneous updates, including but not limited to tagging of newly-constructed streets, adding footways to bus stops to control snapping behavior when OTP creates a graph from OSM, making access tags consistent, and adding/updating park-and-ride facilities.

- In the seven-county area, the total miles of sidewalks mapped increased from 5,855 on January 1, 2017 to 14,746 on January 1, 2019, a 250% increase in coverage. The TriMet team had already added sidewalk tags to thousands of miles of streets within the TriMet service district in 2016, prior to the start of the MOD Sandbox Grant.

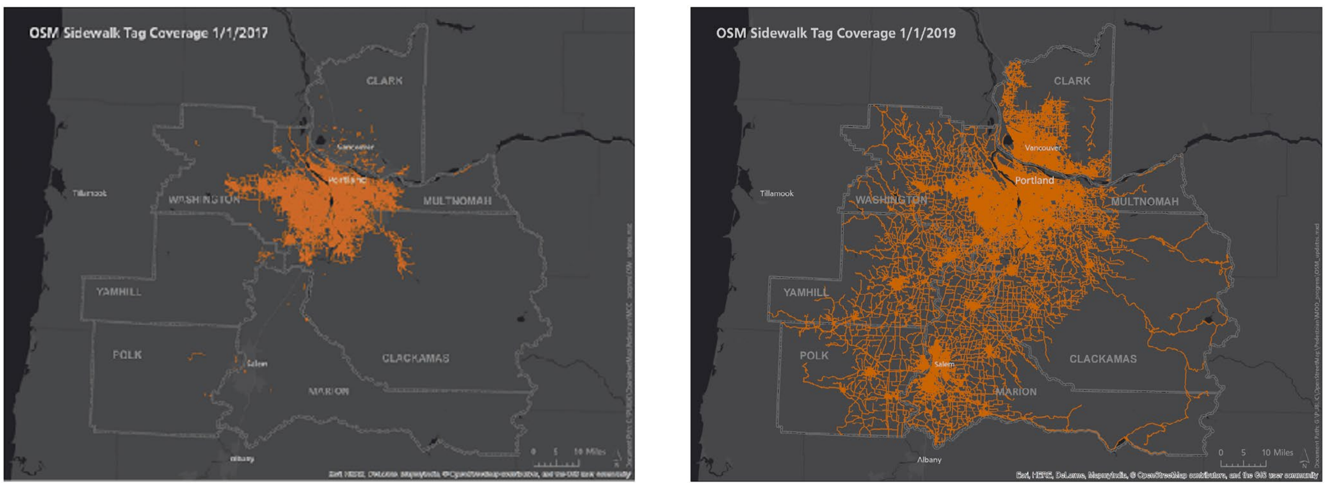


Figure 5-2 *Expansion of OSM sidewalk coverage - January 2017 (left) and January 2019 (right)*

SECTION 6

Integrated Payment Plan

As a wholly in-kind contribution to TriMet's MOD Sandbox project, moovel developed a detailed plan for an integrated payment platform and summarized its insights in a white paper (see Appendix G, Integrated Payment White Paper). This effort explored a practical design for the payment platform as part of a MOD solution. The general principles governing the design, potential limitations of the design, a system architecture, and governance/ownership options to deploy the design into operation are discussed at a high level, as these items will vary due to different configurations, existing policies, and agreements put into place.

For this white paper, MOD is distilled into two primary functions:

- Multi-service provider/mode trip planning
- Multi-service provider/mode payment

Mobility in this context is the ability for an end-user (mobility customer) to get from point A to point B, and a mobility service provider is any entity providing a service that enables this mobility (public transit, shared rides, bikeshare, etc.). In this way, both the mobility customer and the mobility service providers are users of the MOD platform, with the platform connecting users to, and ideally encouraging use of, mobility services.

To successfully deploy and operate a MOD solution, collaboration is needed among public and private partners. This includes collaboration around resources, expertise, and data, with all stakeholders agreeing on data, technology, and payment standards. In approaching an integrated payment solution, it is assumed that the mobility platform is provider-agnostic. For the payment component of the platform, which is the focus of the white paper, this means that the described system is not the exclusive payment platform of any one mobility service provider and is equally accessible by all service providers, both current partners currently integrated into OTP SUM, as well as future providers who might wish to participate in the future.

Objectives

The objective of this integrated payment plan is to describe a practical approach and system architecture for developing an integrated payment component of MOD. To achieve this, the plan focuses on establishing a framework for an integrated payment solution by describing key design principles, high level limitations, and governance options for the solution.

Strategy

Given the service provider-agnostic nature of the platform, it would be an easy comparison to think of the payment platform as a "PayPal for mobility." However, the MOD payment platform is different from other commercial payment platforms because it is designed around the MOD concept. This allows it to meet the primary objectives of MOD, such as providing equitable access to all modes of transportation, consolidating payment across providers, and creating the opportunity for potential financial efficiencies. Although mobility customers already have many payment options available to them (e.g., cash, credit cards, PayPal, Apple Pay, Google Pay, and service provider-managed payment platforms), the MOD payment platform is unique in that it is designed specifically to enable pricing incentives across mobility service providers based on their use in customized combinations and allow the customer to pay for all services in one payment action.

Together with the integrated trip planning features of a MOD solution, the payment platform was envisioned with the ability to encourage increased use and options for the mobility customer. With this in mind, the white paper focused on the pricing policy configuration aspects of the solution. It also highlighted the benefits and challenges that come with this key feature of the system.

Outcome

The integrated payment plan lays out design principles and a proposed system architecture that will allow for a flexible solution that is scalable from the smallest to largest implementations. By configuring the pricing policies in the payment platform, mobility managers will be able to offer new pricing options to customers that are difficult through non-integrated solutions. Many different service providers may in turn leverage the platform to generate greater customer benefit, such as ease of use, and seamlessness across multiple mobility providers/modes. Figure 6-1 illustrates the high-level architecture of the platform and identifies the key components of the solution. Each component is described in greater detail in Appendix G.

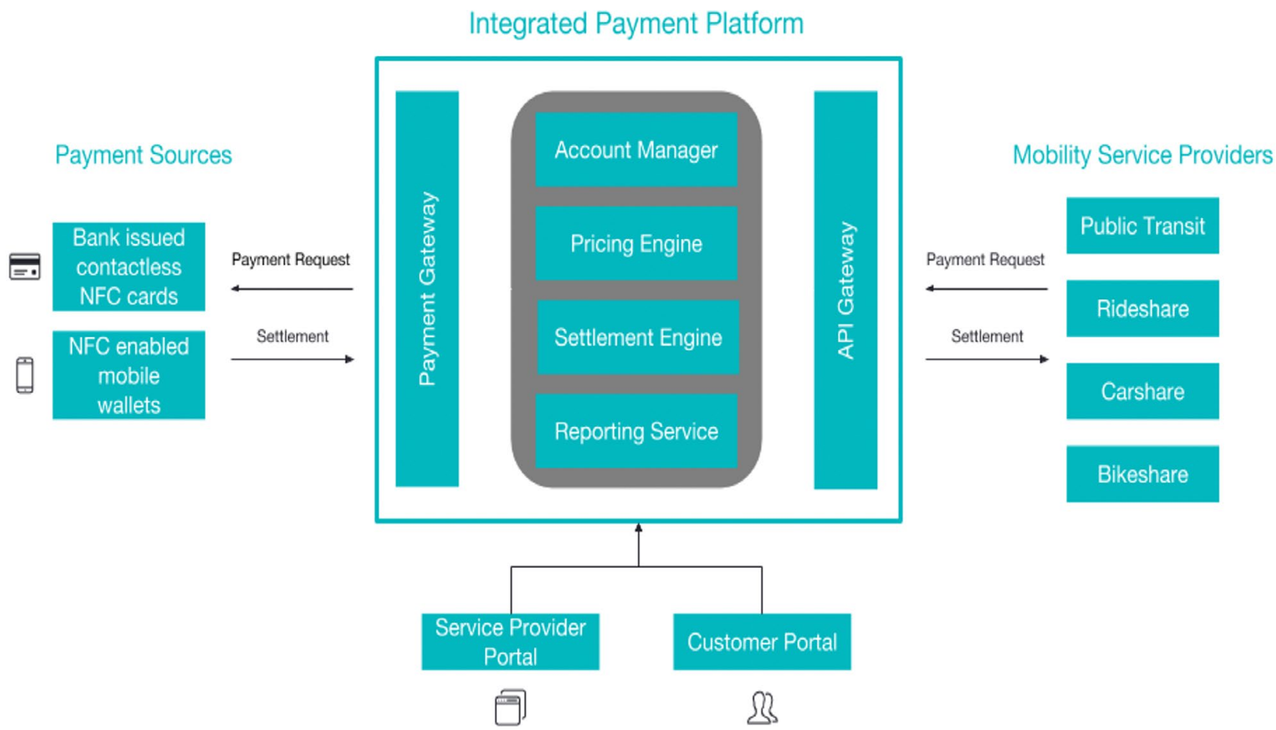


Figure 6-1 *Integrated Payment Architecture*

SECTION 7

Evaluation and Testing

The OTP SUM team employed a multi-pronged, iterative testing strategy to enable continuous improvement of the application. Key evaluation methods and projects included:

- Regular, informal testing of application prototypes by the core team throughout the two-year project, which allowed for rapid enhancements and bug fixes
- Two heuristic usability studies (described below)
- An independent evaluation survey conducted by the UC Berkeley Transportation Sustainability Research Center (described below)
- In depth one-on-one field shadowing (described below)

User Interface Heuristic Testing

As part of the OTP SUM user interface design and development process, two phases of heuristic evaluation were conducted. In a heuristic evaluation, expert testers explore a website and note when it violates commonly-accepted website usability principles. TriMet contracted with PLUS QA to perform this testing. PLUS QA brought in five professional testers with a variety of travel preferences and habits who were given a list of typical trip planning tasks to walk through and report on their findings and impressions. For the heuristic testing of the OTP SUM application, testers evaluated the application against the following usability principles:

- Visibility of system status
- Match between system and the real world
- User control and freedom
- Consistency and standards
- Error preventions
- Recognition rather than recall
- Flexibility and efficiency of use
- Help users recognize, diagnose and recover from errors

The first phase of heuristic evaluation was completed in early October 2018. Results from this analysis were used to inform updates to the OTP SUM application. After that, the second phase of the heuristic evaluation was conducted by the same testers. Major conclusions from both phases are described below, and full results are given in Appendix H (Phase One) and Appendix I (Phase Two).

Heuristic Evaluation Phase One

The heuristic evaluation of the OTP SUM application revealed no major issues in the design that were imperative to fix. However, it was determined there were three issues of primary importance that should be fixed to enhance the user's experience:

- Lack of interaction with the map:
  - Users did not figure out how to set a start location and destination point by using the map only and did not think about right-clicking on the map.
  - Users expected to be able to access more information about a transit line by clicking on it in the map.
- Swiping between options was not intuitive (mobile specific)
- Inconsistent results from the Search feature:
  - Sometimes auto-suggested addresses displayed county instead of city name
  - Duplicate results for some entries
  - Need for more robust business data

The evaluation also detected 13 issues rated as minor usability problems and one cosmetic problem on mobile and reported four suggestions.

As intended during the design process, PLUS QA's testers confirmed that the overall user experience was very similar on desktop and on mobile devices. Other than the swiping issue noted, which was a major issue, only three minor usability problems specific to mobile users were reported (size of interactive area, useful information on two different screens, and small font size).

While testing, evaluators intentionally simulated disconnecting from internet service to observe the impact on the user experience and found that the application handled the disconnection well on both desktop and mobile devices.

Survey results indicated that although users not familiar with TriMet and/or who do not bike as their primary form of transportation were less likely to start using the application; current TriMet riders had more positive impressions of its usability and were more likely to use the application.

Heuristic Evaluation Phase Two

The second heuristic evaluation revealed that OTP SUM application changes implemented between the first and second phases removed major pain points that had affected both the usability of the trip planner and the ability of users to understand the use of SUM modes with transit. The testers reported that it was now much clearer that SUM modes must be combined with transit and found it intuitive to navigate through the different options.

The results also indicated that users not familiar with TriMet were less likely to move away from using their car. However, after interacting with the application, they were interested in trying different options (path, time, cost, effort) for their trip and expressed a desire to further explore the application. Although it is unclear from these anecdotal responses during heuristic testing whether this curiosity would lead to behavioral change, it offers a potential study area for future research based upon the OTP SUM application.

Current TriMet riders had positive impressions of the application's usability in comparison with the current trip planning tool available on trimet.org, and were more likely to keep using the application.

Beta Testing

A group of TriMet customers recruited through the TriMet Riders Club participated in a beta test of the prototype application, which was conducted by the UC Berkeley Transportation Sustainability Research Center, and the results of the beta testing surveys informed further refinement of the user interface design.

Fall 2017 Survey

In Fall 2017, a link to an online survey was emailed to over 30,000 members of the TriMet Riders Club, an opt-in email service that allows people to weigh in on surveys, polls, and focus groups. The survey asked about use of trimet.org and trip planning tools and resulted in 2,217 completed surveys.

As part of that survey, respondents were asked if they wanted to be part of a group to evaluate the Next Generation Trip Planner and were told they would be given $50 in TriMet fares for participating; a total of 1,001 respondents said they wanted to participate. In December 2018, prior to commencing beta testing, these respondents were again contacted to ask if they were still interested in testing and were informed that 250 people[9] would be selected to test and reminded of the $50 incentive. In total, 377 indicated they were still interested.

To qualify to become a beta tester, a recruitment survey was conducted. Screening questions were used to ensure that participants were at least age 18 and lived in the Portland metropolitan area. Questions included in the recruitment survey pertained to:

- Ridership type
- County of residence

[9] The goal was to have 200 beta testers complete the Berkeley survey; to get 200 complete surveys, 50 testers were included as over-recruits.

- Age
- Gender
- Race/ethnicity
- English as native language
- Number in household
- Household income

Respondents were asked to provide their name and email. Frequencies were run to determine how ridership and demographics stacked up with the Portland area population. Based on the frequencies, when selecting the testers, more of the following were selected to ensure that tester characteristics were similar to those of the overall public:

- Infrequent/occasional riders
- People of color
- Clackamas and Washington county residents

Attention was paid to categories for age, gender, and income to ensure a representative mix. Based on these parameters and the frequencies, 250 beta testers were selected from the 377 who applied.

December 2018 Survey

In December 2018, the survey to evaluate user response to the OpenTripPlanner was distributed to respondents via email with a link to the survey. During the launch period, 230 responses were received; of those, 190 were completed and 186 were valid responses. Responses to all survey questions are provided in Appendix J, and notable highlights are discussed below.

The survey asked questions about user travel patterns, household structure, demographics, and use of trip planners. Respondents were also asked to test the newly-developed TriMet trip planner while taking the survey. Respondents had to engage the trip planner to plan a trip and then reported their experience with their search parameters. The survey asked several questions about their response to the newly-developed trip planner, including their impressions of function, design, and utility. About two-thirds (63%) reported testing the trip planner on a computer, 31% reported testing on a smartphone, 4% on a tablet, and 2% on another medium.

Respondents gender distributions were 47% female and 44% male, with the remaining respondents indicating either “Other” (4%), “Prefer not to answer” (3%), or “Transgender” (2%). Age distribution was relatively widespread, with the oldest respondent born in 1937 and the youngest in 2001; most respondents were born in the 1970s and 1980s. Respondents were mostly Caucasian (74%), with Hispanic (7%) and Asian (6%) comprising the two largest minorities. Respondents were relatively well-educated, with 64% reporting a college degree or higher. Respondents were predominantly of middle-income households, with a median response of $50,000–$75,000 in annual income; about 19% had an income greater than $100,000 per year, and about 21% had an income of less than $25,000 per year.

Results showed that respondents had diverse reactions to the trip planner but were generally favorable overall regarding the improvements it presented. Figure 7-1 shows respondent satisfaction with the trip planner on a 1 to 10 scale (with 1 being "Very Poor" and 10 being "Excellent"), indicating that a high plurality (45%) rated it 9 or 10, a high degree of satisfaction with the trip planner. Another 35% rated it 7 or 8, again indicating general satisfaction with the planner, and the remaining share offered responses orated it 6 or lower; only 3% stated that they "did not know." About 9% of respondents rated it 4 or lower, indicating that about 1 in 10 respondents were not satisfied with the trip planner.

Respondents were asked to specifically rate the map functionality of the trip planner on the same scale, and the distribution of responses were favorable with respect to its performance. As shown in Figure 7-2, 26% rated it 10, and about 65% rated it 8 or higher. Only 7% reported map functionality scores of 4 or lower.

Figure 7-1

Overall satisfaction with trip planner

Overall, how would you rate your satisfaction with the trip planner? (N=185)

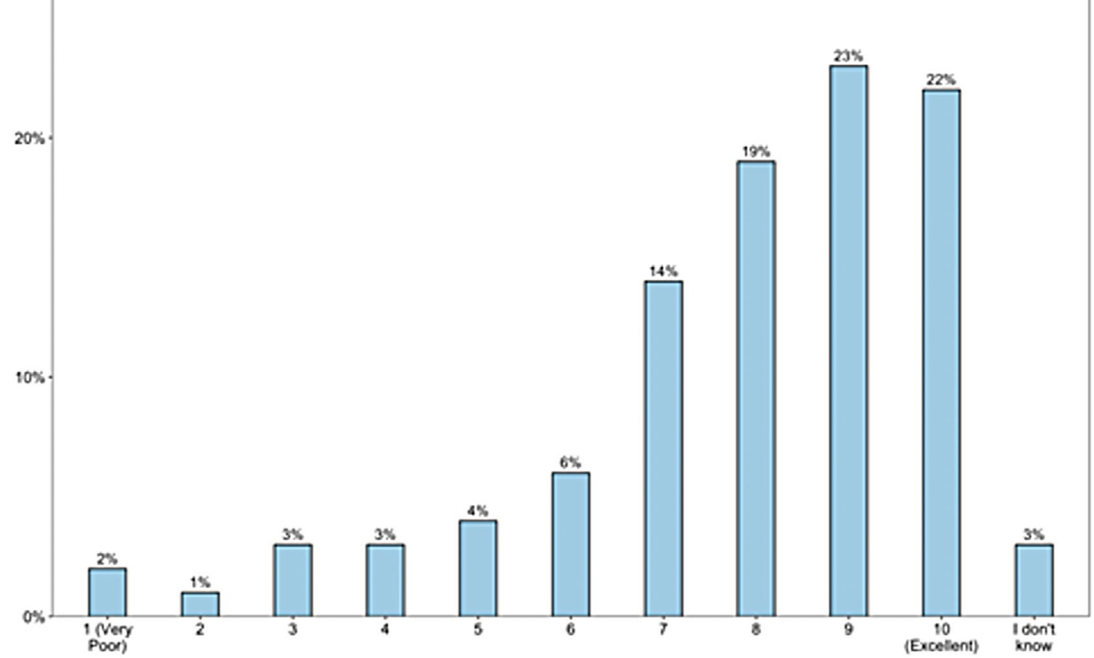
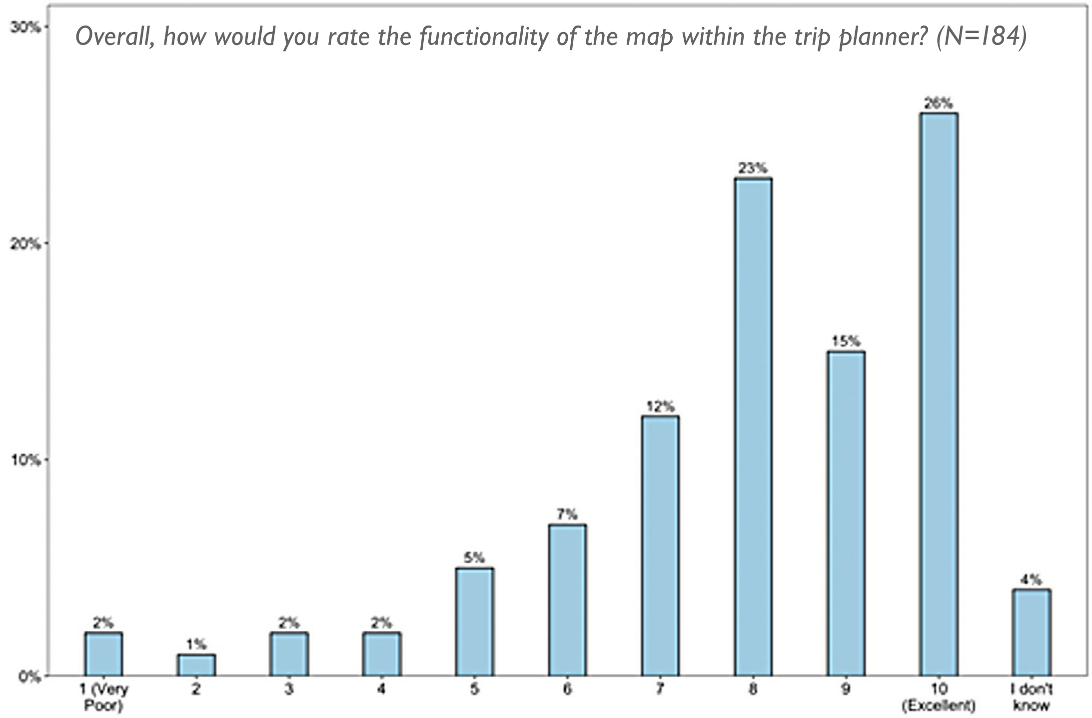


Figure 7-2

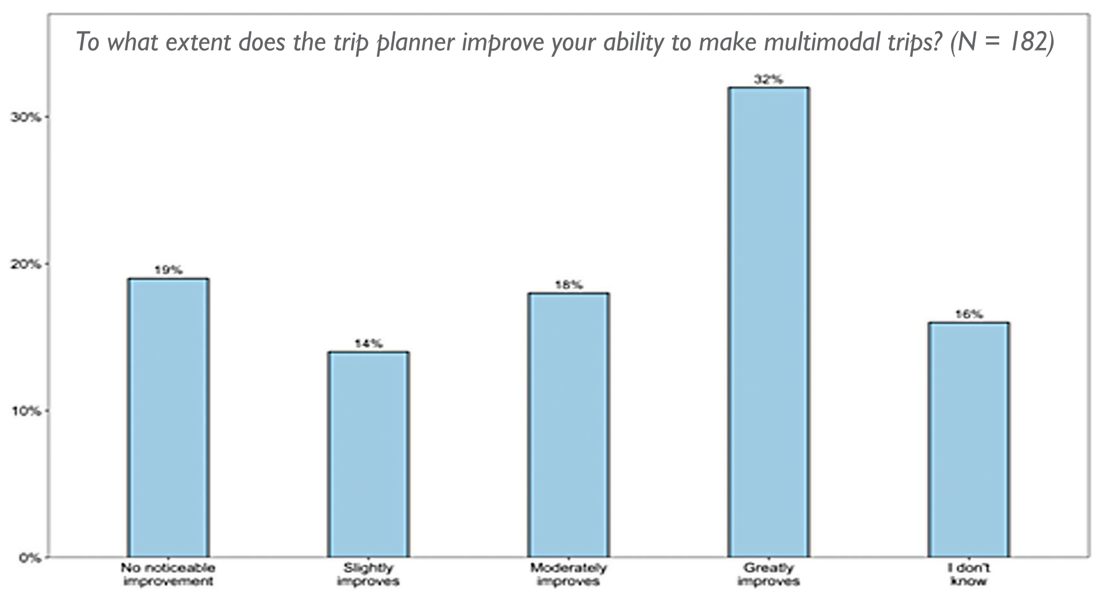
Respondent ratings of functionality of trip planner



Respondents were asked to rate how the trip planner improved various capacities and abilities in the context of trip planning. In general, they noted that the trip planner presented an improvement to these capacities. For example, respondents were asked to indicate the extent to which the trip planner improved their ability to make multimodal trips. Figure 7-3 shows that 32% of respondents indicated that the trip planner greatly improved this ability, and 32% indicated a slight or moderate improvement; about 19% reported no noticeable improvement.

Figure 7-3

Trip planner improved ability to make multimodal trips

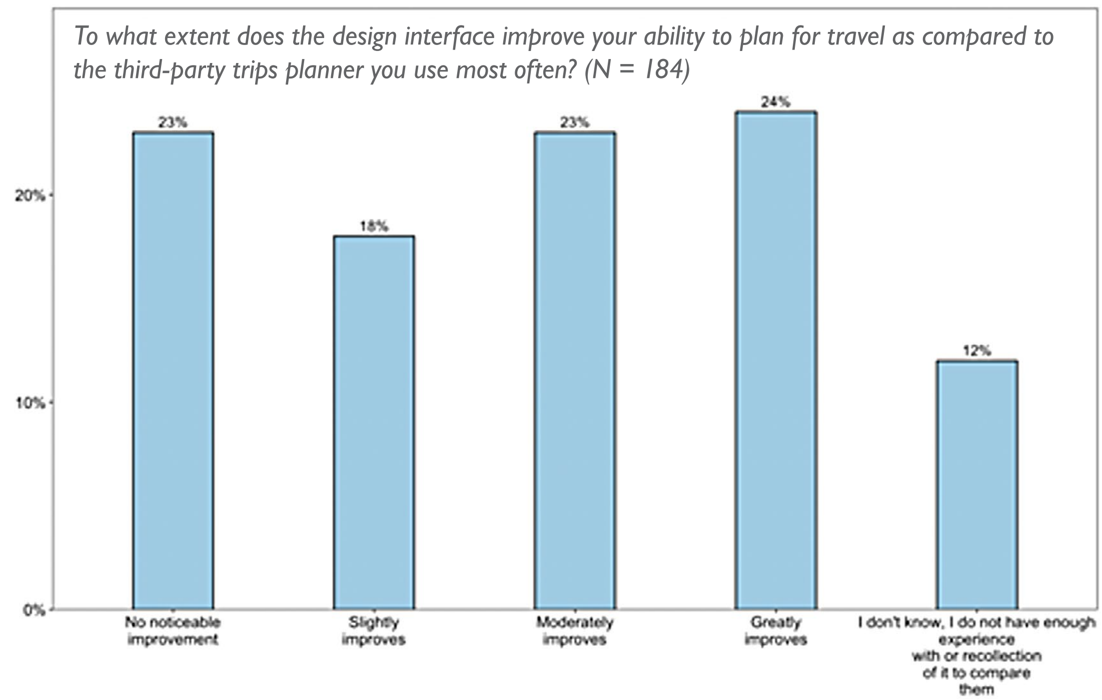


Respondents were asked to indicate the degree to which the design interface improved their ability plan for travel compared to the trip planner they used most often. For most respondents, this was either the current TriMet trip planner (37%) or Google (35%). The results, shown in Figure 7-4, indicate that the trip planner performed relatively well against the trip planners that constituted the current state-of-the-art.

About a quarter of respondents (24%) stated that the design interface greatly improved their ability to plan for travel relative to the trip planner they are currently using; 41% reported that the design interface offered a slight to moderate improvement, and another quarter (23%) reported no noticeable improvement.

Figure 7-4

Trip planner design improvement over most commonly used trip planner



Overall, the survey found that, on balance, respondents felt that the trip planner presented some notable improvements in performance and in the display of information. Although every element of survey results indicated some dissatisfaction with or indifference to the trip planner, it was also the case that a larger share of respondents in nearly every evaluated component felt that the trip planner offered some improvement over their currently-available online tools for trip planning. Broadly, the survey responses suggested that, on balance, the trip planner functioning well and was useful and offered enhancements to respondent capabilities of trip planning within the Portland metropolitan region.

One-on-One Field Shadowing

As part of the evaluation process, experienced TriMet surveyors performed in-depth one-on-one field shadowing interviews to assess the transit/ridesourcing integration in practice using OTP SUM. Test trips were taken throughout the TriMet service district on January 3–14, 2019, including weekdays and Saturdays, at various times of day. Uber provided ride credits for use during test trips, and TriMet provided 1-Day passes for participant use during the trip. Trips were planned on an iPhone using both Chrome and Safari. Participants tested the new trip planner application, completed trips using TriMet and Uber or Lyft, and provided feedback about OTP SUM functionality by completing a survey. Findings are summarized below, and additional details are provided in Appendix K.

Methodology

Respondent Recruitment

In early December 2018, a link to an online recruitment survey was sent to four local community groups—the Urban League, the Native American Youth and Family Center (NAYA), the Asian Pacific American Network of Oregon (APANO), and Elders in Action. Recipients were asked if they would like to take part in a one-on-one shadowing interview to evaluate OTP SUM. Screening questions were used to ensure participants were at least age 18, lived in the Portland metropolitan area, used TriMet to some degree, and were comfortable using Uber or Lyft. No potential participants were screened out based on their responses to these questions. Recipients were informed that they would be accompanied by a trained TriMet surveyor during the test trip. For their participation, they would receive compensation in the form of TriMet Passes.

Questions included in the recruitment survey pertained to:

- Home ZIP code
- Gender
- Disability that requires transportation accommodation
- Race/ethnicity
- Household size
- Household income
- English as native language
- Times/days most convenient for one-on-one shadowing interview to take place

In total, 27 individuals responded to the survey, of which 15 included contact information. Participants were contacted by phone in late December 2018 and early January 2019. For the 11 still interested, one-on-one field shadowing interviews were scheduled and starting locations were selected.

Testing and Evaluation Process

As respondents had never used the OTP SUM application, they were given 20–30 minutes to explore it before being given the test trip destinations, which were pre-selected by the project evaluation team. During each interview, surveyors recorded observations about how each respondent interacted with the UI and noted data pertaining to the trip itself. Participants were expected to plan and navigate the test trip without surveyor assistance; surveyors interjected only when a respondent was obviously struggling or when they explicitly asked how to complete a task in the trip planner. After arriving at the destination, the respondent completed a survey about their overall opinion of and experience with OTP SUM.

Summary of Survey Results

In total, 11 test trips were successfully completed. Respondents provided feedback about their experience, the intuitiveness of the UI, and what they liked and disliked about the application. Survey results and surveyor observations found that participants:

- Liked the integration of the different travel modes and saw value in the addition of transit options such as Uber and Lyft. For example, one testing participant personally thanked project team staff for showing her how to use the application, noting that being able to link ridesourcing with transit made transit a much more viable travel option for her.
- Would like real-time location tracking within the trip planner.
- Think OTP SUM should account for variation in travel time for each leg of a trip during actual travel by incorporating longer travel or transfer times as wiggle room in the trip plan.
- Liked viewing the calories burned calculations.
- Had difficulty locating the Start Over button.
- Used the browser navigations instead of the Start Over button or the back arrow within the travel/time options.
- Said it was not always obvious how to swipe between trip options and access trip details; his feedback was incorporated into design refinements to the user interface following the completion of beta testing.

Challenges

Unsuccessful Trip to Test UberWAV

The original plan was to test the ridesourcing wheelchair-accessible vehicle (WAV) function in the trip planner. A one-on-one shadowing interview was scheduled for a Wednesday at 11:00 AM in downtown Portland with a participant who used a manual wheelchair. A trip was planned from Director Park (815 SW Park Ave) to The Old Spaghetti Factory (0715 SW Bancroft St). OTP SUM could plan a trip that combines Uber and transit but was unable to plan the same trip after selecting the wheelchair-accessible option; the respondent continued to input 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 Uber vehicles in the Portland metropolitan region.[10]

Unable to Plan Some Trips

Prior to each interview, surveyors planned multiple future trips with destinations that successfully combined Uber and transit. Because future trips were based on transit schedules and did not account for real-time vehicle availability (of both transit and ridesourcing 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. Since the surveyors were planning these trips several hours in advance of field work, it was not surprising that some of them changed; ridesourcing vehicle locations can make a major difference in the trip planner's results.

Prior to each interview, surveyors pre-planned trips to ensure they were doable using transit and a ridesource provider. 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 ridesource vehicle may not have been in the area at the time of the actual test trip).

[10] The City of Portland has operating requirements for the availability of WAV vehicles as part of their ridesourcing permits. The OTP SUM project team requested that the City investigate the low availability of WAV vehicles during the beta testing.

SECTION

8

Key Lessons Learned

Project Management

Given the large and dispersed nature of the project team and other project stakeholders, two elements of project management were critical to this project's success. First, communication and collaboration tools enabled remote project team members to communicate and collaborate in real time. These included:

- weekly scheduled meetings (Slack or webinars) to ensure continued communications
- use of Trello for project management
- a dedicated and open TriMet MOD Project shared drive for project management
- use of InVision for application interface development and review
- continued updates of the online project dashboard available to the public at trimet.org/mod to ensure transparency
- RealTimeBoard for live, remote whiteboarding sessions

Annual workshops at major milestones (project kickoff and prototype launch) allowed for in-person collaboration among key project partners and a broader network of stakeholders, including other MOD Sandbox grant recipients and other agencies and organizations working on OTP.

Data

Regional Data Partners

Overall, the project reinforced the quality of the Master Address File and the work that the regional partners were doing in maintaining the data, as few errors were identified. The most common issue pertained to addresses that if moved within the tax lot would theoretically provide a better location for routing. The project also identified some useful quality assurance steps that Metro could use in the future to help maintain the quality of the product. These included identification of duplicates, reviewing points that do not fall in building footprints, and comparing each address's ZIP code to a ZIP code polygon layer.

SUM Provider Data Agreements

At the onset of the project, the project team expected the most difficult part of integrating data from SUM providers to be a technical issue. Ultimately, however, drafting a data-sharing agreement that met both the technical requirements of

OTP and the political and economic requirements of the ridesourcing providers proved to be one of this project's biggest challenges. It took more than a year of iterative design and negotiation to reach data agreements with both ridesourcing partners (Uber and Lyft). From this process, the following lessons were learned:

- Contracts always take longer than anticipated. Begin negotiations with partners as early as possible. Working through high-level negotiations during the proposal stage of a project can eliminate the need for redesigning how a partner's data can be integrated once actual development work is underway. In this project, data-sharing agreements with SUM providers were expected to be completed in the first six months of the project but ultimately took 18–24 months to reach an agreement for integration of SUM provider data during the beta testing phase of OTP SUM.
- Look for opportunities up-front with other grant awardees or other agencies pursuing similar projects outside the grant program context to create a common contract, if applicable, for potential time and cost savings.
- Given the competitive nature of the current ridesourcing market, there is a significant challenge to reach data integration agreements from multiple ridesourcing providers for use in the same application. Providers had rightful concerns over anti-competitive behavior through APIs by competitors and a desire by both leading ridesourcing providers for exclusivity in a given application or program.

Technical Limitations

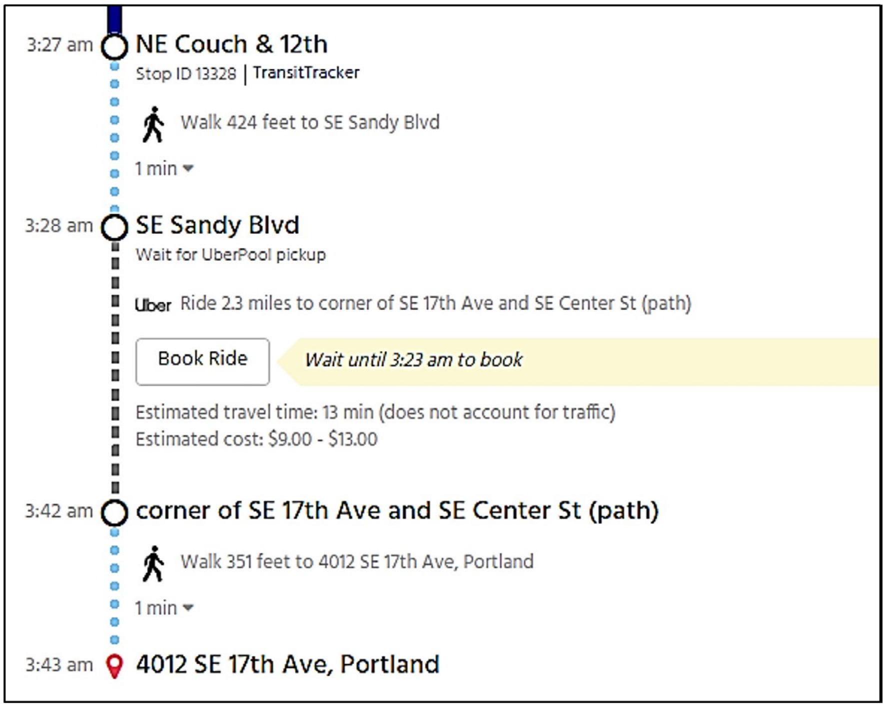
During development of the OTP and Pelias enhancements, the project team faced several technical considerations that limited how certain desired functionality could be implemented as part of OTP SUM.

Data Limitations

The ridesourcing providers' public APIs provide only wait time and cost estimates for trips planned to start now. This prevented OTP SUM from being able to plan accurate future trips incorporating a ridesourcing segment with a transit segment.

Figure 8-1

Ridesourcing information display in OTP



The low availability of WAVs in active ridesourcing fleets made it difficult to successfully plan a trip that combined a transit segment with a ridesourcing-WAV segment, even though one of the ridesourcing providers included WAV as a configuration in its public API. The project team reached out to the Portland Bureau of Transportation, which regulates ridesourcing providers in Portland, to determine whether providers were meeting the City's WAV availability requirements during the testing period for OTP SUM.

Currently, there are no comprehensive data for allowable uses of curb space. This has several implications for how trips can be planned incorporating SUM segments. Because there are no data describing where ridesourcing drivers can and cannot drop off passengers, it is assumed that a trip's origin or destination is a valid pick-up or drop-off location. Similarly, for trips incorporating a car2go segment, the OTP SUM team lacked data on where these vehicles can and cannot be parked based on parking restrictions. Thus, it is at the discretion of the OTP user to find a valid parking space near their destination for that trip leg. The team is aware of several groups currently working to compile curb management data, and if these data are developed to appropriate completeness and robustness, it could be incorporated into OTP in the future.

OSM Limitations

Because it is difficult to see curb cuts in aerial imagery, and street view imagery is usually insufficient to determine ADA compliance of curbs cuts, adding curb-level data was not possible given the scope for this project.

Lack of consensus on sidewalk tagging methods means routers should be able to take advantage of sidewalk metadata associated with street centerlines and with sidewalks drawn out as separate paths.

To take advantage of crossing data, OTP will need significant enhancements that allow it to track which side of a street a pedestrian is using; it currently does not do this.

High-quality, open license street view imagery often is essential when making updates to sidewalk tags, POIs, and more. TriMet is now working with Mapillary to encourage the continued maintenance and availability of such imagery in the Portland metropolitan region.

Aerial imagery collected by the Regional Aerial Photo Consortium is extremely valuable for updating and maintaining OSM. The consortium's multiple-buyer model provided all its members with significant cost savings and would be worth replicating in other regions.

Software Limitations

The core OTP routing engine is over eight years old, and more efficient, robust routing algorithms have been developed in the intervening years. Characteristics of the current routing engine limited the factors that could be considered as part of the routing optimization process. The OTP Project Leadership Committee (PLC) is currently planning a major overhaul of the core OTP routing engine to function on a more modern routing algorithm. Future implementations of OTP SUM will be able to benefit from this enhancement.

Initially, it was thought that all necessary data could be brought directly into Pelias, but a custom data loader needed to be developed to bring in transit-specific data in the GTFS format.

Integrated Payment

The Integrated Payment Plan, as documented in the white paper produced for this project by moovel, highlights several key challenges to implementation of an integrated payment platform:

- Integration with legacy payment systems
- Integration with other mobility service providers
- Development of pricing policy agreements across mobility service providers
- Complexity of pricing incentives, which can grow exponentially as providers are added
- Financial liability; a key governance item will be resolving which party will be liable in the event that funds become uncollectible from a customer

- There are no widely accepted standard APIs for digital transit fares in the US; standard digital fare APIs were recognized as greatly increasing the likelihood of a solution being replicable and easily expandable.

Evaluation and Testing

To reach a successful final product, this project relied heavily on iterative evaluation over the course of the project. In this way, the project team was able to conduct testing and evaluation with a variety of methodologies and audiences at different points in the design process, including both qualitative and quantitative evaluation.

Open Source Software as a Business Model

TriMet achieved significant cost savings by exploring open source alternatives to every new technology system, including internet mapping technologies; the agency developed a method of comparing open source software side-by-side with proprietary solutions against the requirements. The progression of available open source systems, from the back-end infrastructure tools to the front-end customer systems, enabled a rapid progression of open source solutions throughout the agency.

As part of this project, the project team enlisted the Center for Urban Transportation Research (CUTR) at the University of South Florida to develop a white paper on the benefits of and opportunities and challenges presented by open source software in transit. Some of these findings are summarized here and are elaborated upon in the Open Source Transit Software white paper (Appendix B).

With a strong developer community, open source software can have appealing advantages over proprietary software, as it provides more control over fixes and new features; fosters innovation and competition leading to better products; can have a broader user and developer base, which means there are more eyes on the code; and risks and costs are shared within the community, which can be especially appealing for government agencies. In addition, there is no fee for the software, meaning that accessibility enables prototyping and testing. However, not all open source software is the same, nor is all proprietary software, and the advantages and risks should be identified and weighed when performing a software alternatives analysis.

At the same time, for open source projects to be sustainable long-term, it is critical to allocate budget for code merge/integration and participation with the broader OTP developer and user community. At the start of the MOD Sandbox program, neither the TriMet nor the VTrans projects budgeted for coordination with each other and the broader OTP community to ensure that features from these efforts were merged back into the master branch of OTP code. Thus, although there is no annual fee such as is typical for proprietary software, the benefits of open source are fully realized only if some funding is allocated for integration of new improvements and for ongoing maintenance and improvements.

OTP uses open data and standards to generate an intelligent routable network. By accessing APIs from private service providers such as Lyft, Uber, BIKETOWN, and many others, an even smarter seamless network can be developed to generate integrated multimodal trip planning itineraries offering door-to-door service. Because it is open source software that uses open data, it can be replicated and hosted, offering a scalable solution.

OpenTripPlanner Coordination and Management

As an open source software project, OTP has seen significant growth in both its base of users and the number of developers contributing new functionality for inclusion in the application. This growth on both sides of the OTP community presents a challenge. Due to the change management process enabled by GitHub, new functionality typically is stored in separate branches until it is determined that they should be merged into the master branch of the software code. This means that for all OTP users to benefit from new development efforts, there is a significant management effort required to determine worthiness and compatibility of all new functionality branches to merge them into the master branch.

With two significant branches of new OTP development (TriMet and VTrans), this MOD Sandbox project presented a unique opportunity to take a fresh look at how OTP is managed and to develop a sustainable strategy for OTP governance to ensure that OTP's vibrant community of developers and users continues to grow and benefit from each other's work. To that end, a workshop was held June 12–14, 2018, at Cambridge Systematics in Medford, Massachusetts, to discuss necessary steps to merge major outstanding branches/forks of OTP code base into the master to improve the technical process for major additions to OTP in the future and to improve the communication process for major additions to it.

Coming out of this workshop, the OTP PLC developed a work plan for the remainder of 2018, which included merging functionality from the OTP SUM and VTrans OTP-flex efforts and other major OTP development projects back into the master branch of OTP code. This will ensure that future users of OTP are able to benefit from the new functionality developed through these projects.

Behavior Change and Mobility on Demand

In addition to the need for a Mobility Management Center, another lesson learned from this MOD project is the need to think beyond who an agency's customers are and begin to encourage their behavior to facilitate a network of seamless travel options that work together to reduce congestion.

One of the more important learned lessons from this project is the necessity to provide incentives for travelers to take multiple modes as part of a comprehensive travel trip. This was evident in some of the survey comments from customers. A notable number of respondents commented on the potential value of combining modes but did not anticipate finding it useful in their travel plans. Multimodal trip planners, integrated plan-book-pay applications, and customer information are not enough; incentives are necessary to change behavior and overcome a reluctance to transfers. Pilots are necessary to explore effective incentives:

- Personalized itineraries
- Financial incentives
- Marketing
- Development of mobility hubs at major transfer centers that would provide incentives for a transfer point such as easy pick-up and drop-off points, community and social places, facilities such as restrooms, services such as Amazon lockers, dry cleaning, and grocery stores, or pickups to eliminate need for vehicle.

SECTION
9

Next Steps

Ultimately, a Mobility as a Service (MaaS) platform is necessary to support regional mobility service initiatives, including plan-book-pay applications. Without the underlying framework of data, technology, and a Mobility Management strategic plan, applications and tools will not have the foundation necessary to fully support the functionality required to serve the population's mobility needs.

To ensure the success of MaaS, transit agencies need to expand their roles beyond management of public transportation and reconstruct their identity to be full mobility service managers. Private sector partnerships and intergovernmental relationships are crucial to support the goals of MaaS. Public infrastructure around transfer centers, efficient management of modes on the streets, and incentives to help encourage future travelers to use transit and other more sustainable transportation modes must be developed alongside the customer tools to ensure real, effective transportation options.

The success of the integrated mode itinerary planning component within OTP is based on open data and standards to generate an intelligent routable network. By accessing APIs from private service providers such as Lyft, Uber, BIKETOWN, and many others, an even smarter seamless network can be developed to generate integrated multimodal trip planning itineraries that offer door-to-door service. Continued efforts to further standardize and adopt open data principles by all mode providers is critical to furthering MaaS evolution.

Because OTP uses open source software and open data, it can be replicated and hosted, offering a scalable solution. Although OTP comes with its own customizable user interface, the API key will allow other developers to access information and focus on the user experience of the application, offering customers more choices. Successful replication in other cities and continued development will move forward the proof of concept and advance the end product further.

The OTP SUM function developed in this project will be available on the TriMet website and will function alongside TriMet's current iteration of a trip planner, allowing ongoing testing, improvement, and real-world application and feedback while TriMet refines the functionality. In the future, TriMet intends to switch over to this new trip planner and is developing plans for continuing on the path to developing a full plan-book-pay MaaS function for the Portland metropolitan region.

APPENDIX

A

Equity and Accessibility Report

OpenTripPlanner – Shared Use Mobility Integration Project

Equity and Accessibility Plan

Tri-County Metropolitan Transportation District of Oregon (TriMet)

09/20/2017

Introduction

As part of the Mobility on Demand (MOD) Sandbox Program, the Federal Transit Administration (FTA) has awarded TriMet a $678,000 grant to extend the OpenTripPlanner (OTP) platform to integrate transit and shared-use mobility options into one comprehensive application for multi-modal travel comparisons. The purpose of this memorandum is to provide an overview of the Tri-County Metropolitan Transportation District of Oregon (TriMet)'s programs, policies and resources to address accessible and equitable mobility service for all travelers, including communities such as people of color, those with low income, limited English proficient persons, the aging population, and persons with disabilities, including wheelchair users. In addition, it describes how these programs and policies will be implemented as part of the OpenTripPlanner Shared Use Mobility (OTP SUM) enhancements project.

Project Background

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 transit. Adoption of OTP has been strong, with implementation in dozens of cities and countries worldwide. TriMet now proposes to build upon the core of OTP to incorporate shared-use mobility (SUM) options.

TriMet's proposed project includes the development and expansion of two core data frameworks that current and future collaborative OTP initiatives can be built upon, producing replicable software and results for communities across the country. These two core project elements are to:

- Extend the OTP code base to integrate into transit trip planning shared-use mobility modes, such as bike share and TNCs, as well as updated real-time transit information.
- Implement a fully-functional and comprehensive open source geocoder built off the existing open source Mapzen Pelias geocoder.

In addition to core elements on the foundation frameworks, the project will also include:

- Development of a comprehensive new web-based user interface that will allow users to make intermodal trip plans including shared-use modes. The new web-based user interface will also display real-time information and report impacted itineraries to users.
- Improvements to basemap data so the trip planner can support enhanced pedestrian accessibility information and improvements to regional address data that will make location search and geocoding more effective and user-friendly.
- Design and implementation of compatibility for future booking and payment options in moovel's RideTap product so customers can plan and pay for their trips in one app.

TriMet's OTP SUM project will create a complete open platform for the integration of transit and SUM options. The open data, software and user interfaces, responsive on both web and mobile, will help all TriMet customers understand the multi-modal options to meet their mobility needs, including for the critical first and last miles of transit trips where a bus or train alone doesn't directly serve their origin or destination. TriMet recognizes the importance of ensuring equitable functionality and accessibility to the information provided through OTP SUM.

Equity and Accessibility at TriMet

The following sections detail the programs, frameworks, and policies that TriMet uses to consider equity and accessibility in all service and programs provided by the agency within its service area. Equity is a key consideration in the provision of public transportation service, facilities and programs. To that end, TriMet has adopted an Equity Lens framework to guide planning, analysis and decision-making. For more information on these programs and policies, please visit the Equity and Access page of TriMet's website (https://trimet.org/equity/) or contact TriMet's Title VI and Equity Programs Administrator at 503-238-5711.

What is an Equity Lens?

- A practical tool that helps to ensure policies and programs result in equitable outcomes for all residents.
- A tool that helps public agencies to consider equitable treatment of diverse communities and workforce when planning, developing and evaluating policies, programs and services.

The Equity Lens Process

The Lens leads employees through the following stages:

- Assessing current organizational capacity for equity work;
- Describing current direction and strategies;
- Identifying inequities and injustices;
- Reflecting and understanding strengths and challenges;
- Enhancing what is leading to equity and empowerment; and
- Eliminating strategies and root causes leading to inequities and injustices.

Examples of Equity Lens Questions

- Are there equity and inclusion concerns related to this issue? (e.g., accessibility, affordability, safety, culture, gender identity)
- Are the groups most affected by the policy consulted from the early stages of the policy development?
- What human and financial resources are required to address equity and inclusion in the implementation of this policy?
- Can we develop innovative solutions that draw upon the contributions and assets of those people most affected?

Title VI

The United States has a long history of unjust treatment towards people of color. Although we have made great progress over the past few centuries, we still see disparities throughout our society along the lines of race and ethnicity – even in cases where decisions are made with the best of intentions.

The Civil Rights Movement of the mid-1950's and 60's brought the issues of segregation and racial injustice to the forefront of our national consciousness. The movement resulted in the historic passage of the Civil Rights Act of 1964, which included eleven "Titles" outlawing several types of race-based discrimination. One of these "Titles" – Title VI – included the following provision:

> *No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.*

The intent of Title VI is to remove barriers and conditions that prevent minority, low-income, and persons with limited English proficiency (LEP) from equal access to public goods and services. In effect, Title VI promotes fairness and equity in federally assisted programs and activities. Title VI is rooted in the Constitutional guarantee that all human beings are entitled to equal protection of the law, and specifically addresses involvement of impacted persons in the decision-making process.

There are many forms of illegal discrimination based on race, color, or national origin that can limit the opportunity of underrepresented communities to gain equal access to services and programs. In operating a federally assisted program, a recipient cannot, on the basis of race, color, or national origin, either directly or through contractual means:

- Deny program services, aids, or benefits;
- Provide a different service, aid, or benefit, or provide them in a manner different than they are provided to others; or
- Segregate or separately treat individuals in any matter related to the receipt of any service, aid, or benefit.

What does this mean for TriMet?

As a recipient of federal financial assistance through the Federal Transit Administration (FTA), TriMet is subject to the rules and regulations provided through FTA Circular 4702.1B "Title VI Requirements and Guidelines for Federal Transit Administration Recipients" effective October 1, 2012 ("Circular").

TriMet's Director of Diversity and Transit Equity is chiefly responsible for administering and monitoring Title VI requirements, but it is the duty of every employee, vendor and contractor of the agency to ensure compliance with nondiscrimination and to further civil rights protections. The TriMet Board of Directors must also approve the agency's Title VI program prior to its submittal to FTA.

TriMet's commitment to equity can be seen across our agency, the transportation system it manages, and the community it serves. It is embedded in the policies and practices we develop and implement. It is embedded in the investments we make and partnerships we build, our workforce, our approach to contracting and our ever growing connections to our community.

Environmental Justice

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," was signed by President Clinton on February 11, 1994. Subsequent to issuance of the Executive Order, the U.S. Department of Transportation (DOT) issued a DOT Order for implementing the Executive Order on environmental justice (EJ). The DOT Order (Order 5610.2(a), "Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," 77 FR 27534, May 10, 2012) describes the process the Department and its modal administrations (including FTA) will use to incorporate EJ principles into programs, policies, and activities.

The US Department of Transportation has adopted three fundamental environmental justice principles to guide transportation justice efforts:

- Avoid, minimize, or mitigate disproportionally high and adverse health and environmental effects, including social and economic effects, on communities of color and low-income populations.
- Ensure the full and fair participation by all potentially affected communities in the transportation decision-making process.
- Prevent the denial of, reduction in, or significant delay in the receipt of benefits by communities of color and low-income populations.

TriMet makes environmental justice a priority by identifying and addressing the effects of agency capital projects, programs, policies and activities on communities of color and low-income populations.

Limited English Proficiency

The U.S. Department of Transportation (DOT) LEP guidance states that Title VI and its implementing regulations require that DOT recipients take reasonable steps to ensure meaningful access to their programs and activities by LEP persons. The Federal Transit Administration published its LEP Guidance in its Circular 4702.1B "Title VI Requirements and Guidelines for Federal Transit Administration Recipients" requiring recipients to develop an LEP implementation plan consistent with the provisions of Section VII of the DOT LEP guidance.

TriMet is committed to full compliance with Title VI and Executive Order 13166 to provide meaningful access to programs, services and benefits for persons with limited English proficiency, or LEP. From the Title VI Circular:

> Consistent with Title VI of the Civil Rights Act of 1964, DOT's implementing regulations, and Executive Order 13166, "Improving Access to Services for Persons with Limited English Proficiency" (65 FR 50121, Aug. 11, 2000), recipients shall take reasonable steps to ensure meaningful access to benefits, services, information, and other important portions of their programs and activities for individuals who are limited-English proficient (LEP).

In 2010, TriMet completed its LEP Language Assistance Plan and Implementation Schedule after an extensive review of the LEP populations in the TriMet service district and their needs. A special LEP Workgroup recommended a two- tiered approach to meeting the needs of LEP populations: Tier One retains successful programs and activities designed to meet the language needs of LEP populations; Tier Two identifies new areas of focus to further the agency's goal of providing LEP customers with meaningful access to TriMet programs and services. This plan continues to guide TriMet as to how to best serve LEP populations.

Four Factor Analysis

In 2017, TriMet updated its Four Factor Analysis. As per DOT and FTA guidance, there are four factors for agencies to consider when assessing language needs and determining what steps they should take to ensure access for LEP persons:

1) The number or proportion of LEP persons eligible to be served or likely to be encountered by a program, activity or service of the recipient;
2) The frequency with which LEP individuals come in contact with the program;

3) The nature and importance of the program, activity or service provided by the recipient to people's lives; and
4) The resources available to the recipient and costs.

Web Content Accessibility

TriMet works extensively to ensure that its website and web-based applications such as OTP SUM are fully accessible and usable by customers with disabilities. Code for these applications is expected to be accessibility standards-compliant and follow Web Consortium Accessibility Guidelines (WCAG) Level A conformance. WCAG guidelines and success criterial are organized around four principles of accessibility:

- **Perceivable** - Information and user interface components must be presentable in ways that all users can perceive.
- **Operable** - User interface components and navigation must be usable by all users (the interface cannot require interaction that a user cannot perform)
- **Understandable** - Users must be able to understand the information as well as the operation of the user interface (the content or operation cannot be beyond their understanding)
- **Robust** - Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies (as technologies and user agents evolve, the content should remain accessible).
  (Adapted from Web Content Accessibility Guidelines (WCAG) Overview - http://www.w3.org/WAI/intro/wcag.php)

More information on WCAG guidelines can be found at https://www.w3.org/WAI/intro/wcag. New designs for TriMet's website and web applications are typically tested with riders who use screen readers. In the past, this has involved the agency working with the Oregon Commission for the Blind, for example, to either observe a customer with a vision impairment using the site, or to recruit users to test it and submit feedback via email. A similar approach will be taken during the testing phase for OTP SUM.

Public Involvement

TriMet has an established comprehensive public involvement process to ensure minority, low-income and LEP populations are engaged through public outreach and involvement activities. TriMet's Public Engagement Framework was originally submitted to the FTA on January 2013 as part of the response to the FTA's Title VI Program Review, and has been updated as part of this submittal. TriMet's Diversity and Transit Equity Department serves as a resource to other TriMet divisions to integrate these populations into TriMet's public involvement activities.

Equity and Accessibility in OTP SUM

The sections that follow describe the intended actions that TriMet and the OTP SUM project team will take to ensure that equity and accessibility are a key consideration throughout the OTP SUM development, implementation, and testing process. With assistance from the Title VI and Equity Program Administrator and the Diversity and Transit Equity department, the OTP SUM team will implement the frameworks and policies described in the section above to evaluate equity considerations for the OTP SUM application.

Title VI

TriMet will adhere to all rules and regulations provided through FTA Circular 4702.1B, as adopted through TriMet's 2016 Title VI Program Update, throughout OTP SUM development, implementation, and testing.

The new OTP front-end application will be a "mobile first" web app, not a native smartphone app. This means that its full functionality will be available to all internet users, regardless of whether they access the tool from an iPhone, Android phone, desktop computer, tablet, or other type of hardware. Thus, it will not exclude low income persons people who may not own a smartphones but who can access the internet in other ways.

For people who lack access to or comfort with the internet, the enhanced trip planning capabilities will still be available via our call center. The existing deployment of OTP (without SUM integration) is already accessible to customers through call-takers in the customer service department, who provide trip planning assistance seven days a week from 7:30am to 5:30pm. The trip planning application that these call takers use will be updated to include new SUM modes, and the staff will be trained on the new functionality.

Environmental Justice

With guidance from the Title VI and Equity Programs Administrator, the project team will apply the TriMet Equity Lens framework described above to both the technical design of the OTP SUM enhancements, as well as the roll-out and testing of the application itself. This project will leverage TriMet's Public Engagement Framework to ensure that Environmental Justice and Title VI communities are represented as part of the test group.

While the scope of this phase of OTP SUM only includes a plan for payment integration, not implementation of integrated payment, TriMet recognizes that some of its customers might not have access to bank accounts or credit card accounts to link to payment for SUM trips. The project team will work with moovel (responsible for conducting the integrated payment plan) to develop strategies for making future integrated payment functionality accessible to people with access to linked bank or credit card accounts.

As part of the implementation and testing phase of the OTP SUM improvements, TriMet will evaluate the availability and use of the OTP SUM application by geographic area as well as monitor the availability of other support available to TriMet customers to ensure equal access to all public transportation services and agency programs provided by TriMet.

Limited English Proficiency

Informed by the agency's Four Factor Analysis, TriMet's website provides basic How to Ride information in eleven languages besides English (Spanish, Vietnamese, Chinese, Russian, Korean, Japanese, Tagalog, Romanian, Somali, Arabic, Cambodian, and Persian). This includes information on fare payment, rules for riding, safety and security, accessibility, and agency contact information including interpretation services. All these pages also have TriMet's Title VI public notice, complaint procedures, and complaint form in the relevant language. As TriMet has prioritized resources on serving the largest group in the LEP population[1], the Spanish web pages have more extensive content, including a current version of OTP in Spanish. The next generation trip planner will also be available in both English and Spanish, and the project team will conduct a Four-Factor analysis to determine if support for additional languages will be appropriate. TriMet will monitor the use of OTP SUM in order to improve the user experience and meet the needs of LEP populations (as applicable).

Enhancing Accessibility of Recommended Pedestrian Routes

A key component of enhancements to the core OTP routing engine will allow for more detailed pedestrian and wheelchair access routing and directions text to and from transit stops by incorporating updates to the OpenStreetMap (OSM) pedestrian network. The concentrated effort in improving both the accessibility data in the street network and its use in OTP will be a sharp enhancement to equity for persons with disabilities. TriMet is collaborating with the OSM coding community to establish best practices for representing this accessibility information in the base network to serve as a model for communities nationwide. TriMet will build out this accessibility information in the OSM network and provide a model for replicating this work in other regions.

This model will then provide the basis for infusing this information into the OTP core engine so that it can make optimal use for planning pedestrian trips. Further, with this capability included in the OTP core, derivative products such as Transport Analyst will have enhanced capabilities for equity analysis activities. In addition, through other linked applications to this effort (namely, the VTrans project to expand OTP to support demand-responsive transit service), our combined efforts will allow OTP to read the GTFS-flex specification, which will surface itineraries for “flexible” public transit modes like hail-and-ride and deviated-fixed services, furthering improving trip making capabilities for people with disabilities and the aging population who often depend upon these flexible services.

Because the scope of OTP SUM is only to allow passengers to plan trips, with links to SUM providers’ applications (there is no direct provision or subsidy for the SUM segments of trips planned within OTP SUM), equivalent service requirements do not apply for the SUM segments of trips planned within OTP.

[1] Spanish-speaking LEP persons comprise over 4% of the TriMet Service District population, whereas LEP Speakers of the next most common language, Vietnamese, make up less than 1% of the total population. Source: TriMet 2016 Title IV Update, available at https://trimet.org/about/pdf/2016-title-vi.pdf

APPENDIX

B

Open Source Transit Software White Paper

CUTR-2019-01

Open Source Transit Software

A White Paper

Prepared For

IBI Group, TriMet,

and Federal Transit Administration

January 2019

2019

CUTR CENTER FOR URBAN TRANSPORTATION RESEARCH

USF UNIVERSITY OF SOUTH FLORIDA

CUTR.USF.EDU

Contents

Executive Summary

The public transportation industry increasingly deploys technologies and software to support mobility services. As a result, transit agencies must evaluate the appropriate strategies of developing, procuring, and maintaining software products. This white paper provides a review of how open source software (OSS) in the transit industry has evolved into production deployments at transit agencies. It explores the opportunities and risks associated with utilization of OSS as an alternative to closed-source software and platforms. It reviews OSS deployments for passenger information systems, describes conditions that influence the appropriateness of OSS and identifies critical issues that should be addressed as OSS is considered by stakeholders for transit applications.

This white paper frames issues that will help inform software development and procurement decisions of both state and federal oversight and funding agencies as well as individual transit providers. The findings and observations are based on reviews of various documents associated with public transportation OSS applications and numerous interviews with a range of stakeholders who have been involved in the development, governance, and deployment of OSS within the public transportation industry.

Open source software (OSS) offers several potential benefits for the transit industry:

- An opportunity to avoid being locked in to a single vendor
- Avoidance of proprietary software licensing and subscription costs
- An opportunity to leverage the benefits of collaboration and resource sharing with other agencies and with open source community members
- Potential to leverage the intellectual and financial resources of research and grant-making institutions
- Opportunity to have greater control and faster responses with respect to strategic software development priorities
- An opportunity to bring cutting edge products and services to public transportation customers

OSS deployment by transit agencies is most appropriate in cases where transit needs are unique and not broadly shared with other industries. In these instances, there are often few software options available and little competition among vendors for proprietary products, resulting in high costs to acquire and maintain proprietary software. However, many transit agencies have not deployed an OSS package before and may have significant concerns, including questions related to how OSS fits into procurement processes developed prior to OSS being a viable industry option. This report offers several case studies of OSS development that help illustrate the nature of OSS and outline the considerations that should be addressed as they are pursued.

Strategies and recommendations to facilitate the successful implementation of OSS solutions include:

- Working with multiple stakeholders wherever possible to encourage a critical mass of technical expertise and shared interest which helps ensure the sustainability of OSS initiatives
- Development of a governance and funding structure that shares costs and minimizes the exposure of any one partner while maximizing the benefits that each can experience from the partnership
- Engagement in discussions, information exchange and collaborations amongst interested entities to help potential partners have the knowledge to make informed decisions regarding their potential utilization of OSS. This is especially important during the procurement process to ensure that OSS solutions are not unintentionally excluded due to wording in the request-for-information, request-for-proposals, or contract.
- Leverage widely-used and tested guidance and templates and other resources to address the procurement, legal, licensing, governance, and financing issues associated with engagement in OSS
- Explore using the Federal Transit Administration (FTA), America Public Transportation Association (APTA), or other entities to serve in an information-sharing and peer-exchange role so transit agencies can be fully briefed on OSS applications and best practices
- FTA should review the ITS JPO Dynamic Mobility Applications (DMA) program[1], which focuses on the development and release of open source applications that use Intelligent Transportation Systems (ITS) data to transform surface transportation management and information, to determine if a similar program could assist the development of OSS for public transportation

This whitepaper presents the case studies and information on benefits, costs, risks, and mitigations in detail.

[1] https://www.its.dot.gov/research_archives/dma/dma_plan.htm

Objectives

The public transportation industry is becoming increasingly engaged in deploying technologies and developing software to interface with customers and support service quality and logistics functions for providing mobility. The industry is faced with determining appropriate paths forward as information technology plays an ever-larger role in delivering mobility services. This white paper provides a review of how open source software (OSS) in the transit industry has evolved from grant-funded or exploratory projects into production deployments at transit agencies. It explores the opportunities and risks associated with utilization of OSS as an alternative to closed-source software and platforms. It reviews OSS deployments, describes conditions that influence the appropriateness of OSS and identifies critical issues that should be addressed as OSS is considered by stakeholders for transit applications. As a modest size industry with somewhat unique needs, public transportation providers are seeking to provide state-of-the-practice services that work within the context of transparent public sector environments with limited resources and historically modest IT capabilities. This white paper frames issues that will help inform software development and procurement decisions of both state and federal oversight and funding agencies as well as individual transit providers.

This white paper is an output of a collaboration between the IBI Group, TriMet, the Federal Transit Administration, and CUTR that addresses technology support for enhancing public transportation services. The findings and observations are based on reviews of various documents associated with public transportation OSS applications and numerous interviews with a range of stakeholders who have been involved in the development, governance, and deployment of OSS within the public transportation industry.

What Is Open Source Software?

Open source software (OSS) is computer software with source code that is publicly available and can be viewed, copied, modified, or enhanced by anyone with requisite programming skills. The source code contains the underlying computer instructions that implement all the functionality of the software as well as how the software looks. The functionality and look of the application can be modified by changing the source code.

Popular OSS projects include Linux[2], an OSS alternative to Windows (or MacOS) which powers over two thirds of the world's web servers, Android[3], a popular mobile device operating system with over 2 billion monthly active devices, and the web browser FireFox, which currently has around 10% of the desktop browser market share. Chrome, which is based on the Chromium open source project[4], has the largest desktop browser market share with over 70%. In December 2018 Microsoft announced that the newest Microsoft web browser Edge will also

[2] https://www.wired.com/2016/08/linux-took-web-now-taking-world/ ,
[3] https://www.theverge.com/2017/5/17/15654454/android-reaches-2-billion-monthly-active-users
[4] https://www.chromium.org/Home

adopt Chromium as its foundation[5]. Facebook maintains over 440 OSS projects that power its products on web and mobile[6], and Walmart manages about 140 OSS projects for its logistics and web products[7]. In 2018, there were several large acquisition of OSS organizations by major corporations, including Microsoft's purchase of the OSS code-hosting site GitHub and IBM's purchase of Red Hat (a company that distributes software based on Linux)[8], further demonstrating that OSS plays a critical role in today's software industry ecosystem.

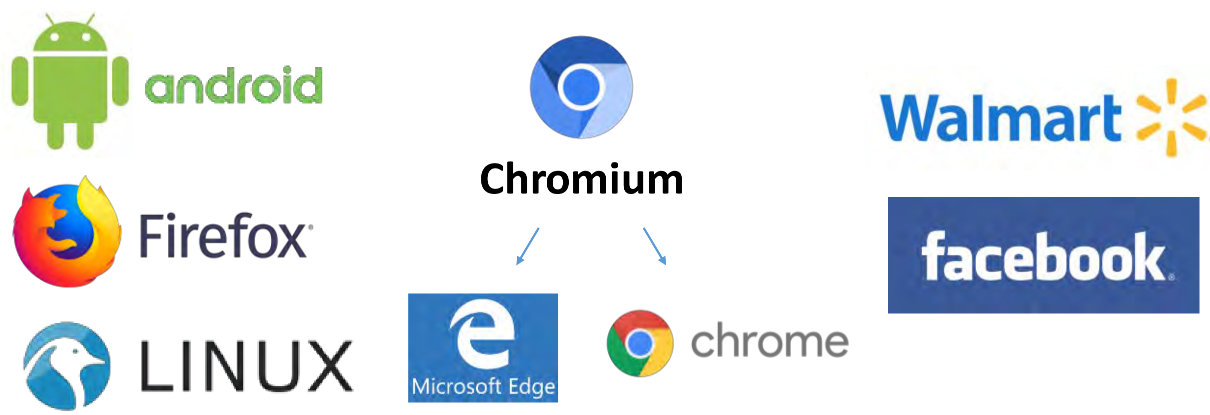


Figure 1 – Open source software is a critical part of many popular products used by millions of people

Software with source code that is not publicly shared and is only modified by the software owner is called proprietary or closed-source software. In this case, the exact formulation of the software is not visible to anyone but the owners. An example of proprietary software is the Microsoft Windows operating system. A person who buys a copy of proprietary software is buying a license to use the software according to its terms, which may include technical support and maintenance, and cannot modify the software capabilities.

The overall goal of OSS is to promote collaboration and sharing among developers and other stakeholders in the community. This can speed the development and dissemination of software solutions and leverage shared resources. Several large foundations have emerged over the last few decades, mainly sponsored by the organizations that use the software, to support general-use industry-critical OSS projects, including the Apache Software Foundation[9] and the Linux Foundation[10]. Organizations such as Code for America[11] have been established to help government embrace the use of open source software.

---

[5] https://blogs.windows.com/windowsexperience/2018/12/06/microsoft-edge-making-the-web-better-through-more-open-source-collaboration/
[6] https://opensource.com/article/18/1/inside-facebooks-open-source-program
[7] https://techcrunch.com/2016/10/03/walmartlabs-open-sources-the-application-platform-that-powers-walmart-com/
[8] https://www.wired.com/story/why-2018-breakout-year-open-source-deals/
[9] https://www.apache.org/
[10] https://www.linuxfoundation.org/
[11] https://www.codeforamerica.org/

Licenses for open source software can vary in scope. Some open source licenses require that anyone who modifies the source code publicly share those modifications and may preclude charging a fee for subsequent users of those modifications. Other more “business-friendly” licenses allow the distribution and sale of modified copies.

OSS solutions may be implemented using the exact same software development programming languages as proprietary solutions. Proprietary software solutions can be “open-sourced” by the licensing entities should they chose to make the program code publicly accessible to other parties. The primary differences between OSS and proprietary software arise from the management structure that governs who can contribute and how contributions are coordinated. Open software allows a broader set of stakeholders to have direct involvement in software development and refinements to respond to their specific needs. Readers interested in further details surrounding OSS are directed to Google’s OSS introduction site[12].

OneBusAway (https://onebusaway.org) and OpenTripPlanner (https://opentripplanner.org) are both examples of OSS being used in the transit industry today. The following section discusses how the OSS communities have evolved surrounding OneBusAway, OpenTripPlanner and other OSS components integrated within public transportation software tools. These two applications, as well as a new OSS geocoder (software package that enables locations to be translated to digital map coordinates) called Pelias, are profiled below. These profiles help illustrate the benefits of OSS and some of the issues to consider before pursuing OSS solutions.

Open Source Software and Public Transportation

Over the past several years, many large and small open source software projects have arisen within the public transportation industry[13]. OpenTripPlanner and OneBusAway are two examples of software projects where a community of developers and users has evolved to support and mature the software so it could be deployed in multiple locations. The development of these OSS packages, while mimicking a broader trend of increasing OSS deployment across the public and private sectors, reflects some specific circumstances that apply to the public transportation industry.

OpenTripPlanner, used for multimodal trip planning, and OneBusAway, used to share real-time arrival information for transit vehicles, have both been deployed at multiple transit authorities and by virtue of being visible to travelers, are highly visible software applications with millions of users. Each of these packages have matured since their conceptualization in 2008 and 2009, respectively, and have simultaneously been financially supported by a spectrum of interests. These projects have evolved to have governance/oversight frameworks in place that enhance their future viability while providing greater assurance of professional oversight. Both OneBusAway and OpenTripPlanner are broadly perceived positively by stakeholders as examples of collaboration and cost sharing with the purpose of benefiting the traveling public.

[12] https://opensource.dev/
[13] https://github.com/CUTR-at-USF/awesome-transit

As these OSS projects have been increasingly deployed, the size of the stakeholder community and the cadre of professionals with technical expertise in their development and application have grown.

Simultaneously with the deployment of OSS in public transportation, the past decade has seen growth in the overall role and awareness of OSS across a broad range of software applications. This increasing awareness and appreciation of the role that OSS can play in public and private sector software applications has furthered the awareness of and acceptance of OSS as a viable option for software development/procurement.

There has also been a trend toward standard specifications for data sets which enables integration with shared software packages. For example, the OneBusAway and OpenTripPlanner both use the General Transit Feed Specification (GTFS) and GTFS-realtime formats[14] to exchange schedule and real-time transit information. These standardized formats reduce the overhead necessary to transform data from specialized formats and allow many agencies already publishing this data to immediately start using these OSS projects.

Also motivating consideration of OSS solutions is a trend of many proprietary software packages (e.g., some Microsoft products) gravitating to a subscription cost structure. Entities are becoming aware of both the significant reoccurring costs (which are now operating costs instead of capital costs) and the rate of cost increases that have occurred with proprietary software. This has increased the sensitivity to software costs and the willingness to explore options. These trends collectively inform the public and decision-makers regarding the evolution of data resources and software capabilities in an ever more technologically sophisticated and dependent world.

The history, nature and governance aspects of each of these projects are described briefly below to establish context. A third newer OSS project, Pelias, a multimodal geocoder and point-of-interest search engine which can be used in coordination with trip planners and real-time information systems like OpenTripPlanner and OneBusAway, is also described in the context of a Federal Transit Administration Mobility on Demand (MOD) Sandbox project.

OpenTripPlanner

History

Development of OpenTripPlanner (OTP)[15] was initiated by Portland, Oregon's transit agency TriMet with a Regional Travel Options grant in July of 2009, bringing together transit agencies and the authors of several open source transit projects in a kick-off workshop. The goal of the

[14] https://github.com/google/transit
[15] Details are available at: http://docs.opentripplanner.org/en/latest/Governance/, http://docs.opentripplanner.org/en/latest/History/, http://docs.opentripplanner.org/en/latest/Deployments/

project was to create an open source multimodal trip planner that could provide directions from one location to another that include transferring to and from transit, biking, and walking within the trip. Prior trip planners were unimodal, meaning that only a single transportation mode such as car, transit, or bike could be used from origin to destination.

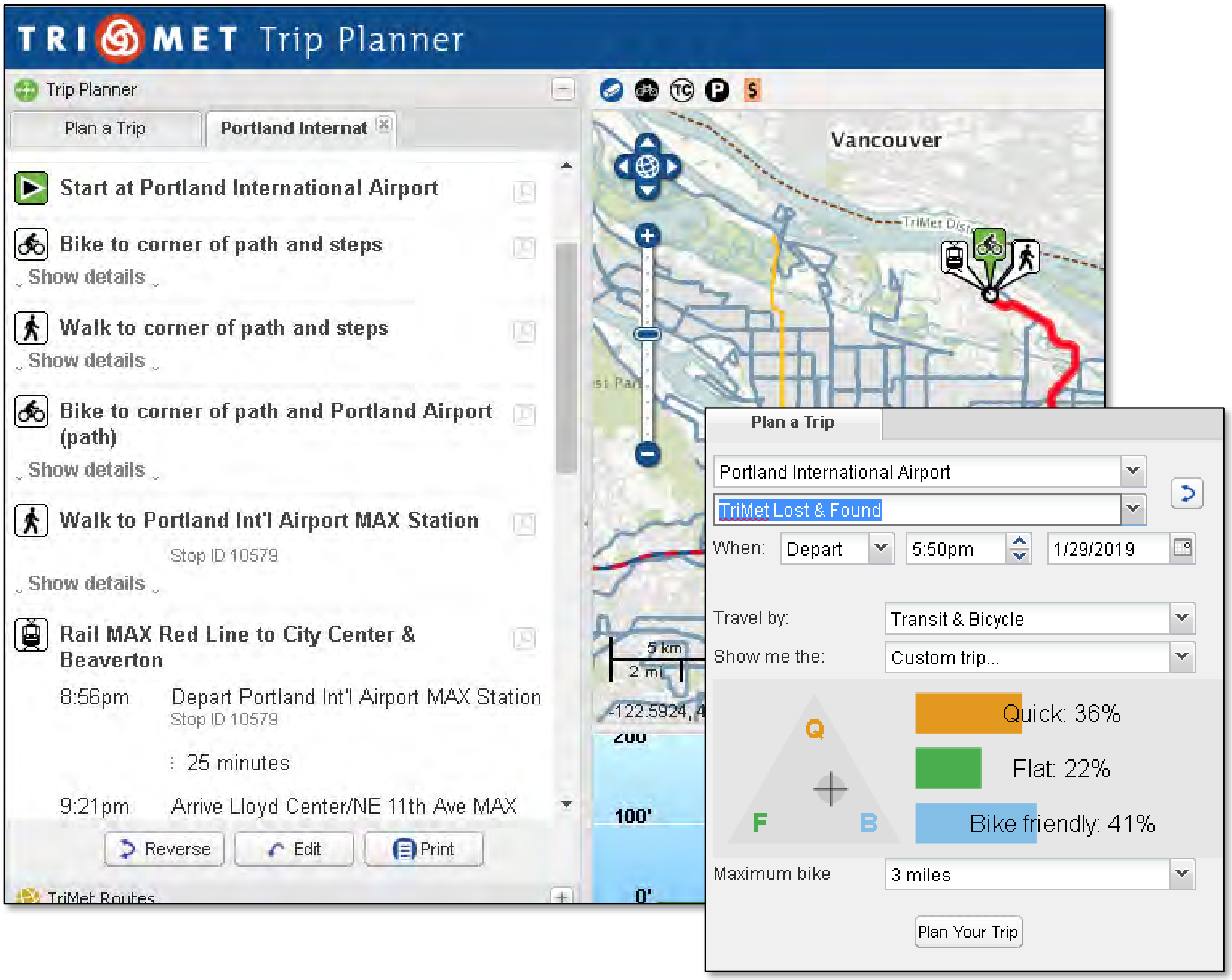


Figure 2 - OpenTripPlanner supports true bike-to-transit multimodal trip planning, as shown in the original TriMet deployment

From 2009 through 2012, OpenTripPlanner development was coordinated by the New York nonprofit OpenPlans. By early 2013, OpenTripPlanner had become the primary trip planning software used by TriMet in the Portland regional trip planner and was also being used by several popular mobile applications in the region. The project has since grown to encompass a global community of users and developers, with OpenTripPlanner-based applications active in at least ten countries throughout the world.

Governance

In summer of 2013, the OpenTripPlanner project was accepted for membership in the Software Freedom Conservancy (SFC). SFC handles the legal and financial details common to many open source projects, helping take some of the burden off individual OSS developers. As part of SFC membership a Project Leadership Committee (PLC) was created to formalize the coordination and management (i.e., governance) of the OTP software. The PLC consists of members from the public and private sector and entities that both operate public transportation as well as develop and maintain software based on OpenTripPlanner, including TriMet, Conveyal (formerly the OpenPlans transportation software team), Ruter Oslo, Cambridge Systematics, University of South Florida, PlannerStack Foundation, Interline, and Helsingin Seudun Liikenne.

The OTP Project Leadership Committee (PLC) makes management decisions by simple majority vote. The PLC holds a quarterly video conference on the first Thursday of June, September, December, and March. The main goal is to have regular agenda-driven meetings that yield clear decisions and action items assigned to specific people without devolving into conceptual discussions that are not actionable. The committee aspires to be composed of active, professional contributors to the OTP project, including representatives of organizations that host official public deployments of OTP. All code changes must be reviewed and approved by at least two people from two different organizations on the PLC and must be relevant to the OTP roadmap, which is also managed by the PLC. The existence and activity of the PLC are important to maintaining the usability, functionality, and consistency of the OTP.

License

OpenTripPlanner source code is licensed to other developers and users under the Limited Gnu Public License (L-GPL), which means that if source code of the project is modified by an individual or organization, that individual or organization is responsible for sharing any improvements or changes to the code along with the new version they have created. However, individuals and organizations can use the OTP software within proprietary solutions without needing to share their proprietary code if they use the OTP as a library project without modifying it.

Deployments/Current Status

In 2013-2014 OpenTripPlanner was a focal point in the Dutch Transport Ministry's MMRI (MultiModal Travel Information) project which encouraged investment in trip planning platforms and services. A consortium of five companies worked together to improve OpenTripPlanner performance in large regional transport networks and account for real-time service modifications and delays and the resulting software was deployed to serve the entire Netherlands, which is the largest OpenTripPlanner deployment in terms of coverage area.

In the fall of 2014, Arlington, Virginia launched a new commute planning site based on OpenTripPlanner for the Washington, DC metropolitan area to weigh the costs and benefits of various travel options. In 2015, the New York State Department of Transportation's 511 transit trip planner began using OTP to provide itineraries for public transit systems throughout the state from a single unified OTP instance. In early 2016, the regional public transport authorities of Helsinki, Finland (HSL) and Oslo, Norway (Ruter) began using a completely open source passenger information system based on OpenTripPlanner. National-scale OpenTripPlanner instances have also been deployed in Finland and Norway. Smart Columbus, recipient of the US DOT Smart Cities Challenge award, is building its travel options app on OpenTripPlanner[16].

OpenTripPlanner deployments as of December 2018 include:

- Los Angeles, California - The metro.net trip planner
- Atlanta, Georgia - The Metropolitan Atlanta Rapid Transit Authority's (MARTA) trip planner and Atlanta region's transit information hub atltransit.org
- Boston, Massachusetts - The Massachusetts Bay Transportation Authority trip planner
- Seattle, Washington - The Sound Transit Trip Planner and to power the trip planning feature of the OneBusAway native apps
- Arlington, Virginia - The commute planning site
- Tampa, Florida - Hillsborough Area Regional Transit also uses an OpenTripPlanner server to power the trip planning feature of the OneBusAway native apps
- Piemonte Region, Italy and the City of Torino
- Valencia, Spain
- Grenoble, France
- Rennes, France
- Poznań, Poland
- Trento Province, Italy
- University of South Florida - The USF Maps App.

In a culmination of the above work, after extensive involvement from over 100 contributors around the world, OTP version 1.0 was released in September 2016. OpenTripPlanner is still under active development. Some of the new features that have recently been developed are described in the FTA Mobility on Demand Sandbox project section later in this document.

[16] https://www.bizjournals.com/columbus/news/2018/11/19/smart-columbus-picks-local-startup-for-trip-planne.html

OneBusAway

History

OneBusAway (OBA)[17] began with the goal of improving the daily commute in the Puget Sound region by providing real-time transit information to travelers via various distribution channels, especially native mobile apps. Initially OBA was a graduate student project at the University of Washington in 2008 with a research objective of better understanding how real-time information benefits impact travelers, eventually becoming the topic of two PhD dissertations (Dr. Brian Ferris and Dr. Kari Watkins). It has since grown into an open source project with an active community around the world.

Figure 3 - OneBusAway includes a suite of open source software for real-time transit information, including native apps, a website, SMS, IVR, and data processing and conversion tools

Development of OneBusAway has been funded and enhanced by contributions from many agencies, foundations, university research centers and individuals, including:

- National Science Foundation
- Bullitt Foundation
- Nokia Research
- Sound Transit (along with King County Metro and Pierce Transit)
- New York MTA
- Hillsborough Area Regional Transit (HART)
- The USDOT Eisenhower program
- TransNOW
- National Center for Transit Research

[17] Details are available at: https://onebusaway.org/the-onebusaway-project/governance/, https://onebusaway.org/the-onebusaway-project/onebusaway-history/, https://onebusaway.org/onebusaway-deployments/

- National Center for Transportation Systems Productivity and Management
- GVU Center
- Google
- The Institute for People and Technology, and the Center for Technology, Decisions, and Dollars
- Seattle Department of Transportation

While no exact cumulative accounting of these investments in development and deployment has been kept, they amount to millions of dollars. In addition to supporting the advancement and deployment of OneBusAway the collaboration has also made possible a growing body of research that examines the impacts of real-time traveler information on the attitudes and behavior of transit customers, which is useful to transit agency management as they evaluate the costs and benefits of deploying real-time information systems.

Governance

The OneBusAway project is governed by a charter[18] which outlines a governance structure and is designed to further establish OneBusAway as a stable platform for deployments and to provide a platform for additional research in multimodal traveler information systems. The charter is intended to minimize administrative effort and facilitate project development. It enables continued advancements to keep pace with changing modal interface options and the inevitable evolution of data bases and customer information needs.

The project governance defines a set of active members. Members are organizations that are active in OneBusAway, including transit agencies, universities, nonprofit organizations, and for-profit companies, but can also be otherwise unaffiliated individuals who are making a significant contribution to the project, such as developers or open data transit activists. New members are added by majority vote of the existing members and mechanisms are identified for removing no longer active members. A 12 member Board of Directors elected by project members annually was established to have overall responsibility for the project. The board members represent different constituencies: 3 from transit agencies using OneBusAway, 3 from universities doing OneBusAway research, 3 from companies and nonprofits involved in OneBusAway development or support, and 3 from individual developers.

The board is responsible for overall project direction and high-level decisions, while technical decisions are made by authorized developers, which can be any of the OneBusAway project members. Board meetings are held monthly by conference call and are open to the public. Decisions are made by consensus whenever possible, either on the monthly conference call or, for time-critical or minor decisions, by email between meetings. If consensus cannot be reached, decisions are made by majority vote of the Board. An annual project meeting is held each January in Washington, DC but allows any who cannot travel to call in and participate.

[18] http://docs.opentripplanner.org/en/latest/Governance/

The OneBusAway project assets are held by different members. In particular, the onebusaway.org domain name, the OneBusAway trademark, and the OneBusAway logo are held by the University of Washington (UW). Contributors to the OneBusAway project sign a contributor license agreement (CLA) that provides a license for use of that source code to the "OneBusAway Open Source Project." There is a plan to incorporate OneBusAway formally as a 501(c)3 nonprofit or affiliate formally with an existing nonprofit to provide a long-term home for the above project assets and licenses, which will be transferred from UW to this entity at that time. Additionally, there is an active effort to establish a process by which transit agencies benefitting from the OneBusAway project could voluntarily contribute funds to the project which would help with overhead in managing the project as a whole, including the maintenance of the native OneBusAway iOS and Android apps that are deployed across the multiple OneBusAway regions and available to download from Google Play and the Apple App Store.

License

OneBusAway source code is licensed to other developers and users under the Apache v2.0 License, which means that individuals or organizations are free to modify the code and distribute derivatives of the project without being required to distribute their own changes to the source code.

Deployments/Current Status

OneBusAway is deployed in numerous domestic and international locations by many organizations including:

- New York, MTA
- Puget Sound, Sound Transit, Washington State
- Hillsborough Area Regional Transit, HART, Florida
- York Region Transit, VIVA, Toronto-area Canada
- Rogue Valley Transportation District, RVTD, Oregon
- San Diego Metropolitan Transit System, SDMTS, California
- Washington Metropolitan Area Transit Authority, WMATA, Washington DC area
- Poznań region, Poland, goEuropa

Some OneBusAway deployments (e.g., Sound Transit, HART) use an OpenTripPlanner server in coordination with a OneBusAway server to power the trip planning functionality within the OneBusAway native app.

FTA Mobility on Demand Sandbox Projects

In October 2016, FTA funded eleven projects under the Mobility on Demand (MOD) Sandbox program designed to rapidly deploy innovative mobility solutions. Two of these projects were based on OpenTripPlanner and are described in the following sections. Because OpenTripPlanner is open source, the end results of these projects can be deployed at any transit agency, allowing other agencies to benefit from these improvements without having to incur development time and costs.

TriMet – Shared Use Mobility in OpenTripPlanner and Transit Geocoding with Pelias

Shared Use Mobility in OpenTripPlanner

In TriMet's FTA MOD Sandbox project[19], TriMet and partners modified OpenTripPlanner to add support for real-time shared use mobility options in trip plans, including bikeshare and transportation network companies (TNC). As a result, Portland, Oregon area travelers can now plan trips that use TNCs and bikeshare to connect to transit. Key project partners included several transit agencies, the Federal Transit Administration, Mapzen (a subsidiary of Samsung that develops open source transportation software), technology companies, Uber, Lyft, and other entities with a total effort of nearly $1 million – conditions collectively signaling the significance of the initiative.

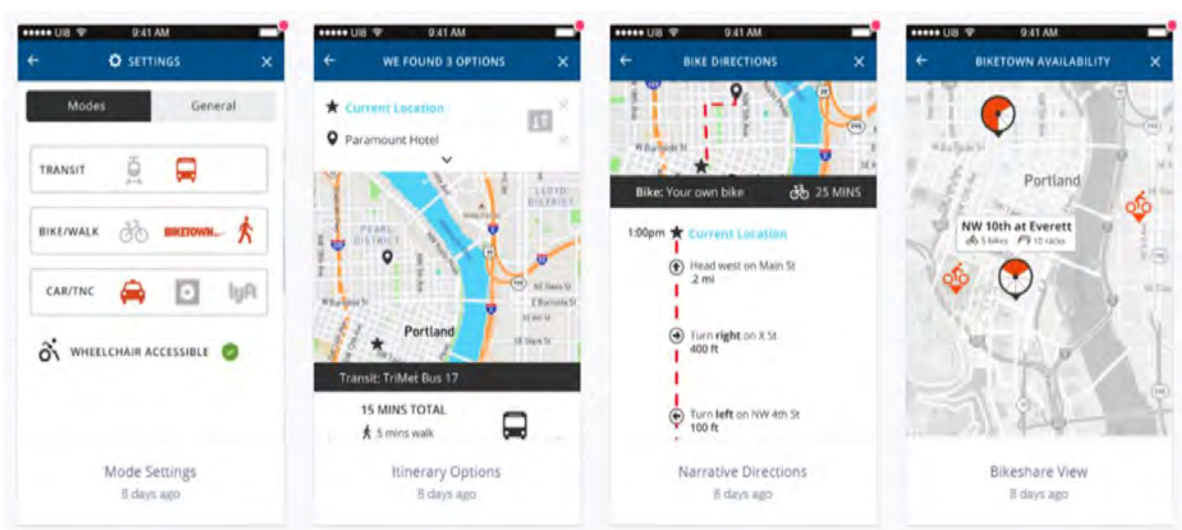


Figure 4 – New Shared Use Mobility Options for OpenTripPlanner developed under the FTA MOD Sandbox project

---

[19] FTA's MOD Sandbox Demonstration Program provides a venue through which integrated MOD concepts and solutions – supported through local partnerships – are demonstrated in real-world settings. https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program

As transit evolves to position itself in the increasingly competitive and diverse set of travel options that urban residents have, one of the challenges that is addressed by this initiative is to enhance the travel choice information available to persons who use public transportation. This sets the stage for other agencies to similarly enhance customer information and, most importantly, starts the process of integrating the transit choice into the broader framework of Mobility as a Service (MaaS). By building around the OTP framework this application enables supportive services to be used in the context of complementing public transit travel choices. Critically, when using OTP transit agencies can ensure that transit service is fairly represented in multimodal options provided to travelers. Positioning transit as an integrated component in trip planning is a critical step toward true multimodal integration of urban travel. It sets the stage for additional multimodal and multifunction integration of information services as mode options and features such as fare payment move toward integration across trip segments.

OTP uses open data and standards (including GTFS, GTFS-realtime, and OpenStreetMap[20]) to generate a multimodal routable network. This project introduced the use of Application Programming Interfaces (APIs) from private service providers, such as Lyft, Uber, BIKETOWN and many others, to add support for these modes. Because these same data sources and formats are available across the country, OTP can be deployed in any location and still have access to local information.

Pelias - Transit Geocoding

The second project goal of TriMet's FTA MOD Sandbox project was to make it easier to search and find transit stops and stations as trip origins and destinations. This goal was accomplished via enhancements to Mapzen's open source geocoder Pelias[21] to optimize it for public transportation information. Geocoding is the process of transforming an address into a latitude and longitude which are used to identify the origin and destination of any trip request. Pelias supports geocoding as well as point-of-interest search, where a location name can also be transformed into a latitude and longitude. Because software projects like OpenTripPlanner and OneBusAway typically require a latitude and longitude as input to their application programming interfaces (APIs), geocoders like Pelias perform an integral task of transforming user input of addresses and place names into latitude and longitude. A non-proprietary and non-restrictive option for address locating that supported searching for bus stop identifiers and names in addition to addresses and other place names is expected to substantially lower the barrier to entry for many transit systems to offer trip planning and achieve significant cost savings for transit agencies, government agencies, and the public when compared to proprietary solutions.

[20] https://www.openstreetmap.org
[21] https://github.com/pelias/pelias

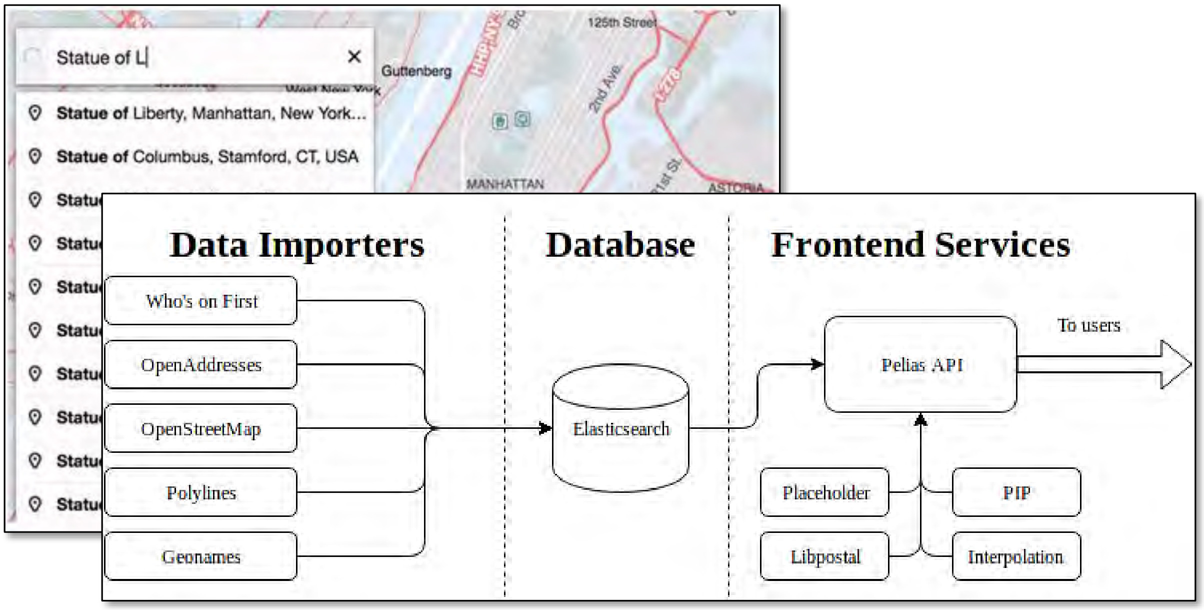


Figure 5 - Pelias is an open source geocoder that now includes transit point-of-interest search

TriMet's FTA MOD Sandbox project had an unexpected change in partners when Mapzen, who had been leading the software development on the Pelias OSS, unexpectedly ceased operations in January 2018[22]. However, because Pelias was open source software, the TriMet MOD Sandbox project team was able to continue using the existing software that had been developed as it was already publicly available on the code hosting site GitHub. Additionally, former Mapzen developers that worked on Pelias continued working on the project to finish the TriMet deployment but as consultants under a new firm, Cleared For Takeoff[23]. The Pelias software has also already been deployed by several other organizations as well, including Jawg, LocationIQ, LocalFocus, The City of Helsinki, NYC Planning Labs, and OpenRouteService (operated by the University of Heidelberg), and has been bookmarked online on GitHub by over 1500 developers, indicating significant interest from the OSS community.

This situation exemplifies a key virtue of open source software. Even though the original developer went out of business, the software is still viable and useful because it is open source. The demise of the corporate entity responsible for its development did not preclude other interests continuing to use and garner the benefits of that software and the intellectual property integrated in its code. If Pelias had been proprietary closed-source software, the FTA MOD Sandbox project would likely not have been able to continue Pelias development after Mapzen ceased to exist. In this circumstance, OSS effectively reduced the risk of innovation: TriMet was able to propose and obtain funding for a cutting-edge software project idea with a group of partners and was able to continue working on the same project after the departure of a key partner. In this way, OSS projects may be better able to out-live the organizations that create them.

[22] https://www.wired.com/story/mapzen-shuts-down/
[23] https://clearedfortakeoff.co/

A key challenge of working with software packages in a niche industry is that the list of readily-available developers who can modify the source code for a project without a learning curve is relatively small. In the case of Pelias, the original software engineers that knew the project best were able to continue development on the project, which resulted in no additional learning curve. If those engineers weren't available, new engineers could have been brought on-board to continue development, although there likely would have been a delay due to a learning curve as the new developers became familiar with the source code. Building governance structures and a community surrounding an open source project can help foster and expand the number of stakeholders who are familiar with the code and can provide development and maintenance services. Mapzen has transferred all their projects, including Pelias, over to the Linux Foundation (a large nonprofit that has operated for almost 20 years and supports the Linux operating system software), which should help with stable project governance going forward[24][25].

As previously mentioned, a key benefit of leveraging the OTP and Pelias OSS projects in the TriMet FTA MOD Sandbox project is that resulting software from the project can be deployed at any agency.

VTrans - Flexible Transit Service in OpenTripPlanner

Another FTA MOD Sandbox demonstration project by VTrans (the Vermont Agency of Transportation) and partners focused on enhancing OpenTripPlanner to plan trips for certain types of demand-responsive transit service. This goal was accomplished by modifying OpenTripPlanner to use the experimental GTFS-flex format[26].

Project partners include:

- Vermont Agency of Transportation
- Trillium Solutions, Inc.
- Cambridge Systematics
- Massachusetts Department of Transportation
- Regional Transportation District, Denver, CO (?)
- Anaheim Resort Transportation. California
- Oregon Department of Transportation
- Bridj
- Vermont Public Transit Association
- Green Mountain Transit, Vermont
- GridWorks
- Santa Clara Valley Transportation Authority, California

[24] https://www.linuxfoundation.org/press-release/2019/01/mapzen-open-source-data-and-software-for-real-time-mapping-applications-to-become-a-linux-foundation-project/
[25] https://www.mapzen.com/blog/mapzen-is-now-a-linux-foundation-project/
[26] https://github.com/MobilityData/gtfs-flex

- Brian Ferris – a founding developer of OneBusAway and OpenTripPlanner
- Cherriots – Salem Keizer Transit, Oregon

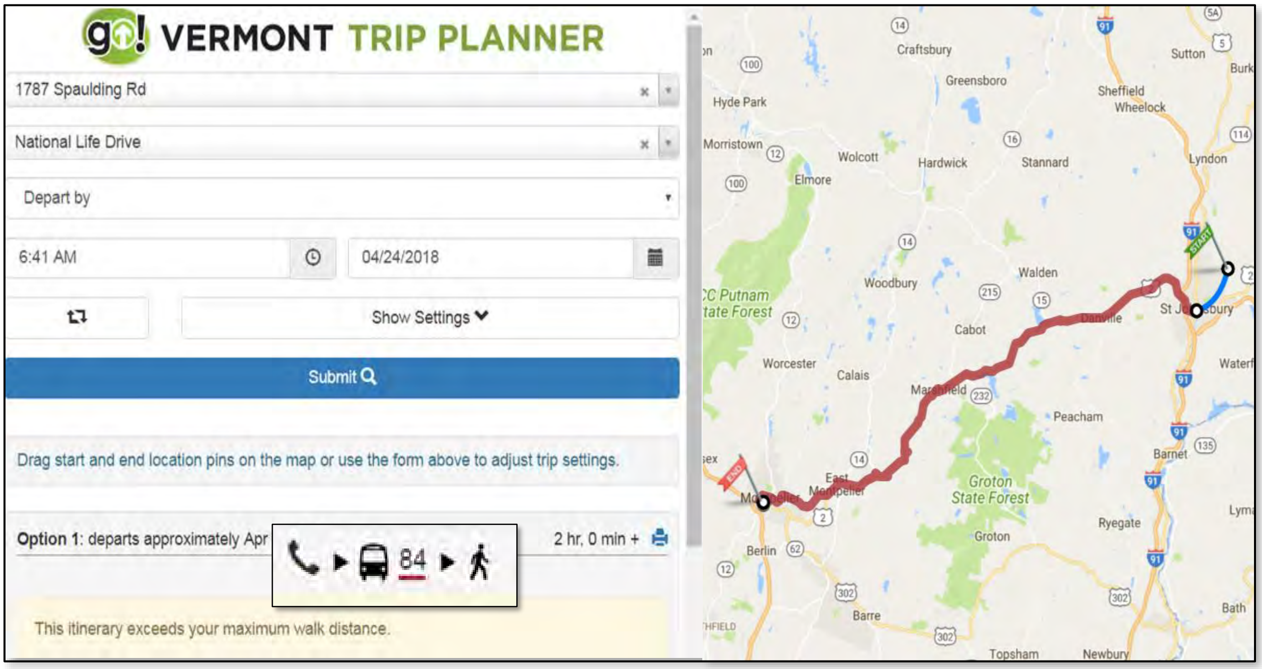


Figure 6 - The VTrans FTA MOD Sandbox project added flexible transit service support to OpenTripPlanner

The project goal was to develop a trip planner that provides access to flexible mobility options while also building on a platform that could be adapted, utilized, and scaled elsewhere. The trip planner includes itineraries that utilize both fixed and flexible modes of public transit via a mobile and desktop-accessible statewide trip planning website application. As a result, any user can define an origin and destination within the state and receive transit itineraries that include flag stops, deviated fixed routes, and dial-a-ride, which are not currently available in other trip planners such as Google Maps. The actual booking of trips for the rider was not part of the FTA MOD Sandbox project scope. The project team also created datasets in the GTFS-flex format for every public transit agency and many private transportation providers in the state as part of this project.

Like the TriMet FTA MOD Sandbox project, all the enhancements developed for OpenTripPlanner are being contributed to the main project so that they can be deployed at other transit agencies.

Technical and Strategic Considerations for Open Source Software in Public Transportation

Based on the experiences briefly described above, particularly the success of high-profile deployments of open source software within public transportation, there is a growing interest in exploring the robustness of the OSS strategy for continued deployment of current applications as well as expansion into other topical areas associated with providing public transportation. The remainder of this paper focuses on considerations relevant to OSS deployment and shares observations and perspectives that decision-makers may find helpful in making project-specific decisions. In many instances the set of issues is not unique to public transportation or even public sector deployment of open source software – the private sector has increasingly invested in open source software projects in recent years as well. Some of the critical issues discussed below, including procurement considerations, are relevant to both proprietary and open source software solutions. Financial, technical, and policy factors come into play in these decisions.

Adopting Open Source Software Can Avoid the Problem of Being Committed (Locked in) to a Single Vendor and Can Reduce Dependence on Monopolistic Technologies/Software Packages

Many transit agencies have experienced situations where they are captive to a dated technology/software package and wholly dependent on a single source provider. This introduces vulnerability and limits the ability for incremental evolution from a legacy system. It can also increase costs, as there is little or no competition for support services. This is especially a risk in the transit industry because the number of competing vendors is small due to the relatively small number of potential customers (i.e., transit agencies). With few competitors, options may be limited, and the risk of an individual company's failure could jeopardize the function of proprietary software. Open source software by its very nature tends to be incrementally updated and is less likely to only be supported by a single entity. Open source software typically provides greater independence, as any capable developer can provide support services. In the case of the Pelias software in the TriMet FTA MOD Sandbox project, the independence of the source code from Mapzen as a corporate entity allowed the project team to continue development even after Mapzen ceased to exist.

However, in the early stages of development, open source software may have a very limited cadre of individuals with a familiarity with the software and/or the application contexts. Thus, there can still be a dependence upon a limited set of personnel who have experience with the project design and implementation and the software. The open source nature of the software does enable new stakeholders to learn and use the existing system, but they would incur a learning curve (cost) to get up to speed on the software and on the specific deployment context. These risks can be mitigated with proper project documentation and code metadata (e.g., versioning systems) posted to freely-available public databases to reduce the learning curve for incoming stakeholders. Additionally, open source software initiatives that have multiple stakeholders and a larger pool of technical participants are in a better position to offer alternative and/or competitive technical experts for development, maintenance, and deployment should existing personnel no longer be available or cost competitive.

In the case of the OneBusAway and OpenTripPlanner projects, existing project members and governance boards are a readily available repository of development expertise surrounding the respective projects. Additionally, several developers (e.g., consulting firms, individuals) responded to an informal survey by the Center for Urban Transportation Research and reported both OneBusAway and OpenTripPlanner development experience. CUTR does not endorse any of these developers, but the list[27] is offered as an example of consultant options that a transit agency would have when pursuing deployments of or enhancements to these projects.

Open Source Software May Be More Responsive and More Flexible

Open source software can be more adaptable and flexible for entities as they can self-determine the timing and nature of software modifications more easily than might be the case if reliant upon proprietary software. For example, as in the case of the FTA MOD Sandbox projects, if transit agencies and partners are willing to invest in development to change an OSS package, they can take the initiative and are not reliant on the willingness of a corporate entity that may have other priorities or constraints for proprietary software products. This can be particularly important in functional areas where there are rapid changes in context and the desire to update software capabilities on a frequent basis. This is also true in niche uses or for inclusion of new innovations.

Similarly, OSS can be focused on specific priorities of the user community that may not be broadly held priorities for the customer base of a proprietary software package. For example, public transportation is very sensitive to equal accessibility to services and information. The industry is also sensitive to ensuring that public transit is adequately represented as a transportation option when multimodal trips that include alternatives such as TNCs are planned. If a feature is important to a small share of potential users, a proprietary developer may not necessarily invest in development of that feature absent a single client willing to pay for the entire development cost. In contrast, the stakeholders in OSS may prioritize such a capability and spread the cost and effort across many agencies.

In some cases, the flexibility and responsiveness of OSS coupled with the industry trends has resulted in a growing perception that OSS represents the cutting edge of software development compared to corporate-housed legacy packages. The results of the FTA MOD Sandbox projects with OpenTripPlanner and Pelias are such an example. To date no other trip planner supports using a TNC and/or bikeshare to connect to transit or flexible transit service. Pelias is the only geocoder that fully supports public transit information. In the case of flexible transit, OpenTripPlanner is also serving to advance the cutting-edge open data format GTFS-flex. By serving as a proof-of-concept for a flexible transit data format,

[27] https://docs.google.com/spreadsheets/u/1/d/1n44CNMCK1vt1nyrsdYz-KD_hYxUMNIm6Me69M6ROBIg/pubhtml

the VTrans project will likely accelerate the open sharing of flexible transit information, which will in turn accelerate the adoption of this data into other trip planners. As a result, flexible transit trips will likely be available to travelers in a variety of open and proprietary trip planners much sooner than if the format wasn't prototyped in OpenTripPlanner.

Cost Sharing Opportunities via OSS

Software applications within public transportation are somewhat unique and often not sufficiently generalizable across a large enough number of potential customers outside of transit to motivate private sector investment based on the hope of subsequent broader industry acquisition. Software targeted to address issues that are broadly relevant to a multitude of users (e.g., accounting packages, word processing, data analysis) have sufficiently broad markets to motivate businesses to invest in software development and subsequently amortize that investment over multiple purchasers. Public transportation is a relatively modest market with context-specific conditions (mix of modes, mix of operators, varying data sources, underlying hardware and software systems with which one must integrate, etc.) and hence are less conducive to private sector development of software packages independent of full client sponsorship. Thus, the prospect of sharing resources via open source software packages, where multiple parties may be contributing to the intellectual property development, provides economic efficiency for transit agencies that would be stressed with bearing the full cost of software development individually.

In interviews with public transit OSS stakeholders it was repeatedly emphasized that public transportation providers had a strong desire to share the benefits of their investments in software as broadly as possible for the benefit of the industry and customer communities. Public transit by its nature utilizes public funds (e.g., fare revenues, taxes, and fees) that subsidize public transportation, and this reinforces the desire to make sure that the expenditure of those funds creates the greatest value for the public as possible.

OSS also reduces and distributes the research and development costs for developing transit software solutions and enhancements. Building on an OSS framework, seed projects developed in federally-sponsored projects or by universities can produce enhancement shared across an established base of current and future users. For example, the simultaneous development of two new features in OpenTripPlanner, bikeshare and TNC routing led by TriMet and demand-response transit support led by VTrans, both funded by FTA MOD Sandbox grants shows how two new cutting-edge features, which aren't available in any other general-purpose trip planning system, could be added by different teams to OpenTripPlanner under separate seed grants. As discussed, these features were both added to the main OpenTripPlanner project so that other agencies could benefit from both new features and not have to incur their own costs to implement something similar.

Open source software can break down the barriers for software developers by providing a base of software to build on thereby directing new resources toward enhancements and advances. Modern OSS management platforms such as GitHub, which provides free source code versioning and hosting for any OSS solution, greatly facilitate the management of and communication surrounding OSS projects. Open source software allows software providers to compete on services and innovations, rather than charging fees to recoup the costs of the initial software development or enhance profits. This can reduce the barriers to entry and increase the competition or incremental advancements or deployment of open source software. In some situations, the availability of open source software has forced proprietary software vendors to reduce costs, which provides additional benefits for software users.

OSS Compatibility with Public Transportation Procurement Requirements and Practices

Public transportation agency procurement requirements and practices are generally very transparent and favor competitive procurements with prescribed evaluation criteria, delivery schedules, and fixed project budgets. These arrangements are less conducive to agile, negotiated, or longer-term agreements that might be more appropriate for development of innovative software, open source or proprietary.

Software development, particularly for new or innovative functions and integration with existing systems or data sets, are inherently complex and uncertain. By their very nature it is difficult to prescribe the activities or ultimate product in requests for proposals or scopes. This is particularly true for transit agencies where software procurement is a relatively rare event. For software development activities, creativity is required and there are often uncertainties until the work is well underway. These conditions lead to a great deal of trepidation regarding arrangements with entities not having an established reputation for successful delivery of services and bias towards established but perhaps not innovative or customizable software. For these reasons the software industry has largely transitioned to an "agile" approach to software development, where the current state of the project and goals are assessed on a weekly basis, and adjustments to the work plan are made accordingly with the client's feedback. However, traditional procurement approaches focus on rigid deliverables defined at the start of a project, which can be difficult to reconcile with an agile workflow if not scoped in the correct manner. Additionally, some agencies do not understand the OSS project model where a governing body is involved in shaping the overall direction of the OSS software, vs. a single vendor with a proprietary solution. This lack of understanding can turn into a fear of the unknown and a greater perceived risk associated with an OSS solution. These circumstances can favor using an existing product as opposed to initiating the development of an open source or proprietary product that is perhaps more appropriate for addressing a given need.

Transit agencies considering OSS may benefit from discussion with transit agency peers who have deployed OSS to help alleviate the lack of knowledge of OSS project management. Peer guidance may help agencies understand when OSS solutions are a good fit for the goals that the agency wants to accomplish. There has been a proliferation of OSS applications across both public and private sectors over the past decade. A substantial body of expertise and experience with OSS provides examples of successful OSS applications and experience base to help understand how best to structure OSS engagements.

An example of this experience includes TriMet, which has established a process to evaluate both proprietary and OSS solutions during their procurement process. A requirement of this process is that TriMet's IT department must be consulted during the purchase of any software. At the same time, for open source projects to be sustainable long term, it is critical to allocate budget for code merge/integration and participation with the broader OSS (e.g., OTP) developer and user community. Appendix A includes elements of the TriMet procurement process.

If agency RFI, RFP, and procurement templates have been developed in context of proprietary vendor solutions, the resulting language may discourage responses from entities working with solutions based on open source software. For example, boilerplate intellectual property requirements that were originally created in the context of proprietary solutions can discourage responses using OSS solutions. As a result, agencies that want to consider open source software solutions should explicitly enumerate OSS as a possibility in request-for-information (RFI), request-for-proposal (RFP), and procurement templates and ensure that there is no blocking language for OSS.

FTA and networks of public transit agency procurement professionals could play a vital role in aggregating existing agency templates that support the proposal of both proprietary and open source solutions and perhaps even develop a generalized template that all agencies could use. FTA could also play a role in connecting peer agencies to help share OSS experiences, especially with agencies that haven't deployed OSS.

Overprescribing a solution or specific implementation requirements in an RFP can potentially hinder innovation and prevent the proposal of OSS solutions that could accomplish the same goals but in a more cost-effective manner. Agencies should focus on stating business needs in RFPs rather the specifying specific solutions in order to attract the broadest spectrum of potential solutions.

Proprietary software packages are owned by an entity that is in the business of soliciting opportunities for deployment. These entities are proactive in marketing to potential customers and responding to RFI's and RFPs. Open source software does not necessarily have an analogous marketing or advocacy function and is dependent upon either a third-party entity championing OSS software and/or agency awareness of the product such that they can ensure that option is considered in the solicitation process. Thus, procuring agencies may need to be more proactive in making OSS software stakeholders aware of development, support, or deployment opportunities.

Typically, for OSS solutions the agency will also want to include additional language in an RFP or contract specifying that enhancements to OSS funded by the agency will also be made available as open source software and the proposing entity will work with the management of the OSS project to contribute the enhancements back to the main project, so other agencies can benefit as well.

Proprietary extensions to open source software

There is a risk that open source software, if not licensed and administered effectively, could be enhanced by companies who create large proprietary extensions to the base open source project that undermine the credibility of or render the original software obsolete with no remuneration to the original investors for the value in the core software. For example, if key features of an open source project become proprietary and require licensing from a vendor, then the value of the underlying open source project is greatly reduced. Proper management of the project by establishing a community of stakeholders that oversee how the software evolves can mitigate this possibility.

The choice of OSS license can also mitigate these concerns. For example, as mentioned earlier the L-GPL license (used by OpenTripPlanner) requires that all direct enhancements to the code be open-sourced as well. The GPL license is an even more restrictive version with a "viral" property that specifies that if any of the OSS project code is mixed with another proprietary project code, that project code must also be openly licensed under GPL.

However, it is possible for a healthy OSS ecosystem to have proprietary enhancements that provide a value-add proportional to the licensing costs charged for the extension. While GPL and L-GPL do not allow this type of extension ecosystem to develop, licenses like Apache v2.0 (used by OneBusAway) are conducive to this model and can be more inclusive of the private sector. The debate of the merits of GPL/L-GPL vs. Apache v2.0 can also be based on philosophical ideals, where GPL/L-GPL falls on the side of the "all software should be open" argument and Apache falls on the side of inviting active collaboration of the private sector by allowing the private sector to mix the OSS solution with its own proprietary software to provide an enhanced product.

To date, to the authors' knowledge, no licensing issues have emerged with either the OneBusAway or OpenTripPlanner projects – all consultants developing enhancements to the projects have made their enhancements open to the public.

Public sector risk aversion favors procuring products and services from established vendors with records of performance

Public sector procurements of various software systems are replete with horror stories regarding cost overruns and delays in delivery or compromised functionality. Often risk mitigation, specifically the ability to accomplish the prescribed task given budget and schedule specifications, are critical factors in procurements which can result in policy boards and senior executives being risk averse and more reluctant to procure services where there is some uncertainty as to the responsible party. In addition to the technical aspects of procurement mentioned above, agencies seek turnkey services such that liability and responsibility can be fully placed on external vendors. Concerns about safety and customer satisfaction appropriately limit the willingness of public sector policymakers to experiment or otherwise take risks. Many of the same reliability and security pitfalls apply to both OSS and proprietary products but policymakers are inclined to rely on the reputations of suppliers or track records which can disadvantage innovative or emerging firms and packages.

These conditions may limit the range of initiatives where OSS might be a viable option at some agencies, particularly if they involve early-stage developmental open source applications. For example, OSS might logically be limited to modest scale projects that could be initiated without explicit public procurement processes. Most agencies have levels of procurement that can be initiated by an executive director without policy board authorization. Smaller scale initiatives mitigate the magnitude of risk and are less impactful if not successful. When smaller scale initiatives are proven successful, the agency can choose to pursue larger OSS-based projects.

This risk aversion also supports initiatives for OSS development that leverage other resources to mitigate the risk to the deploying agency. Specifically, opportunities to use seed funding from state and federal agencies and/or leverage university research funding are attractive as the basis for the initial development of OSS. This approach reduces the resource risk to the ultimate software user community should the project be unsuccessful or be able to be delivered at a price point or with the capabilities initially hoped for. The inherent risk aversion is reduced as experience accumulates and a record of success is established and communicated.

Public transportation providers are supported by local, state and federal public resources and universities are often a source for research and technical support

The consortium of public sector stakeholders favors collaborative agreements that can work around some of the prescriptive characteristics of traditional procurements. Governmental entities funding public transportation are typically supportive of having the benefits of their investment applied as broadly as possible, thus, would generally be supportive of the collaboration and sharing inherent in an open-source strategy. Similarly, given limited public sector funding agencies also want to avoid duplicating efforts if another has already invested in a similar solution. In addition, public agencies are supportive of the benefits of public investments being available to the broader public. Public entities could be subject to criticism if public resources supported development of intellectual property that subsequently enriched individuals or firms disproportional to the public benefits derived from the investment. Collaborative initiatives that have investment by other partners both spread the risk and implicitly enhance the credibility of the initiative. For example, the OneBusAway project described earlier leveraged research funds provided to universities through various programs. OpenTripPlanner was initially grant-funded with TriMet teaming with the non-profit OpenPlans. This partnership/collaboration leverages and agencies' resources and enhances the credibility of the initiative.

Unlike in many private sector businesses where there may be a reluctance to collaborate with another firm as they may be a competitor now or in the future, collaboration and sharing amongst transit entities is looked upon positively as they do not compete

Transit agencies do not compete in the same geography and typically have similar goals and are thus more willing to share costs and knowledge than might be the case in the private sector. A business that invests in a software project for key products would not be inclined to share that knowledge with a competitor as it would influence their competitive situation. On the other hand, software elements that allow broader integration or dissemination of their products or services are often open-sourced to enhance that integration. The absence of interagency competition in public transportation and many other public-sector activities strongly favors the collaborations inherent in open source software.

For example, the simultaneous TriMet and VTrans FTA MOD Sandbox projects show the collaborative flexibility that is possible with open source projects that does not exist with proprietary projects. TriMet and VTrans both engaged different partners to assist with the software development of the new OTP features. These partners then communicated with each other as well as the OTP PLC to formulate a strategy for merging these new features back into the main OpenTripPlanner project, so they did not conflict with one another. The result is that any transit agency will be able to deploy OpenTripPlanner and benefit from the new TNC and flexible transit features, even though they were developed under two separate projects by two separate teams from different organizations.

The mobility, environmental and economic development goals of public transportation often engender passionate commitments to the pursuit of actions to improve public transportation

The OpenTripPlanner and OneBusAway projects exemplify situations where a passion for solving problems that provide public benefits are critical motivations in the development of open source software. The pursuit of solving a problem versus only making money fundamentally change the motivations, collaboration levels, and risks. These passions can replace or supplement the economic incentives for advancing technological solutions and can motivate the collaborations that enable open source software to be developed and sustained. Individuals and private and public sector organizations can make investments into OSS projects, either by providing in-kind donations of labor needed to maintain the projects (e.g., software development, management, or marketing skills), in-kind donation of resources (e.g., discounted access to services needed to maintain or operate the project) or financial contributions needed to cover labor or operations costs. There are many examples of OSS projects receiving donated development, time, and expertise.

Leveraging and sustaining that passion is one of the challenges with assuring a governance structure and path forward for continued evolution and deployment of open source software. Just as in the case of certain businesses, if the leadership or passion behind successful open source software initiatives is not sustained over time there are risks that the talent base necessary to sustain progress can wane. OSS projects can mitigate the risk of losing passionate talent by allowing those stakeholders direct influence over the direction of the project. For example, if a software developer is contributing their own time to maintain the project or implement new features, they should help choose new features to implement that they feel most passionate about.

Open source software and security

Software security is a key concern with any system. OSS offers some unique strengths and concerns with regards to security. The classic arguments against OSS in terms of security are that the transparency of OSS may enable hackers to identify vulnerabilities more easily, therefore raising security concerns. However, the counter criticism is that proprietary software that cannot be audited leads to mistrust and requires one to have high confidence in the vendors' integrity assurances and capabilities. Additionally, the transparency of OSS can also lead to benevolent outside contributors discovering and fixing vulnerabilities before they are found by malicious actors. Some companies even provide significant financial "bounties", or rewards, to developers who discover security bugs in their open source software.

Ultimately the overall security of any software, open source or proprietary, is inherently related to the management of the development and deployment of the software. Development of any software that is rushed with little thought to or concern with security will be more likely to contain vulnerabilities than will code that is carefully written and reviewed for potential vulnerabilities before it is deployed. Additionally, any deployed software that is poorly maintained and updated infrequently, especially when vulnerabilities in the software have been publicly disclosed, are more likely to become victim to hackers that are constantly scanning systems for known vulnerabilities. In contrast, systems that are actively maintained and frequently updated with the most recent security patches are the least likely to fall victim to attack. To the extent that OSS results in more experts reviewing the code, it can provide additional perspectives sensitive to security risks. Concern about the security of OSS is not specific to the transit industry or even the public sector, and discussions of OSS in context of security can be found in software literature.

Security issues may influence the nature of palatable application areas for open source software. Transit agencies are the most sensitive about access to financial information and access to systems that could impact the safety of transportation services. Thus, open source software applications that could potentially interface with financial or safety systems should receive a higher level of security review than OSS that focus on real-time passenger information or trip planning, where the most likely effect of a security breach would be interrupted service to transit riders but not generally impact safety. Transit agencies should also require similar security review for proprietary solution providers depending on the application area.

Public Transportation and Open Source Software Applications Going Forward

OSS applications tend to be somewhat unique, each with its own evolution influenced by specific context conditions surrounding its development. The OneBusAway and OpenTripPlanner projects highlighted earlier have both evolved over a decade and matured into high profile passenger information applications important to public transportation and used by millions of travelers. Pelias project is more recent and characterizes some of the issues and opportunities that surround open source software applications in public transportation.

As public transportation becomes more reliant on information systems to manage data and information, public transportation agencies will be more involved in identifying, obtaining, and managing software packages to enable these functions. A partial list of information systems used in transit includes logistics to control and optimize operations, social media and other venues to interface with customers and stakeholders, and a multitude of technologies and software to handle and support functions (scheduling, fare payment, computer aided dispatch, automatic vehicle location, performance monitoring, safety, etc.), Accordingly, issues associated with utilization of open source software will garner attention from agencies as they are exposed to challenges and opportunities that might be best addressed through open source software.

The discussion below synthesizes some of the lessons learned and observations of stakeholders (Appendix B) interviewed for this whitepaper who have been involved in open source software applications. This discussion is intended to help inform stakeholders as they explore the potential of open source software solutions.

Managing Open Source Software Applications

As an agency first identifies a problem or need there are often incremental actions performed that can mature into an OSS software package and be applied beyond the initial organization that developed it. It may become apparent that the problem is not unique and that efforts to address it might have value to other agencies or might benefit from work already carried out by others. It may become apparent that sharing and, hence, open source software strategies might be appropriate.

If early efforts are deemed successful and fuel subsequent incremental investments in improvements or deployments, at some point attention turns toward mechanisms to ensure that the asset value developed can be sustained and advanced going forward. At this point, stakeholders should consider mechanisms to provide funding and governance. These two issues are implicitly intertwined as partners in collaboration seek some framework around which that partnership can be defined. Both the asset value of the software and the range of stakeholders involved may motivate desires to formalize access or licensing, decision making/governance and the solicitation and distribution of resources (funding and spending) to support product enhancement, maintenance, and/or deployments.

Executing a more formal governance structure can require agreements on funding commitments and formal funding mechanisms. Such a structure can avoid the prospect of some agencies "freeloading" on the efforts of their peers. Similarly, maintaining complex software packages requires ongoing maintenance to ensure security, compatibility with supporting software and hardware, and hosting; costs that can be shared if the package has gained multiple users.

Early in development, funding often comes from the entity deploying the software and/or from commitments of foundations, research institutions, or governmental entities with a broader problem-solving mission. Depending upon the context, subsequent software development, particularly refinements benefiting the body of stakeholders or the pursuit of enhancements that will be broadly deployed across multiple users, favor a shared funding strategy particularly if the resource requirement for enhancements become significant. One respondent noted that it's easy to attract grants and support and programmer enthusiasm for adding innovative new features to software packages but far more difficult to secure funding/support for the "boring" routine maintenance functions.

In some cases, informal arrangements and a willing host entity can enable packages to mature substantially without a formal financial pooled fund framework. Collaboration of stakeholders can distribute the burden across stakeholders without formalizing transfers of funds between entities. Both OneBusAway and OpenTripPlanner currently follow this model. Each has established a governance structure but neither has transitioned to a pooled fund strategy to cover administrative and development costs (deployment costs are appropriately covered by the deploying entity). As a result, centralized project and community management tasks have, largely been sustained by stakeholders including several passionate individuals who have provided leadership and investments of time not necessarily underwritten by clients. Examples of these tasks include contributing enhancements back to the main project, reviewing contributions by others before they are merged back into the main project, and community maintenance such as responding to questions about the project from new or prospective users.

Stakeholders in the OneBusAway and OpenTripPlanner communities both emphasized that as a best practice they are now including a line item in new development and support contracts to devote the time to contributing enhancements back to the main project. Agencies have embraced this approach, with some even wanting to issue press releases to publicly celebrate the task when it was complete. However, the tasks of reviewing others' contributions and community maintenance remain largely volunteer efforts, and stakeholders of both OSS project communities expressed a desire to identify a source of funding to help support these tasks.

Pooled funding for initiatives of mutual interest by public sector entities occur in fields beyond supporting open source software. Research initiatives, specification and standard development, and lobbying are among the areas where multiple public sector entities or consortiums of public, private and foundation interests collaborate in funding a shared initiative. This sharing typically is framed around some common metric that reflects the relative magnitude of benefit each entity might receive from the respective investment. For example, number of customers, population, budget size, or other factors might be a basis for cost allocation. The presence of the cost structure can help ensure an equal sharing of the burden and formalize responsibilities in a contractual sense such that a motivation for participation moves from being a volunteer to be a financial stakeholder and/or contracted entity.

The cost of implementing and executing such a framework could potentially divert resources from the project and/or create other barriers or challenges for moving forward. For example, making a financial commitment to a formal entity may have a higher burden of approval and risk for a public sector agency than is the case for lending staff time and resources (meeting room space, server hosting, etc.) to support a project. However, the formality of having an established entity may make it easier for a public entity to enter into agreements because a formal entity may have more credibility with senior executive and policy level decision-makers than would less-formal relationships. OneBusAway members are currently investigating a model by which agencies can contribute funds towards some of these centralized project management efforts—the results of this initiative, if successful, may serve as a model for other public transportation OSS projects going forward.

Conclusions and Recommendations

The public transportation community has benefited significantly from the above referenced open source software applications and this sets the stage for additional industry collaborations. Public transportation is becoming more data-driven and technologically-complex and will inevitably continue to deploy greater amounts of software going forward. This is particularly true as public transportation evolves beyond its current traditional roles to embrace broader responsibilities for mobility management. To the extent that there are unique software development challenges to address public transportation stakeholder needs that are not met by proprietary software or where it is cost effective to spread the software development cost over multiple industry stakeholders, open source software will continue to provide opportunities.

Following are some key observations and recommendations:

1. OSS has gained greater public awareness as more software applications have relied on OSS or OSS components. Open and crowd-sourced data, the movement toward software subscription pricing, the rapid evolution of technology requiring frequent software updates and modifications all support consideration of OSS software for addressing transportation industry software needs.
2. Vendor lock-in with proprietary software is a key concern of agencies, citing past experiences where they have been subject to high costs for new features or maintenance costs with no alternatives. By deploying an OSS solution, an agency has options over who deploys and maintains the software. If one contractor doesn't perform adequately, the agency can change

to a new contractor and keep all previously funded enhancements and customizations. Additionally, if an agency expands their internal IT department, they have the option of bringing the solution in-house, reducing or eliminating consultant costs.

3. Proprietary software licensing/subscription costs are increasingly an issue for public transportation agencies. Software costs have been increasing with movement towards a subscription pricing model and transit agencies are more aggressively seeking alternative means of meeting their software needs via the deployment of software that they control.
4. The public nature of public transportation funding and the passions of many public transportation stakeholders to meet the needs of customers and enhance public transportation services strongly align with the concept of collaboration and resource sharing that underlie the concept of open source software.
5. OSS initiatives benefit from research, grant, or other seed money's sources to mitigate the initial risk of innovative software development. As the base of stakeholders grows and success is demonstrated, there is a greater willingness of agencies to participate and invest in OSS enhancements and deployments.
6. As OSS packages/applications mature, a framework for governance and funding organically develops. There is no formula for moving through this maturation process. Facilitating that maturation is beneficial to the stakeholders and should be encouraged – hopefully without dampening the passion and enthusiasm that can be critical to early-stage development.
7. Unlike proprietary software, OSS software projects typically do not have personnel dedicated to marketing, advocacy, and education. Thus, it behooves public transportation industry professionals who are seeking software capabilities to explore the prospect of OSS solutions and structure solicitations and procurements to enable OSS consideration. Discussions with peers that have deployed OSS are strongly encouraged.
8. One of the challenges for OSS software is ensuring the development of a breadth and depth of technical expertise to support the software. For complex software solutions the extent of experience in deployments and enhancements can be as or more important than the value of the code itself. An effective governance structure and management of the OSS project can facilitate the growth and distribution of expertise among numerous stakeholders.
9. OSS packages have developed reputations for addressing cutting-edge needs in the industry and attracting top-level talent. For example, as a result of the FTA MOD Sandbox projects OpenTripPlanner is the first trip planner in the industry to support routing by flexible on-demand transit as well as shared use mobility services like TNCs, and Pelias is the only geocoder to support public transportation information. There is a growing body of expertise dedicated to OSS software and growing venues for OSS developers to share experiences and learn from each other. Critical issues such as funding, licensing, governance, and others can benefit from experience sharing. The Federal Transit Administration and the American Public Transportation Association could play an important role in information-sharing and peer-exchange regarding OSS opportunities and experiences.
10. OSS deployments within public transportation might be facilitated with brief concise reference materials that can explain and communicate OSS to stakeholders in public transportation in geographies where OSS initiatives are being contemplated. This might include a 1 to 2-page

narrative describing what OSS is, explaining how it has been used, providing paragraph length descriptions of successful initiatives, and linking to additional resources. As mentioned above, peer exchanges between agencies that have and have not deployed OSS solutions would be a valuable educational opportunity to ensure that agencies aren't unintentionally neglecting OSS options when procuring new solutions.

11. There are several other emerging OSS applications within the public transportation industry that stakeholders have deployed by more than one agency but do not have an established governance structure, including TheTransitClock[28] which generates arrival time predictions from vehicle locations, TimeTablePublisher[29] for creating timetables, TransAm[30] for asset management, and RidePilot[31] for computer-aided scheduling and dispatch. In some cases, the motivation for deployment stemmed from emerging new needs and in others they stem from a desire to see more robust, more current, or more attractively priced packages them are currently available.
12. FTA should review the ITS Joint Program Office (JPO) Dynamic Mobility Applications (DMA) program[32], which focuses on the development and release of open source applications that use Intelligent Transportation Systems (ITS) data to transform surface transportation management and information, to determine if a similar program could assist the development and deployment of OSS for public transportation. A similar program focused on transit could potentially support administrative functions for established transit OSS projects and help incubate emerging transit OSS applications, potentially including those mentioned above. Neutral organizations such as a professional associations or universities could assist in this process.

The public transportation industry has been fortunate to have a growing number of open source software packages that have been broadly accepted and deployed in multiple agencies both domestically and internationally. These initiatives have given the concept credibility and provided an experience base on which stakeholders can build. The collaborative sharing nature inherent in OSS applications are culturally a perfect fit for the public service nature of public transportation. Several of the issues and challenges associated with software deployment are shared across proprietary and OSS applications. As noted above, OSS offers a viable option for transit agencies for a growing number of applications and merits consideration by public transportation stakeholders as they seek to use software solutions to address the increasingly complex technologically and data intensive nature of public transportation.

The Federal Transit Administration has supported the development of OSS application through various grant and funding programs and the success and open source nature of these investments has benefitted multiple agencies beyond those that were direct recipients of

[28] https://thetransitclock.github.io/
[29] https://github.com/OpenTransitTools/ttpub
[30] http://camsys.software/products/transam
[31] http://camsys.software/products/ridepilot
[32] https://www.its.dot.gov/research_archives/dma/dma_plan.htm

development funding. This model provides a promising approach for addressing other emerging software needs that may be unique to public transportation and not of sufficient generalizability or market size to engender private development investment. OSS can enable shared development costs and ensure software development investments offer value beyond the initiating agency.

Appendix A

Example of the Spreadsheet Evaluation Analysis used by TriMet for Software Procurement

Software Alternatives Analysis

Software Options	Summary			Core Technologies				Costs					Criteria for Open Source Software Options						Basic Required Features/Functions (1 - None, 5 - Meets Requirements)					
	Reviews	Benefits	Risks	Code Base	Database	Web-Base	Map Base	Software Costs	Hardware Costs	Annual Licensing Fee	Annual Maintenance/ Support Fee	IT Resources (significant or nominal)	current software version	support options	docu-mentation	user base	developer base	oss license						
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								

Detailed Requirements Analysis

Detailed Requirements		Option 1	Option 2	Option 3
Costs	Base Sofware Cost			
	Annual Mainteance Fee			
	Annual Support Plan			
	Hidden Costs			
	Development Time (estimated for tools)			
	Development Time (estimated for advanced functions)			
	Hardware Requirements			
	Software Requirements			
	Training Costs			
OSS Criteria	market share			
	support options			
	maintenance/longevity			
	reliability			
	performance			
	scaleability			
	useability			
	security			
	flexibility/ customizability			
	inter-operability			
	legal/license issues			
	other issues			
System Requirements				
Required Tools/ Functions				
Advanced Functions				

Appendix B

Participants providing materials and information:

- Julian Simioni, Cleared for Takeoff
- Thomas Gran, Entur, Norway OTP maintainer
- Richard Kinney, Hillsborough Area Regional Transit
- Shannon Haney, Hillsborough Area Regional Transit
- Kari Watkins, Georgia Tech
- Alan Borning, University of Washington
- Devin Braun, San Diego Metropolitan Transit System
- Bibiana McHugh, Portland TriMet
- Thomas Craig, Trillium Software
- Ross MacDonald, Virginia, VTrans
- Sarah Anderson, Cambridge Systematics
- Sheldon Brown, Cambridge Systematics
- Drew Dara-Abrams, Interline Technologies
- Nathan Selikoff, Omnimodal

About the Authors

Sean Barbeau, Ph.D., Principal Mobile Software Architect for R&D, CUTR

Sean Barbeau has led numerous research projects that focus on the design, development, deployment, and evaluation of new technologies related to location-aware services, multimodal apps, and mobile devices. He serves on the Board of Directors for the OneBusAway Open Source Project and is a member of the Project Leadership Committee for the OpenTripPlanner project. He also serves as the lead software engineer for the OneBusAway Android app and Alexa skill, which have served over 1 million transit riders, and has been heavily involved in open data initiatives, including the evolution of the General Transit Feed Specification (GTFS) and GTFS-realtime data formats. He has over 40 peer-reviewed papers and conference presentations and 16 patented inventions. He holds a B.S. and M.S. in Computer Science from USF as well as a Ph.D. in Computer Science and Engineering from USF.

Steven Polzin, Ph.D., Director of Mobility Policy Research, CUTR

Steven Polzin carries out research and analysis on transportation policy issues of local, state, and national significance. He worked for transit agencies in Chicago, Cleveland, and Dallas before joining the Center for Urban Transportation Research. His research focuses on transportation planning, decision-making, data analysis, travel behavior and public transportation. Dr. Polzin holds a bachelor's degree in Civil and Environmental Engineering from the University of Wisconsin-Madison and master's and PhD degrees in Civil Engineering from Northwestern University. He served as a member of the Board of Directors of the Hillsborough Area Regional Transit Authority (HART) for 13 years and was a member of the Hillsborough Metropolitan Planning Organization Board of Directors for seven years.

APPENDIX

C

Project Management Plan

Project Management Plan (PMP)

OTP SUM: OTP Integration of Transit with Shared-Use Mobility Real-Time and Data Enhancements Mobility on Demand Sandbox Program

Prepared for
Federal Transit Administration (FTA)
U.S. Department of Transportation

Prepared by
Tri-County Metropolitan Transportation District of Oregon (TriMet)

March 9, 2017

Table of Contents

Contents

List of Figures

List of Tables

No table of figures entries found.

1 PROJECT OVERVIEW

1.1 Background

The Open Trip Planner (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 transit. Adoption of OTP has been strong, with implementation in dozens of cities and countries worldwide. TriMet now proposes to build upon the core of OTP to incorporate shared-use mobility (SUM) options.

TriMet's OTP SUM project will create a complete open platform for the integration of transit and SUM options. The open data, software and user interfaces, responsive on both web and mobile, will help customers understand the multi-modal options to meet their mobility needs, including for the critical first and last miles of transit trips where a bus or train alone doesn't directly serve their origin or destination

1.2 Project Summary

TriMet's proposed project includes the development and expansion of two core data frameworks that current and future collaborative OTP initiatives can be built upon, producing replicable software and results for communities across the country. These two core project elements are to:

- Extend the OTP code base to integrate into transit trip planning shared-use mobility modes, such as bike share and TNCs, as well as updated real-time transit information.
- Implement a fully-functional and comprehensive open source geocoder built off the existing open source Mapzen Pelias geocoder. Geocoding, or 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 transit systems to offer a trip planning tool and can achieve significant cost savings for transit agencies, government agencies, and the public.

In addition to core elements on the foundation frameworks, the project will also include:

- Development of a comprehensive new web-based user interface that will allow users to make intermodal trip plans including shared-use modes. The new web-based user interface will also display real-time information and report impacted itineraries to users.
- Improvements to basemap data so the trip planner can support enhanced pedestrian/ wheelchair accessibility information for customers; and improvements to regional address data that will make location search and geocoding more effective and user-friendly.

- Design and implementation of compatibility for future booking and payment options in moovel's RideTap product so customers can plan and pay for their trips in one app.

The resulting systems, all open source software and open data, will support the rapid deployment of the intermodal transit trip planner throughout the transit industry. The open source trip planner is sustainable beyond the Mobility on Demand (MOD) demonstration, and will be able to leverage new enhancements as they get rolled out to the OTP development community and transit industry. Future enhancements could include full integration with a mobile ticketing platform, meeting a common request of transit customers. Collaboration in the transit and open source software development community is growing in strength; it is important to leverage these resources as new software is constantly under development. This collaborative approach will continue to empower public transit agencies to provide low cost, sustainable, scalable solutions to customers at a national level.

1.3 Project Tasks and Deliverables

Below are the major tasks of the project and associated deliverables for each of the tasks.

Task 1. Project Management

IBI Group will be responsible for managing the project with assistance from the FTA project manager. This task provides for the overall project's management and coordination. Included in this effort are:

- An initial kickoff meeting
- Development of a project management plan (PMP)
- Maintenance of a project scope, schedule, and budget
- Project progress reporting to FTA via periodic meetings and quarterly reports

The recipient will conduct the project in accordance with the FTA Master Agreement (https://www.transit.dot.gov/about/regional-offices/region-10/fy-2016-master-agreement) and Circular 6100.1E (https://www.transit.dot.gov/regulations-and-guidance/fta-circulars/research-technical-assistance-and-training-program).

Deliverables:

- Kickoff meeting, including meeting materials and notes
- Draft PMP
- Final PMP
- Periodic meetings (e.g., conference calls, site visits)
- Quarterly progress reports

Task 2. Evaluations and Reports

2a. Equity and Accessibility

TriMet will develop a plan for how the project will address accessible and equitable mobility service for all travelers, including communities such as low income, the aging population, and persons with disabilities, including wheelchair users. In particular, the plan will discuss how the project will provide *equivalent* service for all travelers.

Deliverables:
- Draft plan on MOD equity and accessibility
- Final plan on MOD equity and accessibility

2b. Evaluation Data Collection and Coordination with the Independent Evaluator

The MOD Sandbox Demonstration local team will support the independent evaluation by providing input and review during evaluation planning and execution. The local team will coordinate with the independent evaluator to assist it in developing an evaluation plan and will provide the independent evaluator baseline and post-treatment qualitative data or qualitative and quantitative data as specified in the evaluation plan. The MOD Sandbox Demonstration local team will support the independent evaluator by providing access to the local team staff for surveys, interviews, and/or focus groups as identified in the evaluation plan. The local team will assist the independent evaluator with organizing and conducting surveys, interviews, and/or focus groups of team staff and MOD users as identified in the evaluation plan.

Examples of data that may be provided to the independent evaluator include, but are not necessarily limited to, the following:
- Please list as appropriate.
- Number of API calls, trip planner sessions, and percentage of correct geo-coder inquiries per typical weekday.

Deliverables:
- Baseline and post-treatment evaluation data

2c. Knowledge Transfer

The MOD Sandbox Demonstration local team will assist the FTA with MOD knowledge transfer. Such knowledge transfer activities may include, but may not necessarily be limited to, coordinating and communicating with other USDOT MOD activities, participating in USDOT-sponsored MOD Sandbox workshops and meetings, sharing information with other MOD Sandbox Demonstration sites, and communicating with industry organizations to provide awareness and knowledge transfer of the project and its scope, status, and results. Examples of industry organizations are the American Public

Transportation Association (APTA), Community Transportation Association of America (CTAA), ITS America, and Transportation Research Board (TRB).

The local team will assist FTA in producing briefing and presentation materials concerning their MOD Sandbox Demonstration project as needed and may be requested to produce supporting multimedia materials (pictures, video clips).

Deliverables:
- Presentation and briefing materials, including pictures and video clips
- OTP roadmap developed as part of the initial workshop
- Overview summary of the OTP system at the end of the project

2d. Field Demonstration

The MOD Sandbox Demonstration site will operate and maintain the MOD system for 6 months, as well as support the data requirements of the evaluation as discussed in Task 2c.

Deliverables:
- Demonstration

2e. Project Report

Towards the end of the project, TriMet will produce a project report describing the MOD system and documenting the project process, results, lessons learned, recommendations for future research, etc. from the local perspective. Evaluation results do not need to be included in the project report as the independent evaluator will be responsible for producing an evaluation report for the site.

The project report will be required to meet FTA reporting guidelines. The FTA reporting guidelines may be found at:
- http://www.fta.dot.gov/about/12351_8850.html and
- https://www.transit.dot.gov/research-innovation/preparationinstructionsforftafinalreportsjune2013

Deliverables:
- Draft project report
- Final project report

Task 3. Application Development

Application development includes enhancements to TriMet's existing OTP-based multimodal trip planning application, including both the underlying multimodal routing engine and the user- facing web interface.

Routing capabilities will be extended to reflect ongoing trends in traveler behavior and open data availability. Enhancements include the ability to incorporate shared-mobility services into multimodal trip planning (for example, use of a TNC service such as Uber or Lyft to access transit). Advances in the quality and availability of real time transit data will also be incorporated, with enhancements to the routing engine's ability to consume real-time data and modify trip plans accordingly. Other enhancements include support for the General Bikeshare Feed Specification (GBFS), and improved support for planning and describing wheelchair-accessible trips.

In addition to the enhanced routing capabilities, a comprehensive new web-based user interface (UI) will be developed. The new UI will incorporate aspects from existing OTP front-end projects, including TriMet's existing interactive trip planner, the otp.js library, and Conveyal's Modeify project. The new UI will be written using modern web development practices and frameworks, including the React framework and Redux architecture. This architecture emphasizes modularity and reusability of components in a variety of contexts; the intention is to build a library that not only serves as the foundation for a comprehensive new OTP UI but also serves as a resource for developers working on complementary project

Deliverables:

- Itinerary-based trip planning
- Search options and profiles
- Real-time integration
- Shared-use mobility integration
- Wheelchair/pedestrian routing
- Extended UI functionality
- Integration with TriMet website

Task 4. Geocoder Development

Mapzen is well positioned to implement a reference platform that will allow government transit agencies to feed their authoritative address data into a fully featured publicly accessible geocoding service. This can be done by leveraging the existing OpenAddresses framework and the public Mapzen Search API.

Although Mapzen Search already ingests OpenAddresses data on a regular basis there is a significant amount of work to be done to make it easier for agencies to feed their address data into this system. Mapzen will work with TriMet and Metro to forward a sustainable, intuitive, and resilient solution that will allow any authoritative address data to be added to the open transit ecosystem and ensure that sufficient user tutorials and documentation exist throughout the system. It is important to note that all the work will be open-sourced and based entirely on open data.

Mapzen will focus on validating this system across other agencies, not only those involved directly in the MOD project to ensure that it is in fact repeatable.

Deliverables:

- User research study
- Interactive data management tools
- Data ingestion pipeline
- Local installation package
- Point-based house number interpolation
- Testing and validation framework

Task 5. Data Improvements

Improvements will be made to the OpenStreetMap (OSM) basemap data so the trip planner can support enhanced pedestrian/ wheelchair accessibility information for customers. Regional address data will also be significantly improved to support location search and geocoding.

Deliverables:

- OSM improvements
- Regional address improvements

Task 6. Integrated Payment Plan

moovel will design and implement compatibility for future booking and payment options in moovel's RideTap product so customers can plan and pay for their trips in one app.

Deliverables:

- Report of findings to be included in final project report

1.4 Schedule of Tasks, Milestones, and Deliverables

Figure 1-1 Project Schedule

Table 1-1 Deliverables Schedule

Task No.	Task	Deliverable(s)	Delivery Date (months from project execution)
1	Project Management	Kickoff meeting materials and notes	One month
		Draft PMP	One month
		Final PMP	Two months
		Administrative Tasks (periodic meetings, conference calls, site visits)	Ongoing
		Progress reports	One month after end of Federal fiscal quarter
2	Evaluations and Reports	Draft MOD equity and accessibility plan	Six months
		Final MOD equity and accessibility plan	Six months
		Evaluation Data Collection and Coordination with the Independent Evaluator	To be specified in the evaluation plan
		Knowledge Transfer: Presentation and briefing materials, including pictures and video clips	As requested
		Field demonstration start	Twenty four months
		Field demonstration completion	Twenty four months
		Draft project report	Twenty three months
		Final project report	Twenty four months
3	Application Development	Itinerary-Based Trip Planning (Conveyal Milestone 1)	Three months
		Search Options and Bikeshare (Conveyal Milestone 2)	Six months
		Real-time Integration (Conveyal Milestone 3)	Nine months
		Shared-Use Mobility Integration (Conveyal Milestone 4)	Twelve months
		Wheelchair/Pedestrian Routing (Conveyal Milestone 4)	Twelve months
		Extended UI Functionality (Conveyal Milestone 5)	Fifteen months
		Integration with TriMet Website (TriMet Milestone)	Eighteen months
4	Geocoder Development	User Research Study (Mapzen Milestone 1)	Three months

Task No.	Task	Deliverable(s)	Delivery Date (months from project execution)
		Data Ingestion Pipeline (Mapzen Milestone 2)	Twelve months
		Interactive Data Management Tools (Mapzen Milestone 3)	Eighteen months
		Local Installation Package (Mapzen Milestone 4)	Nine months
		Point-based House Number Interpolation (Mapzen Milestone 5)	Six months
		Testing & Validation Framework (Mapzen Milestone 6)	Twenty one months
5	Data Improvements	OpenStreetMap Improvements (TriMet Milestone)	Twenty one months
		Regional Address Improvements (Metro Milestone)	Twenty one months
6	Integrated Payment Plan	Integrated payment plan and report (moovel Milestone)	Twenty four months

1.5 Budget

1.5.1 Budget by Fiscal Year

The total budget of the project is $1,002,000, of which $678,000 is the MOD Sandbox Federal amount, and $324,000 is in-kind contributions by project team partners. Anticipated budget breakdown by Federal fiscal year is as follows:

FY 2017 $379,000
FY 2018 $448,750
FY 2019 $174,250

1.5.2 Budget by Task

Budget breakdown by task is contained in Table 1-3 below.

Table 1-3 Project Budget by Task

Tasks and Other Activities	MOD Sandbox Federal Amount ($)	MOD Sandbox Cost Share ($)	Total Cost ($)

Task 1: Project Management	$80,000	$20,000	$100,000
Task 2: Evaluations and Reports	$40,000	$50,000	$90,000
Task 3: Application Development	$270,000	$70,000	$340,000
Task 4: Geocoder Development	$200,000	$64,000	$264,000
Task 5: Data Improvements	$70,000	$20,000	$90,000
Task 6: Integrated Payment Plan		$100,000	$100,000
Travel and Incidentals	$18,000		$18,000
Total Cost	**$678,000**	**$324,000**	**$1,002,000**
Cost Share Breakdown	68%	32%	

1.6 Evolution of the Project Management Plan

To be an effective management and communication tool, the plan must be a living document that is updated as conditions change. At a minimum, the project management team will review the PMP quarterly, and as major milestones are achieved. The version changes for the PMP are recorded in Appendix A.

1.7 Reference Materials

Additional information on schedule and budget can be found at the project website (https://trimet.org/mod/).

2 PROJECT TEAM ORGANIZATION

2.1 Organizational Structure

The organizational chart on the following page shows the key members of the OTP SUM team. The team is structured primarily around the main software development tasks (for OTP and the Pelias geocoder). In addition to being the client agency and lead on the grant, TriMet is responsible for integration of OTP SUM and the Pelias geocoder with existing systems at the Agency, including the TriMet.org website. IBI Group provides project management support, stakeholder outreach, and overall technical coordination between the development teams.

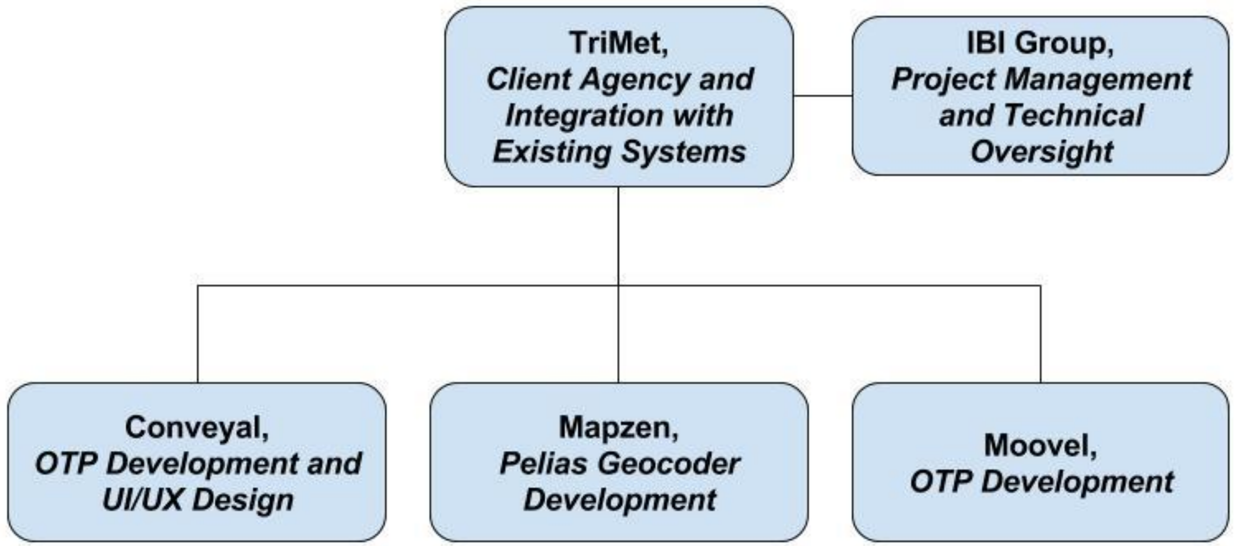


Figure 2-1: Key Project Team Members Organization Chart

2.2 Team Roles and Responsibilities

The roles and responsibilities of the team are highlighted below.

- TriMet
  - Lead Agency
  - Project Management
  - Local implementation of OTP and Pelias geocoder
- IBI Group
  - Project Management
  - Stakeholder Coordination
  - Technical Oversight
- Conveyal
  - Development team for OTP routing engine and front-end JS library
  - UI/UX Design
- Mapzen
  - Development team for geocoding engine, and OpenAddress data ingestion tool
- Moovel
  - Integrated payment plan

2.3 Staffing Plan

The staffing plan is outlined below in Tables 2-1, which identifies the tasks in which the key staff will be involved and the key staffs' general functions.

Table 2-1 Project Key Staff and Functions

Organization	Name	Contact Information	Project Task Number(s)	Role/Function
TriMet	Bibiana McHugh	mchughb@trimet.org	All	Principal Investigator
	Madeline Steele	steelem@trimet.org	1, 2c, 5	Project coordination, OSM data improvements lead

	Tom Lin	lint@trimet.org	3, 4, 5	General tech support, Geocoder testing
	Frank Purcell	purcellf@trimet.org	3	General OTP support
	Grant Humphries	humphrig@trimet.org	3, 4	Implementation of Pelias geocoder and OTP
	John Zimmerman	zimmermj@trimet.org	3, 4	Implementation of Pelias geocoder and OTP
	Ginger Shank	shankv@trimet.org	2b, 2d	Evaluation project lead, Beta testing project lead
	Dave Whipple	whippled@trimet.org	3	UI/UX design and TriMet branding
	Hannah Quinsey	quinseyh@trimet.org	2a	Accessibility advisor
	Jake Warr	warrj@trimet.org	2a	Equity advisor
IBI Group	Ritesh Warade	ritesh.warade@ibigroup.com	1, 2c	Project management, Stakeholder outreach
	Jon Campbell	jon.campbell@ibigroup.com	1, 2c	Project management, Stakeholder outreach
Conveyal	Dave Emory	demory@conveyal.com	3	OTP development lead
	Kate Chanba	kchanba@conveyal.com	3	UI/UX design lead
	Landon Reed	lreed@conveyal.com	3	OTP development
Mapzen	Diana Shkolnikov	diana@mapzen.com	4	Pelias development lead
Moovel	Ali Waters	ali.waters@moovel.com	6	Integrated payment plan

	Regina Clewlow	regina.clewlow@moovel.com	6	Integrated payment plan

3 PROJECT COMMUNICATIONS, MONITORING AND CONTROL

3.1 Coordination and Communications

Communications between the project team and the USDOT and its contractors will be primarily between the project team lead and FTA project manager. However, direct communications may be made between various MOD program entities (e.g., between the project team evaluation lead and independent evaluator) while informing the FTA project manager of the correspondence.

The following sections describe the proposed mechanisms for communicating and coordinating among the various program and project participants, and at the various management levels of the project. Meetings may be conducted in person or via conference call or webinar.

3.1.1 Communications and Meeting Plan

- Kick-off meeting to discuss the project goals and expectations, specifically the project approach, tasks and deliverables, partner roles and responsibilities, staffing plan, schedule, budget, and travel requirements.
- Bi-weekly (every other week) project status meetings and conference calls to review project activities and status. The meetings can be with all project team members or only among project management team members. An agenda and standard check-list will be developed to assure all aspects are covered at the meeting.
- Monthly project status meetings between OTP SUM project management team and FTA Project Manager.
- The USDOT may conduct site visits periodically throughout the project as a part of its project management and oversight responsibilities.
- The USDOT may organize workshops or communities of practice among the various program participants to discuss and address certain issues or topics of interest among MOD Sandbox Demonstration sites and/or the transit industry.

3.2 Project Tracking

The project will be tracked via the following methods and measures:

- A project website (https://trimet.org/mod/) has been developed for tracking progress. Most of the website is public facing, incorporating the following project tracking elements:
    - Interactive Gantt chart tracking task progress
    - Quarterly reports
    - Trello dashboard for real time task status, to-do lists and schedule milestones
    - Event and meeting summaries
- An internal version of the website also includes budget tracking

3.3 Scope, Schedule and Budget Management

The following sections outline the approach for managing the project scope, schedule and budget.

3.3.1 Scope Management

The request for scope changes will be first discussed within the project team and then elevated to FTA project manager for approval. A cooperative agreement revision/amendment is required by FTA for material changes in the work scope, in accordance with FTA Circular 6100.1E (IV.6)

3.3.2 Schedule Management

A Gantt chart and deliverables table will be used to monitor the schedule. During project meetings, team members will review the schedule status, and discuss actions/directions required to resolve schedule issues, if any. Minor schedule adjustments – those that do not affect the overall project schedule/timeframe – may be approved by the project team lead in consultation with the FTA project manager. Significant schedule changes will be decided by the project team and then elevated to FTA project manager for review and approval. A significant schedule change may be accomplished via an administrative amendment as outlined in FTA Circular 6100.1E (IV.6)

3.3.3 Cost/Budget Management

Cost/budget will be managed by the project team lead following Federal rules, regulations, and laws and local (e.g., state) rules, regulations and laws. Invoices will be submitted after the project team lead (or designated official) reviews the project progress, schedule, and expenditures. Payments will be based on progress (costs incurred for a period of time) or milestone completion. Requests for payments will be conducted in accordance with FTA Circular 6100.1E (V.8).

It is not anticipated that the budget for this project will change. Budget revisions, if any, will be conducted in accordance with FTA Circular 6100.1E (IV.6).

3.4 Change Management

As this is primarily a software development and implementation project, software changes are managed by GitHub repositories. Public repositories are available for all major project components. Software changes for TriMet specific implementations of OTP and Pelias are maintained in a separate, public repository. Other agencies can follow similar procedures.

3.5 Quality Management

Partners such as Conveyal and Mapzen will provide the main branch of stable code release as well as branches for development and staging. All deployments will be fully tested before going into production.

3.6 Risk Management

Potential risks and possible mitigation measures are identified in Table 3-1. These risks will be closely monitored and evaluated using the project progress review process. The table will be updated when status changes or new risks are identified.

Table 3-1 Potential Project Risks

Potential Risks	Mitigation Measures	Status
Data providers (such as Uber, Lyft, Biketown) will not provide required data in required format	TriMet working with other MOD Sandbox grant recipient agencies and TransitCenter to harmonize data requests from providers and work together to reach agreements with data providers.	OTP SUM team developing initial data request and requirements
OTP improvements will be delayed	OTP SUM team conducting progress review meetings every two weeks with development team	Development teams are on schedule
Geocoder improvements will be delayed	OTP SUM team conducting progress review meetings every two weeks with development team	Development teams are on schedule

4 PROJECT REPORTING

4.1 Project Reporting

The following reports will be produced to provide information on the project progress:

- Quarterly Progress Report – The project team lead shall submit a quarterly progress report (in MS Word format) to the FTA project manager via e-mail by the end of the month following the federal fiscal quarter, namely April 30, July 31, October 31, and January 31. The report shall include the significant accomplishments for the quarter; anticipated work for the following quarter; issues, if any, and recommended solutions; expenditures of the quarter and to date (cumulative), and submittal status of deliverables (see also FTA Circular 6100.1E [IV.4.d]). These reports will be posted in TRAMS by the FTA project manager.
- Milestone Progress Report – The project team lead (or the designated official) will provide a brief summary of the project progress, including milestone status, for the quarter in TRAMS as outlined in FTA Circular 6100.1E (IV.4.d). The report will be completed by the end of the month following the federal fiscal quarter.
- Federal Financial Report – The project team lead (or designated official) will submit a financial status report for the quarter in TrAMS as outlined in FTA Circular C 6100.1E (IV.4.c). The report will be completed by the end of the month following the federal fiscal quarter.

4.2 Document Review/Revision/Acceptance Process

The deliverable review flow is as follows: draft for internal team review and comment → revision (if required) → draft for FTA review and comment → revision/final draft → team review (and revision if required) → submit to FTA for final review (and comment if required) → approval or final revision if required. The document review schedule will be closely monitored and tracked.

Appendix A Document Version Changes

Version No.	Date	Description of Changes	Status
1	03/16/2017	Initial draft	
2	3/29/2017	Removed section 1.5.2 – Budget by Category at direction of Nazy Sodhi, FTA.	

APPENDIX

D

Kickoff Workshop Report

TriMet MOD Grant Kickoff Workshop Report

TriMet
OTP SUM: OTP Integration of Transit with Shared-Use Mobility, Real-Time, and Data Enhancements

Mobility on Demand Sandbox Program
Workshop Kickoff Report
January 18-19, 2017

PROJECT SUMMARY

Overview

TriMet's project includes the development and expansion of two core data frameworks that current and future collaborative OpenTripPlanner (OTP) initiatives can be built upon, producing replicable software and results for communities across the country. These two core project elements are to:

- Extend the OTP code base to integrate shared-use mobility modes into transit trip planning, such as bike share and Transportation Network Companies (TNCs), and updated real-time transit information.
- Implement a fully-functional and comprehensive open source geocoder built off the existing open source Mapzen Pelias geocoder. Geocoding, or 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 transit systems to offer a trip planning tool and can achieve significant cost savings for transit agencies, government agencies, and the public.

In addition to developing and expanding core elements on the foundation frameworks, the project will also include:

- Development of a new, comprehensive web-based user interface that will allow users to make intermodal trip plans including shared-use modes. The new interface will also display real-time information and report impacted itineraries to users.

- Improvements to basemap data, enabling the trip planner to support enhanced pedestrian/wheelchair accessibility information.
- Improvements to regional address data that will make location search and geocoding more effective and user-friendly.
- Design and implementation of compatibility for future booking and payment options in moovel's RideTap product, allowing customers to plan and pay for their trips in one app.

The resulting systems, all utilizing open source software and open data, will support the rapid deployment of the intermodal transit trip planner throughout the transit industry. The open source trip planner is sustainable beyond the Mobility on Demand (MOD) demonstration, and will be able to leverage new enhancements as it gets rolled out to the OTP development community and transit industry. Future enhancements could include full integration with a mobile ticketing platform, meeting a common request of transit customers. Collaboration in the transit and open source software development community is growing in strength; it is important to leverage these resources as new software is constantly under development. This collaborative approach will continue to empower public transit agencies to provide low cost, sustainable, scalable solutions to customers at a national level.

Project Goals and Objectives

Goal: Improve the open source, non-proprietary OTP system and make it easier to deploy for other transit agencies.

Specific objectives:

- Allow users to get information about and compare Shared Use Mobility (SUM) options in addition to transit, bike, and walking options in OTP
- Provide users with a more accurate matching of addresses when using OTP
- Improve the usability and design of the web-based OTP interface
- Provide users with real-time information regarding their trip plans, and any impacts thereon

Project Key Partners

Organization	Organization Type	Role	Contact
IBI	For-profit entity	Project Management	Ritesh Warade
Conveyal	For-profit entity	Application Development	David Emory
Mapzen	For-profit entity	Geocoder Development	Diana Shkolnikov

Oregon Metro Data Resource Center	MPO	Regional address data maintainer/provider	Robert Kirkman
moovel	For-profit entity	Integrated payment plan	Regina Clewlow

WORKSHOP GOALS AND OBJECTIVES

On January 18th and 19th, 2017, TriMet held a two-day workshop to kickoff the OTP SUM project. With attendees representing not only the OTP SUM project team, but also other OTP stakeholders, the workshop had the following goals and objectives.

Goals:

- Establish a vision for OpenTripPlanner incorporating the various OTP initiatives underway
- Kickoff and coordinate technical development for the TriMet OTP SUM project

Objectives/Expected Outcomes:
Everyone leaves workshop with common understanding of:

- What their development objectives are
- What they need to do to meet TriMet technical requirements
- How their tasks interface with the other components of the project and broader OTP ecosystem

WORKSHOP ATTENDEES

Participating Agencies and Companies	Out-of-Town	Local	Remote	Total

AC Transit Piush Dahal Manjit Sooch			2	2
Cambridge Systematics Paul Sorenson David Benoff Simon Jacobs	3			3
City of Portland & PBOT Steve Hoyt-McBeth Anne Hill		1	1	2
Conveyal David Emory Kate Chanba Landon Reed	3			3
CUTR Sean Barbeau			1	1
IBI Ritesh Warade Jon Campbell	2			2
LA Metro Doug Anderson Mike Gibbs	2			2
Lyft Debs Schrimmer		1		1
Participating Agencies and Companies	**Out-of-Town**	**Local**	**Remote**	**Total**
Metro Robert Kirkman Tom Rippetoe Caleb Winter		3		3
moovel Regina Clewlow Courtney Longfellow Ali Waters Michal Nakashimada Scott Wilson Erin Collins	1	5		6
ODOT Mathew Barnes	1			1
Ride Connection		1		1

Kevin Chambers				
RTD Jonathan Wade Brett McDavid Judy Wang	3			3
Trillium Transit Aaron Antrim Thomas Craig		2		2
Uber Jon Isaacs Andrew Freeman		2		2
VTA Marshall Ballard			1	1
Totals: 20	**17**	**15**	**8**	**38**
TriMet		13	2	15

Note:
Out-of-Town = person(s) traveled from outside Portland Metro Area to attend in person
Local = person(s) from Portland Metro Area/vicinity and attended in person
Remote = person(s) attended remotely

WORKSHOP AGENDA

AGENDA **TriMet Mobility On Demand Sandbox Workshop** OpenTripPlanner (OTP) and Pelias Enhancements January 18-19, 2017	**LOCATION** TriMet Administrative Office Harrison Square Building Saltzman Conference Room (Located on P2, Parking Level) 1800 SW 1st Avenue Portland, OR 97201

DAY 1 WEDNESDAY JANUARY 18th		
8:30am	COFFEE/BAGELS	
9:00am	Nazy Sobhi, FTA	**Opening Remarks** MOD Sandbox Grant Award
9:05am	Gustave Cordahi, Booz Allen Hamilton	**Independent Evaluation of MOD Sandbox Projects**
9:10am	Participant Introductions	**Participant Introductions** Briefly state: name, organization, position, role/interest in project
9:30am	Ritesh Warade, IBI Group	**OpenTripPlanner (OTP) Initiatives Overview** - The OTP initiatives underway - How do these initiatives fit together? - What do we want to accomplish over the next two days?
9:45am	Bibiana McHugh, TriMet	**OTP Shared-Use Mobility (SUM) Project Overview** - Workshop Overview - OTP SUM Project Scope and Objectives
10:00am	Group Discussion	**Vision for OTP (SUM, FLEX, and other initiatives) in the MOD SANDBOX Context - Part 1**
11:00am	BREAK (breaks will be 20 minutes to allow people to check messages, etc.)	
11:20am	Group Discussion	**Vision for OTP (SUM, FLEX, and other initiatives) in the MOD SANDBOX Context - Part 2**
12:20pm	Neil McFarlane, TriMet General Manager Metro Councilor Bob Stacey	**Welcoming Remarks**
12:30pm	LUNCH (provided)	

DAY 1 WEDNESDAY JANUARY 18th		
12:45pm	Ritesh Warade, IBI Group	**Recap and Role of Next Sessions:** - Brief recap and additional observations on the prior sessions - Overview of afternoon sessions and their goals
1:00pm	David Emory and Kate Chanda, Conveyal	**Technical Presentation - Conveyal**
1:30pm	Thomas Craig, Trillium Solutions	**Technical Presentation - Trillium and Cambridge Systematics**
2:00pm	Diana Shkolnikov, Mapzen	**Technical Presentation - Mapzen**
2:30pm	Regina Clewlow, moovel Group	**Technical Presentation - moovel**
2:40pm	BREAK	
3:00pm	Bibiana McHugh, TriMet	**Technical Presentation and Discussion - TriMet**
4:00pm	Group Discussion	**Planning for Technical Breakout Sessions** (unconference sign-up style)
4:45pm	Bibiana McHugh	**Wrap-Up** - What's happening tomorrow? - Other next steps
6:00pm	**DINNER** Rock Bottom Brewery 206 SW Morrison St Portland, OR 97204	

Note: Afternoon technical presentations will include main project components and preliminary technical issues.

<table>
<tr><th colspan="3">DAY 2 THURSDAY JANUARY19th</th></tr>
<tr><td>8:30am</td><td colspan="2">COFFEE/BAGELS</td></tr>
<tr><td>9:00am</td><td colspan="2">Technical Breakout Sessions
• Routing Engine: Flex+SUM+RT+Accessibility
• UI/UX: Journeys and Scenarios; Testing Process
• Geocoding: Integration with OTP/Trimet Website</td></tr>
<tr><td>10:30am</td><td colspan="2">BREAK</td></tr>
<tr><td>10:45am</td><td colspan="2">Technical Breakout Sessions
• OTP Infrastructure & Testing: Build Management Decisions and Test Procedures/Change Management/Component Integration
• UI/UX: Flex+SUM+RT+Accessibility</td></tr>
<tr><td>12:30pm</td><td colspan="2">LUNCH (provided)</td></tr>
<tr><td>1:00pm</td><td colspan="2">Technical Breakout Sessions
• OTP Web Services/Middle Tier
• UI/UX: Integration with Trimet
• Fares/Incentives in OTP</td></tr>
<tr><td>2:30pm</td><td>Breakout Group Leads</td><td>Breakout Groups Report-Back
- Summary of what was covered
- Roadmap for next steps</td></tr>
<tr><td>3:45pm</td><td>Group Discussions</td><td>Business Strategies
- Identify Key Barriers for Agency Adoption
- Brainstorm, Discuss, and Prioritize Options and Solutions
- Business Strategy (marketing, procurement processes, etc.)
- Open Source Community Building Strategy</td></tr>
<tr><td>4:45pm</td><td colspan="2">Wrap-Up
- Key Observations
- Summary and Conclusions
- Identify Next Steps
- Meeting and Conference Call Schedules
- Draft Project's Scope, Plan and Schedule</td></tr>
<tr><td>6:00pm</td><td colspan="2">FINISH</td></tr>
</table>

SUMMARY DAY 1

The first day of the workshop was focused on laying the groundwork for the OTP SUM project. This began with project introductions, with FTA describing the MOD Sandbox grant program, Booz Allen Hamilton overviewing the program evaluation process, and Trimet and IBI outlining the goals and objectives for the workshop. The remainder of the day was spent laying the groundwork for the OTP SUM project.

<u>OTP Vision</u>
During the morning session, discussion focused on developing a long range vision for OTP as an open source initiative. Through this discussion, we were able to identify what OTP currently does really well for agencies, where additional focus and development is necessary, as well as determine technical priorities for tackling those issues. Key priorities that emerged from this discussion include:

- The integration of SUM and FLEX services into the OTP trip planning engine
- Future integration (in some form) of transit and SUM fare and payment information
- Improved open source alternative for OTP dependencies such as map tiles, geocoders

<u>Technical Presentations</u>
The afternoon sessions featured members of the OTP SUM development team introducing their proposed technical approach and functional requirements for the

project. Conveyal introduced their proposed React/Redux architecture to update OTP to a modern, responsive design, as well as mock-ups of the UI elements that will help OTP users integrate SUM modes into their transit trips. Mapzen provided an overview of Pelias, their open source geocoding engine, describing opportunities for customization when implementing a local instance for a project such as OTP SUM. In addition to the two primary OTP SUM development teams, moovel introduced their fare payment applications, describing how they have integrated SUM modes into their mobile applications. Also, Trillium Transit and Cambridge Systematics introduced their development approach for the VTrans MOD project to integrate GTFS-Flex into OTP.

For additional detail on the technical presentations, please consult the following appendices.

Appendix 3: Conveyal_TriMet_MOD_Kickoff
Appendix 4: Trillium - TriMet workshop flex presentation
Appendix 5: MapZen - MOD Kick-off 2017
Appendix 6: moovel TriMet OTP Kickoff

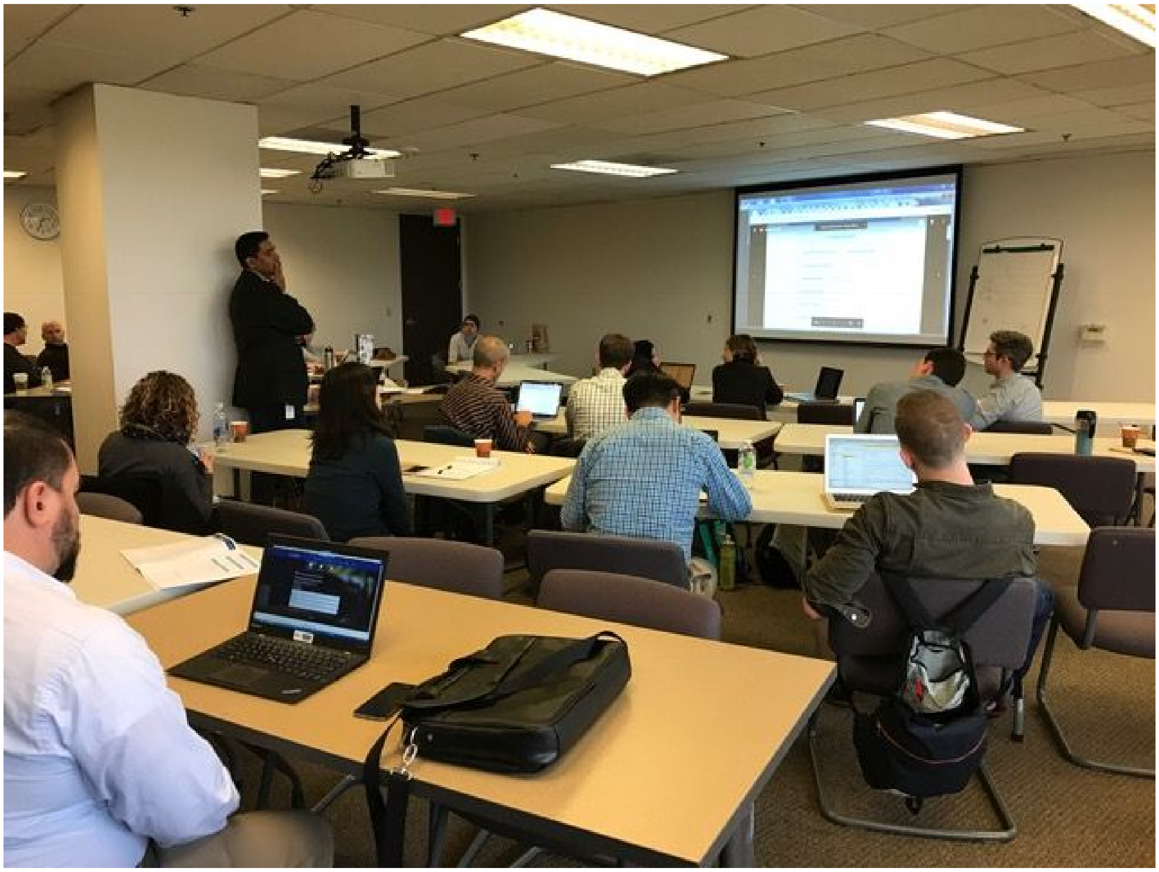
<u>TriMet Technical Overview and Requirements</u>

Bibiana McHugh provided a technical overview of Trimet's objectives and functional requirements for their implementation of the new OTP SUM front and back end. This included discussion of the functionality of existing geocoding solution used by TriMet (SOLR), which will need to be matched/surpassed by Pelias as part of OTP SUM. In addition, topics for future discussion emerged including the desired development process/approach for OTP/SUM and Pelias, defining a roadmap for integration of OTP SUM with the existing website, and ADA and other accessibility requirements on system design. This session closed with an overview of the management and collaboration tools and communication channels that will be used by the OTP SUM team.

For additional information, please see Appendix 7: TriMet Trip Planning Roadmap and Requirements

The day concluded with collaborative planning of the next day's technical work sessions.

SUMMARY DAY 2



TECHNICAL BREAKOUT SESSIONS

The workshop's second day consisted primarily of working sessions to tackle the technical questions and issues identified during the previous day's discussions, and leverage having so many OTP stakeholders and developers together to jump start design and development of the components of OTP SUM. Over three one and a half hour sessions, eight different working groups met. Each of these is described below.

1. Fares/Incentives in OTP

The Fares and Incentives working session focused on how to best incorporate fares into OpenTripPlanner, as well as the challenges of fitting fares into a data model such as GTFS. The discussion drew from the experiences of agencies such as LA Metro, who built a separate fare database and logic to handle fares during trip planning. In addition, they discussed the issue of how to handle fares in the OTP Graph. Solving for minimum fares would often yield cheap, but impractical trips. Instead, sorting by fare after identifying trips that best fit user preferences would be a way to better reflect how users incorporate consideration of fare into their trip planning process. Finally, the group touched on integration of fare payment and potential for incentives within OTP, looking at moovel's deep link integration of ride-hail trips with Lyft as an example.

2. Geocoding: Integration with OTP/TriMet Website

The geocoding session began with participants describing their agencies' experience with current geocoding solutions, emphasizing challenges such as complexity (incorporating transit-specific locations and price [high API license fees]). This pivoted to a discussion of requirements for Pelias, including address interpolation, location bias, and accounting for spelling errors in user input. The session concluded with a discussion of what needs to happen to update Pelias from its current state to meet TriMet's requirements, with a focus of incorporating custom data into the Pelias ElasticSearch data store.

3. OTP Infrastructure & Testing

a. Build Management Decisions

During this session, representatives from TriMet and Conveyal discussed the development process and build management tools for OTP SUM. TriMet and Conveyal both outlined how they each currently approach development and builds. In addition, Mapzen gave an overview of their development processes for the Pelias geocoder to inform Trimet's local install. This session ensured that the development teams and TriMet will be working in the same environments and frameworks during the OTP development process.

b. Test Procedures, Change Management, and Component Integration

This session established a testing and change management strategy for the OTP SUM project. TriMet will establish build, stage, and production environments, which will be consistent across project components. Integration testing and and acceptance tests were discussed. A variety of acceptance testing approaches were described, and future discussion among the project team will be necessary to finalize the OTP testing plan. Security considerations were also discussed including sensitive information (not an issue during current phase, but becomes a challenge with payment integration) and system stability concerns (rate limiting, load balancing, etc.).

4. OTP Web Services/Middle Tier

This session focused on whether UI's should interface directly with the server-side OTP routing engine or rely on a middle tier service to intercept API calls. Considerations for a middle tier included the ability to plan multi-leg (i.e. trip chaining) trips as a "stitched itinerary" as well as flexibility for what trip planning engine powers a particular UI instance. Several agencies shared their experiences using trip planner middle layers including RTD, whose middle tier filtered landmarks and other transit specific locations, and LA, whose middle tier ran fare calculations for planned trips. Key to this discussion was what aspects of a trip should be handled in the back end (common to all OTP implementations) and what should be handled by a middle tier (configured for each implementation).

5. Routing Engine: Flex+SUM+RT+Accessibility
This session focused on how to best integrate SUM, flex-service, real-time, and accessibility data into the OTP back-end routing engine. For accessibility, OTP can already leverage OpenStreetMap tags, which are being updated as part of this project to better map pedestrian and wheelchair accessibility. For SUM modes, the focus was on reaching consensus on what information is necessary to help OTP users plan a trip that includes a SUM mode. While additional discussion is needed to finalize SUM data requirements, key considerations were identified, including availability and time/space granularity of data. Whatever format the SUM data is provided in, it needs to be able to translate lat/long and time into availability and price information for that mode. Further discussion focused on user preferences for SUM trips, as well as the different types of trip planning scenarios (ie- real time data for planning a trip right now, or aggregate data for exploratory, narrative trip planning).

6. UI/UX: Flex+SUM+RT+Accessibility
This session focused on incorporating SUM and flex services into the OTP user experience. One particular challenge for both SUM and flex trips is communicating the complexity/details of these services (i.e.- the need to book a trip, or be on a certain side of the street to flag a stop), without overwhelming the user with text, particularly if the user is accessing OTP on a mobile device. This included discussion of what information about SUM trips (availability, wait times, estimated price) should be communicated to users, as well as graphic design considerations for how to display SUM or flex portions of trips. Next steps include: further developing icon sets and message sets for SUM and flex trips, and figuring out narrative directions vs. map visualization for SUM and flex trips.

7. UI/UX: Integration with TriMet
This session focused on how to integrate the new React/Redux OTP components into the existing TriMet website. Currently the homepage functions as a three task "app" with the trip planner, transit tracker, and service alerts. With the implementation of the new OTP, keeping the tool as integrated as possible is a priority. In addition, the interaction between OTP and Pelias was discussed, with OTP components passing user search inputs to TriMet's Pelias instance for geocoding.

8. UI/UX: Journeys and Scenarios; Testing Process
The final UI/UX work session focused on identifying user "journeys and scenarios." By mapping out how users will interact with OTP SUM, from first awareness to exiting the trip planner, the design team can tailor the application's UI to best meet user needs and expectations. A major consideration during this discussion was how to get people to use something they're less familiar with. The UI/UX must emphasize the "added value" of the updated OTP SUM over other trip planning tools. In addition, different users will have different preferences about taking multimodal trips. Getting the default setting for these preferences correct will be critical, as well as finding a balance between making it

easy for users to change their preference settings and not overwhelming users with choices/options/complexity. This session also touched on an initial discussion of the user testing that will occur during this project's second year.

<u>9. Technical Work Session Debrief</u>
Following the technical work sessions, representatives from each session gave a brief (5-10 minute) report back to the full group of workshop attendees. This gave everyone a level of familiarity with what was accomplished over the course of the day. In addition, teams were able to recognize areas of overlap or interaction between project elements that would benefit from additional discussion or meetings.

BUSINESS STRATEGIES DISCUSSION

To close out the kickoff workshop, all attendees reconvened for a discussion and brainstorming session about business strategies for OTP. This included strategies for both the broad OTP initiative, as well as individual agency implementations of OTP. Agencies in attendance explained their primary reasons for implementing OTP, including:

- The desire to not rely on third-parties for core agency services,
- Critical functionality is missing from 'out of the box' trip planning tools
- High cost of other (proprietary) trip planning options.

In addition, the group identified key barriers to further adoption of OTP by more agencies, which include:

- Procurement processes not designed to handle open source projects
- Lack of resources to do OTP build and integration
- Perception of IT as secondary service

Considering these two perspectives, the group discussed what OTP stakeholders could do to encourage adoption and improve the experience for agencies, with the end goal of making OTP the go-to option for agencies looking to implement a first trip planner or upgrade their trip planning capabilities. Peer exchanges and skill shares between agencies could help increase familiarity with and reduce uncertainty/anxiety over open source solutions such as OTP. In addition, the possibility of an OTP consortium of agencies, consultants, and developers, along with a clear visual branding of OTP could help spread familiarity of OTP amongst agency executives. An OTP consortium could also provide a structure for oversight and coordination across various OTP initiatives. The experience of other transit tech consortia was discussed, raising the questions:

- Are we headed towards consortium overload? With the proliferation of transit technology/data consortia, will stakeholders have enough bandwidth/capacity to meet the goals of these consortia?
- Are resources stretched to thin/diluted because of this?
- A lot of these groups are asking:
    - How do we fund this?
    - What value are we bringing to members?
    - How do we make it a durable initiative?

The current collaboration among the MOD Sandbox OTP projects, as well as the other active OTP initiatives is a critical first step to build an active network of stakeholders contributing to OTP. This will lay the groundwork for any future more formal OTP organization.

CONCLUSIONS

Key Observations

- There is momentum behind making significant changes and improvements to OTP in the coming few years, and especially as a result of the MOD grants
- The various parties - agencies, consultants, and vendors - involved in the various OTP improvement efforts need to, and are coordinating their effort
- TriMet, as the convenor of this workshop, can and is willing to help coordinate the various OTP improvement efforts

Next Steps

- Set up regular coordination calls/meetings for the various streams of activity for the TriMet OTP SUM project
- Set up coordination calls/meeting between the various other OTP improvement projects

APPENDIX

E

Pelias Geocoder External Assessment

FEHR & PEERS

Pelias Geocoder Evaluation

TriMet's OpenTripPlanner Shared-Use Mobility (OTP SUM)

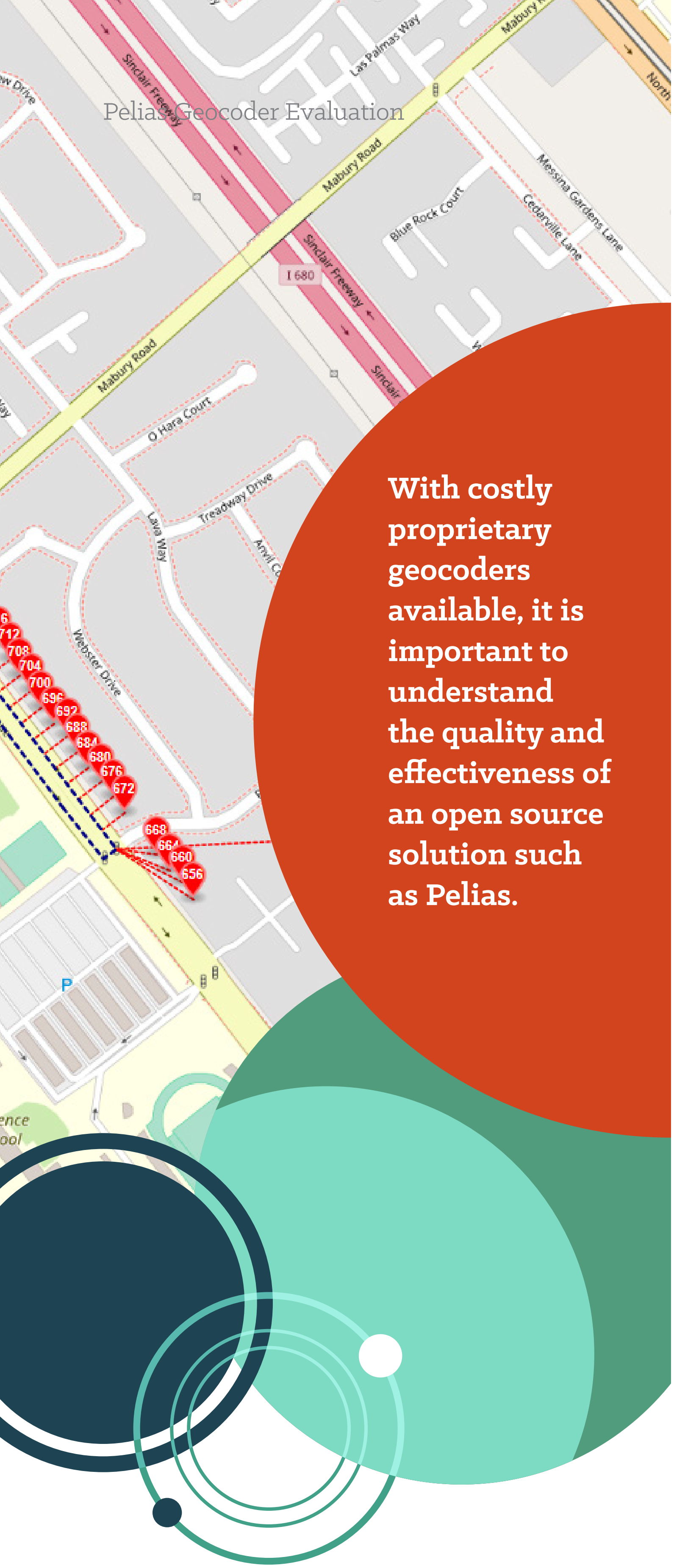
December 2018

TRIMET

MOD
MOBILITY ON DEMAND


RIGHT
2 LANES
ONLY
MAX
SW Morrison ST
HEALTHCARE
TRAINING
MAX

Table of Contents



With costly proprietary geocoders available, it is important to understand the quality and effectiveness of an open source solution such as Pelias.

Pelias Documentation Review

As part of the TriMet's OpenTripPlanner Shared-Use Mobility (OTP_SUM) Mobility on Demand MOD Sandbox Grant, Fehr & Peers has reviewed the functional geocoder for the trip planner. The geocoder is Pelias, an open source geocoder built on top of Elasticsearch for fast and accurate geocoding. Geocoding is a core function for any trip planner, especially with the TriMet deployment of Open Trip Planner. With costly proprietary geocoders available, it is important to understand the quality and effectiveness of an open source solution such as Pelias.

Pelias.io

Pelias.io is the homepage for the software. The home page thoroughly reviews the functionality of the geocoder, including but not limited to the architecture, broken down into three parts:

1. **Data importers**
2. **Database**
3. **Frontend services**

The main documentation page is built on Couscous and in addition to the homepage, it contains Code of Conduct, Contribute, and Fun Facts! The homepage has links to the Pelias GitHub site for many more components of the geocoder. The GitHub site links to information on all the underlying architecture, including API integration with Pelias and independent links to the respective software project's own home pages.

GitHub.com/pelias

The Pelias GitHub https://github.com/pelias account maintains much of the documentation. It currently includes 70 repositories catering to the development of the various components of the Pelias software. The Pelias repository https://github.com/pelias/pelias also contains the same information as pelias.io. More importantly, the existence of the software in GitHub allows a developer community to contribute to the betterment of the source code, enhance example projects, and share this open source software for individually hosted versions. The creators and curators of Pelias have made a conscious effort to extend an invitation to contribute to the software development, as can be found in the contributing section of the documentation. Subscribing to the issue board allows a contributor or user to follow development and issues encountered with the respective repositories.

Contribute Data

Core repositories to follow for the TriMet OTP_SUM project are where jurisdictional addresses are loaded in the Open Addresses project. The TriMet team built an integration platform to Open Addresses for the purpose of integrating address data for Pelias to geocode. The Address contribution software is located at https://mod.netlify.com/intro. The TriMet address contribution tool allows a method for easily uploading address data from a URL, .csv, or .geojson file, an ArcGIS service or a zip folder with applicable data types.

Pelias Installation Testing

Independently installing and running Pelias is the optimal method to test it. The documentation for deployment and installation was very clear and easy to follow. Leveraging the power of Docker and the provided documentation https://github.com/pelias/docker/ installation was navigable for an experienced Linux user with root access. It was installed on a Linux CentOS 7.5 with 2 processors running 8 GB of memory. Depending on file sizes setup can take a few hours.

Pelias Docker Installation

As recommended in the installation instructions, the initial deployment was made using the Portland metro project. This provided an opportunity to test the installation process and verify successful installation. It allowed Fehr & Peers to test Pelias based on the Portland metro area. The frontend services tested were Placeholder, point in polygon (PIP), and Interpolation, as referenced https://github.com/pelias/pelias#frontend-services.

Pelias Docker Project San José Metro

Using the GitHub repository for the docker projects folder https://github.com/pelias/docker a new project was created. The new project was the San José Metro. This was created then merged into the existing docker repository. Based on existing metro areas, the code was modified and can be found at https://github.com/pelias/docker/tree/master/projects/san-jose-metro. Using the data loaded from the address contribution software mentioned in the **Contribute Data** section, this project was successfully created and installed. Additionally, an open street map extract was found on the https://metro-extracts.nextzen.org.

The initial Metro Extract was specifically for the City of San José. It didn't include the majority of Santa Clara County. Another metro extract exists for the entire San Francisco Bay Area. The importance of the metro extract resides in the ability of the geocoder to find the applicable street to geocode to. Initially, we used the San José metro extract. However, the extract didn't include a few of the adjacent cities. Once we redeployed the source code with the larger San Francisco Bay Area metro extract, the geocoder was operational in San José's neighboring cities.

Interpolation Demo

Installing the geocoder enabled Fehr & Peers to test out functionality for geocoding. The reverse geocoding worked well. Placeholder, PIP, and Interpolation all worked and confirmed the functionality of the Pelias software. By simply clicking on the map in the interpolation frontend, all addresses loaded and associated to the metro extract streets show their location. The following page includes two images of the Interpolation tool from Pelias in downtown San José. **Figure 1** shows West Santa Clara Street and **Figure 2** show South Market Street.

Figure 2. South Market St, San José

Pelias Review and Conclusions

Accessing and installing Pelias was very easy to follow from the provided documentation. Leveraging the Docker repository allows for rapid deployment and installation of the software with little concern as docker manages the installation. Using specific metro extract areas can impact the functionality of the geocoder. Understanding the required data resources to create a fully functional geocoder is critical to the success of the installation. The use of the Pelias geocoder does require staff experienced in deploying a Dockerized software solution. Additionally, if it is to be used in an area not listed in the projects folder, one must code the pelias.json file to load the applicable addresses and the open street map extract area.

Editing the code is quite straightforward. However, there is no specific documentation on this. Savvy coding staff should be more than capable of using a previous example to their respective area. Overall, the documentation of the Pelias geocoder is substantial and well written to support additional deployments, testing, and participation in furthering the software development.

Leveraging Pelias for integration with additional software requires use of its API and a hosted installation. The hosted installation would be similar to the one shown for deployment of the San José metro projects. Integrating the API with additional software has some documentation of examples but could benefit from additional examples. This is expected to be rather routine for software developers and frontend developers to leverage the API call within their code. Pelias has a great future as an open source geocoder and the potential to integrate with many more projects in the future. The power of it being open source enables it to be tested widely and bugs exposed for correction. It is clear TriMet chose wisely for a geocoder to integrate into their new version of trip planner.

Pelias has a great future as an open source geocoder and the potential to integrate with many more projects in the future. The power of it being open source enables it to be tested widely and bugs exposed for correction.

APPENDIX

F

Regional Address Improvements Final

MAF Improvement Project

Contents

Summary

In 2018 TriMet and Metro created a partnership that aimed at improving the Master Address File (MAF), the region-wide address database. The goal of the project was to improve the quality of the MAF to increase the reliability of TriMet's new trip planner. Of roughly 800K addresses, only 0.49% address records were identified to have potential issues. Additionally, 3.75% (29,713) address records were found to need spatial adjustments to improve the accuracy of the new trip planner. The project team identified five areas of improvement as follows:

- Duplicate addresses
- Geocoding issues
- Address points not within buildings
- Address Prefix issues
- Zip code issues

When implemented, these improvements will make the MAF compliant with TriMet's requirements.

Metro shared the findings with the regional address maintainers, the authoritative sources of the address data. The improvements to the MAF are expected to be reflected staring on the first quarterly publication of the Regional Land Information System (RLIS) of 2019.

Background

In 2016 the U.S. Department of Transportation awarded TriMet a Mobility on Demand (MOD) SandBox grant to expand its trip planner, the OpenTripPlaner (OTP). A goal of the MOD grant is to breach the first and last mile gap of the transit systems. This requires door to door routing and the inclusion of additional modes of transportation. To achieve this goal, TriMet partnered with Metro, the Portland metropolitan area planning organization, who compiles a region-wide address database, the Master Address File (MAF). Metro's jurisdiction is comprised of 25 cities and the unincorporated areas of Clackamas, Multnomah, and Washington counties. Those partnering municipalities voluntarily contribute a variety of data to Metro, including addresses. Metro aggregates these data and publishes it for general consumption on a quarterly basis.

The TriMet-Metro project team evaluated the current state of the MAF as it pertains to the MOD grant objectives. The team identified five areas of potentials errors and where improvement would be needed:

- Duplicate addresses
- Geocoding issues
- Address points not within buildings
- Address Prefix issues
- Zip code issues

Methodology

The initial data used as the baseline was the August 2018 RLIS quarterly MAF. After identifying all the potential issues in the MAF, the project team started working systematically through every area of improvement identified. Every issue was investigated, a solution was formulated, and all the resulting addresses that needed to be improved were flagged and coded accordingly. At the end of this process, all the flagged addresses were moved to a database to be shared with the address data maintainers.

Additionally, the project team reviewed and flagged erroneous address points known to TriMet. TriMet has maintained a list of erroneous addresses in what is referred later in this document as the "TriMet's patch list."

The following workflows describe succinctly the methods applied to correct the five types of issues:

Duplicate points:

All MAF points were compared to find duplicate points. Points were considered to be duplicates if the address number, unit number, prefix, street name, street type, and jurisdiction city were identical.

Geocoding issues:

The MAF points were geocoded to the streets locator, and those that could not be matched automatically (< 1%) were flagged. The distance between the original MAF point and the geocoded point was calculated. Points were reviewed by descending distance differential. All incorporated areas were reviewed to a distance differential of 1400 ft. All areas (including unincorporated) that are part of zones MFR, MUR, SFR were then reviewed to 825 ft.

Points moved to building footprints:

Address points within a tax lot and not in a building footprint were moved to the centroid of the largest building (minimum 450 sq ft) on the tax lot. Tax lots owned by certain governments, utilities, and railroads were excluded.

Prefix issues:

Address points that have, or are likely to have, an incorrect prefix were identified by creating Thiessen polygons for each MAF point. Then, the resulting polygons were dissolved according to their prefix (N, S, NE, SW...). The number of points in each dissolved polygon was tallied, and those with the fewest points were manually reviewed as they were likely to be outliers.

ZIP Code corrections:

All MAF addresses were validated through the USPS ® Coding Accuracy Support System (CASS ™). Address records where the CASS validation corrected the 5 digit zip code were checked against the RLIS ZIP Code boundaries. All other addresses were also validated against the RLIS zip code boundaries.

Findings

Of 791,844 address points, only 0.49% address records were flagged for potential issues. An additional 3.75% (29,713) address records were found to need spatial adjustments. In this case, the address point locations did not intersect a building footprint. 86.8% of the address records in the TriMet patch list were identified and tagged for correction.

Duplicate points:

- 2674 records tagged as duplicates
    - 1296 addresses records have one or more duplicates based on the methodology

Geocoding issues:

- 2320 records reviewed
- 327 records flagged (14%)
    - 146 records with high confidence of a bad location (6.3%)

Points moved to building footprints:

- 29,713 address points (geometry) moved to building centroid (3.75% of all MAF points)

Prefix issues:

- 232 records tagged

ZIP Code corrections:

- 7042 records tagged for zip5 correction
    - 725 of those were not in RLIS zip code boundary

TriMet patch list:

- 205 records on the patch list
    - 178 (86.8%) records were identified and tagged

Total issues flagged:

- 3,917 records with unique Metro address ID’s (0.49% of all MAF points)
- 4,137 records in total
    - 220 records had multiple errors

In-kind Contribution

Metro provided in-kind contributions of staff time to the project. This included project management, technical expertise and labor. Management oversite was not tracked for the project. The in-kind value is $14,216.72. The table in Appendix A summarizes the contribution and the value as fully loaded labor.

Ongoing

The findings and supporting data have been distributed to the address maintainers. Metro requested all RLIS Partners (locator jurisdictions who assign addresses and maintain address point feature classes that are included in the RLIS MAF) to review the findings for their jurisdiction and where appropriate update the source for inclusion in the RLIS MAF. The deadline to implement and incorporate the improvements was set to the first quarterly (February) publication of the 2019 RLIS cycle. It is important to note that Metro does not have authority over the MAF data contributors. It is expected that the improvements will be implemented gradually as the contributors adjust their processes and production schedules.

Appendix A

Proje	Descr	Accou	Fu	De	Pro	Date	Emp	Name	St	Hours	Amount	Fully-Loaded Labor	Journal	Sour	Uni	Ledge	Peri	Ye
95660	TriMet GIS Support	501000	140	01320	89222	8/26/2018	000393	Erickson,Steven K	RG	17.50	$ 892.50	$ 1,960.15					2	2019
95660	TriMet GIS Support	501000	140	01320	89222	9/9/2018	000393	Erickson,Steven K	RG	11.00	$ 561.00	$ 1,232.09					3	2019
95660	TriMet GIS Support	501000	140	01320	89222	9/23/2018	000393	Erickson,Steven K	RG	5.00	$ 255.00	$ 560.04					3	2019
95660	TriMet GIS Support	501000	140	01320	89222	10/7/2018	000393	Erickson,Steven K	RG	7.00	$ 357.00	$ 784.06					4	2019
95660	TriMet GIS Support	501000	140	01320	89222	10/21/2018	000393	Erickson,Steven K	RG	1.00	$ 51.00	$ 112.01					4	2019
95660	TriMet GIS Support	501000	140	01320	89222	12/2/2018	000393	Erickson,Steven K	RG	2.00	$ 102.00	$ 224.02					6	2019
95660	TriMet GIS Support	501000	140	01320	89222	12/16/2018	000393	Erickson,Steven K	RG	29.00	$ 1,479.00	$ 3,248.25					6	2019
95660	TriMet GIS Support	501000	140	01320	89222	8/26/2018	012057	Murillo,Luis David	RG	10.00	$ 346.93	$ 761.94					2	2019
95660	TriMet GIS Support	501000	140	01320	89222	9/9/2018	012057	Murillo,Luis David	RG	3.50	$ 126.88	$ 278.66					3	2019
95660	TriMet GIS Support	501000	140	01320	89222	9/23/2018	012057	Murillo,Luis David	RG	1.00	$ 36.25	$ 79.61					3	2019
95660	TriMet GIS Support	501000	140	01320	89222	10/7/2018	012057	Murillo,Luis David	RG	4.50	$ 163.13	$ 358.27					4	2019
95660	TriMet GIS Support	501000	140	01320	89222	10/21/2018	012057	Murillo,Luis David	RG	6.00	$ 217.50	$ 477.68					4	2019
95660	TriMet GIS Support	501000	140	01320	89222	11/18/2018	012057	Murillo,Luis David	RG	2.00	$ 72.50	$ 159.23					5	2019
95660	TriMet GIS Support	501000	140	01320	89222	12/2/2018	012057	Murillo,Luis David	RG	1.00	$ 36.25	$ 79.61					6	2019
95660	TriMet GIS Support	501000	140	01320	89222	12/16/2018	012057	Murillo,Luis David	RG	16.00	$ 580.00	$ 1,273.82					6	2019
95660	TriMet GIS Support	501000	140	01320	89222	12/30/2018	012057	Murillo,Luis David	RG	33.00	$ 1,196.25	$ 2,627.26					6	2019
Grand Total										149.50	$ 6,473.19	$ 14,216.72						

APPENDIX

G

Integrated Payment White Paper

Practical Design of a Mobility on Demand Payment Platform

Written by moovel in collaboration with Tri-County Metropolitan Transportation District of Oregon (TriMet)

January 18, 2019

Table of Contents

Introduction

In fall 2016, the Federal Transit Administration (FTA) awarded 11 grants to public transportation providers to demonstrate multimodal, integrated mobility on demand projects through their Mobility on Demand (MOD) Sandbox Program. The goal of this FTA initiative is to create a “multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature.” As a recipient of a MOD Sandbox Program grant, TriMet has expanded the OpenTripPlanner (OTP) platform to include other mobility options such as ride-hailing, bike sharing and car sharing for riders to plan mixed-mode trips with a powerful, open source trip planning toolkit that other transit agencies are able to leverage.

As part of this project, TriMet will deliver a web-based user interface that allows users to plan intermodal trips, provides enhanced pedestrian accessibility information for customers, and establishes the design for a future MOD solution where users can book and pay for multimodal trips through a single interface. This whitepaper explores a practical design for the payment platform of a MOD solution. The general principles governing the design, potential limitations of the design, a high-level system architecture, and governance/ownership options to deploy the design into operation are discussed at a high level, as these items will vary due to different configurations, existing policies, and agreements put into place.

What is Mobility on Demand?

Mobility on Demand (MOD) gives people customized, reliable, and flexible transportation options by allowing them to search, book, and pay for public and private multimodal transportation services using real-time information about travel options, time, and cost. MOD will enable cities and their citizens to address congestion and environmental issues by increasing public transit adoption and car sharing. At its core, MOD is a solution that puts the customer first, allowing them to craft their journey to their unique needs, priorities, and preferences.

For this whitepaper, MOD is distilled into two primary functions:

- Multi-service provider/mode trip planning
- Multi-service provider/mode payment

Mobility in this context is the ability for an end-user (mobility customer) to get from Point A to Point B, and a mobility service provider is any entity providing a service that enables this mobility (public transit, shared rides, bike share, etc.). In this way, both the mobility customer and the mobility service providers are users of the MOD platform, with the platform connecting users to, and ideally encouraging use of, mobility services.

To successfully deploy a MOD solution, collaboration is needed among public and private partners. This includes collaboration around resources, expertise, and data, will all stakeholders agreeing on data, technology, and payment standards. In approaching an integrated payments solution, it is assumed that the mobility platform is provider-agnostic. For the payment component of the platform, which is the focus of this whitepaper, this means that the described system is not the exclusive payment platform of any one mobility service provider, and is equally accessible by all service providers.

Objective of the Whitepaper

The objective of this whitepaper is to describe a practical approach and system architecture for developing an integrated payment component of MOD. The whitepaper focuses on establishing a framework for an integrated payment solution by describing key design principles, high level limitations, and governance options for the solution.

Given the service provider-agnostic nature of the platform, it would be easy (and largely correct) to think of the payment platform as a "PayPal for mobility." However, the MOD payment platform is different from other commercial payment platforms because it is designed around the MOD concept. This allows it to meet the primary objectives of MOD, such as providing equitable access to all modes of transportation consolidating payment across providers and creating the opportunity for potential financial efficiencies. While mobility customers already have many payment options available to them (e.g., cash, credit cards, PayPal, Apple Pay, Google Pay, and service provider-managed payment platforms), the MOD payment platform is unique in that it is designed specifically to enable pricing incentives across mobility service providers, and based on their use in customized combinations, and allow the customer to pay for all services in one payment action

Together with the integrated trip planning features of a MOD solution, the payment platform is envisioned with the ability to encourage increased use and options for the mobility customer. With this in mind, this whitepaper will focus on the pricing policy configuration aspects of the solution. It will also highlight the benefits and challenges that come with this key feature of the system.

State of the Industry

Integrated payment solutions exist in various forms today. The following provides an overview of the solutions that are currently in operation.

Whim

Whim is a service provided by a Finnish company, MaaS Global (https://maas.global/), which provides a mobile app-managed monthly subscription service for the use of various mobility services (e.g., public transit, taxi, bike share, and car share). The service allows customers to select from several monthly plans, which range from providing discounted pay-as-you-go usage of each service to unlimited use of all services at a discounted rate. A key focus of the service and accompanying app is also connecting customers to those services so that it becomes the go-to source for customer mobility. The service is currently in operation in Helsinki (Finland), Antwerp (Belgium), and West Midlands (UK).

KVV

moovel Group GmbH and Karlsruhe Transport Authority (KVV) partnered on the launch of the joint mobility mobile app, KXX.mobil, powered by moovel. The app focuses on connecting customers to mobility services, and provides trip planning and departure times for all KVV services, as well as connections to bike sharing. The customer is also able to purchase transit tickets and reserve and pay for bicycles directly through the app. moovel has built the app as a white label platform that can be used to bring MOD services to other regions.

Suica/Octopus

The Suica system in Tokyo and the Octopus system in Hong Kong are in many ways the prototypes for MOD payment platforms. Initially implemented to support transit payment, both of these systems now allow customers to pay for transit and non-transit services using the transit provider-issued cards. This includes payments for mobility services, such as bike share and taxis, as well as retail payments at convenience stores, vending machines, and other retail locations.

These systems include many of the components of a modern MOD payment platform, including the account management and multi-party settlement discussed in this whitepaper. Where they differ is that they are both card-based, closed-loop-only payment systems. This means that all third-party support requires frontend integration to accept the systems' proprietary payment media and that a customer's payment options are limited to the value they load on to that media. This is in contrast to the proposed design presented in this whitepaper, which focuses on an open architecture and multiple payment options.

North American Transit

Many North American transit agencies are in the process of implementing account-based payment systems, or upgrading their legacy card-based payment systems to support transit fare collection. This includes implementations in Portland (Oregon), Seattle, New York, Boston, and many smaller metropolitan regions.

The account-based systems retain the account management and multi-party settlement functions of the legacy card-based systems, such as Suica and Octopus, while adding open architecture design, real-time transaction processing (i.e., pricing and authorization), and open payment functionality. In doing so, these systems are potentially well suited to become service provider-agnostic payment platforms like the one described in this document. Making that shift, however, will require the establishment of third-party pricing agreements with other mobility providers, and the design and deployment of frontend tools that enable the required pricing policies and settlement rules to be easily configured within the systems.

Foundational design principles

This section describes proposed design principles that create the foundation of the proposed payment platform architecture discussed later in the document. These key design elements allow the integrated payment solution to be open, partner agnostic, and user friendly.

Service Provider-Agnostic

A foundational design principle is that the solution be service provider-agnostic. This means that the solution will be as open, secure, and user friendly as possible to provide a low barrier of entry for all service providers. This simplifies the operation and eliminates the need for media integration as part of the payment platform. In other words, the solution must allow the integration of several different funding or payment sources, including closed-loop and open payment options. Additionally, service providers must support acceptance of different funding or payment sources integrated through the platform, allowing each service provider to provide and promote their own "payment media" (e.g., transit fare card, stored funding source, contactless bank card) to access any of the services integrated to the system.

This open and agnostic design allows for a variety of different solutions for the integrated platform. This design provides flexibility across transportation providers, allowing account-based payment platforms currently in place for transit and toll payments to potentially serve as an integrated payment platform. Through the use of standard integration or application programming interfaces, it also allows third-party integrated payment platforms to be leveraged, while still simplifying the integrations by the different service and funding providers.

Pre-Calculated Payments

The payment platform will need a pricing engine to support platform-specific pricing incentives (e.g., cross-service provider discounts). It is impractical for the payment platform to manage the core pricing policies for each mobility service provider, and for this reason, all service providers must send pre-calculated payments when a service is requested or provided. Based on known activity of the mobility customer, the payment platform will be able to modify the pricing (i.e., provide a discount), and send notification of the modified settlement back to the service provider.

Pricing Incentive Configuration

While the payment platform will accept pre-calculated payments, a key feature of the system is the ability to apply a pricing incentive (e.g., discount) to those payments. The ability for service providers or a third-party to define and configure those incentives is one of the most important and complex components of the payment platform. The *System Architecture* section of this whitepaper will provide more detail on the design and necessary features of this component.

Payment Options

The payment platform must provide flexible payment options support for both mobility service providers and mobility customers. For this reason, both closed-loop payments (i.e., using a payment platform-managed payment account, such as a transit smart card) and open payments (i.e., using payment cards such as Visa and Mastercard) processed through the platform are envisioned. Closed-loop solutions allow users that may be underbanked or unbanked to load value to a payment instrument using their preferred payment method.

Similar to PayPal, it will be up to the mobility customer, as a user of the platform, to elect how they want their transactions flowing through the platform to be processed. A customer may elect to fund an account held within the payment platform, or link an open payment instrument to their MOD account. It's also possible that payments could be split between these two options, and that a closed-loop account could be funded by entities other than the mobility customer (agency refunds, bonuses, transit benefits, etc.).

Account Registration

To use the payment platform, a customer would need to create and register an account within the system. As discussed in the prior sections, this "user account" could be linked to a payment account maintained within the payment platform, or an open payment instrument that is used to process payments through the payment platform.

Upon registration, the customer will be provided with account access. The customer will select use of the payment platform and sign into their account when selecting a payment method for mobility services ("Pay with my MOD payment account"). It is also possible that service providers could register customers "on the fly" during payment ("Setup a new MOD account and pay"), but this use case would require additional vetting to ensure that the customer is notified of the registration and is able to link additional service providers as necessary.

Challenges and Limitations

Implementing an integrated payment platform will encounter new challenges, and some of these can be anticipated. This section will highlight key challenges and limitations that will likely be faced in design and deployment of an integrated payment solution.

Integration with Legacy Payment Systems

Integration with legacy electronic payment systems, and card-based transit payment systems in particular, presents specific challenges for deployment of the MOD payment platform. Many legacy systems are designed to work in an offline mode, where price calculation is performed by payment terminals, using the balance stored on the physical media (e.g. the closed-loop card). The balance on the card is updated at the time the service is provided, without any external communications. Significant system design changes would be required to modify a payment transaction from a particular customer and process the payment through the MOD payment platform, instead of by the service provider's existing system.

Pricing Incentive Configuration

Pricing policies can be complex, and vary greatly among mobility service providers. The complexity of these policies grow exponentially when looking at pricing incentives that involve multiple providers. One of the challenges in implementing an integrated payment platform will be enabling the flexibility and variety in pricing policies that service providers want, while limiting complexity to a level that keeps the system usable and maintainable.

A related challenge will be defining and enforcing access rights for creating and managing the pricing rules contained within the pricing engine of the payment platform. This is both a technical and operational challenge, as service providers will likely want direct control in some instances, but this relies on having the appropriate agreements in place among the providers and appropriately maintained access rights to a useable configuration portal. This pricing engine and configuration portal is discussed in more detail in the *System Architecture* section.

Cross-Provider Media Acceptance

Any concept for payment integration usually leads to some discussion of payment media (e.g. physical card) consolidation. The ability to use a single payment card brings significant complexity of frontend equipment integration across multiple vendors, which cannot be understated. This temptation is not driven by consumer expectation, as most customers use a variety of payment instruments in their daily life, depending on the goods or service being paid for. This is also not essential to achieve the key goal of an integrated payment platform – enabling pricing incentives to drive mobility usage – which only requires payments flow through the platform, regardless of the physical media used to initiate or complete the payment. For all of these reasons, the solution described in this whitepaper focuses on account integration and not hardware integration.

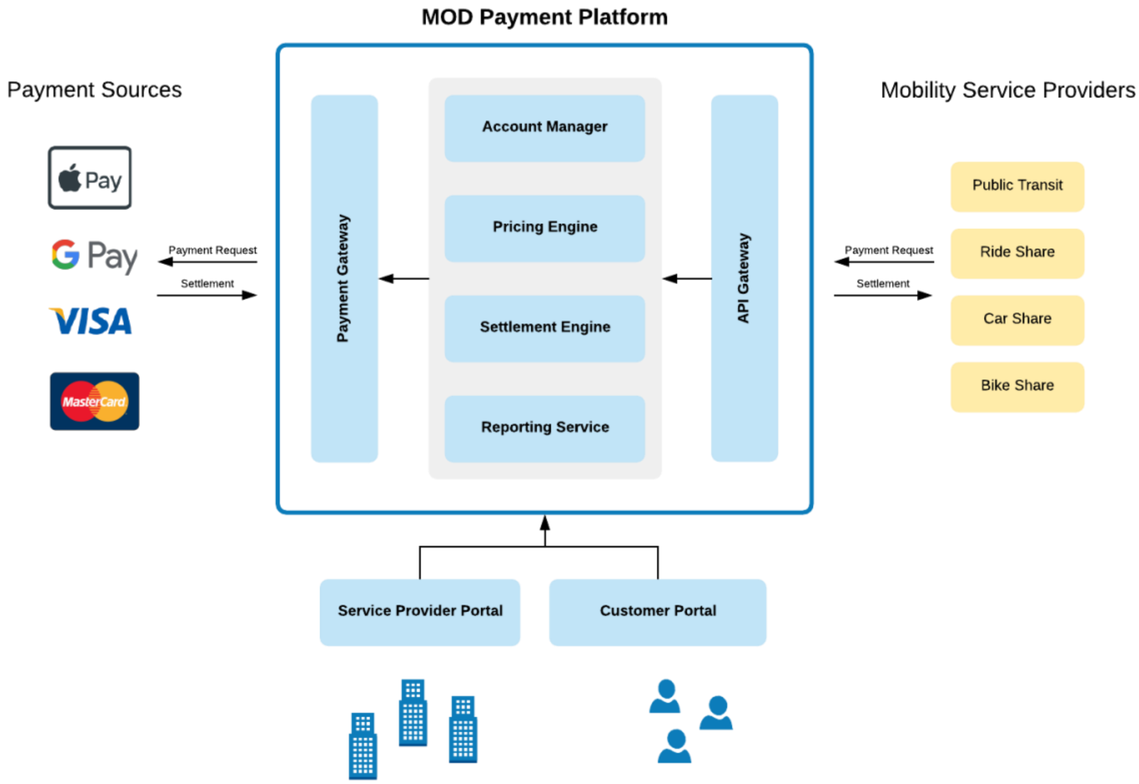
Financial Liability

One of the primary responsibilities of the owner/operator of the MOD payment platform will be the collection of funds from customers (across various payment sources), and settlement of those funds to the service providers. As such, the payment platform, and therefore the owner/operator, will be authorizing payment transactions sent from the services providers.

A key governance item will be resolving which party will hold the liability in the event that funds become uncollectable from the customer. In some cases, it may depend on the source of the funding. In cases where the payment platform is passing payment requests on to third-parties (e.g., credit/debit issuers) there may be existing rules in place that hold those parties liable to the payment platform owner/operator. Even in these cases, it may make sense for the owner/operator of the payment platform to guarantee payment to the service providers for authorized payments, as it will centralize any debt collection, and provide service providers reassurances in use of the platform. Financial liability is discussed further in the *Platform Governance Options* section of this whitepaper.

System Architecture

The proposed system architecture for a MOD payment platform is based on the design principles described earlier. The diagram below illustrates the high-level architecture of the platform and identifies the key components of the solution. Each of these components are described in greater detail in the following sections.



Account Manager

The Account Manager component of the system will maintain accounts in the payment platform for each mobility customer. As described above, the account may include a balance that is maintained within the payment platform and used to process closed-loop payments or a linkage to an open payment instrument against which payments are processed.

A common feature for all accounts maintained within the payment platform, whether they are used for closed-loop payment or open payment, is a detailed transaction history of usage by the customer for those services that are integrated into the platform (and linked by the customer). It is this recording of usage that will enable the platform to identify when the customer is eligible for a discount or similar benefit.

Because the customer must be able to identify the account to third-party service providers, all accounts are effectively registered, and so the designation between user and payment account, common to most transit systems, is not necessarily required. Account creation and registration is discussed further in the following sections.

Pricing Engine

The Pricing Engine component of the system will maintain the pricing rules configured within the payment platform and perform the calculation of any benefits due to a customer based on the transaction records received. As discussed earlier, it is anticipated that all service providers will send pre-calculated payments for the services provided, so that the payment platform does not need to enforce the unique pricing structures of each service provider that is integrated into the platform. Under this model, the payment platform will modify the calculated price (and notify the service provider) only if the MOD-specific pricing rules configured within the platform result in a discount or similar benefit to the customer.

A key element of the MOD-specific pricing rules will be incentives based on the use of multiple mobility service providers. Only the payment platform will have the requisite knowledge of this usage by the customer, as service providers will initially only have knowledge of the customer's use of their service. For this reason, these pricing rules must live in the payment platform and represent the key benefit of having the platform in place. Configuration of these cross-provider rules is discussed further in the following sections.

Payment Gateway

The Payment Gateway component of the system will process the fully priced transactions. For closed-loop payments, the Payment Gateway will pass the transaction back to the Account Manager. For open payments, the Payment Gateway may process payments through a variety of payment options supported by the platform (and selected by the customer). These could include a credit or debit card on file, or third-party payment platforms, such as Apple Pay, Google Pay, or PayPal. This component of the system will require the solution to be fully PCI-compliant, a responsibility that will fall upon the owner/operator of the platform.

Settlement Engine

The Settlement Engine component of the system will determine the financial, or settlement, positions of each service provider integrated into the system, and send funds to or request funds from the service providers, based on settlement calculations. The frequency of settlement, and the rules governing funds remittance, will be based on operating rules established for the platform.

The core element of the Settlement Engine must be an enterprise-level commercial accounting system with full Accounts Receivable/Accounts Payable (AR/AP) functionality. This system will enforce strict accounting controls and enable full auditing and reporting of all financial transactions flowing through the system. An interface to banking networks could enable automated settlement between participants, but manual execution of the settlement process is also possible.

Reporting Service

A key benefit to the integrated payment platform operator, mobility service providers, and mobility customers will be detailed reporting on the use of mobility services. A reporting service, ideally including an advanced data analytics engine, would be able to produce this information in various forms, from executive-level dashboards to data feeds used for import into other systems. What data is available to users, and in what format, will be managed through user-access rights.

Customer and Service Provider Portals

Web portals will provide users access to the functions of the MOD payment platform. Individual portals will be required for mobility customers and mobility service providers. The two portals will provide different functionality, yet be similar in the use of configurable user-access rights and intuitive User Interface/User Experience (UI/UX) design.

The mobility customer portal will provide the customer access to account creation, account management, and customer service functions. A customer will be able to create a new account (with a unique identifier) and link to the services where the account can be used for payment. The customer will also be able to view their transaction history and track the benefits granted through the platform.

The service provider portal is where the service providers would configure the payment platform-managed pricing policies, view settlement information, and access other reporting functions. As discussed elsewhere in this whitepaper, the configurability of the pricing policies, UI/UX to support that configuration, and user-access control to those functions will present one the greatest challenges in designing and deploying the solution.

Application Programming Interface Gateway

The very nature of the MOD payment platform, and its use by a wide variety of third-party mobility service providers, mandates that it be built on an open architecture. Key to the open architecture is an Application Programming Interface (API) Gateway that manages all communication between the payment platform and mobility service providers, as well as communication to other internal and external systems, such as the web portals and banking networks used for settlement.

It is critical that the API gateway make use of an enterprise-level API management tool to support API creation, documentation, versioning, access, and certification of third-party integrations. The owners of the payment platform may look to similar third-party payment platforms, such as PayPal, in designing the APIs for the system.

A whitepaper could be written on the design of the APIs alone. However, there are a number of key functions that the APIs must support:

- Account creation and management
- Payment processing request and response
- Settlement execution

Each of these functions, as well as additional functions identified throughout development, will require detailed definition as part of the payment platform design. The APIs will continue to grow in number and functionality as new service providers are integrated and the vision of mobility on demand is realized.

Mobility Pricing and Settlement

As discussed earlier, one of the greatest challenges in developing and deploying any integrated payment platform solution will be establishing the agreements that define the pricing policies and settlement rules across the integrated service providers. Equally challenging will be developing the tools that enable simple configuration of those rules within the system. While many of today's account-based fare collection systems are flexible in the rules they can support, a full design effort will be required to determine where gaps exist. Some of the key decisions around pricing and settlement are explored in this section.

Pricing Options

Pricing options configured within a MOD payment platform define what a mobility customer is charged when they use mobility services, and are truly limitless in their possibilities. With that said, common pricing policies can largely be broken up into two groups, subscription-based pricing and pay-as-you-go pricing.

Subscription-Based Pricing

Subscription-based pricing is packaged pricing that entitles customers to usage of multiple mobility services on a limited or unlimited basis for a flat rate per defined usage period. An example of subscription-based pricing is the Whim service described in the *State of the Industry* section of this whitepaper. This type of pricing is straightforward and can provide huge benefits to customers that plan to use mobility services as their primary mode of transportation, but can be complex in the agreements required between the various mobility service providers.

Pay-As-You-Go Pricing

Pay-as-you-go pricing is a model where the customer pays for each mobility service separately as they are used. Pricing incentives can be provided as discounts for various services, or discounts when the services are used in combination. There are also hybrid approaches, where a flat subscription payment entitles customers to discounts on pay-as-you-go services. Pay-as-you-go pricing models are typically simpler with respect to the agreements between the providers, as funds are collected for each service used, but more complex in the number and type of pricing rules that must be configured within the system.

Settlement Rules

The configuration of settlement rules may be related to pricing policies (i.e., what the customer pays), but are often largely unrelated. In a pay-as-you-go pricing model, service providers may be settled with exactly what a customer pays for use of their service, but it is just as likely that the agreements put in place require the sharing of discounts provided to the customer, irrespective of where the customer sees the discount applied. For subscription-based pricing, this separation between pricing and settlement is even more apparent. The flat fee paid by the customer may be split among the providers based on usage, a flat percentage, or any other settlement formula one could imagine.

The good news is that most modern fare collection systems, as well as some other payment platform solutions, provide this level of abstraction between payment and settlement, and are highly configurable with respect to each. As stated earlier, the real challenge will be in establishing the agreements that define these rules, after which a detailed design process will be required to identify any gaps between the configuration supported by an existing system and the desired functionality.

Platform Governance Options

A final consideration with respect to deploying an integrated payment platform is defining the governance structure, or who will own and operate the system. Although there are several different configurations for an integrated solution, we will examine, at a high level, three potential options. It is likely that this will be defined by where the system originates from, but it is also possible that the governance structure changes if an existing system is repurposed to serve as the MOD payment platform for a region.

Transit Agency Owned

As discussed elsewhere, modern account-based transit fare collection systems are well suited to serve as payment platforms, given the alignment in the core elements of their design. If this approach is taken, it is likely that a transit agency will continue to own and operate the system. In many ways, this is a natural fit, given the transit agency is also a service provider and understands the operation of the system. In this case, the agency can assume several different roles:

- Funding source – An agency such as TriMet may wish to allow Hop Fastpass™ stored value to fund a 3rd party services, such as a scooter, ride-hailing, car-sharing, or bike sharing
- Service provider – As the local transit agency in the region, the owner/operator of the integrated payment source would also be a service provider (in this case, the transit provider)
- Owner/Operator – As the owner and operator of the integrated payment platform, the agency would assume operation and maintenance responsibility for the integrated payment platform

There are several factors to consider when assessing this option, which can be summarized into two core areas: business and technical. The following considerations are not comprehensive, but are intended to provide examples as this option is evaluated.

Some business considerations are:

- Is the agency well positioned to establish the requisite agreements with private operators and other service providers?
- How will the agency approach the financial liability discussed in the *Challenges and Limitations* section?
- Is the agency able to support the internal staffing and external (e.g., 3rd party clients) resources needed for the integrated payment platform?

Taking a similar approach for technical considerations:

- If using an existing solution, is the solution is capable and scalable enough to achieve the overall goal of the integrated platform?
- Does the existing solution require modifications to the core architecture to support the new integrated payment platform?

Government or Joint-Powers Owned

Another potential option is a system that is owned and operated by a central government agency, which may in turn establish a joint-powers agreement with the service providers. In the latter scenario, some ownership stake may be shared between the participating service providers. A governmental entity, such as a Department of Transportation (DOT) that oversees the transportation infrastructure, may be well positioned to facilitate a large regional, integrated solution such as a statewide payment system. In this option, the governing agency may also be a service provider or funding provider within the integrated payment platform.

This option has the benefit of shared control, which may be attractive to the participants, but may also be complex in establishing the operating rules that govern the responsibilities of each party. At a statewide or large regional level, the joint-owned solution can provide convenience by coordinating and aggregating mobility services over a large transportation network. Agencies that are looking towards an integrated platform to influence commuter behavior on a large scale that spans several different jurisdictions may find that a separate platform for mobility payment integration is best owned and operated by a neutral government agency or joint-powers authority.

Commercially Owned

Finally, a third option is a platform owned by a commercial company. As an example, this is the type of system offered by MaaS Global, described in the *State of the Industry* section of this whitepaper. A key benefit is the for-profit nature of the solution can lead to long-term maintenance and frequent enhancement of the solution, at no cost to public agencies. This solution also outsources the establishment of third-party agreements to the company running the system. A potential downside of this approach is limited control and enforcement of equity by the service providers, including public transit operators and other government agencies.

Summary

Using these design principles and the proposed system architecture will allow for a flexible solution that is scalable from the smallest to largest implementations. By configuring the pricing policies in the payment platform, mobility managers will be able to offer new pricing options to customers that are not possible through non-integrated solutions. Many different service providers may in turn leverage the platform to generate greater customer benefit.

The proposed solution focuses on being vendor-agnostic, identifying common core components, and allowing software vendors to add features and functions to differentiate themselves in the marketplace, without increasing the complexity of integration. Through the use of standardized APIs, service providers may integrate with multiple vendors without unique and complex integrations for each city, region, or state. As seen in Europe, where transit agencies use standard APIs for their digital fare catalog service, this greatly increases the likelihood of having a solution that is replicable and easily expandable.

APPENDIX

H

Heuristic Evaluation Phase One

TRIMET MOD APP
HEURISTIC EVALUATION
-
QA PLAN & RESULTS

1. Profiles of participants

Our group of testing consisted of 5 professional testers. They tested the application at https://modbeta.trimet.org/map/#/.

Why did we use professional testers?

- Because they are exposed mostly to functionality and compatibility testing every day, they interact with a wide variety of products and have a good understanding of what makes things easy for a user to navigate a website, use an app, etc... Our testers are experts at evaluating a product from a user experience perspective.
- Our testers are familiar with our process for describing, documenting issues and providing constructive feedback.
- One of our testers is an expert in accessibility testing and was able to provide her perspective on the usability of the MOD App for users with different impairments: visual, mobility, cognitive and hearing.

Profile of our testing group

The testing group was selected for variation in transportation habits and preferences.
The group was not specifically selected for variation in age, ability, income or language.

	Gender	Uses Bike for Trans.?	Pub. Trans. User?	Uber/Lyft User?	Car2Go User?	Favorite Mode of transportation	Pub. Trans. Usage Frequency	Plan trips on Web/Mobile ?
User 1	F	Y	Y	Very rarely	Y	Bus, Bike, Walking	Frequently	Both
User 2	M	N	N	N	N	Car	Rarely/Never	Mobile
User 3	M	N	Y	Y	N	Bus, Uber/Lyft, Walking	Frequently	Both
User 4	M	N	Y	Y	Y	Bus, Walking	Frequently	Both
User 5	M	Y	Y	Y	Y	Bike, Walking	Rarely	Mobile

2. Strategy

The heuristic evaluation is set to take place in two phases to accommodate the schedule. Here is what we think would be the best approach.

The first study, conducted in October, consisted of an extended heuristic evaluation on all devices, including load performance and a light accessibility assessment. This report is on the results of that study.

The second study, scheduled in November, will be a light heuristic evaluation, focusing on the impact of the changes implemented after the first evaluation.

This allows ample time for designers and developers to decide which of the identified issues to address, as well as execute any changes in design or code.

3. Evaluation Method

Participants were given a list of tasks (realistic scenarios) to walk through just like a user would. They went through the product's flows and respective interfaces independently and analyzed the process and results against the goals and defined heuristics. When coming across an issue or an area for improvement, they recorded it. The participants were encouraged to deviate and play with the system in any way that felt intuitive to them, as well.

3.1 Tasks to be performed by testers

- Plan a bike trip to Pier Park from your current location. Check how long it would take you to go there knowing that your average speed is 4 mph and check what effort to expect based on the elevation.
- You are meeting with a friend tomorrow at Nike Headquarters in Beaverton at 3pm. At what time would you need to leave?
- Plan a trip to depart now from PlusQA to Portland International Airport.
    - What would be the fastest time if you don't have your own car?
    - Then you change your mind… what would be the cheaper cost if you cannot use a car or shared car as a transportation mode and don't want to walk more than ¼ mile?
- Your friend is visiting and you need to plan the day. You start your day at OMSI to go for a bike ride on the east side of the Willamette using Biketown. Then you want to bring your friend to the zoo using car2go. Then, you decide to come back to OMSI using transit.
- Plan a trip from the Portland Airport to Anna Bananas in St. Johns.
    - Plan transit only.
    - Plan transit plus Uber.
    - Plan transit plus Lyft.
    - Which one would you choose to take and why?

In the process of addressing these questions, users had the opportunity to experience getting transportation directions, finding distance and ETA, planning a trip and interpreting a trip plan. In addition, they were asked whether they would prefer that BikeTown trips only planned from and to bike hubs.

3.2 Other types of feedback from testers

At the end of the testing, we collected users' impressions with the following questions:

- What is your overall impression of the product?
- How did using the trip planner make you feel?
- What did you like best about the application?

- What did you like least about the application?
- How likely would you be to use this application yourself over another trip planner? Which trip planner?

3.3 Heuristics

We used a combination of heuristics based on Nielsen and Molich's ten user interface design heuristics and Ben Shneiderman's eight golden rules.

- Visibility of system status.
- Match between system and the real world.
- User control and freedom.
- Consistency and standards.
- Error prevention.
- Recognition rather than recall.
- Flexibility and efficiency of use.
- Help users recognize, diagnose and recover from errors.

3.4 Internet

While testing, we intentionally simulated a slow Internet service (below 3G) to observe the impact on the user experience.

3.5 Devices

Each tester tested on one Desktop and one Mobile device. Our devices and browsers included:

- Internet Explorer 11, Windows 8.1
- Microsoft Edge, Windows 10
- Firefox 62, Windows 10
- Safari 11, MacOS 10.13
- Chrome 69 (or latest), MacOS 10.13
- Safari, iPhone 8 iOS 11
- Safari, iPad Air 2, iOS 11
- Native Browser, Samsung Galaxy S9, Android 8.0
- Native Browser, Samsung Galaxy Tab A 10.1", Android 8.0

3.6 Record issues

- Reports were written to be as detailed and specific as possible and included the issue found, together with relevant details such as what the task attempted was, where they encountered the problem and why it is a problem. Reports also provided evidence; screenshots or videos to document the findings.
- Violated Heuristic was listed
- Severity of the issue was provided, following this classification system:

    0 = Not a usability problem but a suggestion
    1 = Cosmetic problem: does not need to be fixed unless extra time is available on project
    2 = Minor usability problem: fix is a low priority
    3 = Major usability problem: it is important to fix; high priority
    4 = Usability catastrophe: imperative to fix this before product can be released

- The detailed findings were organized by severity and heuristic

4. Findings

4.1 Heuristic Evaluation

MAJOR USABILITY PROBLEMS: IT IS IMPORTANT TO FIX - HIGH PRIORITY

#	Description of the problem	Screenshot (Link)	Heuristic violated	Severity	Recommendations
1	***Lack of interaction with the map*** Users did not figure out how to set a start location and destination point by using the map only. Users did not think about right-clicking on the map.	https://www.dropbox.com/s/7a09s17l8992jbm/Map_RightClick.png?dl=0	Flexibility and efficiency of use	3 = Major usability problem	Displaying a pin when users click on the map would help them to think about right clicking to retrieve more options.
2	***Mobile Specific*** ***Swiping between options is not intuitive*** There is no visual indication to guide users in accessing the different best bets or options. Currently, it is done via swiping but there is no indication of the required action. Users ended up not visiting the other options.	https://www.dropbox.com/s/2jseil8dxzgevzm/Swiping.png?dl=0	Visibility of system status	3 = Major usability problem	Arrows could help users to know they can access other options by swiping.
3	***Inconsistency in the address - Use of county instead of city*** Sometimes, auto-suggested addresses display the county instead of the city name. Users are uncertain if they selected the right address because they don't know the county.	https://www.dropbox.com/s/cxyrvoqgj30nqmu/TR_10.png?dl=0	Consistency and standards	3 = Major usability problem	Avoid using county names as users might not know them if they are not from the area
4	***Duplicate locations*** Some locations are duplicate or their full names cannot be seen so users think of them as duplicates. Users are unsure they picked the right address.	https://www.dropbox.com/s/07vsi51mzvblzy9/Finding%2016.png?dl=0	Consistency and standards	3 = Major usability problem	Provide unique address

		https://www.dropbox.com/s/pgaxjycriciehng/TR-SearchingLocations.png?dl=0			
5	***Incomplete results when searching for a business*** Users were not able to find some of the business, like PlusQA or Trimet	https://www.dropbox.com/s/sakenxevyo6aybc/Screen%20Shot%202018-10-15%20at%2012.13.11%20PM.png?dl=0	Consistency and standards	3 = Major usability problem	Make search database more robust, or hide the ability to search by business name

MINOR USABILITY PROBLEMS

#	Description of the problem	Screenshot (Link)	Heuristic violated	Severity	Recommendations
Aesthetic and minimalist design					
6	***Start location/Destination point can be difficult to spot on the map*** The color of the Start location/Destination pin is unique but its color blends with the bus line number sometimes making it difficult for the user to quickly see the beginning and the end of a trip. It does not catch eyes well and takes time to get used to.	https://www.dropbox.com/s/wihzrsoeiecppo7/StartDestination%20points.png?dl=0	Aesthetic and minimalist design	2 = Minor usability problem	Add contrast in the colors for the location/Destination points

Recognition rather than recall					
7	***Non-informative tab name*** The name "General" next to "Mode" made all users wonder what information can be found under that tab	https://www.dropbox.com/s/rq6i1hedm4jt56q/Findings%2013.png?dl=0	Recognition rather than recall	2 = Minor usability problem	Change the name "General" to something more descriptive. (Parameters maybe?)
8	***Mobile Specific*** ***Useful information on two different screens*** Price info is seen on a different screen than the trip info. It would be very convenient for users to have all info on a same screen	https://www.dropbox.com/s/m2trbm5ykp1r6fi/Findings%2022.jpg?dl=0	Recognition rather than recall	2 = Minor usability problem	Add info about time, bus, etc and price on a same screen
9	***Missing Total Cost*** When combining transit and Uber/Lyft in a trip, it might be nice to include a total price for the trip. Users like the ability to use cost to compare trips.	https://www.dropbox.com/s/ww9btma0al59wlp/Martin-4.png?dl=0	Recognition rather than recall	2 = Minor usability problem	It would be nice if the cost was totalled up for trips with multiple costs.
10	***Inconsistency in providing details about a trip*** User does not get any details about the route when "walk" only is selected. All other modes provide details about the trip.	https://www.dropbox.com/s/xijswt54ms2erii/TR-Walk.png?dl=0	Recognition rather than recall	2 = Minor usability problem	Add details about the trip even for the Walk mode
Help users recognize, diagnose, and recover from errors					
11	***Error messages not informative enough*** *Error message does not provide indication about why the trip could not be planned* - when clearing the departure/arrival time - randomly for some trip when transit and car are selected - Notification on disabled location tracking does not	https://www.dropbox.com/s/y0mvhydshjoo4dh/TR-Arrival%3ADeparture.png?dl=0 https://www.dropbox.com/s/jabo5k61o	Help users recognize, diagnose, and recover from errors	2 = Minor usability problem	- Have a message more specific to the problem - Notification should give user an idea on where to navigate to enable location tracking

	indicate a path how to enable location - when Start/Destination point are invalid	5q5afs/ErrorMessage.png?dl=0 https://www.dropbox.com/s/7qt7wkp9edw6w6u/TR_1.png?dl=0 https://www.dropbox.com/s/7djiykmobsg02je/ErrorMessage2.png?dl=0			
Flexibility and efficiency of use					
12	***Mobile Specific*** ***Small interactive area*** On tablets, only a small arrow leads to trip info. For fat fingers, it requires several tries before accessing the info	https://www.dropbox.com/s/n1bvvmxce2saw8s/SmallArrow.png?dl=0	Flexibility and efficiency of use	2 = Minor usability problem	The entire trip footer under the map could be tappable
13	***Main airport address doesn't show when searching "airport"*** User searches for "airport" and does not see the main terminal as a suggested destination. User must search "Portland International Airport" to see this.	https://www.dropbox.com/s/w7q1ltgn819pun2/Screen%20Shot%202018-10-15%20at%202.12.23%20PM.png?dl=0	Flexibility and efficiency of use	2 = Minor usability problem: fix is a low priority	Associate certain keywords with popular destinations.
Match between system and the real world					
14	***Bicyclists can't go by bike only*** Trip by bike includes alternating walking and biking sections (even when bike friendly is selected). Bikers are interested in trip that can be done by bike only.	https://www.dropbox.com/s/zg447i6tfm94rb4/Martin-1.png?dl=0	Match between system and the real world	2 = Minor usability problem	Suggest routes that can be done by bike only

15	***Unclear significance of "Polyline Measure" icon*** The label for the "Turn off Polyline Measure" icon does not speak the user's language enough. Users are not clear what this feature is for.	https://www.dropbox.com/s/ots1apus0bmo1qu/Findings%202.png?dl=0	Match between system and the real world	2 = Minor usability problem	Explanatory text appears when clicking the icon
Consistency and standards.					
16	***Misleading button*** Share/Save button indicates that user should be able to share the trip info or save it. However, it only copies the URL.	https://www.dropbox.com/s/5oc6y4zadxkztnn/TR_6.png?dl=0	Consistency and standards.	2 = Minor usability problem	It would be better to give users the possibility to share the route directly, using Messenger or Email for example, without making additional steps like opening applications manually.
17	***Map loads Portland by default - no current location on the map on Desktop*** On Desktop, there is no location pin which shows the user their current location. Users tend to expect a map to load with the current location.	https://www.dropbox.com/s/a9di1gytjrh3hjx/Findings%201.png?dl=0	Consistency and standards	2 = Minor usability problem	Display the current location pin even on Desktop
Visibility of system status					
18	***Misleading information about walking distance*** Setting the parameters for Maximum walk applies to a section of the itinerary instead of the entire trip. When users select the walking distance it is most likely for setting the maximum distance for the entire trip.	https://www.dropbox.com/s/glwssn5n1i24ilz/Findings%2017.png?dl=0	Visibility of system status	2 = Minor usability problem	The label under the general tab could be changed (Maximum walk per section for example).

COSMETIC PROBLEM: DOES NOT NEED TO BE FIXED UNLESS EXTRA TIME IS AVAILABLE

#	Description of the problem	Screenshot (Link)	Heuristic violated	Severity	Recommendations
19	***Mobile Specific*** ***Small font size*** Selected Mode icons are too small and not recognizable	https://www.dropbox.com/s/0gownk42f749zme/TR_16.jpg?dl=0	Flexibility and efficiency of use	1 = Cosmetic problem	Icons big enough that users can recognize them

NOT USABILITY PROBLEMS BUT SUGGESTIONS

#	Description of the problem	Screenshot (Link)	Heuristic violated	Severity	Recommendations
20	***Biker specific*** When planning a bike trip, there is no way to know which streets are better for biking. User can see Best Bet selection but the most bike-friendly option is not specifically shown.	https://www.dropbox.com/s/yxks3pwvqjayhhd/BikeFriendly.png?dl=0	Match between system and the real world	0 = Not a usability problem but a suggestion	If the user is directed to bike on less-than ideal streets for biking, it might be nice to include a little message to use caution or highlight which areas have heavier car traffic
21	***Bus or max lines are not clickable on the map*** Except for the individual bus stops, Bus or MAX lines are not clickable on the map. Clicking on them does not highlight them or give the user their name (such as Red Line Beaverton). This makes the map less interactive. If people are not familiar with this city, there is no way for them to learn the lines by just engaging with the map.	https://www.dropbox.com/s/5u7nuf8zsqxum7j/Findings%207.png?dl=0	Consistency and standards	0 = Not a usability problem but a suggestion	Display info about bus and max lines on the map upon clicking
22	***Transit Centers are not highlighted on the map*** Most of the commuters	https://www.dropbox.com/s/gxcythal3l2o	Consistency and standards	0 = Not a usability problem	Display transit centers with a different icon on the map, perhaps with

	navigate their routes in accordance with the transit centers. Those can be highlighted in bigger icons so that users can see them on the map easily, without much effort or research.	41k/Findings%208.png?dl=0		but a suggestion	the ability for user to click into it to see more details
23	***User cannot combine bike and car options*** Some car2go cars accept bicycles now, as do some Lyfts and Ubers.	https://www.dropbox.com/s/txvpghx3x5bovz5/bikeandcar.png?dl=0	User control and freedom	0 = Not a usability problem but a suggestion	The Trip Planner should try to accomodate trips with both bike and car in a bike-friendly city like Portland.

ACCESSIBILITY

#	Description of the problem	Screenshot (Link)	Heuristic violated	Severity	Recommendations
24	***Missing Disability icon*** if you are a person with a disability, an injury, or elderly, you probably wouldn't select "walk" but there is no option to leave that unselected without selecting "bike."	https://www.dropbox.com/s/36i76hxdli73oyv/Disability_icon.png?dl=0	Match between system and the real world	2 = Minor usability problem: fix is a low priority	Add a disability icon a mode of transportation
25	***Colors are not contrasted enough*** For a colorblind person, all the colors on the map are confusing. It is difficult to differentiate the user's trip from the transit lines. Non-colorblind users also pointed out that the map is cluttered.		Aesthetic and minimalist design	2 = Minor usability problem: fix is a low priority	User suggested to use a brighter color for the suggested route
26	***Keyboard focus issues*** The app has major keyboard focus issues, e.g. user who is using TAB instead of mouse cannot focus on Date/Time and	https://www.dropbox.com/s/2ugquabmd76vxih/TR_17.png?dl=0	Visibility of system status	2 = Minor usability problem: fix is a low priority	Ensure keyboard focus is present and ordered in a logical way

	Modes tabs. Sometimes the focus is completely missing, sometimes it's too pale.				
27	***VoiceOver*** Buttons are missing labels.	https://www.dropbox.com/s/qfkegoi327ylj5m/TR_18.png?dl=0 https://www.dropbox.com/s/xz116eb9yuoi36t/TR_18_2.png?dl=0	Visibility of system status	2 = Minor usability problem: fix is a low priority	Add ARIA labels to each field

4.2 Additional information

Answers to the question from Task 4 - *Plan a trip from the Portland Airport to Anna Bananas in St.Johns. What is your prefered transportation mode?*
4 users out of 5 chose transit only over car mode.

User 1	Transit only because it is cheaper.
User 2	Transit only because it is cheaper.
User 3	Max and Bus. This is the cheapest option.
User 4	Transit - much cheaper and time is only 30 more minutes.
User 5	Lyft - if it is in my budget and if I have to be there urgently.

Answers to the following question: Do you prefer that BikeTown trips only planned from and to bike hubs?

User 1	I would choose whatever bike is closest to me, regardless of if it's at a hub, but I would drop it off at a hub.
User 2	I don't use Biketown.
User 3	I don't use Biketown.
User 4	I would choose whatever bike is closest, especially if it's dark or I'm desperate. I would drop it off at a Hub to avoid a fee.
User 5	Picking up and dropping off at hubs would be most useful, but perhaps

	would be nice to have an option to select that as well as the pick-up-and-drop-off-wherever option.

Additional user observations which were personal preferences or otherwise subjective were collected during the evaluation. See Appendix.

4.3 Survey

What is your overall impression of the product?

User 1	User 2	User 3	User 4	User 5
Today I experienced some functionality bugs that got in the way. Google still functions better, e.g. I could not find 'PlusQA' using TriMet app. Many options are confusing: Now/Arrive/Depart or Walk/Bike/Biketown	It's nice but there are some functionality issues affecting the Web app which makes the user experience not very pleasant.	I think Google Maps gives you more information and it is easier to use than this app. Please note that I am familiar with Google Maps and this is a very subjective opinion. Also if I compare features from this app to Google Maps, like selecting multiple locations at the same time to plan a trip, I would rather use Google Maps to plan my trips in Portland.	It is decent. I would definitely use it, but it would not be my primary choice. I would definitely use it to get the most recent service alerts and the bus arrival and departure times. Other apps would not give more accurate information to me than TriMet's own planner. At least as a commuter, I would think so.	Trip planner was pretty easy to use and intuitive. They seem to know what most people are looking for in such a tool. It is pretty well designed and I like the map's features.

How did using the trip planner make you feel?

User 1	User 2	User 3	User 4	User 5
Stressed out in case of complicated tasks. The app is good for one way trips planning though; it's also good when you know the particular	Selecting trip options is a little bit tricky. Not very easy to select modes.	I feel a little bit frustrated that there was an option to select "Car" but results were given as a Trimet route was not available.	It was not impressed, but they added some cool features, like Lyft, Uber and Car2go. I liked the CTAs to these companies' websites.	Mostly felt good about my experience. I felt a little frustration when trying to plan a trip with car2go, or when trying to access the wrong

stop ID you're looking for				location listing for certain searches (Nike World Headquarters in particular).

What did you like best about the application?

User 1	User 2	User 3	User 4	User 5
It had the specific stop IDs, it's useful when knowing the stop ID you are looking for	Trip Details at the bottom of the direction. I like how it breaks down the cost between transportation options.	The feature that I liked the most was to be able to select the "Maximum Walk" distance.	I like the stops and the info you can get from the individual stops. That is so helpful. You can access timetables by clicking on any stops. I liked the different colors on the map and the gray background. It has a good looking layout.	I liked the usability of the map and its filter features. It is nice to be able to see the MAX/bus lines in a colorful and interactive way

What did you like least about the application?

User 1	User 2	User 3	User 4	User 5
At this point the app has major functional bugs, e.g. searching for Biketown will display results under 'Walk' title. I often could not 'unselect all' or 'select all' modes. This ruins the overall impression.	Selecting modes. No suggestion about what type of transportation I would be able to get to my destination the fastest.	I don't like the colors used in the map for parks. I am used to seeing a "green" color to identify the parks or recreational public areas. Same as the color of the water of the river. The map seems dark and not too attractive.	Missing traffic info. Missing traffic info in the itineraries as well. The destination icon blends in with some of the colors on the map. Also, the user cannot combine their selections, it does not give much freedom to the user. They cannot compare prices with Lyft, Uber, Car2go and Biketown.	Planning a bike trip and having the trip planner effectively tell me to get off my bike and walk for every other step. Not being able to unselect all transit options

How likely would you be to use this application yourself over another trip planner?

User 1	User 2	User 3	User 4	User 5
I will be using this app when I'm looking for the particular stop ID rather than planning a trip.	Since I drive everywhere, I would probably just continue using the Google Maps app on my phone.	If I were a Portland resident, I would probably use the app to plan specific trips but I would rather use Google Maps as my everyday app.	I will certainly use it, but TripGo would still be my primary choice. I do not trust the schedules or service alerts on TripGo though, so TriMet would give me the most reliable info - as there are many construction and delays going on in Portland nowadays. What I love about TripGo is it always shows you where you are on the route, so you can track yourself in the route to see at which bus stop you need to get off the bus or Max.	I would try it out. Generally Google Maps provides these services and more, including up-to date traffic info, but sometimes its public transit info can be spotty. I currently also use an app called PDX bus, which provides real time bus arrival data. That would be a key feature to include before I really make the migration to a new app.

4.4 Defects

We detected 8 functional issues: one is specific to a MS Edge on Windows, 3 are specific to mobile and 4 occur on all devices.

#	Platform	Issue	Screenshot
1	Microsoft Edge, Windows 10	Location/Destination field displays two X buttons which supposedly are having different functionality	https://www.dropbox.com/s/gygqbocbg3yd17a/TR_4.png?dl=0
2	All devices and browsers	Itinerary / Print Detail page is not scrollable	https://www.dropbox.com/s/jcld7a7qwx0pvg7/TR-Itinerary%3APrint%20Scroll.png?dl=0
3	All devices and browsers	After a trip is planned, if users use the back button from the browser more than once,	https://www.dropbox.com/s/fhu6idnmlxrp64n/backbutton.mo

		the app becomes unresponsive	v?dl=0
4	All devices and browsers	When the user sets the walking speed as 4 MPH, and they want to walk for only a mile, the itinerary asks them to walk more than a mile.	https://www.dropbox.com/s/glwssn5n1i24ilz/Findings%2017.png?dl=0
5	All devices and browsers	Truncated long addresses affecting usability	https://www.dropbox.com/s/61wzwzcjy9yb49h/TR_6_b.png?dl=0
6	Mobile Devices only	Edit button is off screen on tablet	https://www.dropbox.com/s/1rnolmt6wlptft6/Martin-6-mobile.png?dl=0
7	Tablets only	Main selection modals are not properly formatted for Tablets. There is too much white space.	https://www.dropbox.com/s/4rw05zscgbvjron/Findings%2020.png?dl=0
8	Mobile Devices only	Mobile - Direction detail page is not scrollable sometimes	https://www.dropbox.com/s/5qv9j2wg9r4byu7/TR-Mobile-Scrolling.jpg?dl=0

4.5 Conclusion

The heuristic evaluation of the MOD App revealed that there are no major issues in the design that are imperative to be fixed. However, we determined there are 5 issues of primary importance that would need to be fixed to enhance the user's experience.
-> # 1 Lack of interaction with the map
-> #2 Mobile Specific - Swiping between options is not intuitive
-> #3, 4 and 5 - Inconsistent results from the Search feature

We detected 13 issues rated as minor usability problems, 1 cosmetic problem on mobile and reported 4 suggestions.

The overall user experience is very similar on desktop and on mobile devices. Besides #2, which was a major issue, we reported only 3 minor usability problems specific to mobile users (#12 - size of interactive area, #8 - useful information on two different screens and #19 - small font size).

The first day of our evaluation, the application was not fully functional, especially the search feature and the display of the map on mobile devices. Users #1 and #2 encountered those issues which affected their findings and general perception of the application.

While testing, we intentionally simulated disconnecting from Internet service to observe the impact on the user experience. The application nicely handled the disconnection from Internet on both desktop and mobile devices.

From an accessibility perspective, we detected major problems that would prevent users with disabilities using assistive technology (keyboard-only and screen readers, for example) from interacting with the application.

The survey results indicated that while users who are not familiar with Trimet and/or who do not bike as their primary form of transportation are less likely to start using the application, current Trimet riders had more positive impressions of its usability and were more likely to use the application.

APPENDIX - ADDITIONAL OBSERVATIONS

#	User(s)	Explanation	Screenshot(s) if applicable
1	Users 1 and 2	When users choose Car mode for their trip, transit must also be selected. Therefore an itinerary cannot be executed entirely with Car only. Users are forced to use another app for planning a trip with car only.	
2	User 4	I noticed that the app gives you a "Service Update" message which is really helpful to let the user know that there is a faster route, in this case taking the 19, MAX Red Line to get to the Airport. This message, however, does not indicate that the user will have to walk more that 1/4 of a mile if they select this route. Remember that in this case user cannot use a car and don't want to walk more than 1/4 of a mile.	
3	Users 1 and 5	User is unable to plan a trip with car2go only because public transit cannot be un-selected. Perhaps the Zoo is not an allowed destination for car2go, but user is not provided with that information.	https://www.dropbox.com/s/gskhospbp94o0kk/Martin-5.png?dl=0
4	User 4	Transit Stop dots appear only after a certain zoom in range - this might be undesirable for some users.	
5	User 4	Car2go and Biketown info does not show the last updated info - this might be misleading to some users especially when they cannot find the car or the bike there, after they walk to these locations. It would be helpful to have a timestamp of when it was last updated.	https://www.dropbox.com/s/ky3hr9y6ed15ese/Findings%203.png?dl=0
6	User 4	The map misses the traffic info and graphics on the map The traffic info does not also appear on the itinerary. Traffic affects the bus schedules heavily, and the normal commute times with and without traffic are unknown to the user. Google Maps has the traffic info, even for the Bus view I believe.	https://www.dropbox.com/s/co3h45di80174om/Findings%204.png?dl=0 https://www.dropbox.com/s/ewc3ghzigrhvmed/Findings%204b.png?dl=0

7	User 4	User can choose arrive now option (to their destination), and the itinerary suggests them to leave 5 or 10 mins ago. That is illogical.	https://www.dropbox.com/s/0s8mm28cm7tfmji/Findings%205.png?dl=0
8	User 4	Plus icons on the map indicates hospitals, but clicking on them gives no information, even their name to the user	https://www.dropbox.com/s/45yc5nrpckftuj9/Findings%209.png?dl=0
9	User 4	Max and WES Stops have the same stop icons with the Bus Stops. Some users go with Max only, so distinguishing them might be helpful to users.	https://www.dropbox.com/s/jcyl5wowjgotfgw/Findings%2010.png?dl=0
10	User 4	Recently searched addresses should appear at the top of the search results, instead of the bottom	https://www.dropbox.com/s/h852lkxoqg8auhr/Findings%2011.png?dl=0
11	User 4	User cannot combine Walk and Ride options. For some reason they are asked to choose only one of them. This seems to be slightly illogical, since most of the time user has to walk to a biketown location.	https://www.dropbox.com/s/wmz6lmnydvd5dn6/Findings%2012.png?dl=0
12	User 4	User can choose only one of the Car options and that is confusing. User should be able to choose many car options at the same time to compare prices as well.	https://www.dropbox.com/s/5podfamgxuzgx59/Findings%2018.png?dl=0
13	User 4	Biking distance is limited to 10 miles. This can be an issue to some users.	
14	User 3	I believe there is a contrast issue with the time selector and the modes selector. I think there should be a line that divides both tabs or different colors to differentiate one from another. In this case the contrast would give the user the ability to intensify differences between this two tabs.	https://www.dropbox.com/s/cih7pzlsr3jqfsv/Screen%20Shot%202018-10-09%20at%202.58.22%20PM.png?dl=0

15	User 2	No description of what "Nike - Biketown" is. This may not be immediately understood by tourists or those unfamiliar with the program.	
16	User 2	No detailed direction to destination when user selects "walk" only	https://www.dropbox.com/s/xijswt54ms2erii/TR-Walk.png?dl=0
17	User 1	Notification on disabled location tracking does not indicate a path how to enable location	https://www.dropbox.com/s/7qt7wkp9edw6w6u/TR_1.png?dl=0
18	User 1	In the first tab, it is confusing that "Now" is included alongside "Depart" and "Arrive."	https://www.dropbox.com/s/w3cczj7km4gvdma/TR_5.png?dl=0
19	User 1	It's not clear that 'Current Location' is populating correctly, because the user sees the text 'Current Location' instead of the actual address.	https://www.dropbox.com/s/oulh9d1k43hc8z1/TR_7_b.jpg?dl=0
210	User 1	Search doesn't capture user typos or misspellings.	https://www.dropbox.com/s/9yc7fr5rooh0z8o/TR_9.png?dl=0
21	User 1	I didn't see the check mark and x buttons on the time selector at first so it wasn't exactly clear how to submit.	https://www.dropbox.com/s/aod93wxhvaqka4g/TR_12.png?dl=0
22	User 1	Bikestop icons were showing after I unselected Biketown	https://www.dropbox.com/s/0t5idnnw4stkwbm/TR_16.png?dl=0

APPENDIX

I

Heuristic Evaluation Phase Two

TRIMET MOD APP HEURISTIC EVALUATION

-

RESULTS OF THE FINAL SURVEY

1. Profiles of participants

Our group of participants consisted of the same 5 professional testers who tested the application during phase 1.

	Gender	Uses Bike for Trans.?	Pub. Trans. User?	Uber/Lyft User?	Car2Go User?	Favorite Mode of transportation	Pub. Trans. Usage Frequency	Plan trips on Web/Mobile ?
User 1	M	N	N	N	N	Car	Rarely/Never	Mobile
User 2	F	Y	Y	Very rarely	Y	Bus, Bike, Walking	Frequently	Both
User 3	M	N	Y	Y	N	Bus, Uber/Lyft, Walking	Frequently	Both
User 4	M	Y	Y	Y	Y	Bike, Walking	Rarely	Mobile
User 5	F	N	Y	Y	Y	Car, Walking, Bus	Rarely	Both

2. Evaluation Method

Participants, who were already familiar with the application, were given 45 min to interact freely and independently with the application, both on Desktop and Mobile of their choice.

Then, participants have been asked to respond to a survey with the following 8 questions, using a 1 to 10 rating scale with 0 = "not at all likely", 5 = "neutral" and 10 = "extremely likely":

1. Overall, planning trips was intuitive and easy
2. The map was easy to understand and interact with
3. Finding the location I wanted to find was easy
4. The "Travel Options" tab was easy to understand and use
5. Using mobile web was as easy as using desktop
6. How do you perceive the changes made to the application?
7. How do you feel using the application?
8. After having interacted with this application, how likely would you be to change your transportation habits?

3. Findings

1. Overall Score

#	*Questions*	*Average*
1	Overall, planning trips was intuitive and easy	8.2
2	The map was easy to understand and interact with	8.4
3	Finding the location I wanted to find was easy	7.8
4	The "Travel Options" tab was easy to understand and use	7.8
5	Using mobile web was as easy as using desktop	8.6
6	How do you perceive the changes made to the application?	8.6
7	How do you feel using the application?	8.2
8	After having interacted with this application, how likely would you be to change your transportation habits?	5.4

2. Results per user

Question #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
User 1	8	8	9	7	10	8	9	5[b]
User 2	8	9	3[a]	8	7	9	7	7
User 3	9	9	9	9	9	10	9	7
User 4	8	8	9	7	8	8	7	2[c]
User 5	8	8	9	8	9	8	9	6
Average	*8.2*	*8.4*	*7.8*	*7.8*	*8.6*	*8.6*	*8.2*	*5.4*

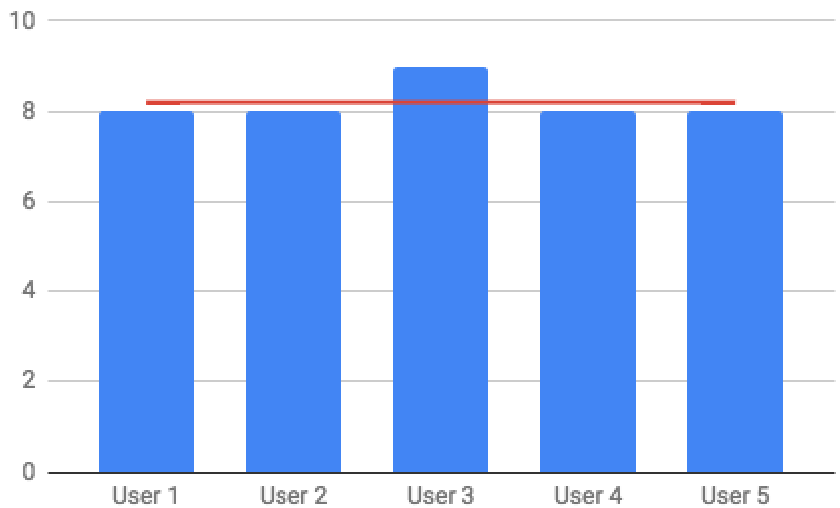
[a] the person scored that question low because the Search does not always provide results when searching for a name of a location instead of an address

[b] the person is primarily a car user but is open to the idea of using the app because of the multiple options available for planning trips.

[c] the person is mostly a bike rider; that application won't influence his behavior.

3. Results per question

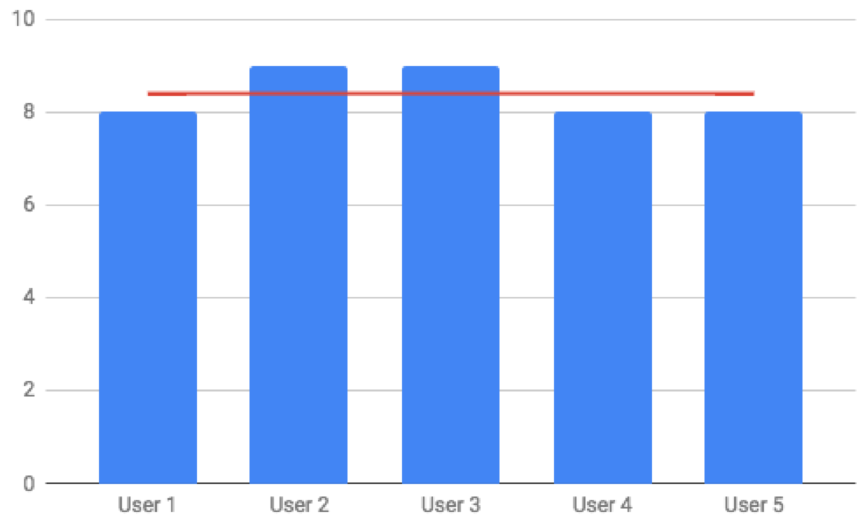
Question 1: Overall, planning trips was intuitive and easy



Comments

I had a great user experience when planning trips for now or in the future.
Yes, it was easy to plan trips on both desktop and mobile.
The best feature for me is the Biketown integration. Although I don't use Biketown, it seems like it could be convenient for some people to Bike to the nearest MAX station for instance. Having the ability to plan that into your trip is great.
It was easy to plan trips and get different options
Having a calendar popping up to select depart/arrival date in the future is very convenient. For future trips, selected time follows 12-hour format while the time in the tab follows 24-hour format

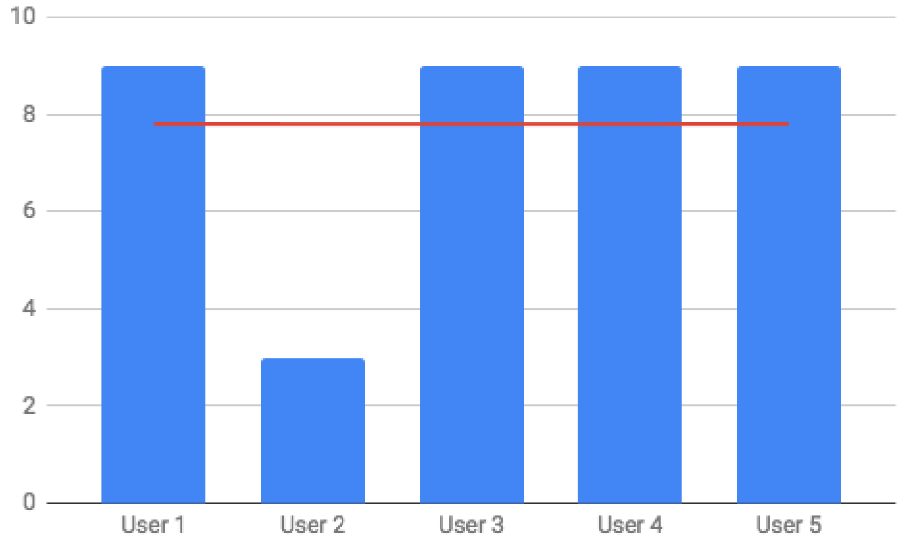
Question 2: The map was easy to understand and interact with



Comments

The map was easy to interact with.
Yes, the map was easy to interact with. Tooltips on each object were very helpful, as well as 'From here' and 'To here' links on those tooltips!
The map is easy to understand. However the Transit routes option in the map view has almost the same colors than the generic streets. It is too blend in for getting the information quickly.
It's very easy to switch between different filters for icons (Biketown, car2go, etc.). I was confused by the fact that Zipcar was included on the map, but is not an option on the Travel options tab.
Biketown locations do not appear in the Beaverton and Hillsboro areas, even though those bikes are there too.

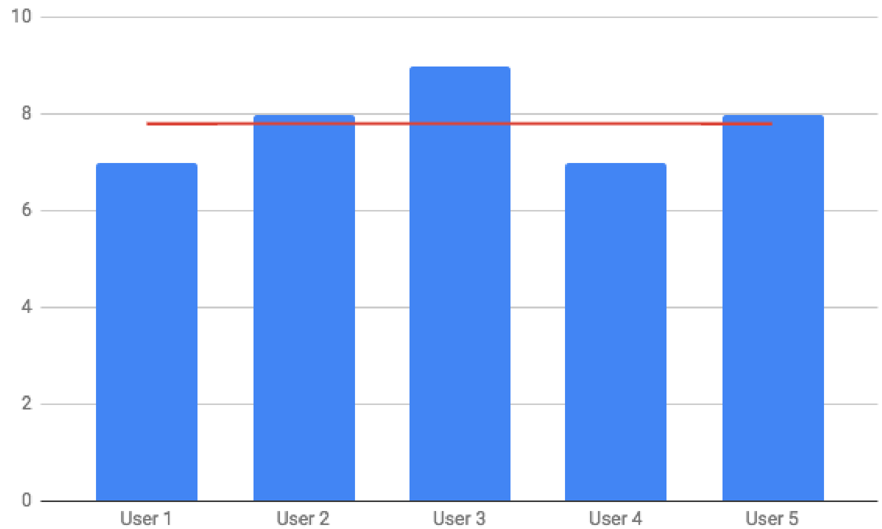
Question 3: Finding the location I wanted to find was easy



Comments

Auto suggested location finder works well, and it's very accurate. However some retail store locations cannot be found through the "destination" field by searching their names and I had to enter their actual address. Overall, very good!
Some locations that I wanted to find by typing their name into Search were missing (e.g. Plus QA, the Movement Center, Cinemark showing 1 result in Beaverton only, etc).
On iPad, when the user taps on the current location, it does not say you are here or current location, as the hover state does on the Web.
Location search is much improved. No more double results, and no more "Could not plan trip," as long as you don't select car2go.

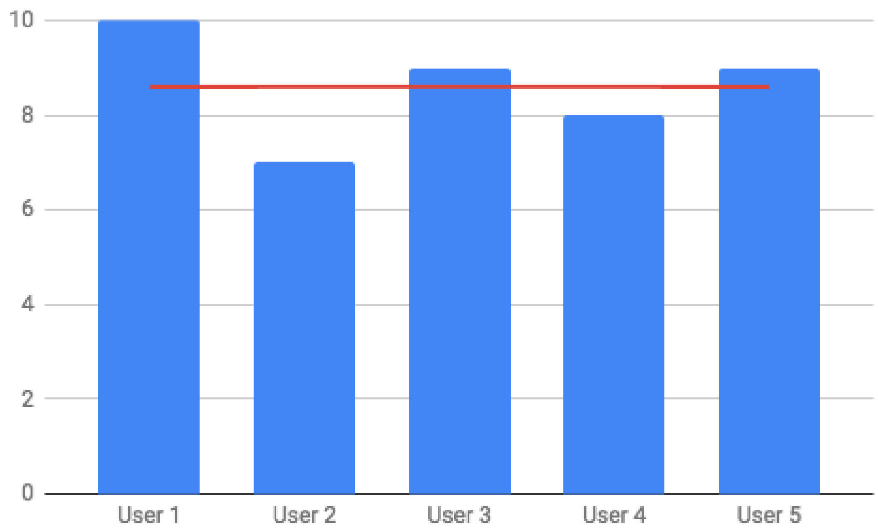
Question 4: The "Travel Options" tab was easy to understand and use



Comments

Within the Travel Options tab when user select the options in Travel Preferences section, The "Best Bet" option turns out to be not the cheapest nor the fastest route. Most of the times options 2 and 3 are faster and cheaper. For example, when user selects "Speed" as Travel Preferences, the fastest route displays as option 3.
It was much easier than before! However I got a bit lost when I wanted to combine some options: e.g. walking a certain number of miles and using Biketown for half of the route only. Since there are other options available that do not include taking transit (e.g. walking only/biking only), I considered it should be possible too (e.g. walking 3 miles + Biketown).
Very much so. The plus and the Trimet icons makes so much sense now. It is now clear that user would choose the other intermediaries to use Trimet as the final part of their transportation.
I was unable to include car2go in my trip in any way. Tried Setting car2go + transit to locations out of transit reach and got "Could not plan trip."
When the user intends to walk long distances, the max walk is set for 5 miles only - even when the destination is 10 miles away. Also, the Bike and Biketown CTAs are longer than the other CTA on the Web and shorter than the others on Tablets. This is a minor inconsistency in the layout.

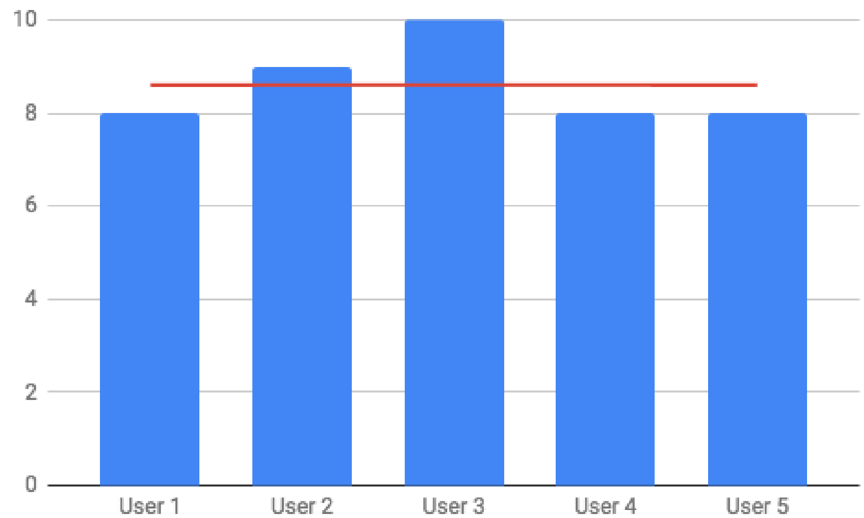
Question 5: Using mobile web was as easy as using desktop



Comments

I actually found it much easier to plan a trip on mobile than desktop. Drop-down option and carousel buttons to show the multiple ways to get to the destination is helpful.
It was mostly easy. Some features took me a while to find though. For example, 'Start Over' CTA is hidden at the bottom of an expanded search results option. I got a bit confused when I wanted to 'start over' while viewing the map (search results collapsed or not visible).
Yes. The only thing that was annoying was the Routes CTA overlapping with the From and To locations at times.
Mobile view is much better than before. Most screens make good use of the space on screen to display info, perhaps with the exception of the Set date/time screen, which still looks nice.

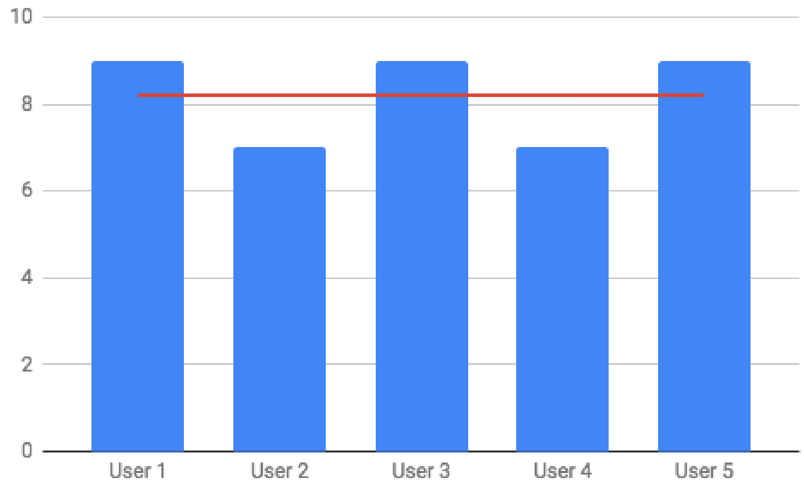
Question 6: How do you perceive the changes made to the application?



Comments

Overall, it's much better and definitely app has improved.
The thing I loved the most was the tooltips with 'From here'/'To here' links on each object on the map. I also loved the idea with the calories count and the feature allowing me to choose the max/min walking distance.
I like it a lot.
Changes improve the usability of the app, particularly the removal of double results and the improved experience on mobile.
Changes improved a lot my experience with the app, especially when trying to use rideshares. It is now very clear that we have to combine rideshare with transit. I did not understand that before.

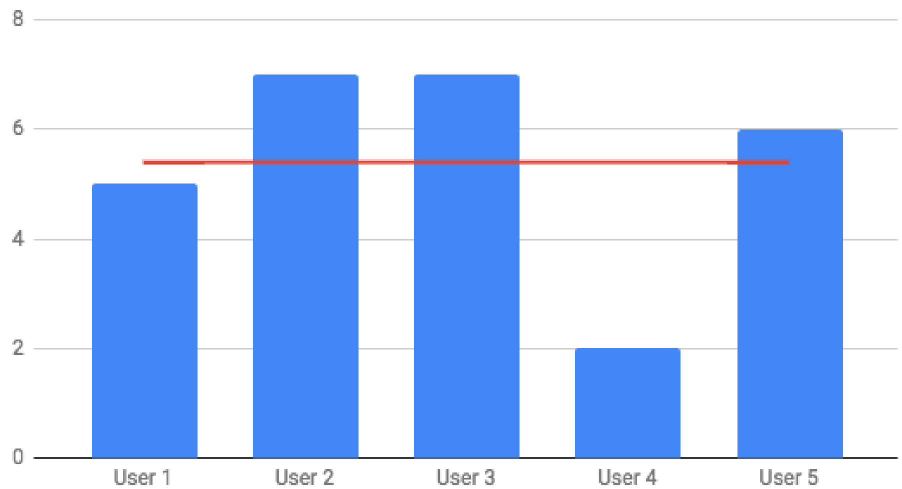
Question 7: How do you feel using the application?



Comments

I like it a lot and in particular the suggestion of multiple traveling options and the travel's cost.
The app is indispensable for Portland inhabitants and tourists, as it helps to navigate throughout the city using all possible kinds public transportation, combining it with other options (Uber, Lyft, etc).
It looks sleek and competitive. I can see it as a contender to the others, and this is something I can say it now!
The app allows you to coordinate up to two transportation methods and includes fare estimates for uber/lyft rides. This seems like it would be really helpful for people who live just outside of normal bus/max routes, if they need to commute to and from the stop.

Question 8: After having interacted with this application, how likely would you be to change your transportation habits?



Comments

I personally travel everywhere with my car, but if one day I need to use public transportation, I will use this app because it plans my trip, gives me options and also I get an estimate how much the trip will cost me.
I noticed that when I selected Walk Only option and expanded search results, it gave me multiple instructions on how to turn here and there. Would be lovely to have an audio option for that!!
One thing that will make me use different apps still is the lack of real time tracking on the map. When users are in the itinerary, the map does not highlight them on the map continuously and so they don't see how far away from the destination or which bus/max stop they are on.
I am biking everywhere. Even though the app is easy to use and informative, I won't change my habit.
I really like getting different options of transportation (transit and rideshare), paths and price from one app. I am a car driver but for short distance in downtown, I feel like I have what I need to use alternative transportation.

4. Conclusion

The survey results revealed that changes implemented between phase 1 and 2 removed major pain points that were affecting the usability of the app (Search feature, lack of interaction with the map, swiping between options) and the understanding of the use of rideshare with transit. It is now very clear that Rideshare must be combined with Transit and it is intuitive to navigate through the different options.

The results also indicated that users who are not familiar with Trimet are less likely to move away from using their car. However, after interacting with the app, those same users were very interested by getting different options (path, time, cost, effort) for their trip and expressed their curiosity to explore more the app. We cannot say if that would be enough for them to adopt a new habit.

Current Trimet riders had positive impressions of its usability and are more likely to keep using the application.

APPENDIX

J

Limited Beta Testing Results

MOD Sandbox Independent Evaluation
TriMet Open Trip Planner Shared-Use Mobility

Preliminary Survey Results

Transportation Sustainability Research Center, UC Berkeley

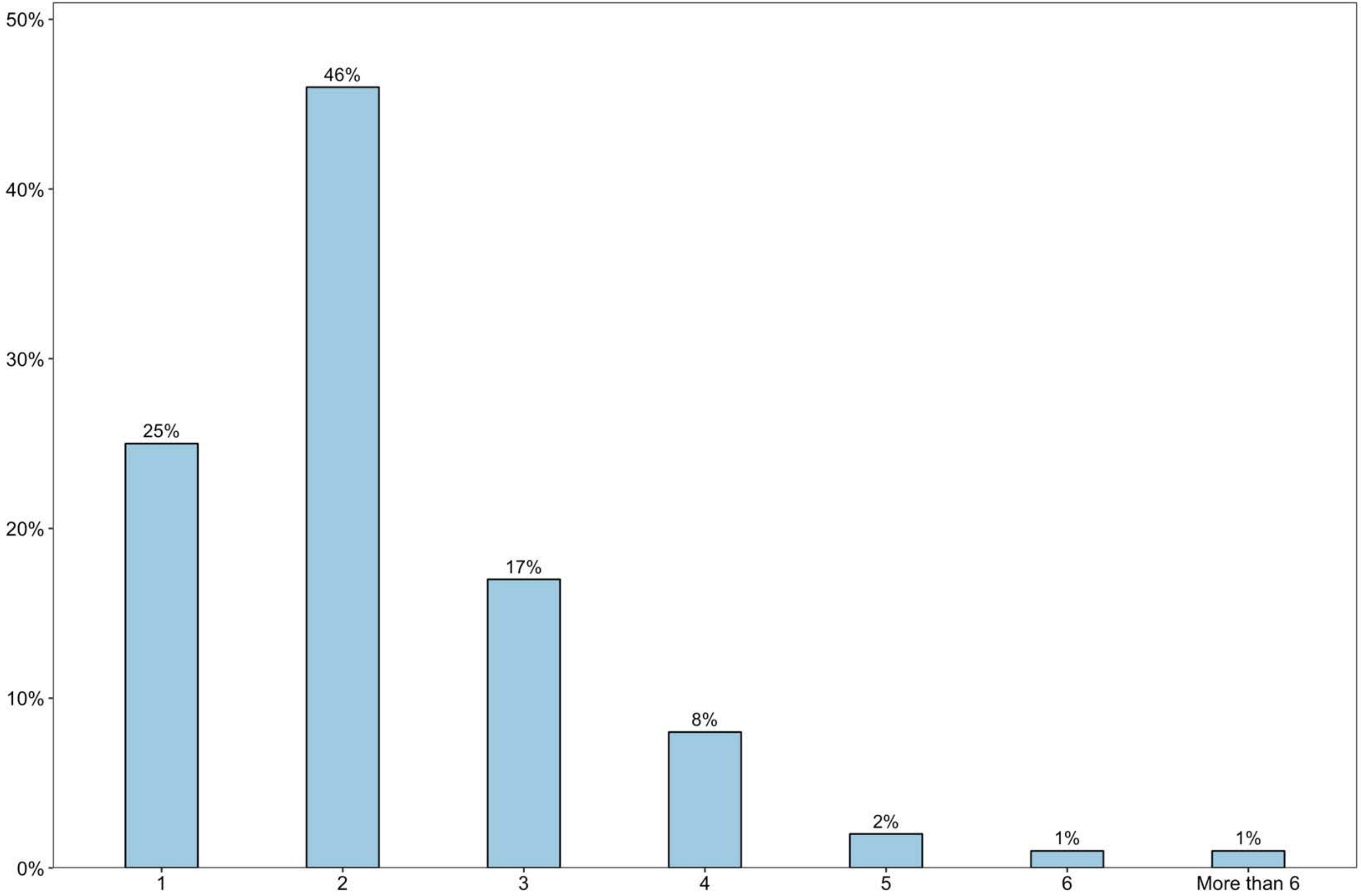
ICF

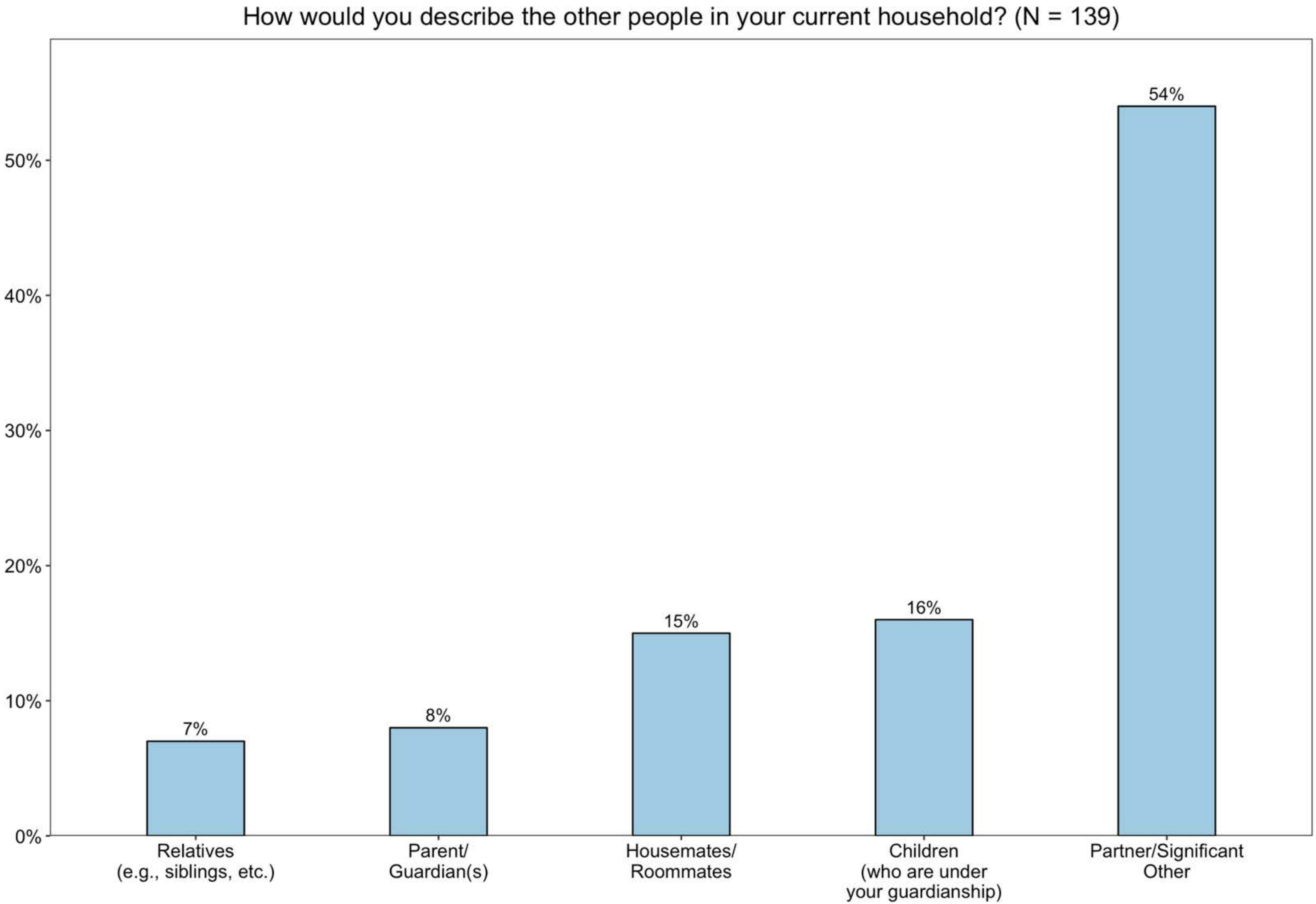
January 2019

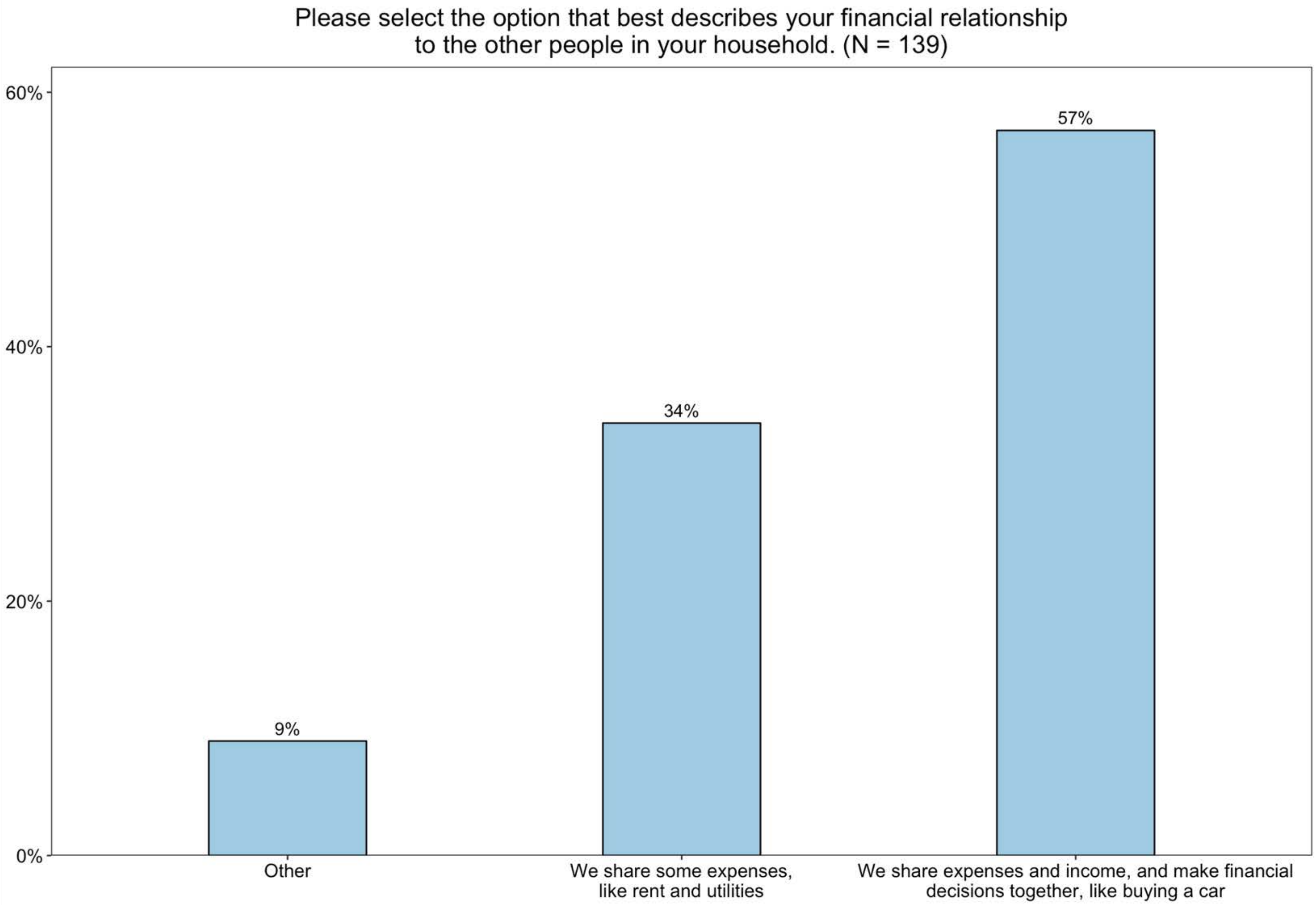
Introduction

- Results summarize responses from a survey distributed through TriMet
  - 250 surveys were distributed to Riders Club members selected by TriMet
  - 10 TriMet Adult 1-Day Passes (a $50 value) offered as an incentive to anyone who took the survey
- Launched from 12/7/2018 to 12/23/18
- Total number of responses: 230
- Complete responses: 190
- Complete and valid responses: 186

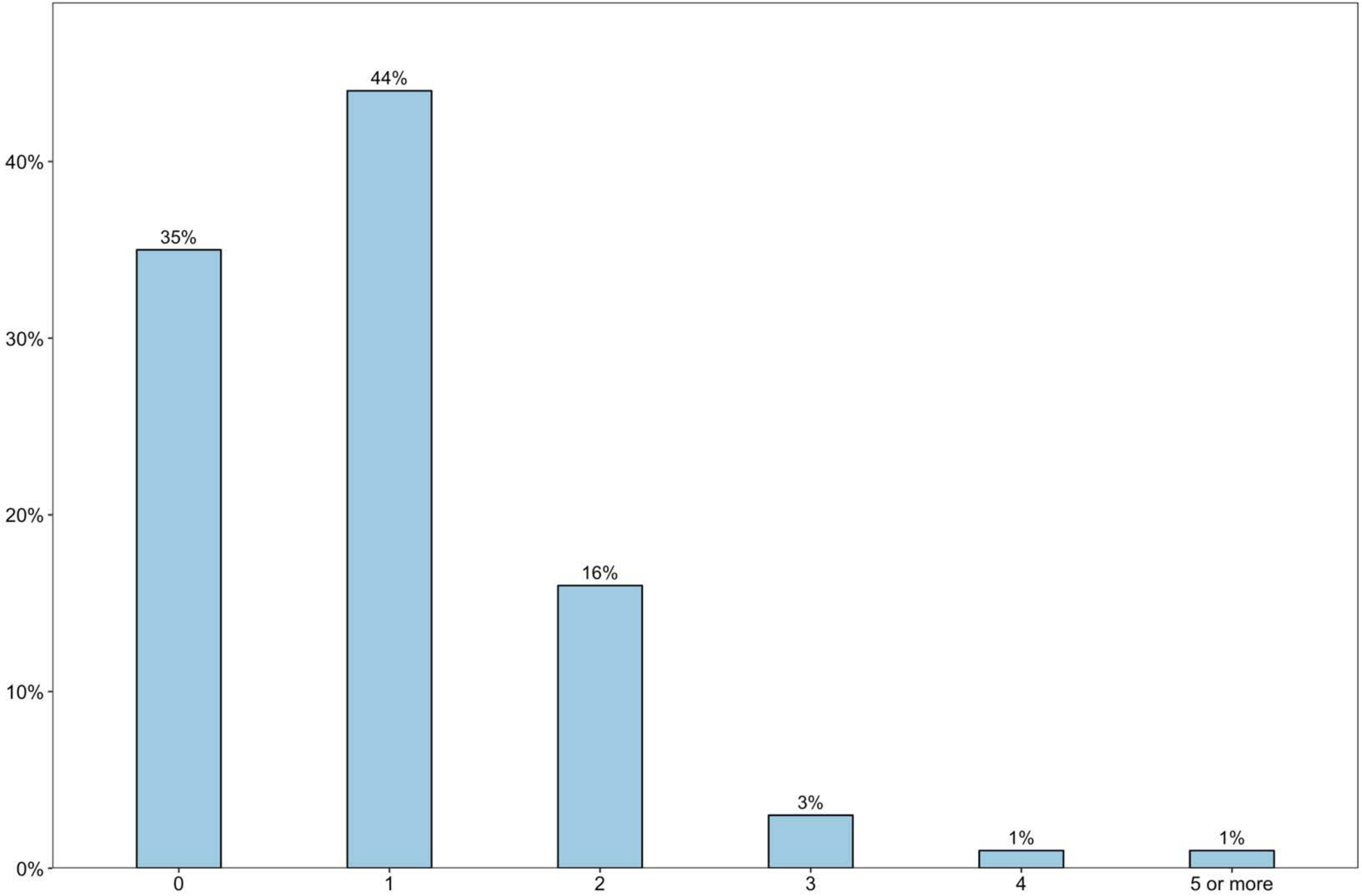
Including yourself, how many people live in your current household? (N = 186)

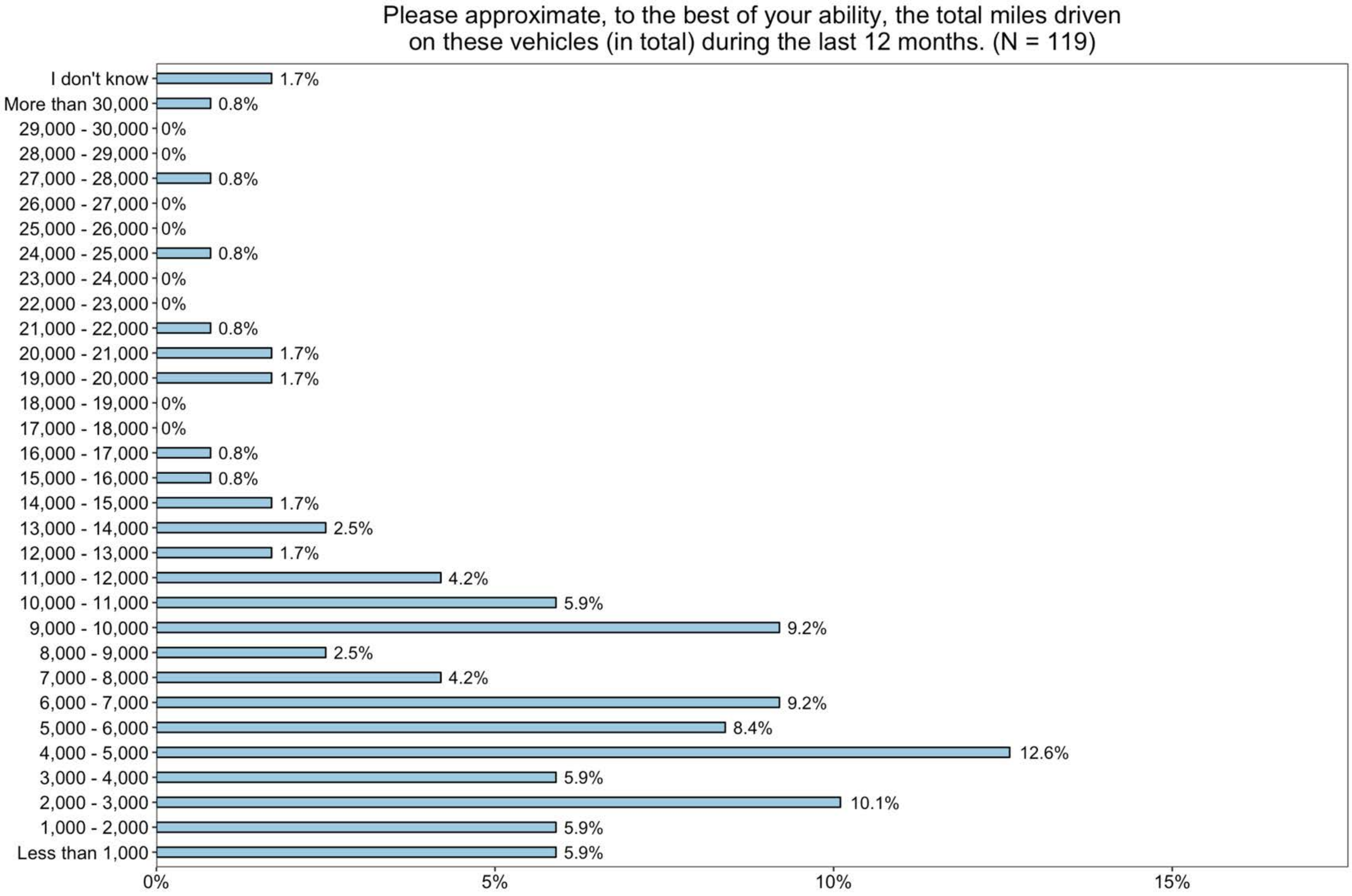



How would you describe the other people in your current household? (N = 139)
50%
40%
30%
20%
10%
0%
7%
8%
15%
16%
54%
Relatives (e.g., siblings, etc.)
Parent/ Guardian(s)
Housemates/ Roommates
Children (who are under your guardianship)
Partner/Significant Other

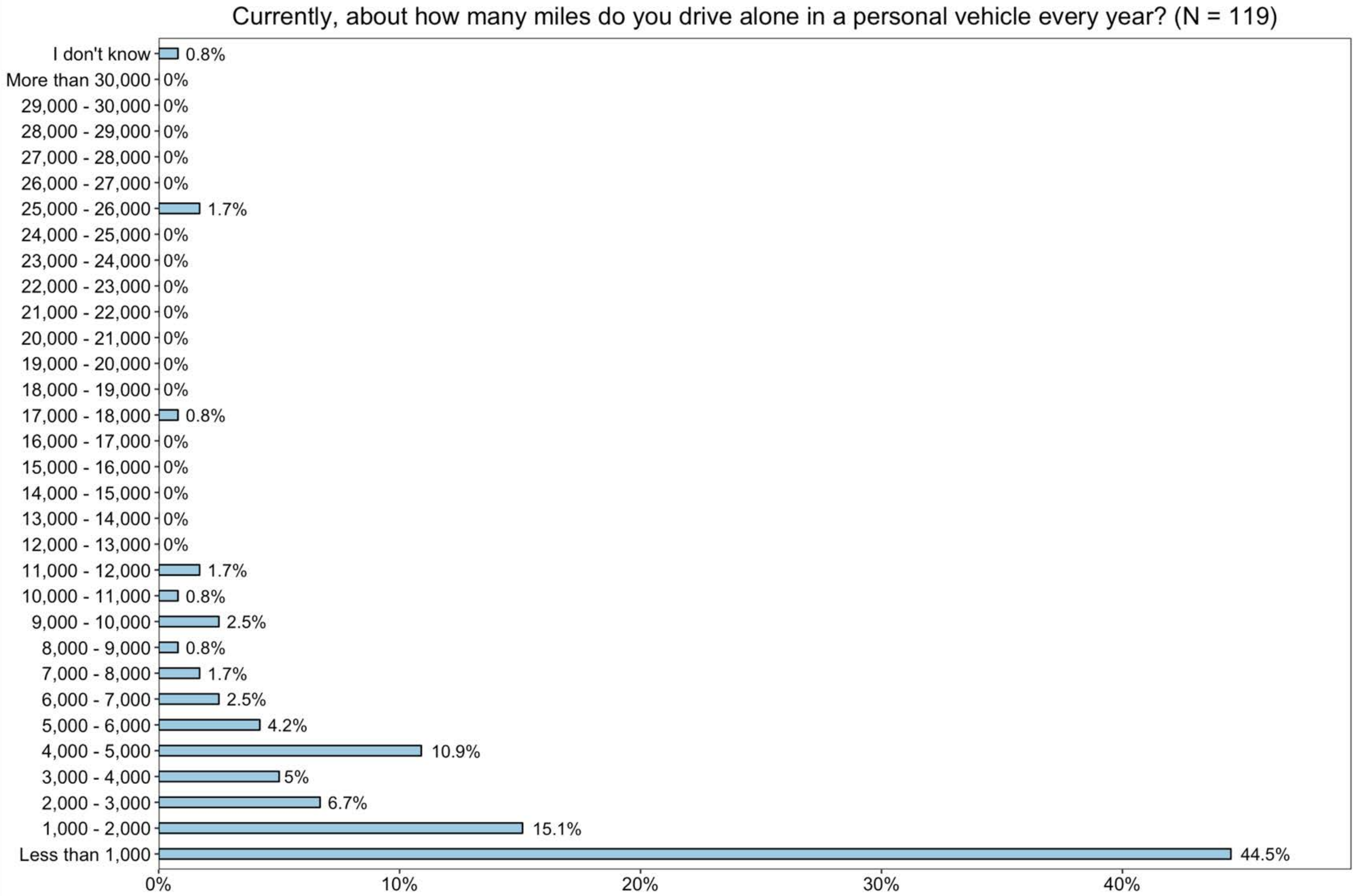

Please select the option that best describes your financial relationship
to the other people in your household. (N = 139)
60%
40%
20%
0%
9%
34%
57%
Other
We share some expenses, like rent and utilities
We share expenses and income, and make financial decisions together, like buying a car

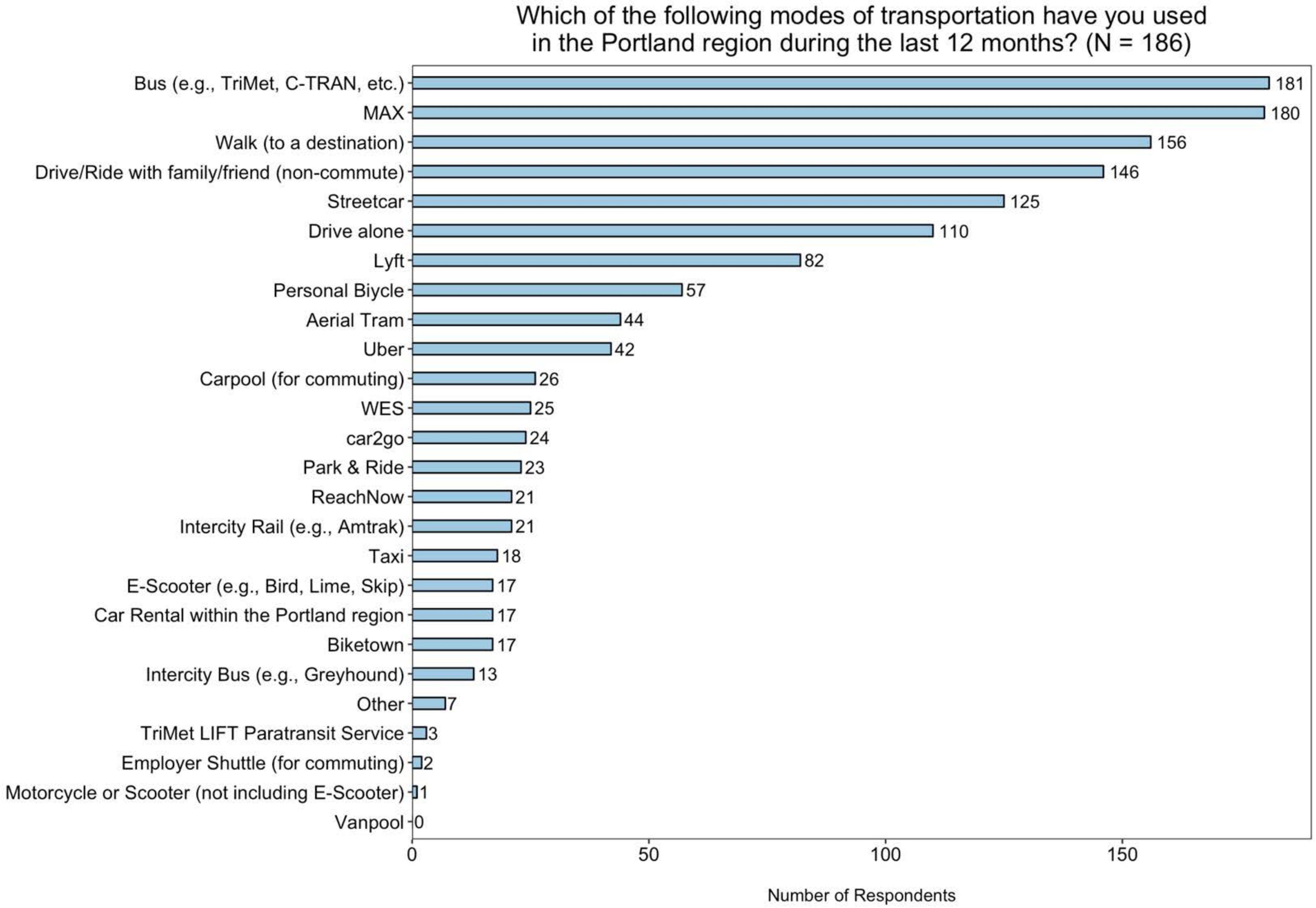
How many vehicles do you/does your household currently own or lease? (N = 186)



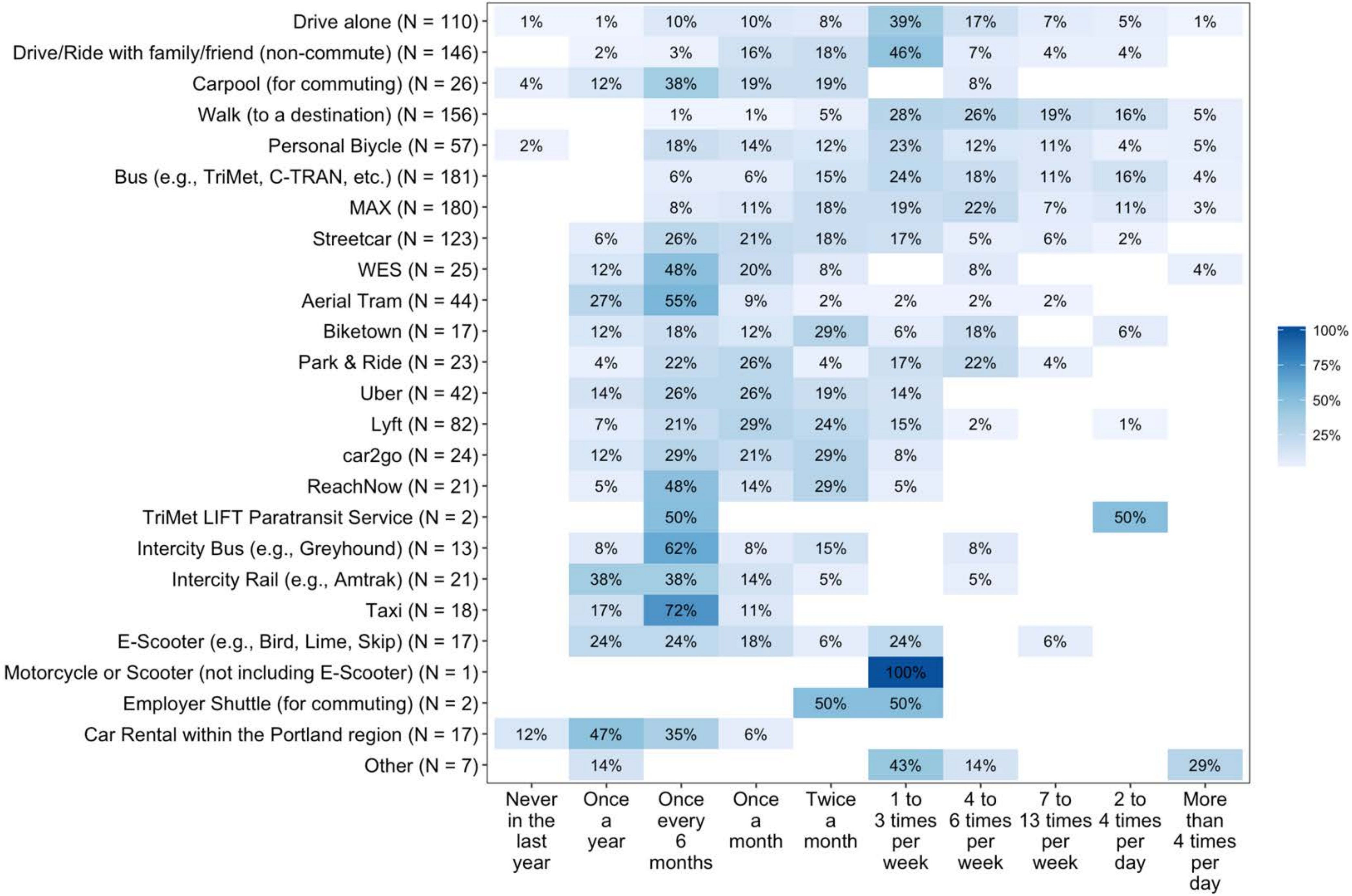


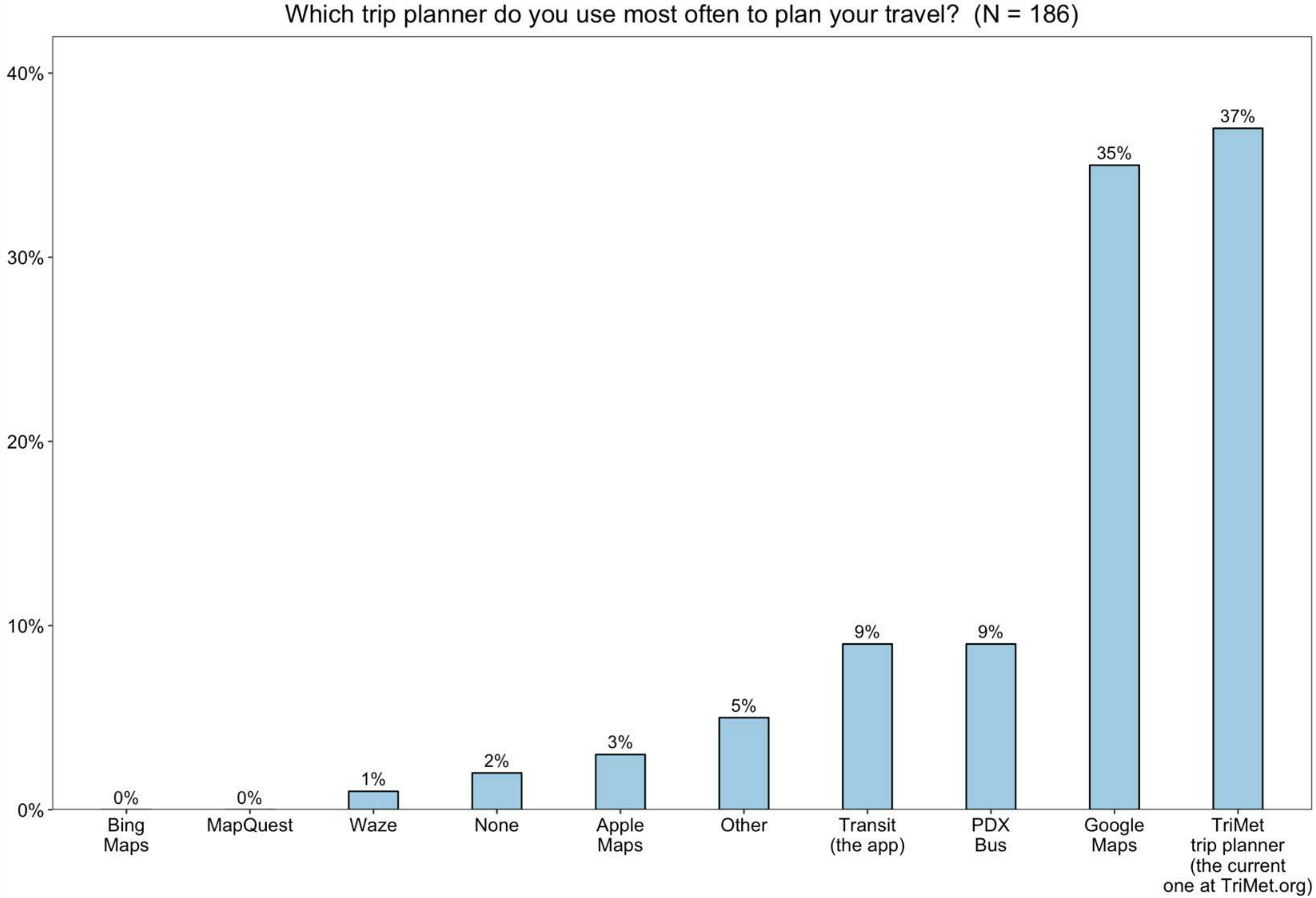
Please approximate, to the best of your ability, the total miles driven
on these vehicles (in total) during the last 12 months. (N = 119)
I don't know 1.7%
More than 30,000 0.8%
29,000 - 30,000 0%
28,000 - 29,000 0%
27,000 - 28,000 0.8%
26,000 - 27,000 0%
25,000 - 26,000 0%
24,000 - 25,000 0.8%
23,000 - 24,000 0%
22,000 - 23,000 0%
21,000 - 22,000 0.8%
20,000 - 21,000 1.7%
19,000 - 20,000 1.7%
18,000 - 19,000 0%
17,000 - 18,000 0%
16,000 - 17,000 0.8%
15,000 - 16,000 0.8%
14,000 - 15,000 1.7%
13,000 - 14,000 2.5%
12,000 - 13,000 1.7%
11,000 - 12,000 4.2%
10,000 - 11,000 5.9%
9,000 - 10,000 9.2%
8,000 - 9,000 2.5%
7,000 - 8,000 4.2%
6,000 - 7,000 9.2%
5,000 - 6,000 8.4%
4,000 - 5,000 12.6%
3,000 - 4,000 5.9%
2,000 - 3,000 10.1%
1,000 - 2,000 5.9%
Less than 1,000 5.9%
0%
5%
10%
15%

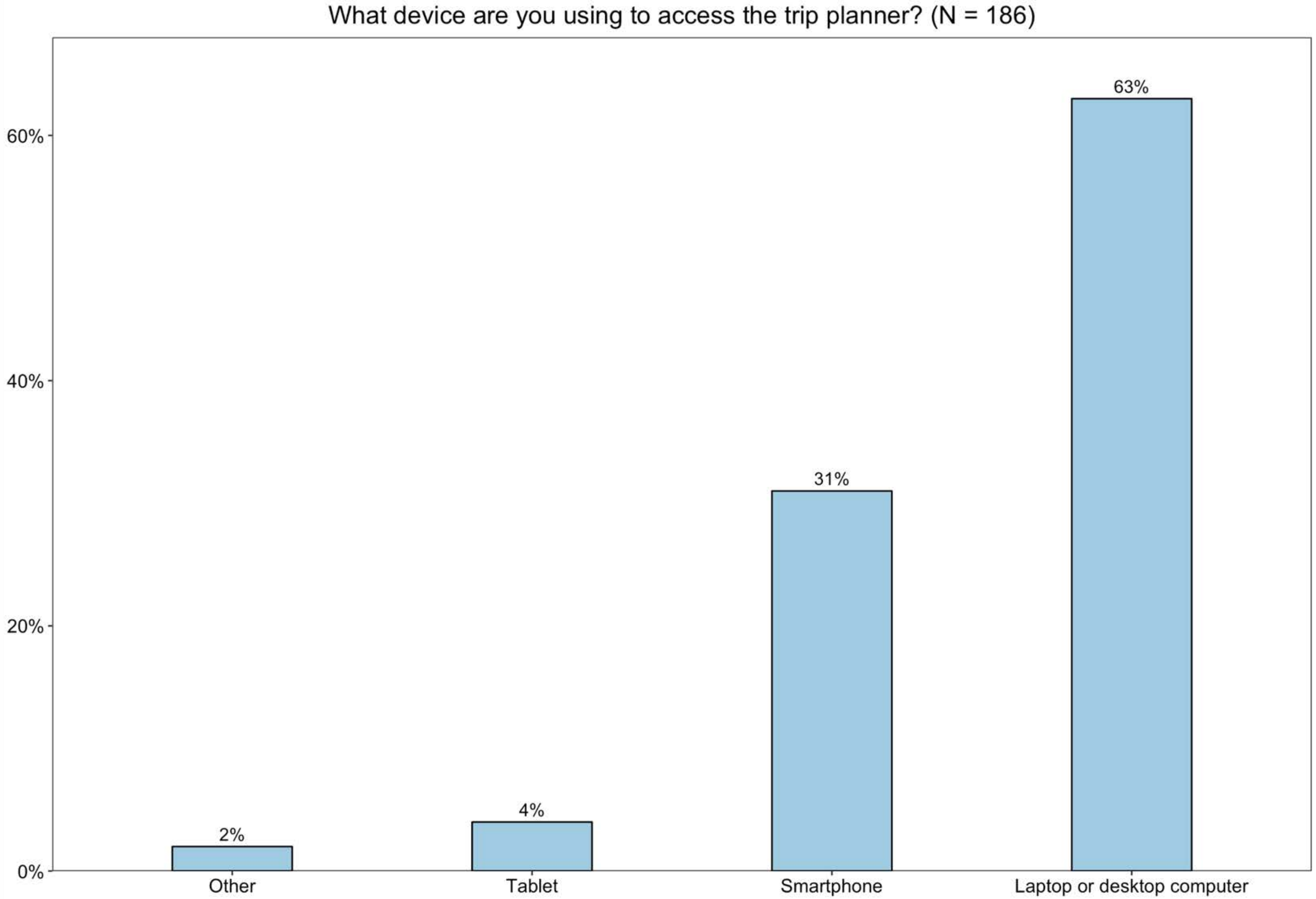

Currently, about how many miles do you drive alone in a personal vehicle every year? (N = 119)
I don't know 0.8%
More than 30,000 0%
29,000 - 30,000 0%
28,000 - 29,000 0%
27,000 - 28,000 0%
26,000 - 27,000 0%
25,000 - 26,000 1.7%
24,000 - 25,000 0%
23,000 - 24,000 0%
22,000 - 23,000 0%
21,000 - 22,000 0%
20,000 - 21,000 0%
19,000 - 20,000 0%
18,000 - 19,000 0%
17,000 - 18,000 0.8%
16,000 - 17,000 0%
15,000 - 16,000 0%
14,000 - 15,000 0%
13,000 - 14,000 0%
12,000 - 13,000 0%
11,000 - 12,000 1.7%
10,000 - 11,000 0.8%
9,000 - 10,000 2.5%
8,000 - 9,000 0.8%
7,000 - 8,000 1.7%
6,000 - 7,000 2.5%
5,000 - 6,000 4.2%
4,000 - 5,000 10.9%
3,000 - 4,000 5%
2,000 - 3,000 6.7%
1,000 - 2,000 15.1%
Less than 1,000 44.5%
0%
10%
20%
30%
40%

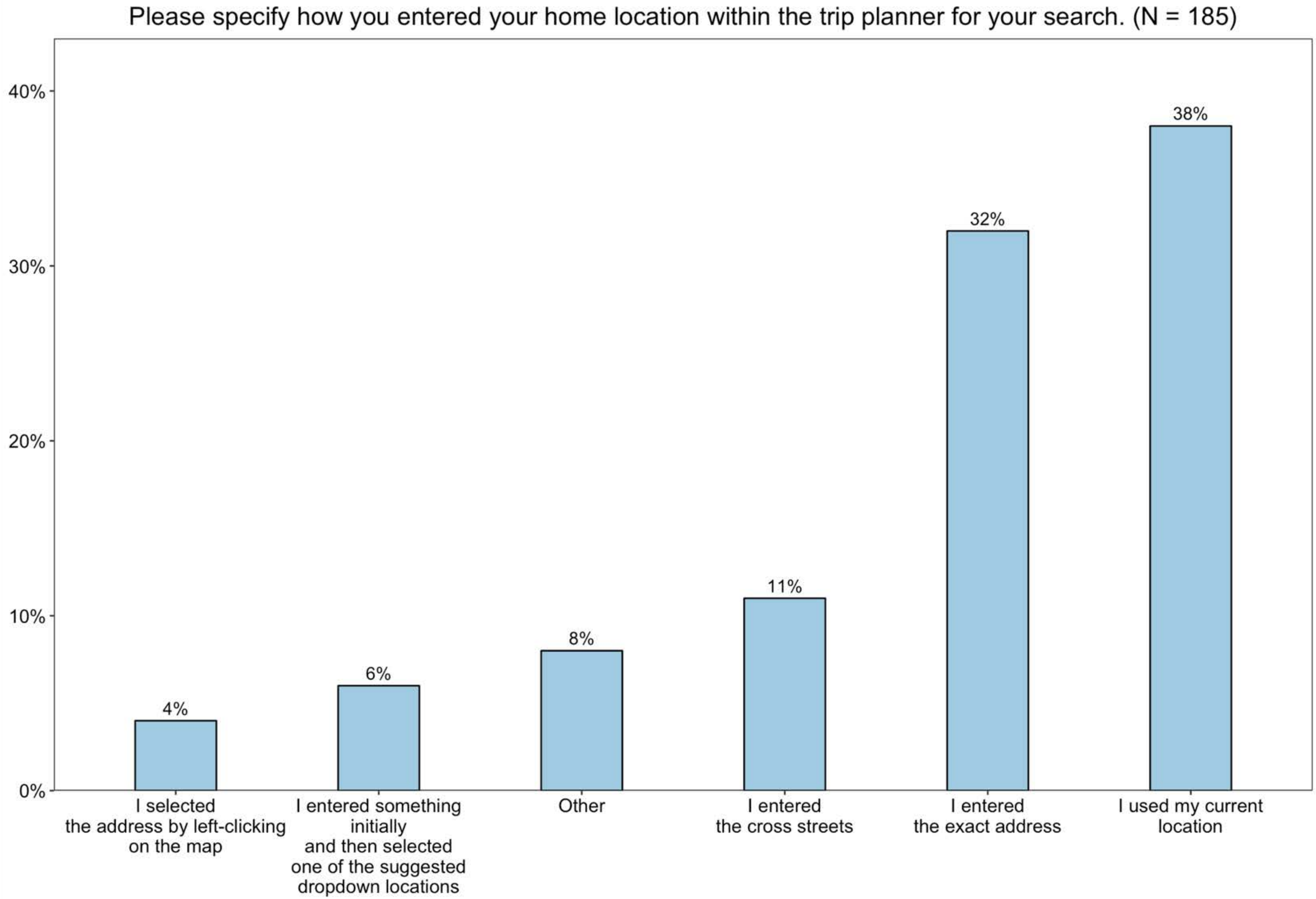

Which of the following modes of transportation have you used
in the Portland region during the last 12 months? (N = 186)
Bus (e.g., TriMet, C-TRAN, etc.) 181
MAX 180
Walk (to a destination) 156
Drive/Ride with family/friend (non-commute) 146
Streetcar 125
Drive alone 110
Lyft 82
Personal Biycle 57
Aerial Tram 44
Uber 42
Carpool (for commuting) 26
WES 25
car2go 24
Park & Ride 23
ReachNow 21
Intercity Rail (e.g., Amtrak) 21
Taxi 18
E-Scooter (e.g., Bird, Lime, Skip) 17
Car Rental within the Portland region 17
Biketown 17
Intercity Bus (e.g., Greyhound) 13
Other 7
TriMet LIFT Paratransit Service 3
Employer Shuttle (for commuting) 2
Motorcycle or Scooter (not including E-Scooter) 1
Vanpool 0
0
50
100
150
Number of Respondents

Please indicate how frequently you currently use the following modes.

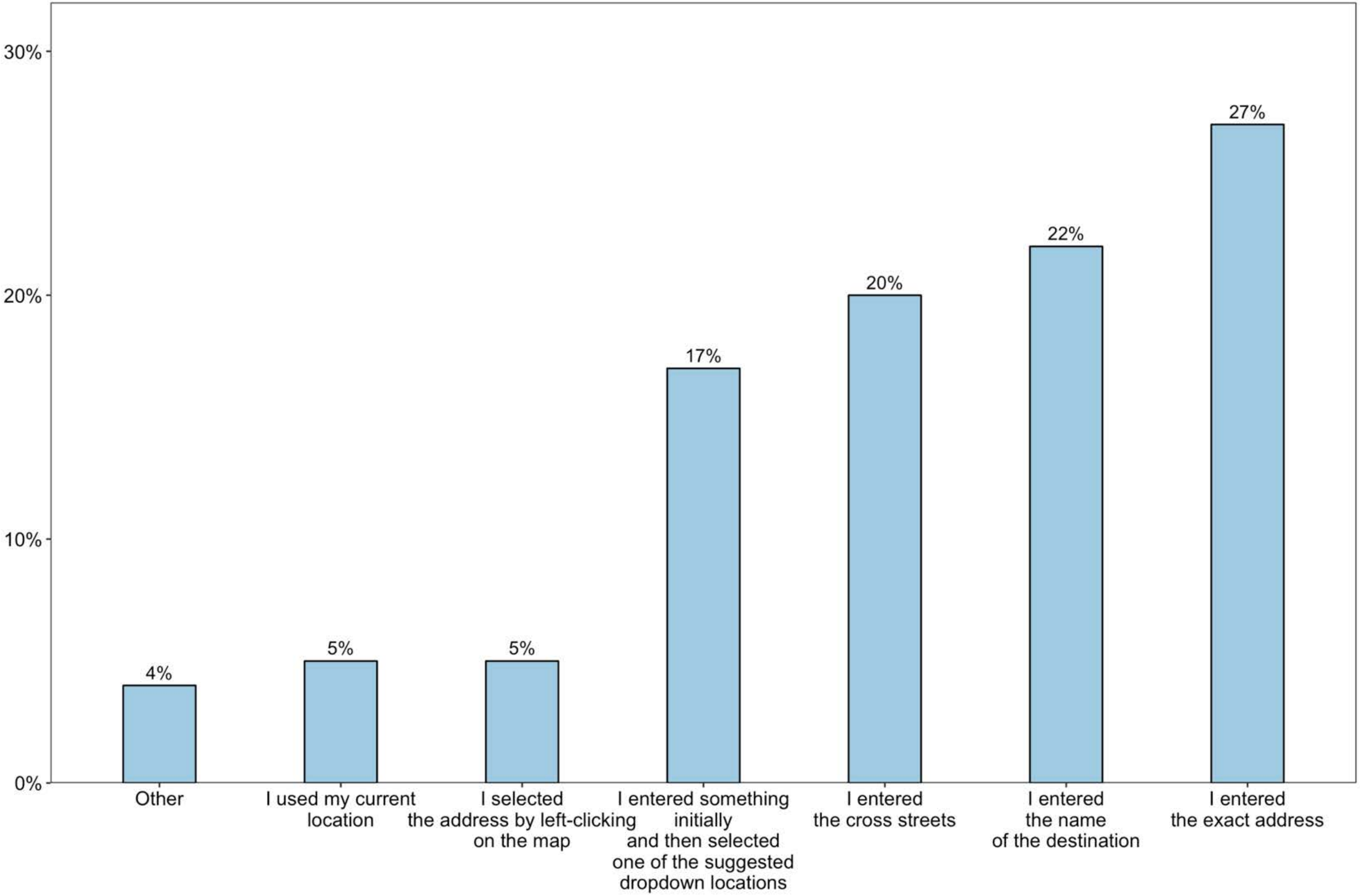



Which trip planner do you use most often to plan your travel? (N = 186)
40%
30%
20%
10%
0%
0%
0%
1%
2%
3%
5%
9%
9%
35%
37%
Bing Maps
MapQuest
Waze
None
Apple Maps
Other
Transit (the app)
PDX Bus
Google Maps
TriMet trip planner (the current one at TriMet.org)

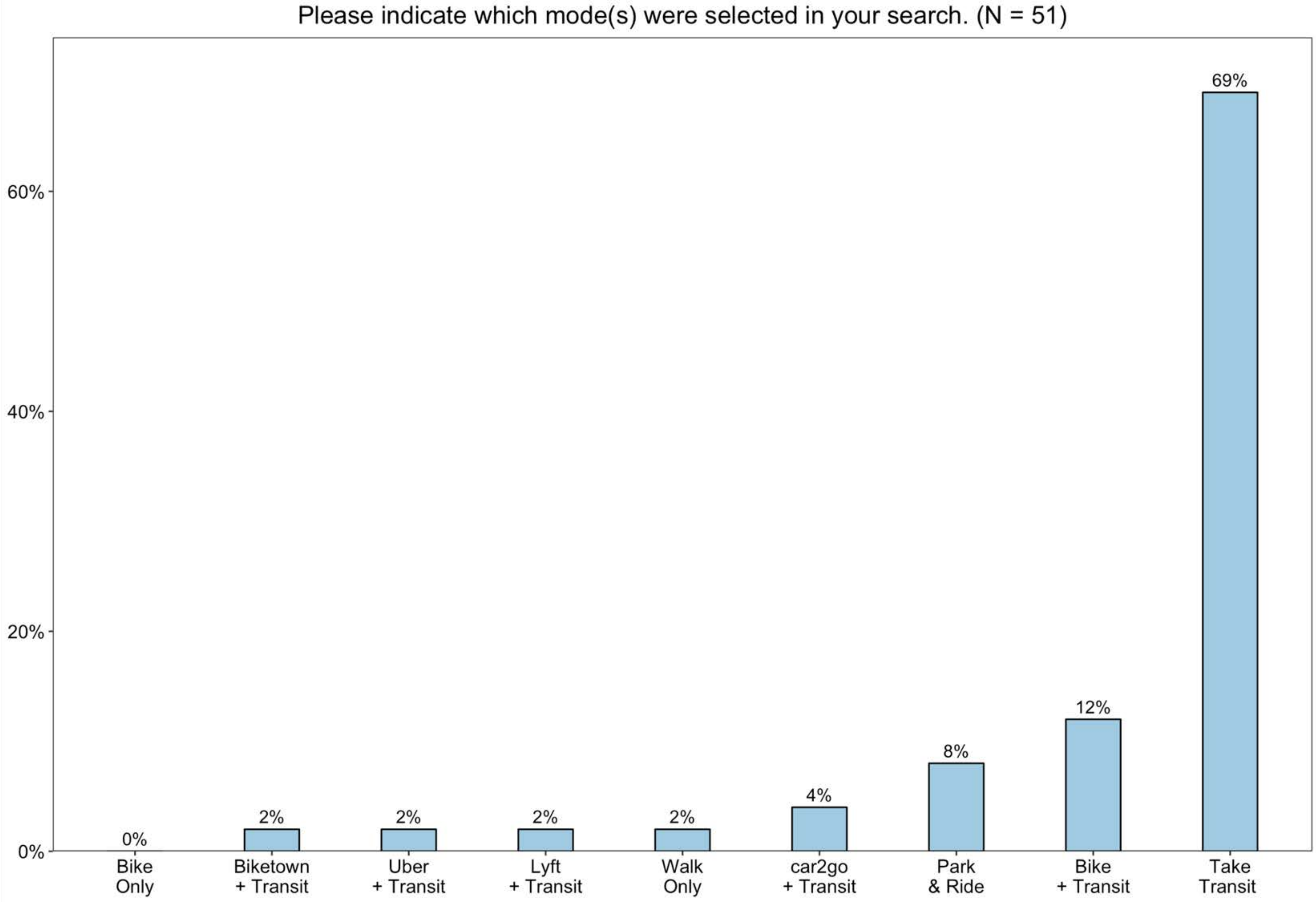

What device are you using to access the trip planner? (N = 186)
60%
40%
20%
0%
2%
4%
31%
63%
Other
Tablet
Smartphone
Laptop or desktop computer

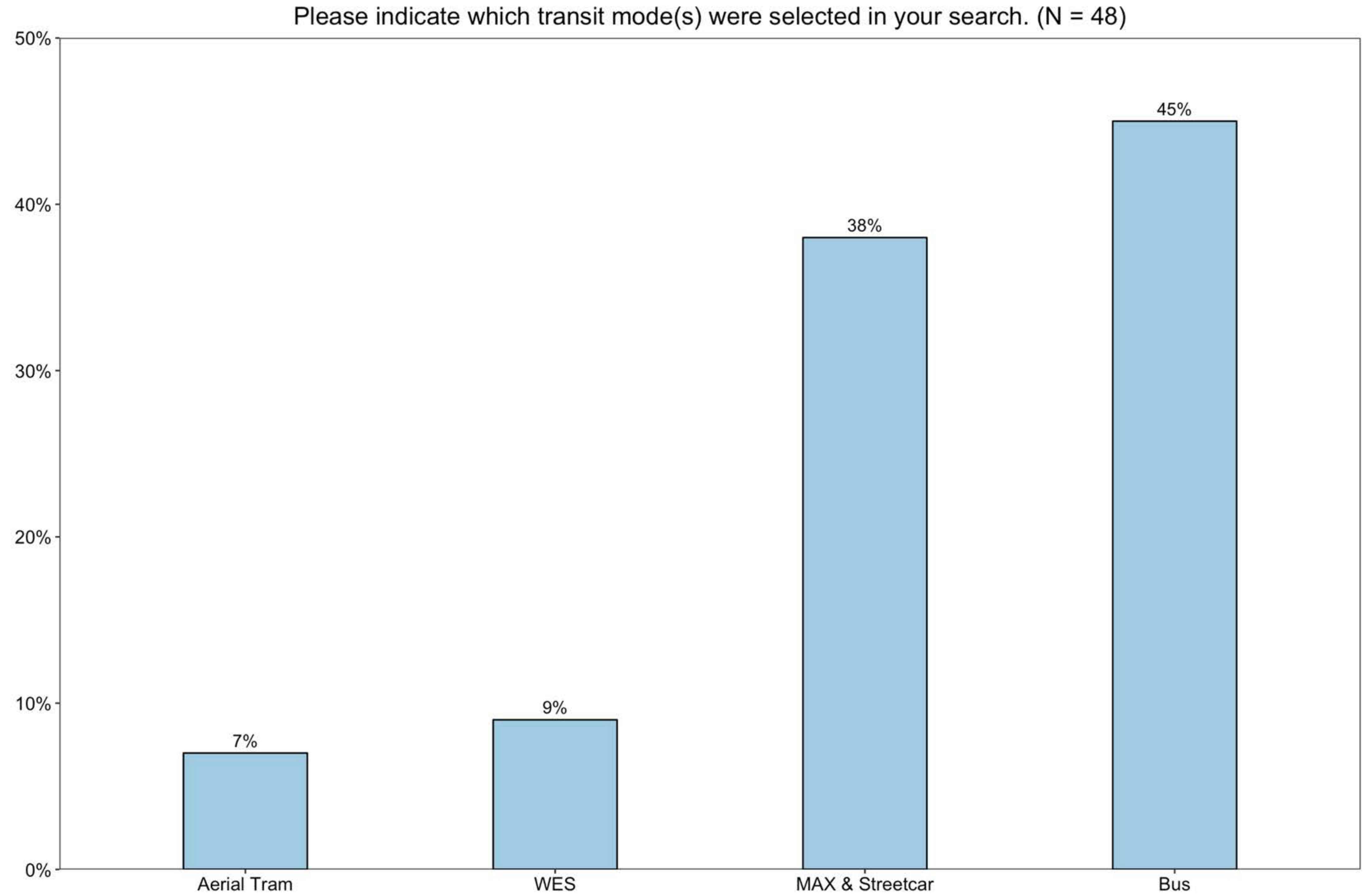

Please specify how you entered your home location within the trip planner for your search. (N = 185)
40%
30%
20%
10%
0%
4%
6%
8%
11%
32%
38%
I selected the address by left-clicking on the map
I entered something initially and then selected one of the suggested dropdown locations
Other
I entered the cross streets
I entered the exact address
I used my current location

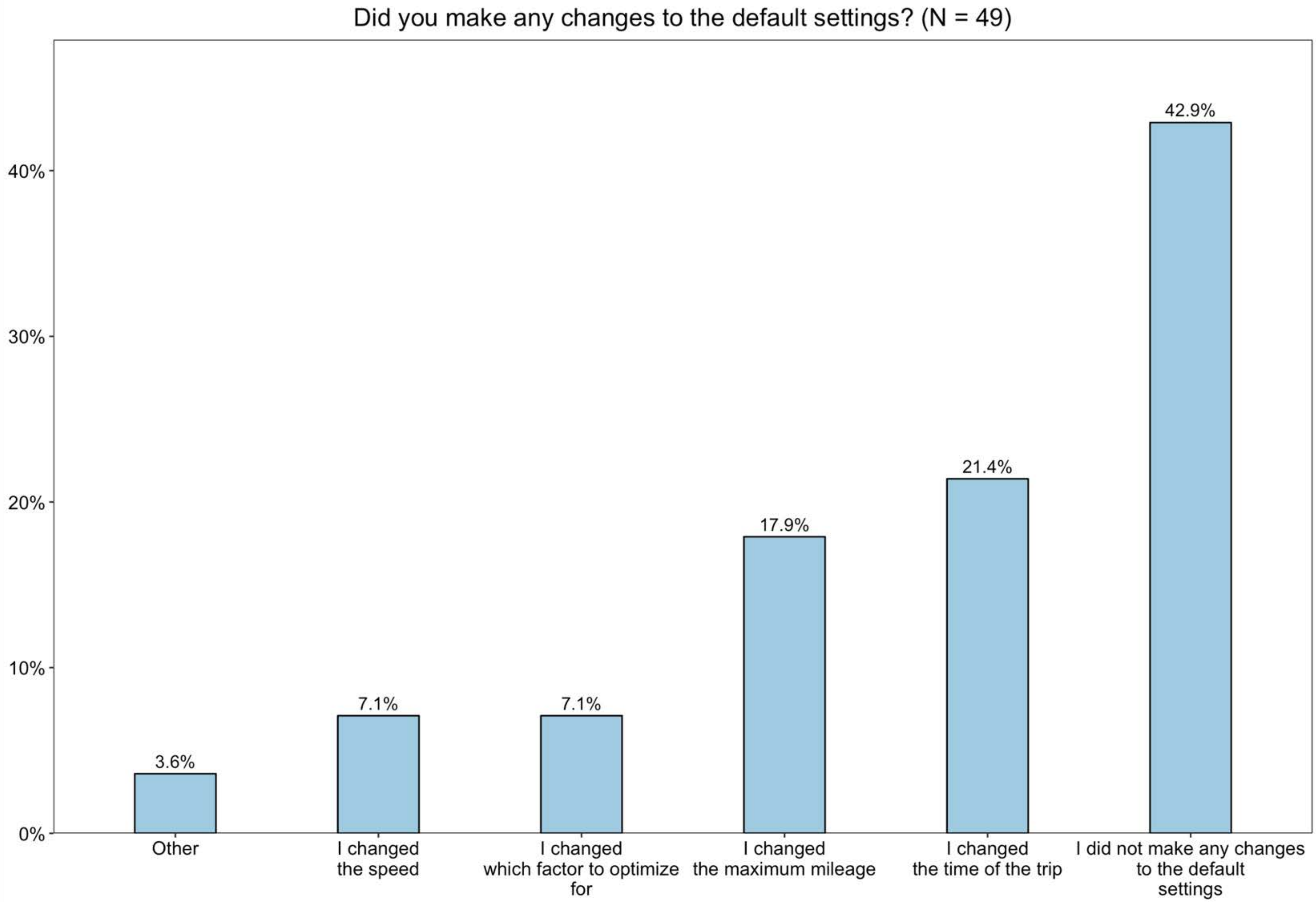
Please specify how you entered the destination within the trip planner for your search. (N = 184)

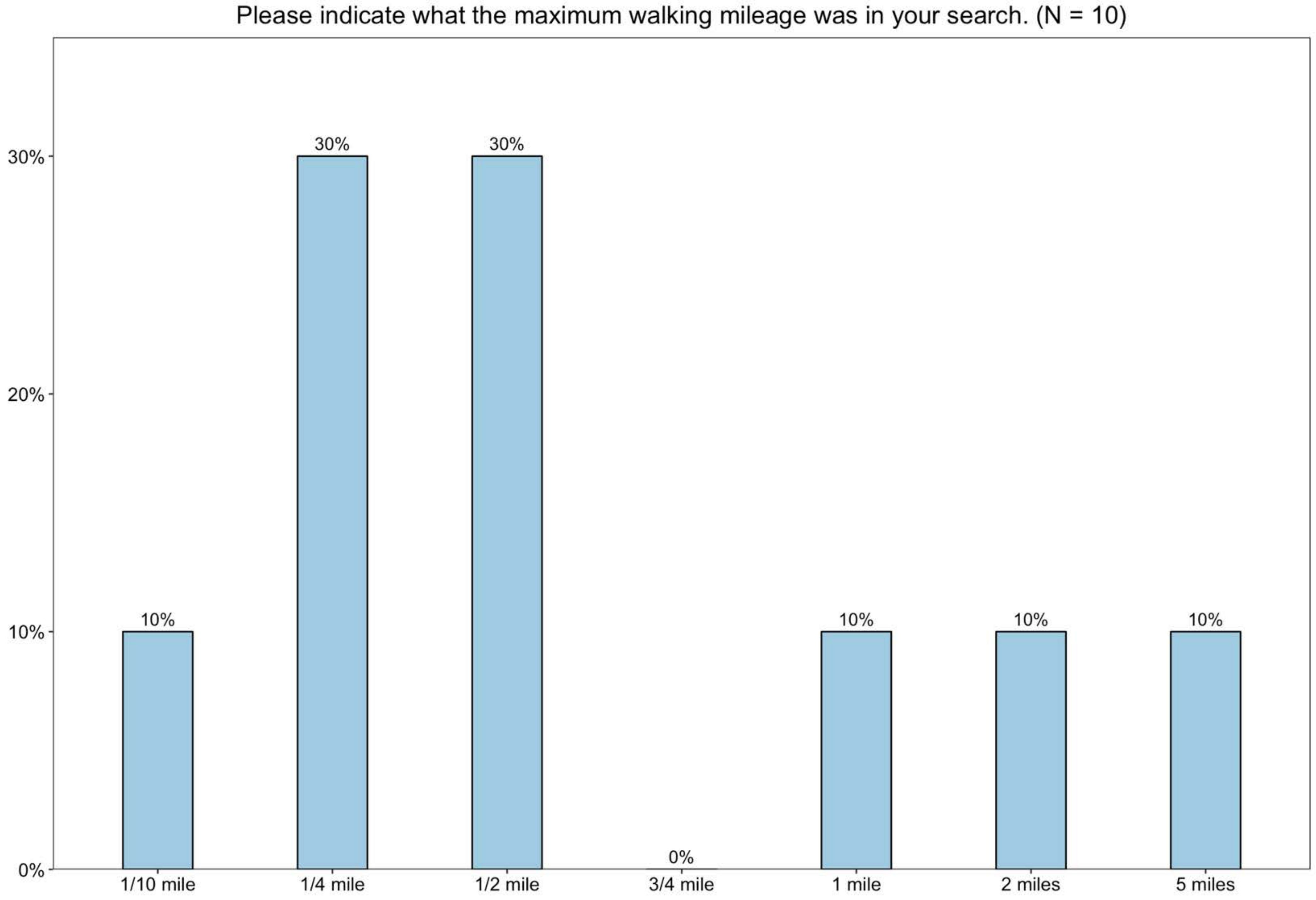


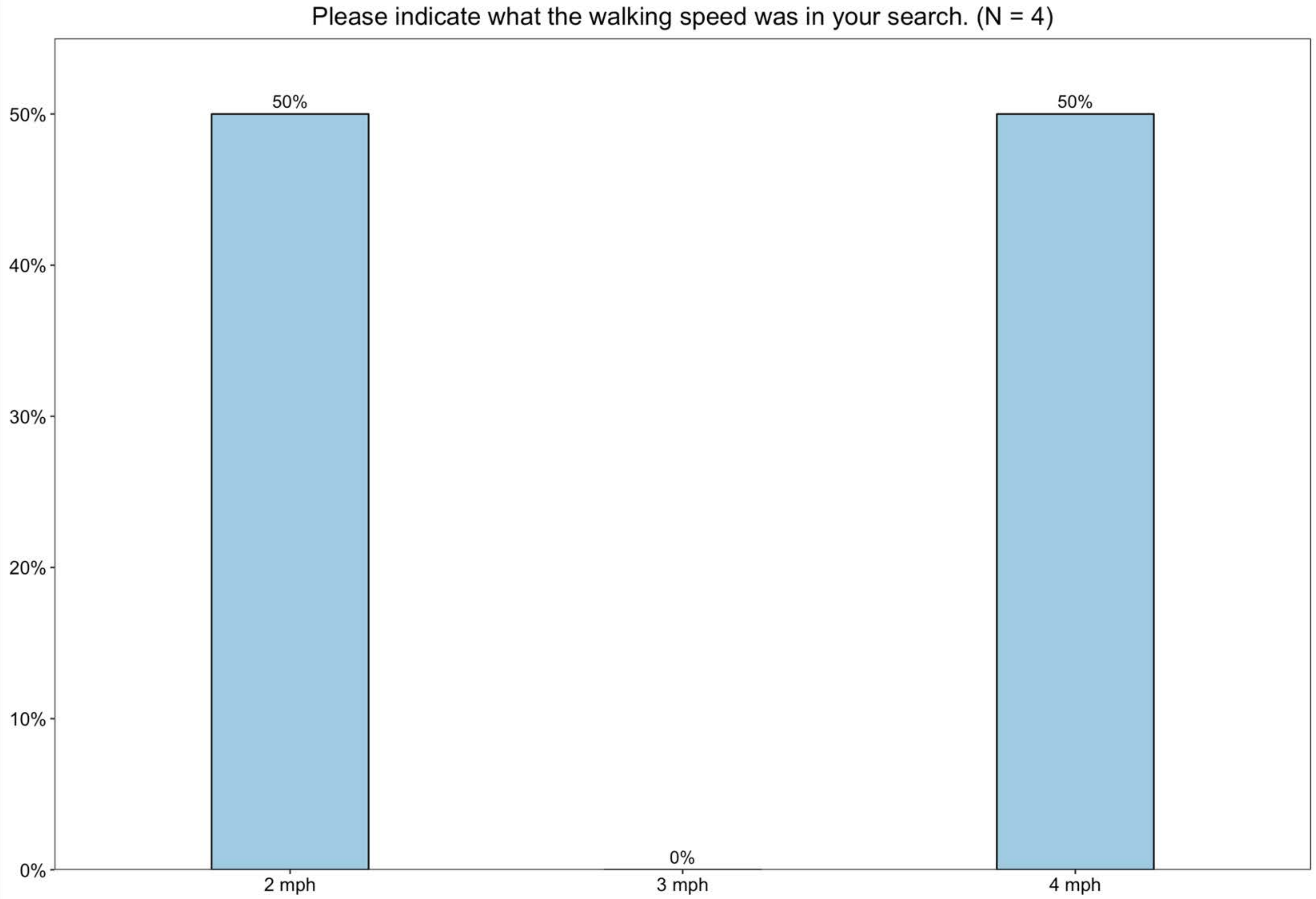
Please note that the following questions about modes and settings (next 7 slides) only apply to respondents who **did not** enter a URL, and instead were asked to specify their exact search parameters. To get the full spectrum of responses, we will need to analyze the URLs. This preliminary draft does not yet contain this.

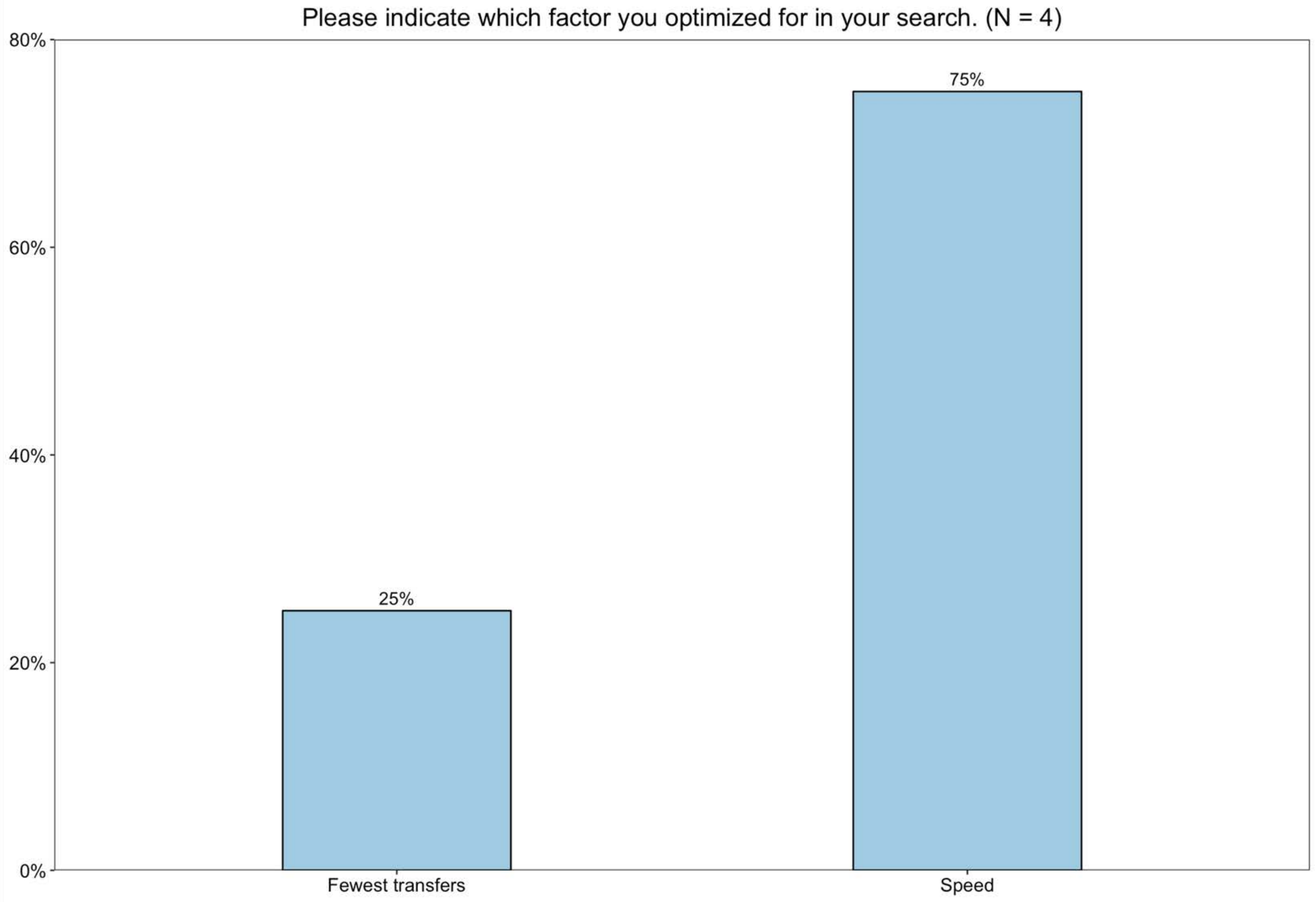

Please indicate which mode(s) were selected in your search. (N = 51)
60%
40%
20%
0%
0%
2%
2%
2%
2%
4%
8%
12%
69%
Bike Only
Biketown + Transit
Uber + Transit
Lyft + Transit
Walk Only
car2go + Transit
Park & Ride
Bike + Transit
Take Transit

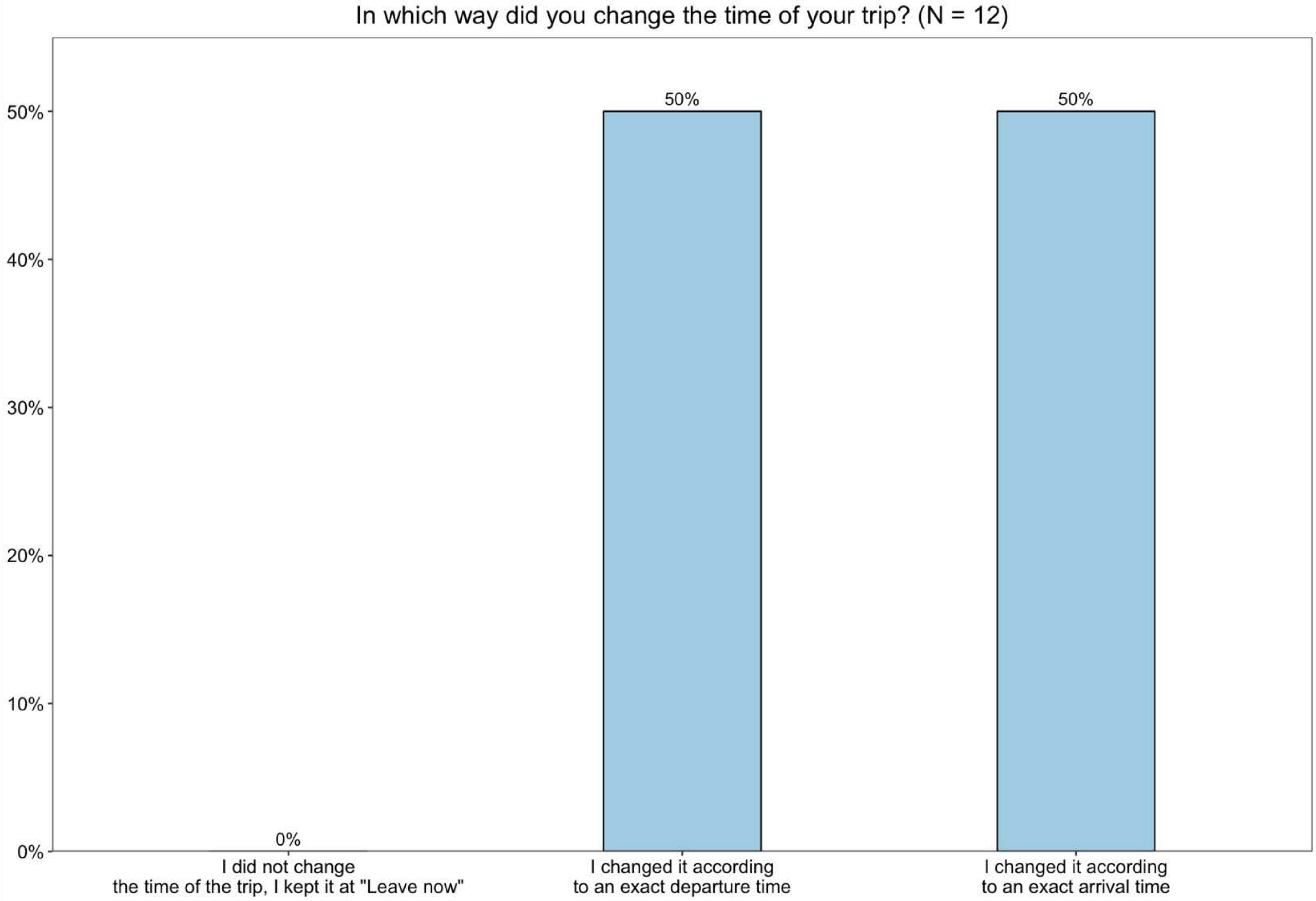

Please indicate which transit mode(s) were selected in your search. (N = 48)
50%
40%
30%
20%
10%
0%
7%
9%
38%
45%
Aerial Tram
WES
MAX & Streetcar
Bus

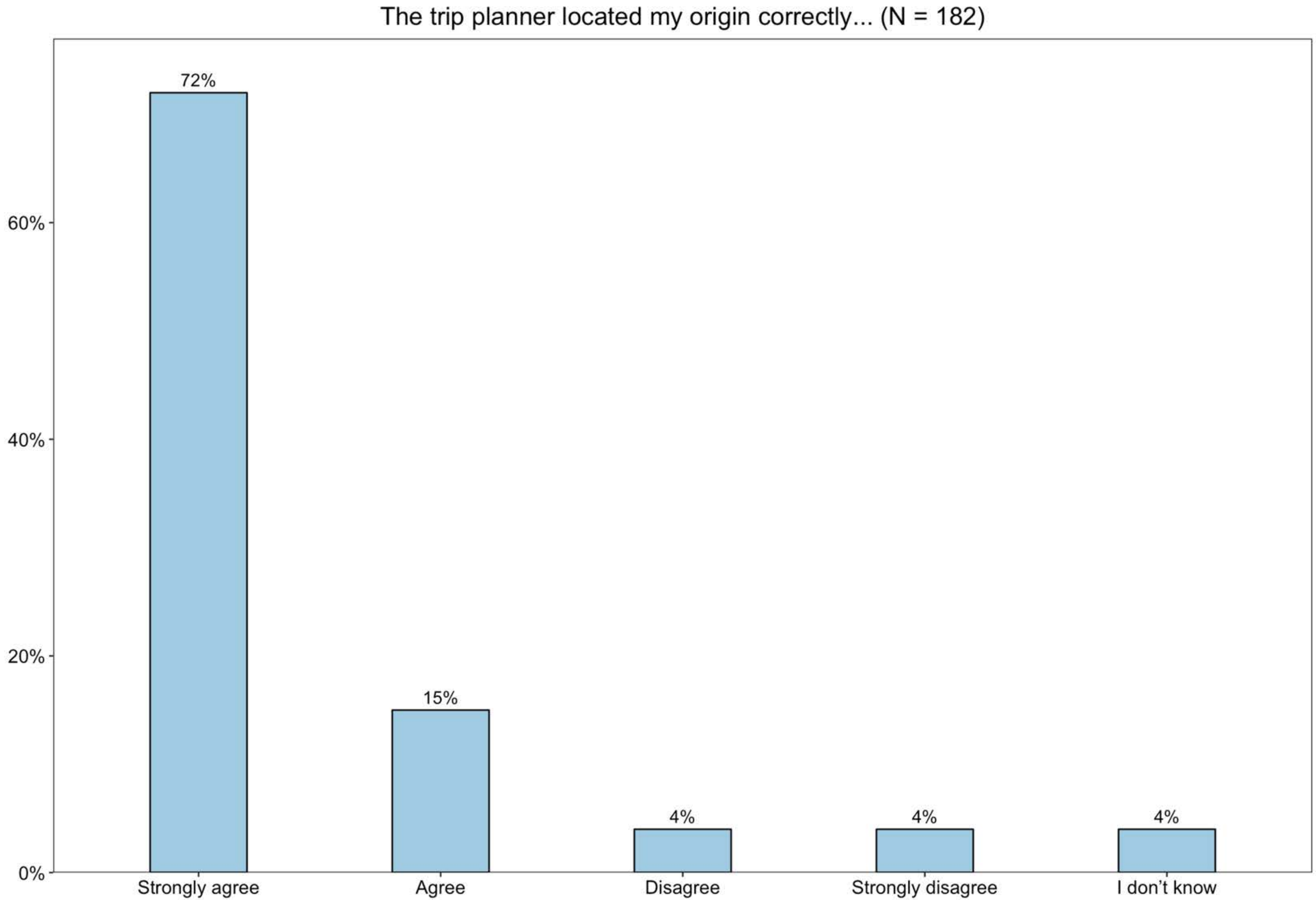

Did you make any changes to the default settings? (N = 49)
0%
10%
20%
30%
40%
3.6%
7.1%
7.1%
17.9%
21.4%
42.9%
Other
I changed the speed
I changed which factor to optimize for
I changed the maximum mileage
I changed the time of the trip
I did not make any changes to the default settings

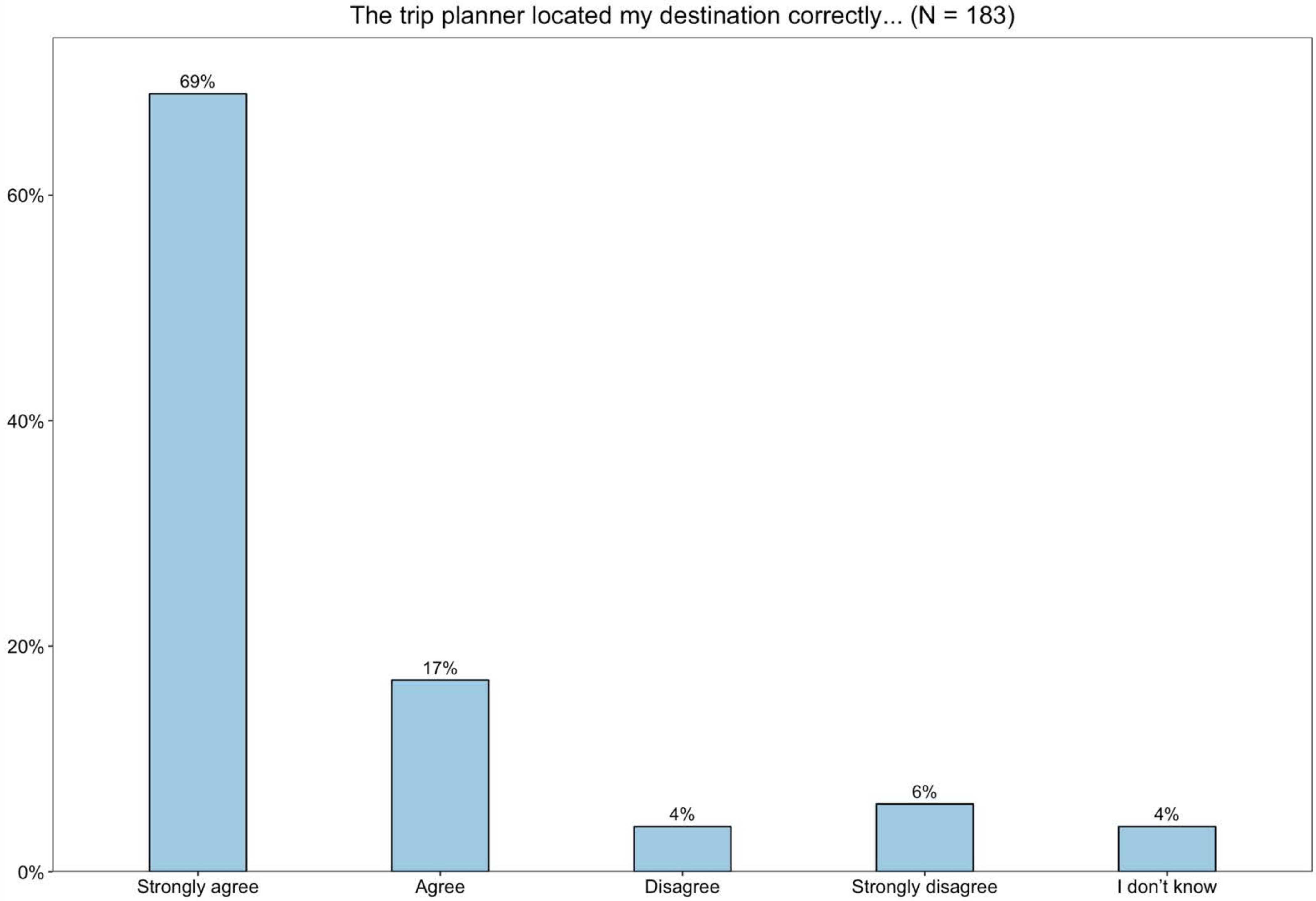

Please indicate what the maximum walking mileage was in your search. (N = 10)
30%
20%
10%
0%
10%
30%
30%
0%
10%
10%
10%
1/10 mile
1/4 mile
1/2 mile
3/4 mile
1 mile
2 miles
5 miles

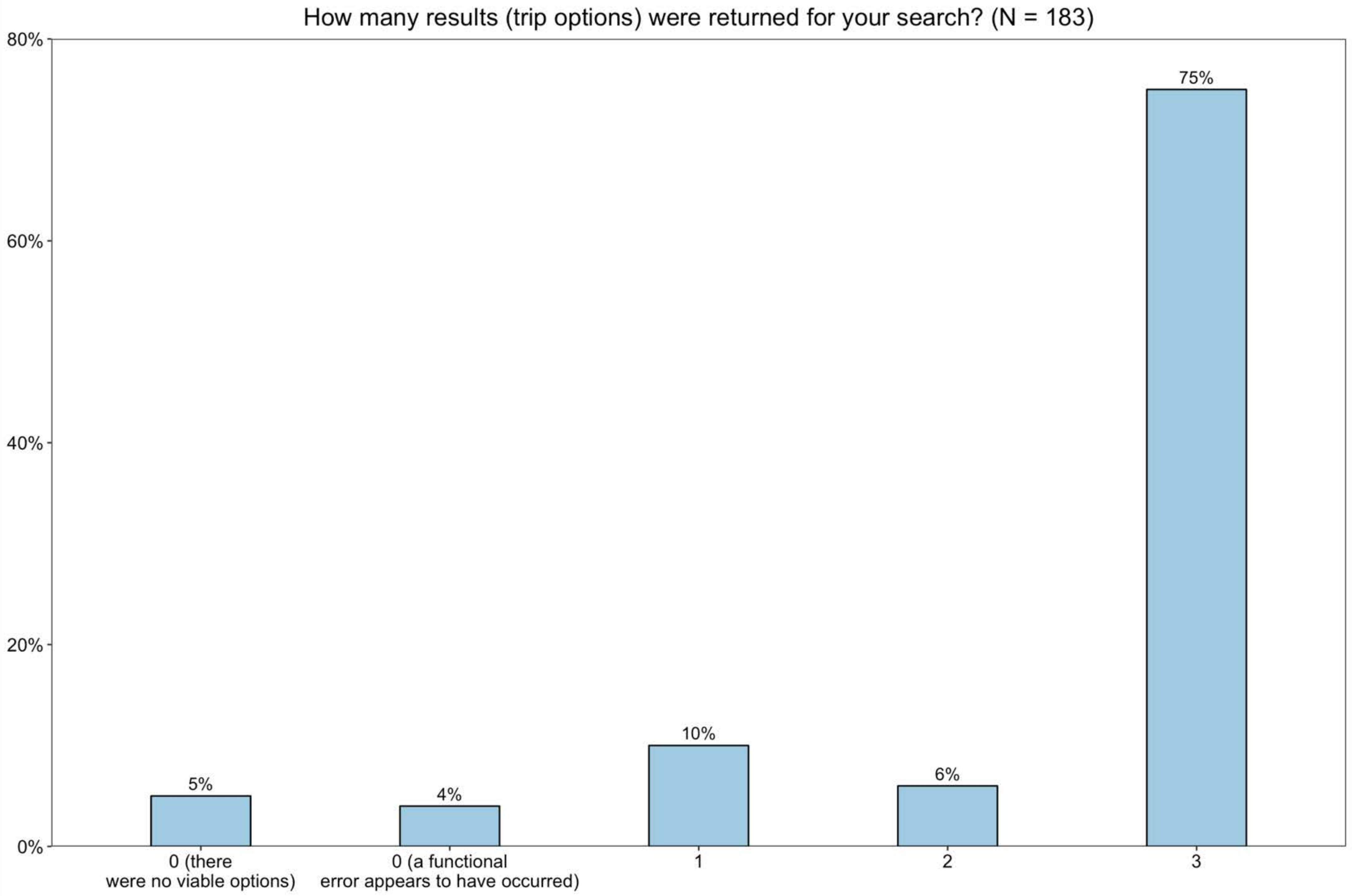

Please indicate what the walking speed was in your search. (N = 4)
50%
50%
0%
0%
10%
20%
30%
40%
50%
2 mph
3 mph
4 mph

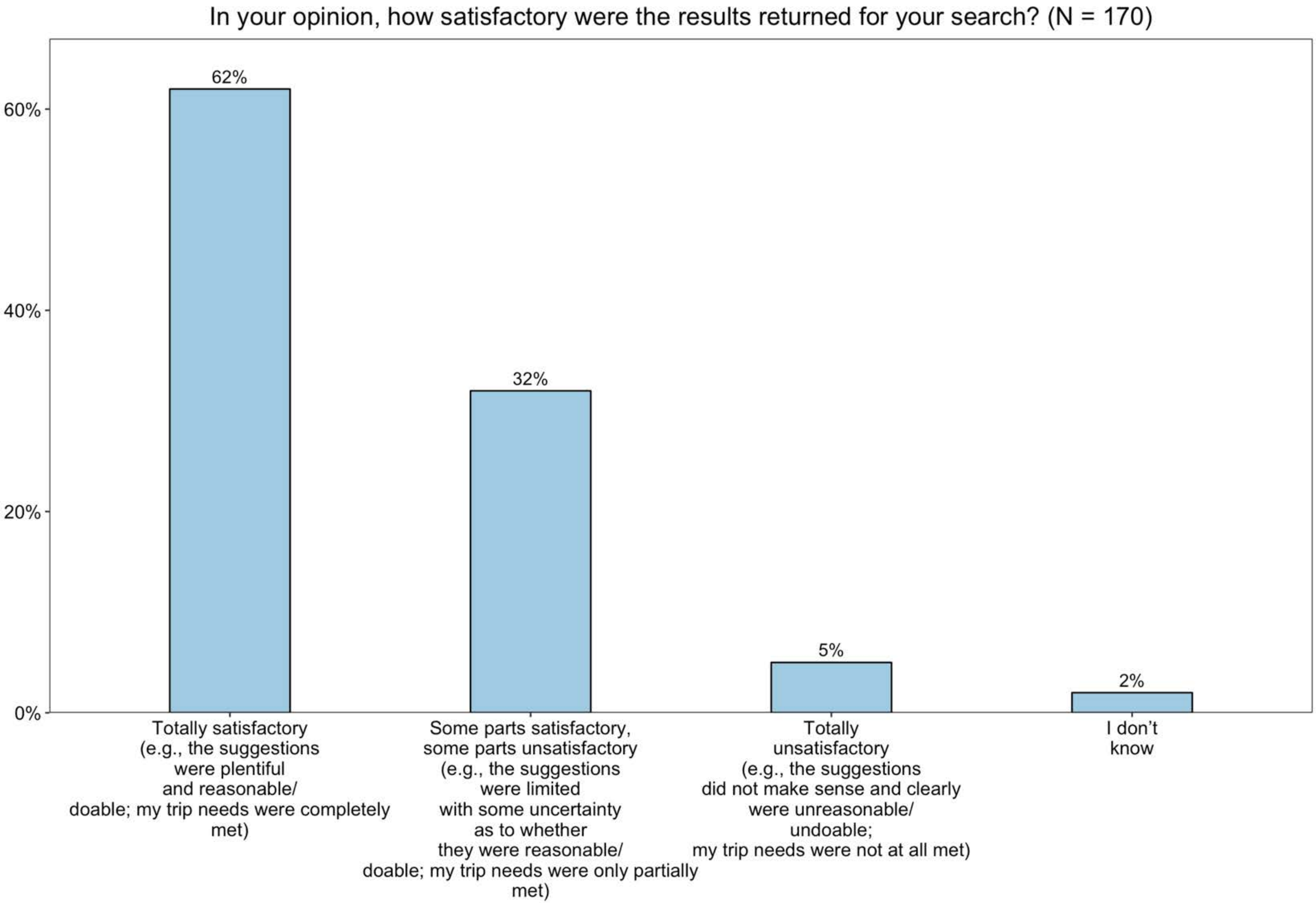

Please indicate which factor you optimized for in your search. (N = 4)
80%
60%
40%
20%
0%
25%
75%
Fewest transfers
Speed


In which way did you change the time of your trip? (N = 12)
50%
40%
30%
20%
10%
0%
0%
50%
50%
I did not change the time of the trip, I kept it at "Leave now"
I changed it according to an exact departure time
I changed it according to an exact arrival time


The trip planner located my origin correctly... (N = 182)
72%
15%
4%
4%
4%
60%
40%
20%
0%
Strongly agree
Agree
Disagree
Strongly disagree
I don't know

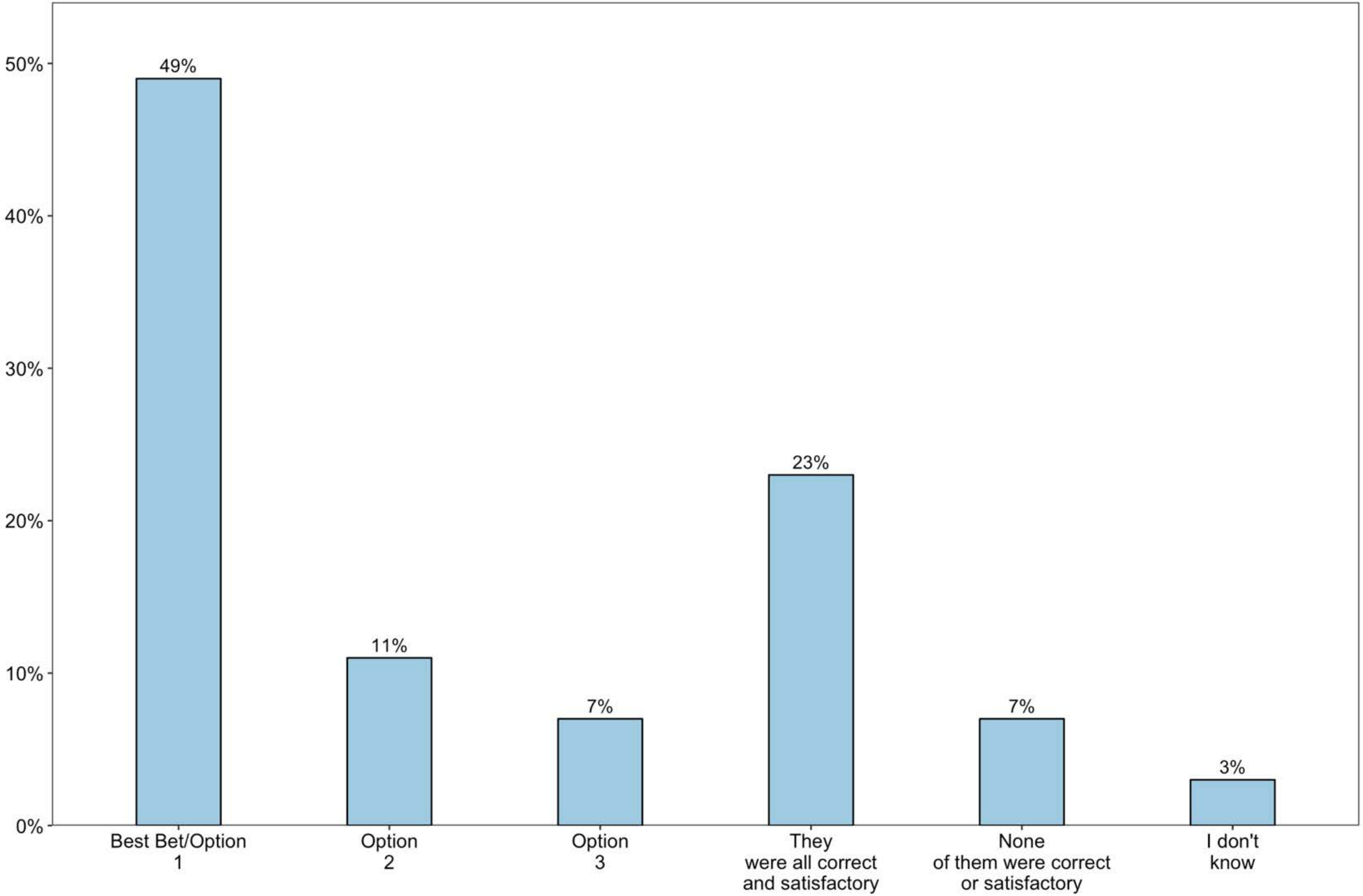

The trip planner located my destination correctly... (N = 183)
69%
17%
4%
6%
4%
60%
40%
20%
0%
Strongly agree
Agree
Disagree
Strongly disagree
I don’t know

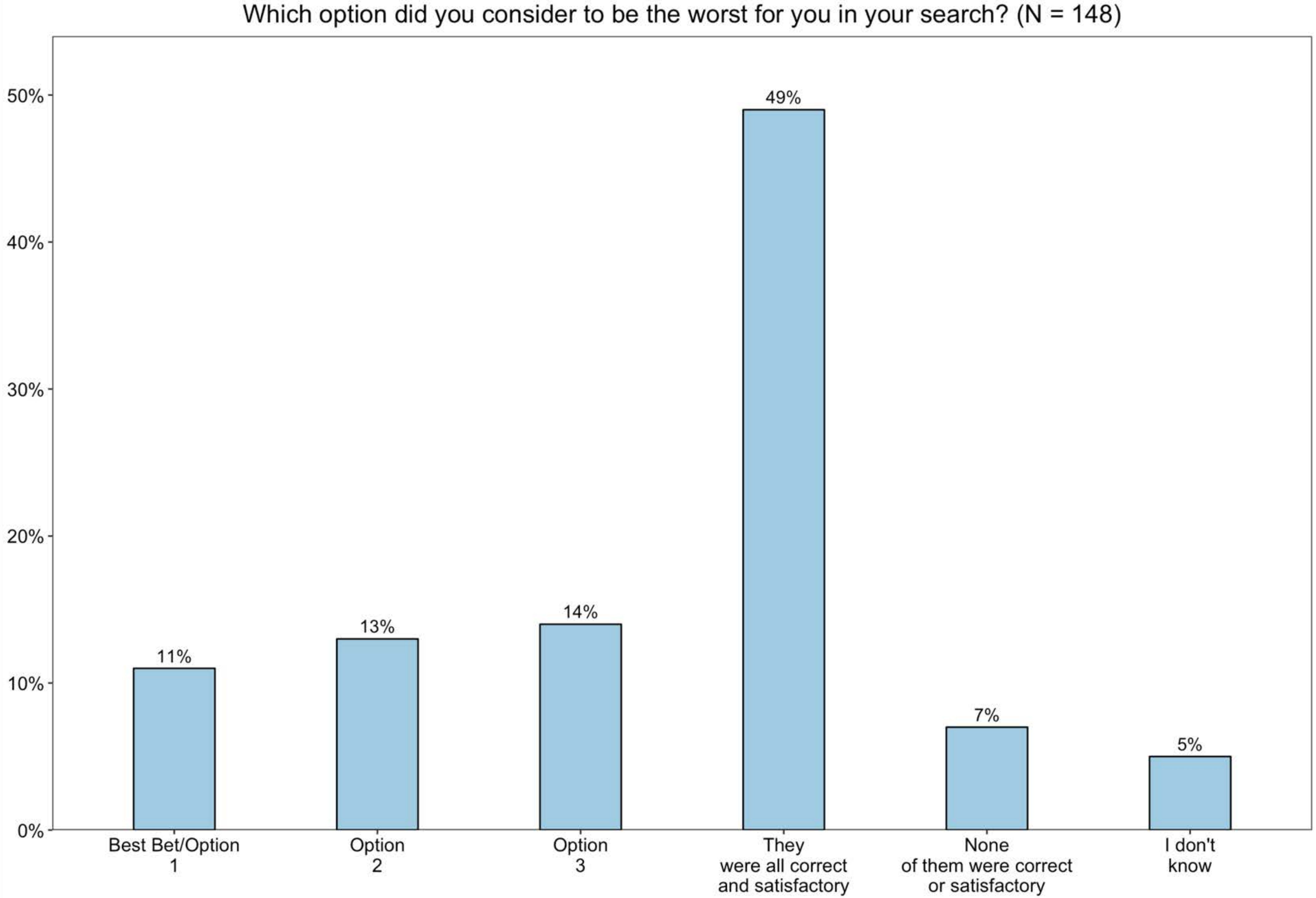

How many results (trip options) were returned for your search? (N = 183)
80%
60%
40%
20%
0%
5%
4%
10%
6%
75%
0 (there were no viable options)
0 (a functional error appears to have occurred)
1
2
3

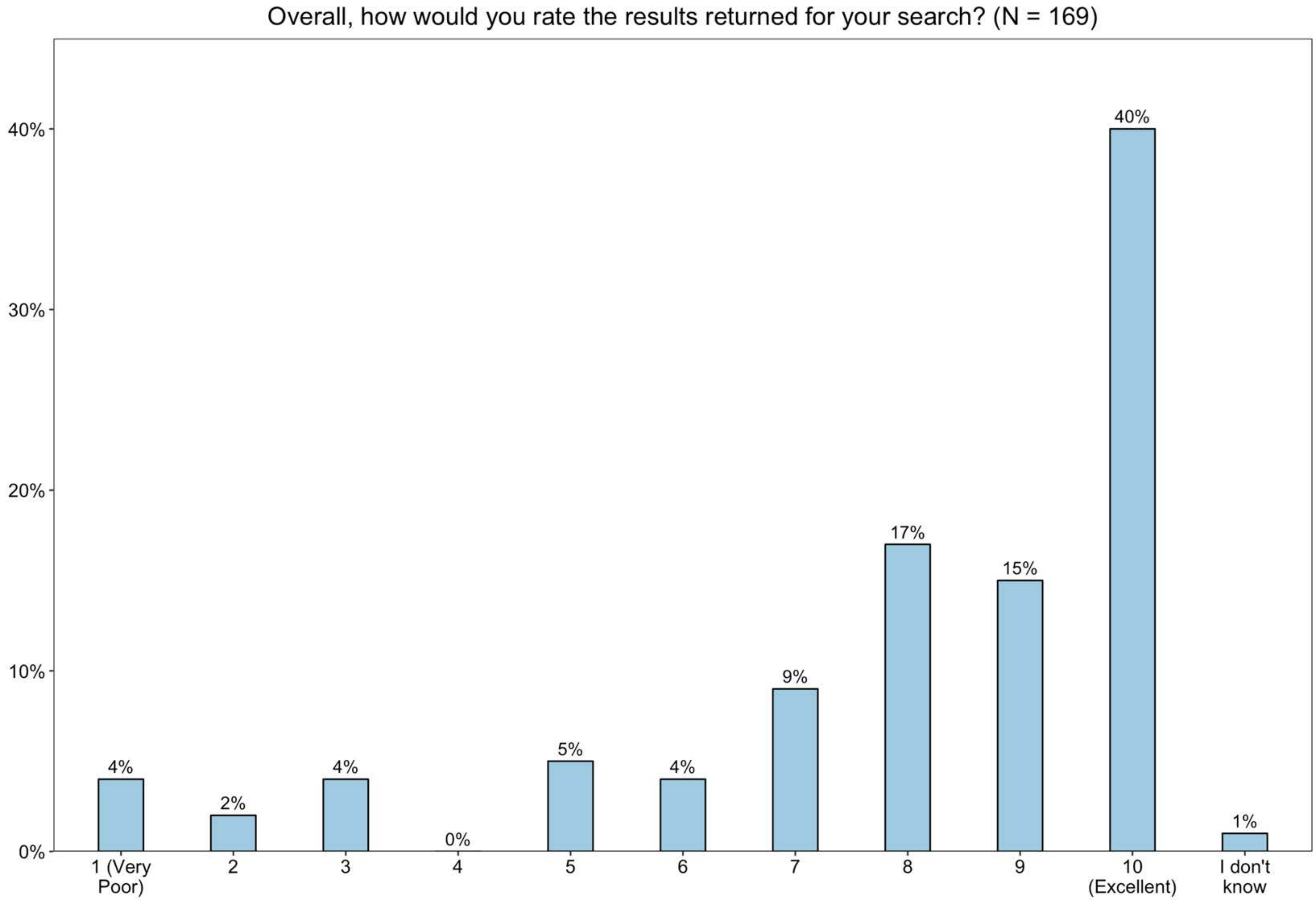


In your opinion, how satisfactory were the results returned for your search? (N = 170)
62%
32%
5%
2%
60%
40%
20%
0%
Totally satisfactory (e.g., the suggestions were plentiful and reasonable/ doable; my trip needs were completely met)
Some parts satisfactory, some parts unsatisfactory (e.g., the suggestions were limited with some uncertainty as to whether they were reasonable/ doable; my trip needs were only partially met)
Totally unsatisfactory (e.g., the suggestions did not make sense and clearly were unreasonable/ undoable; my trip needs were not at all met)
I don’t know

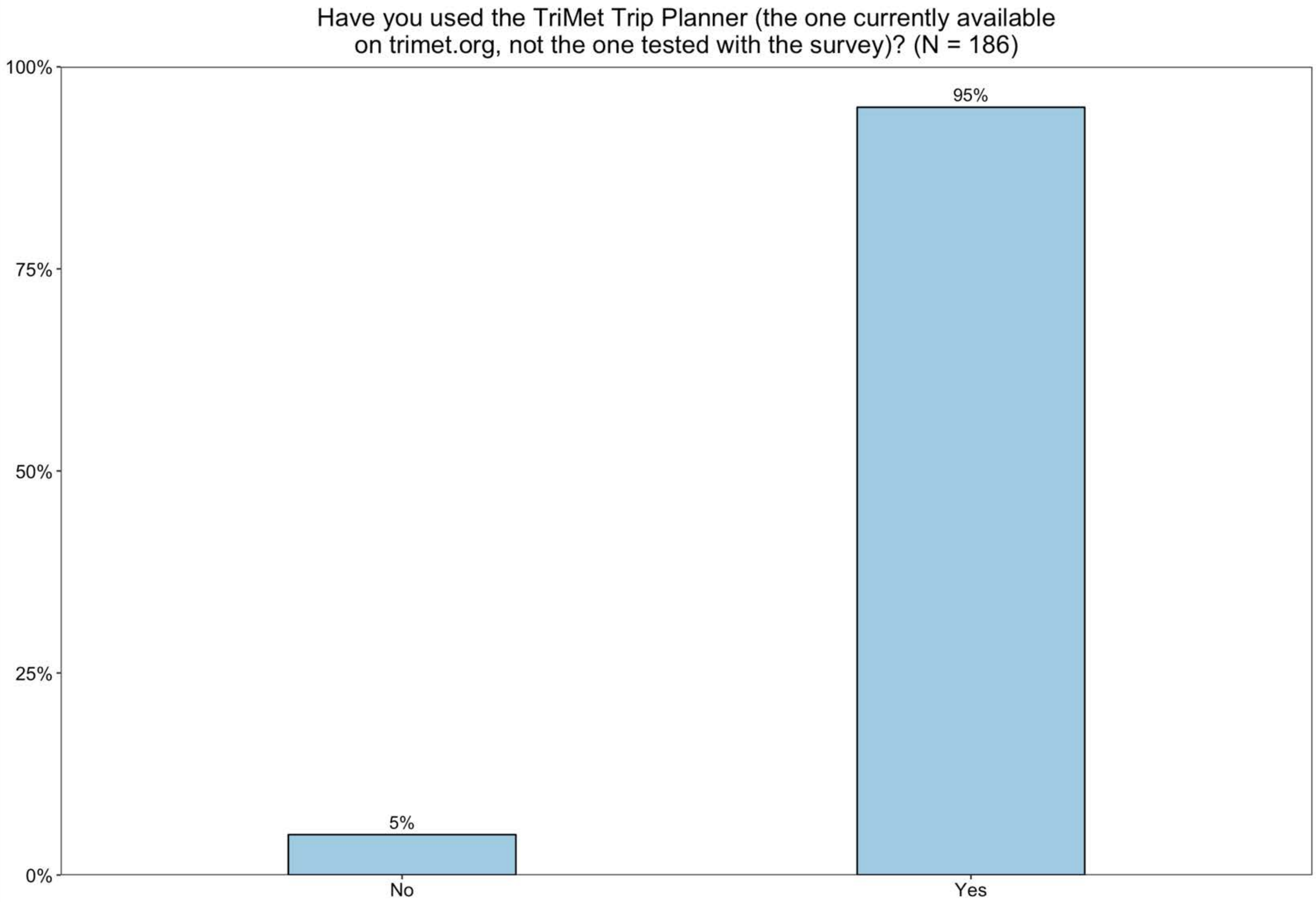
Which option did you consider to be the best for you in your search? (N = 149)



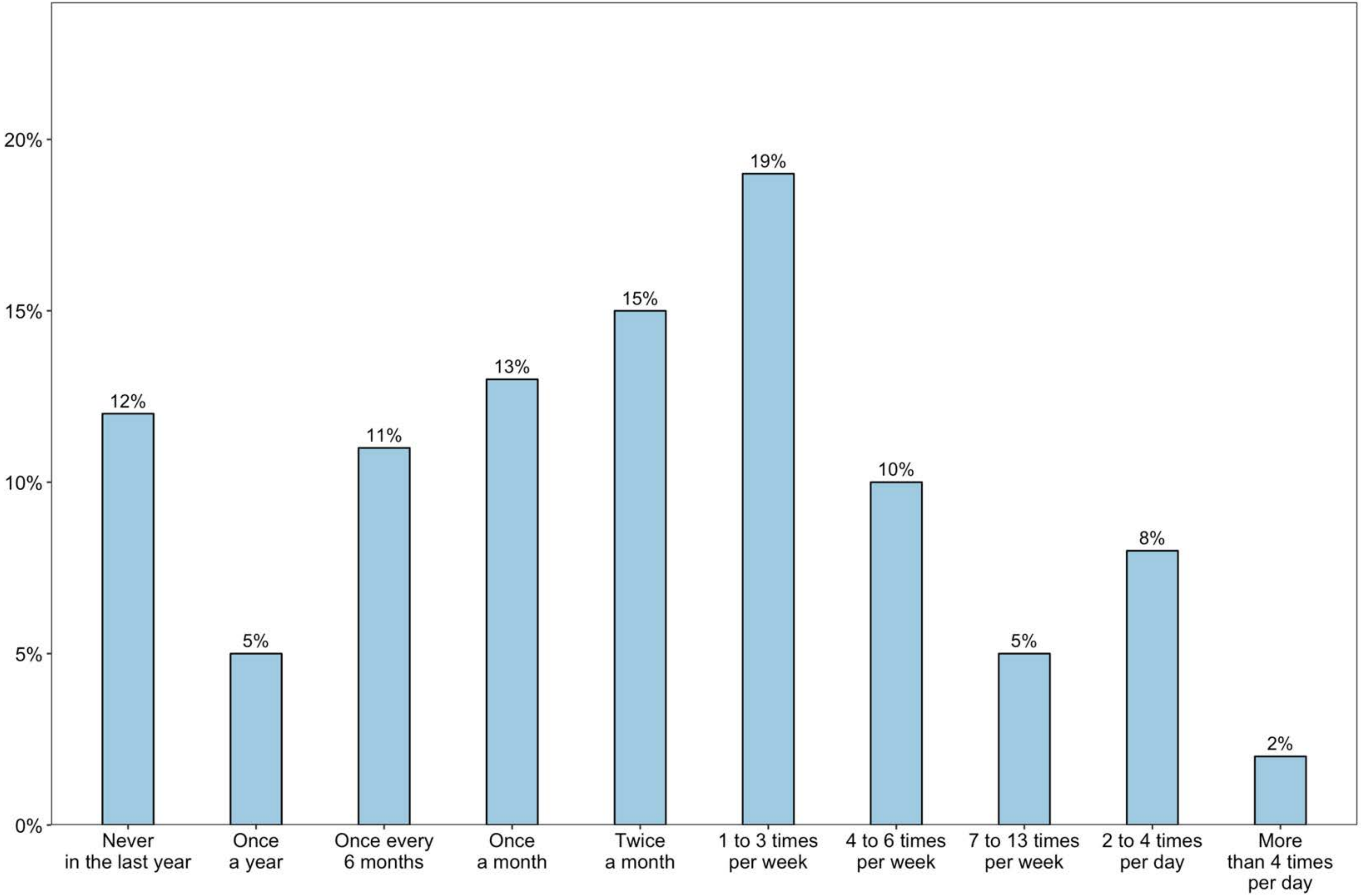

Which option did you consider to be the worst for you in your search? (N = 148)
50%
40%
30%
20%
10%
0%
11%
13%
14%
49%
7%
5%
Best Bet/Option 1
Option 2
Option 3
They were all correct and satisfactory
None of them were correct or satisfactory
I don't know



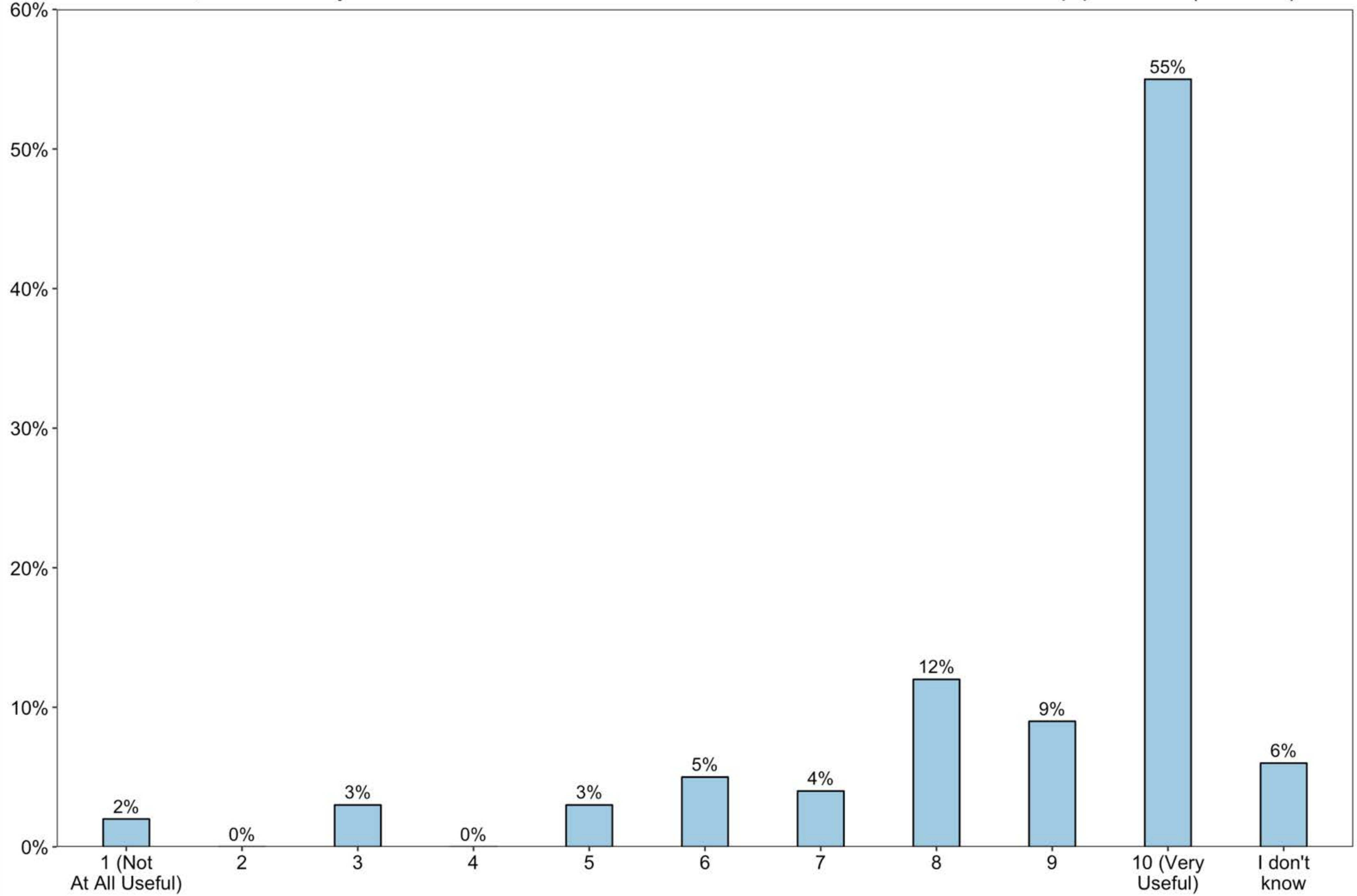
Overall, how would you rate the results returned for your search? (N = 169)
40%
30%
20%
10%
0%
4%
2%
4%
0%
5%
4%
9%
17%
15%
40%
1%
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know

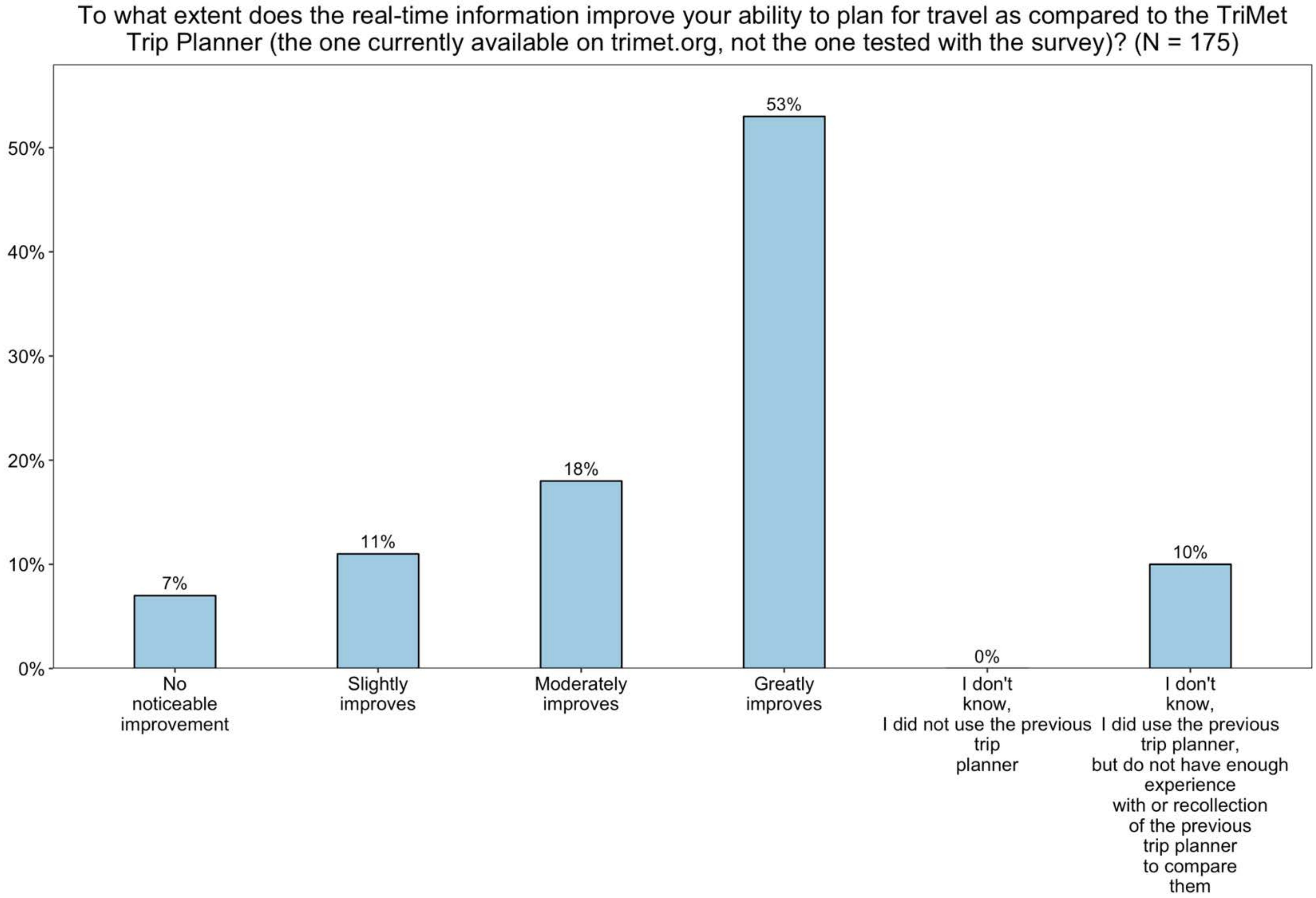

Have you used the TriMet Trip Planner (the one currently available
on trimet.org, not the one tested with the survey)? (N = 186)
100%
75%
50%
25%
0%
95%
5%
No
Yes

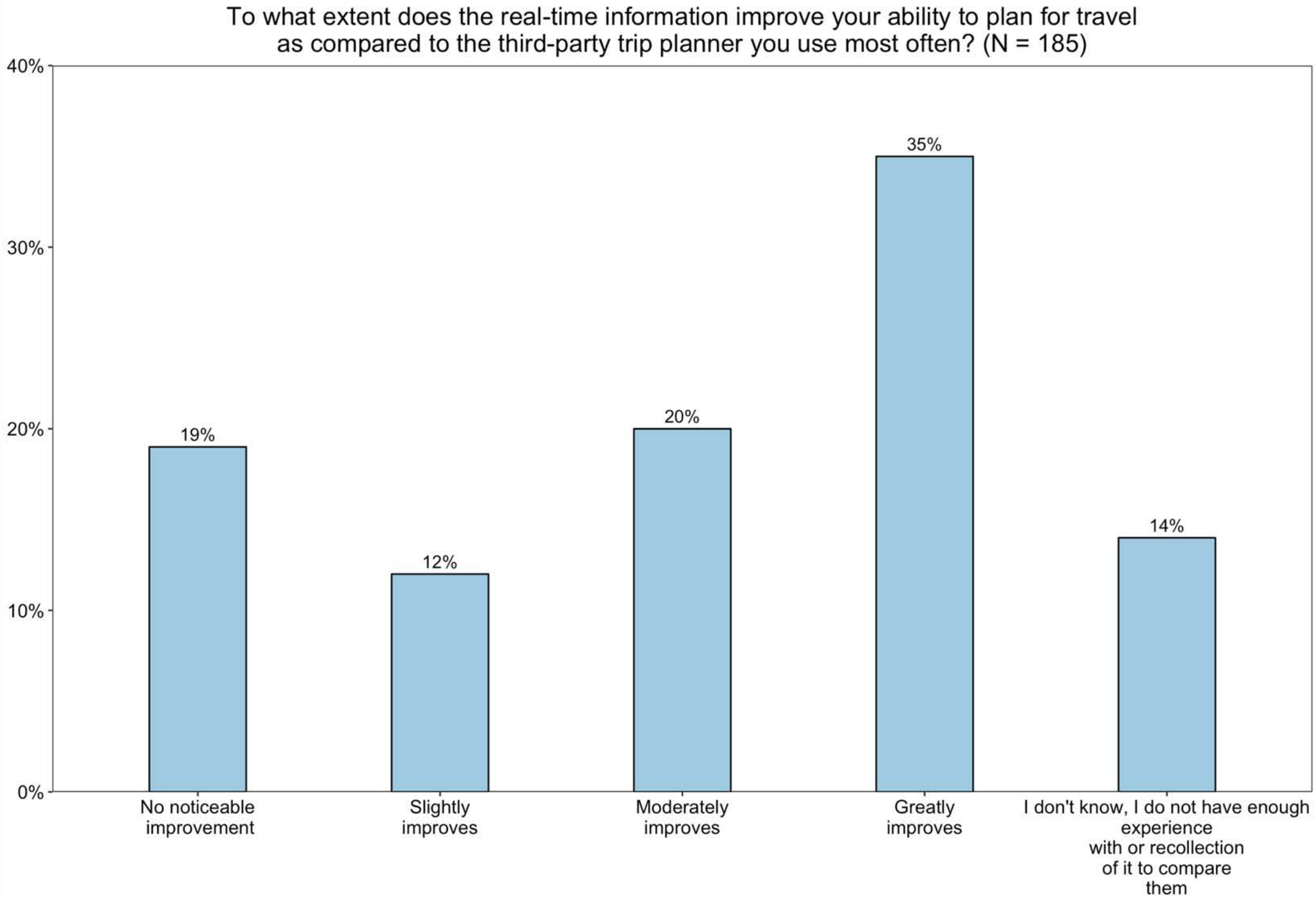
On average, how frequently do you use it? (N = 176)

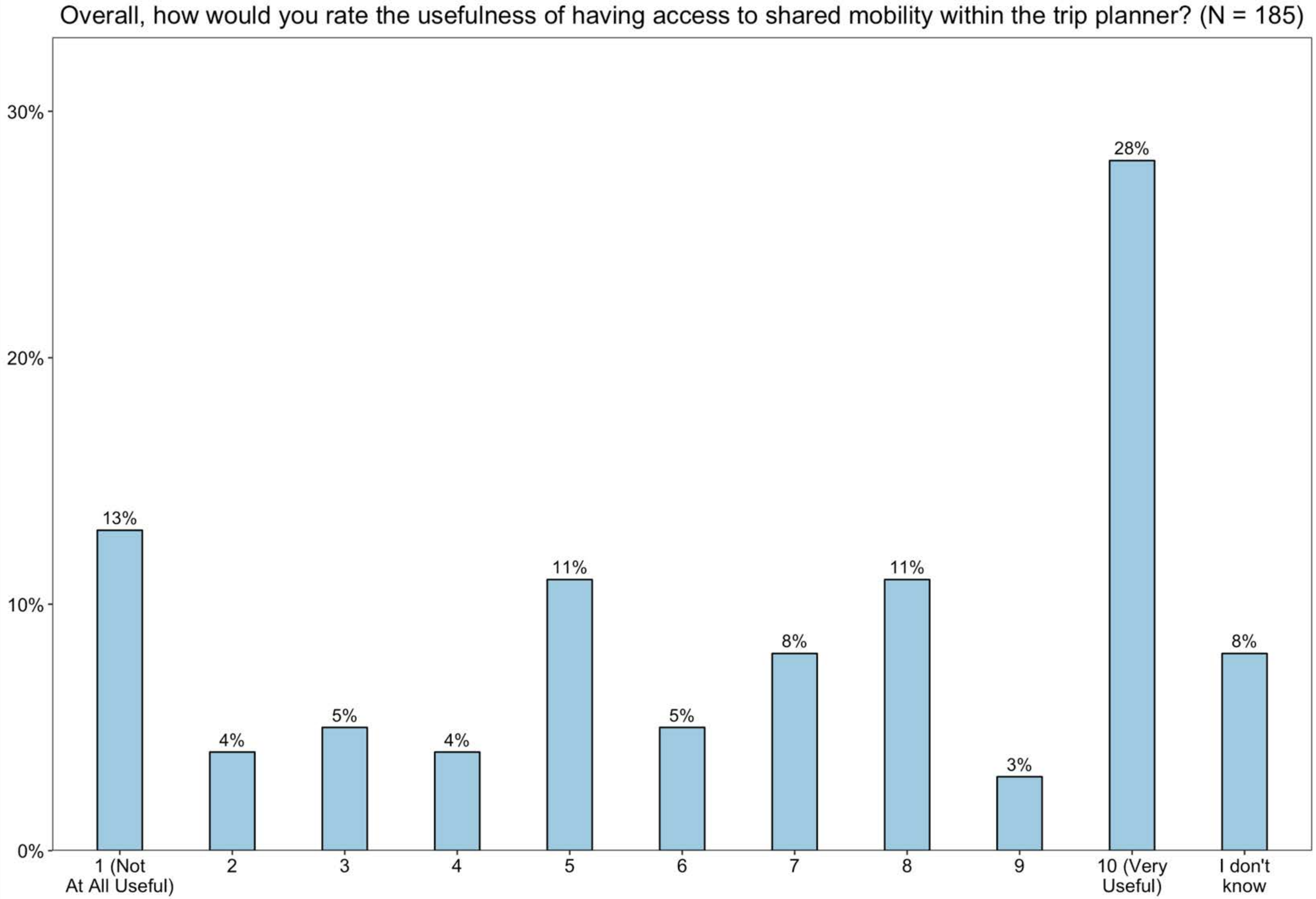


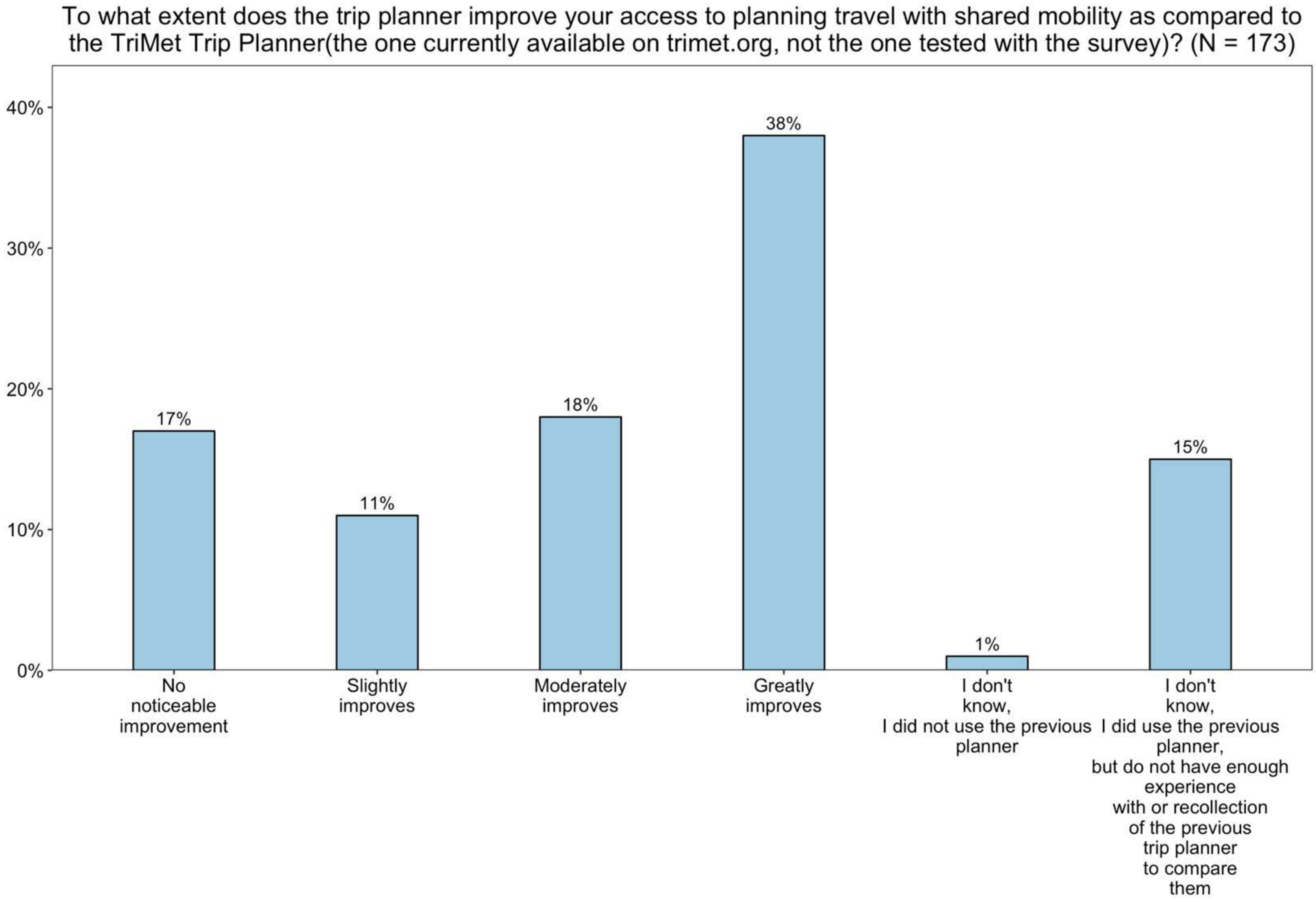
Overall, how would you rate the usefulness of the real-time information within the trip planner? (N = 185)

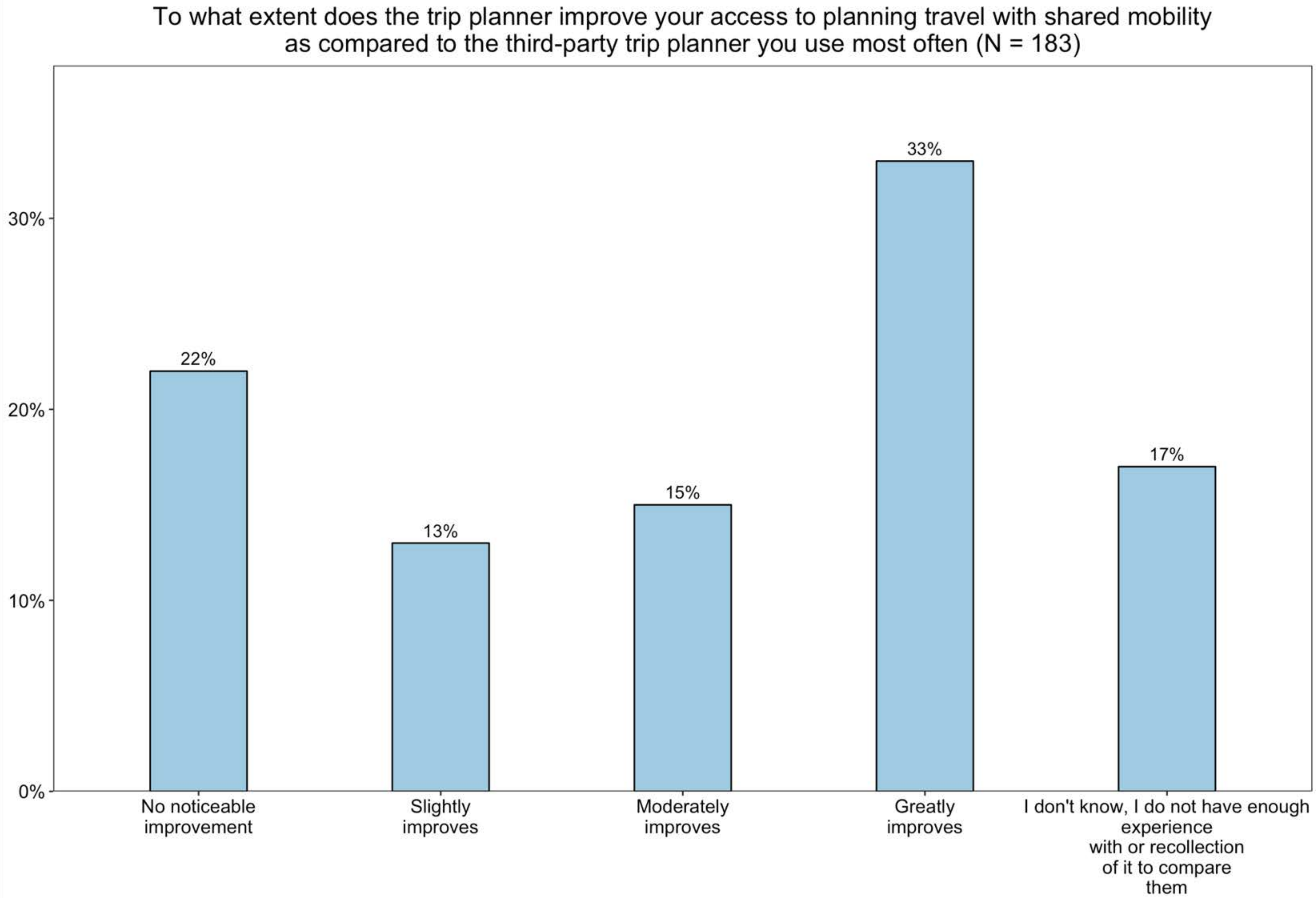


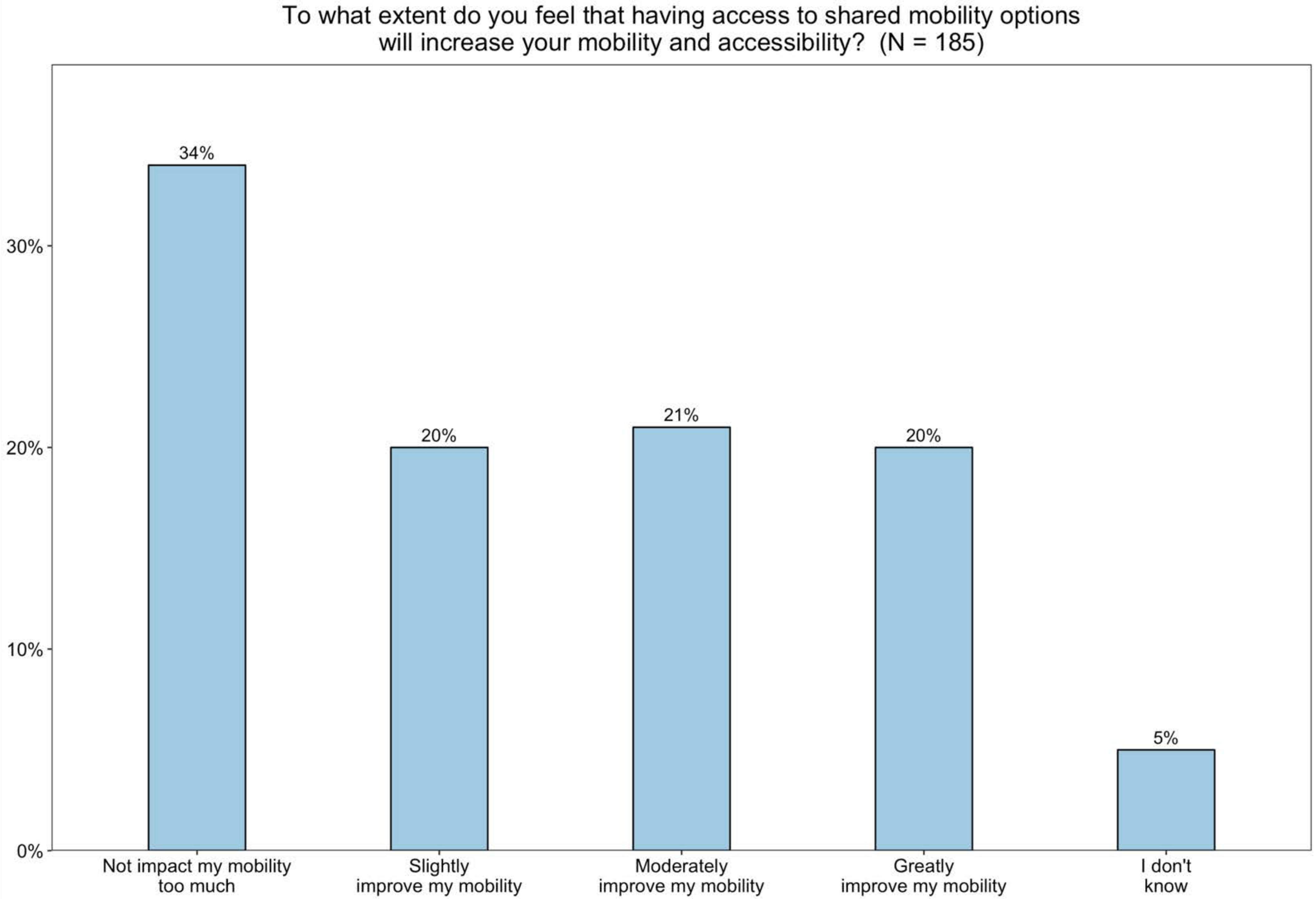

To what extent does the real-time information improve your ability to plan for travel as compared to the TriMet Trip Planner (the one currently available on trimet.org, not the one tested with the survey)? (N = 175)
0%
10%
20%
30%
40%
50%
7%
11%
18%
53%
0%
10%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I did not use the previous trip planner
I don't know, I did use the previous trip planner, but do not have enough experience with or recollection of the previous trip planner to compare them


To what extent does the real-time information improve your ability to plan for travel as compared to the third-party trip planner you use most often? (N = 185)
40%
30%
20%
10%
0%
19%
12%
20%
35%
14%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I do not have enough experience with or recollection of it to compare them

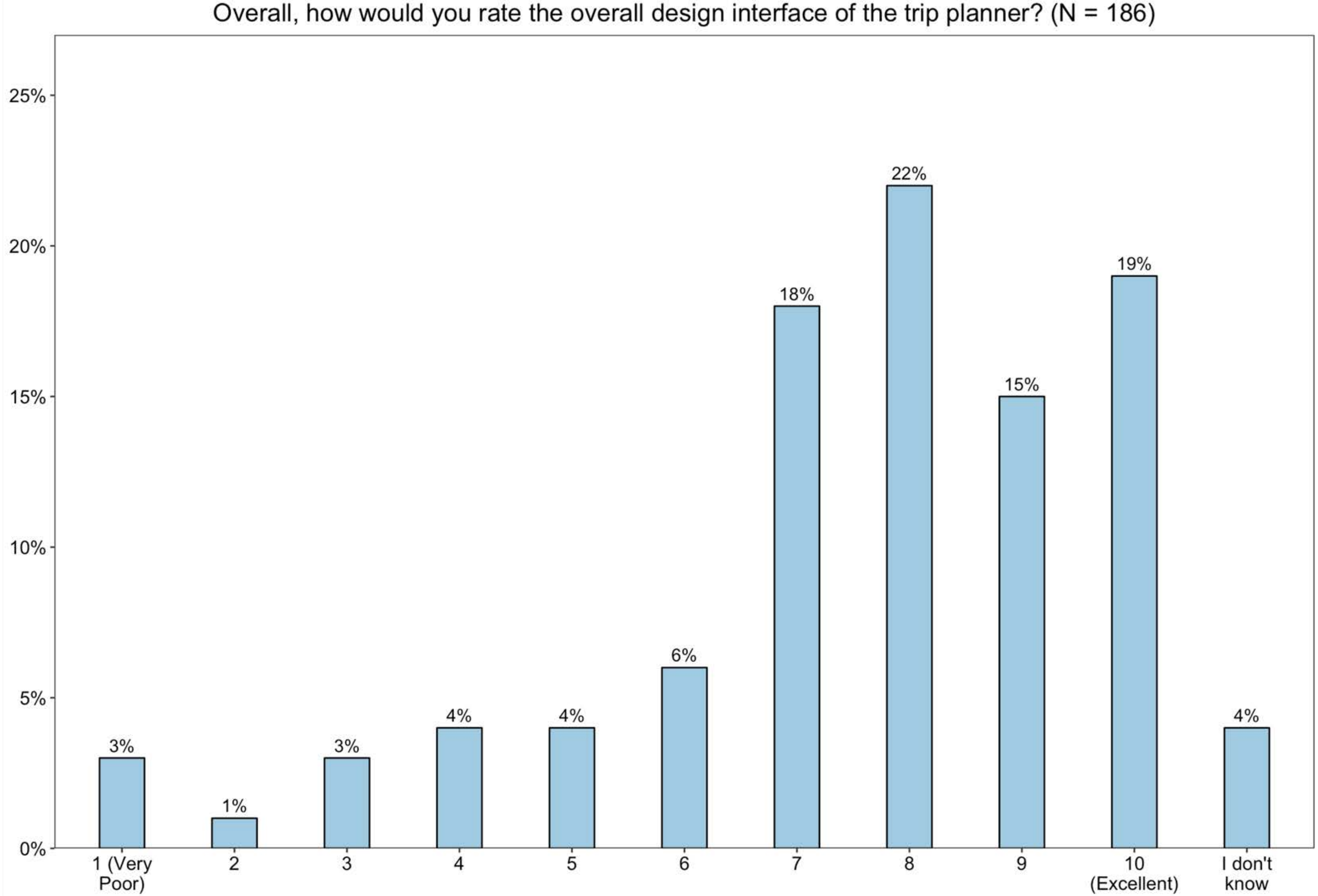

Overall, how would you rate the usefulness of having access to shared mobility within the trip planner? (N = 185)
30%
20%
10%
0%
13%
4%
5%
4%
11%
5%
8%
11%
3%
28%
8%
1 (Not At All Useful)
2
3
4
5
6
7
8
9
10 (Very Useful)
I don't know


To what extent does the trip planner improve your access to planning travel with shared mobility as compared to the TriMet Trip Planner(the one currently available on trimet.org, not the one tested with the survey)? (N = 173)
40%
30%
20%
10%
0%
17%
11%
18%
38%
1%
15%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I did not use the previous planner
I don't know, I did use the previous planner, but do not have enough experience with or recollection of the previous trip planner to compare them

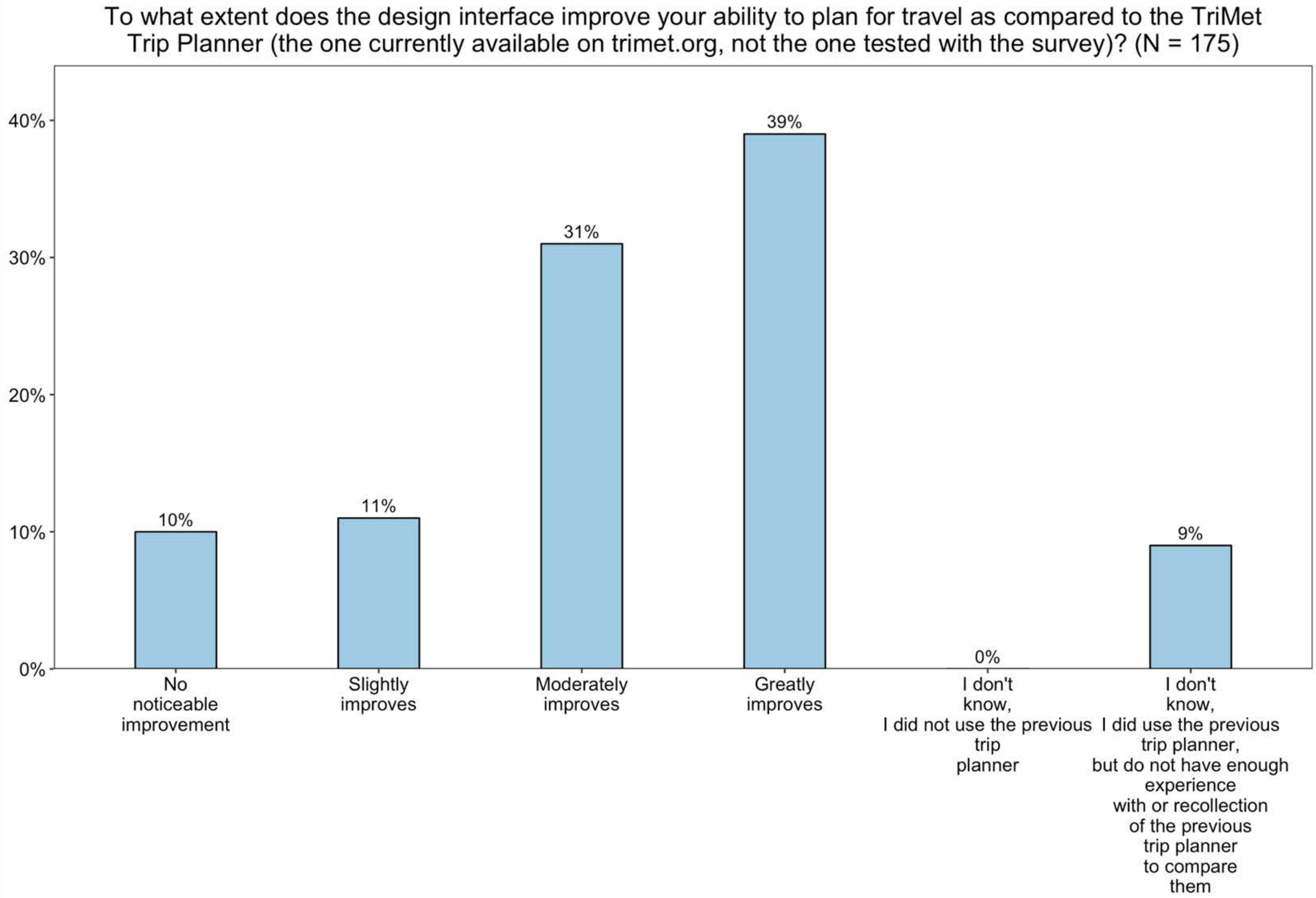

To what extent does the trip planner improve your access to planning travel with shared mobility
as compared to the third-party trip planner you use most often (N = 183)
30%
20%
10%
0%
22%
13%
15%
33%
17%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I do not have enough experience with or recollection of it to compare them

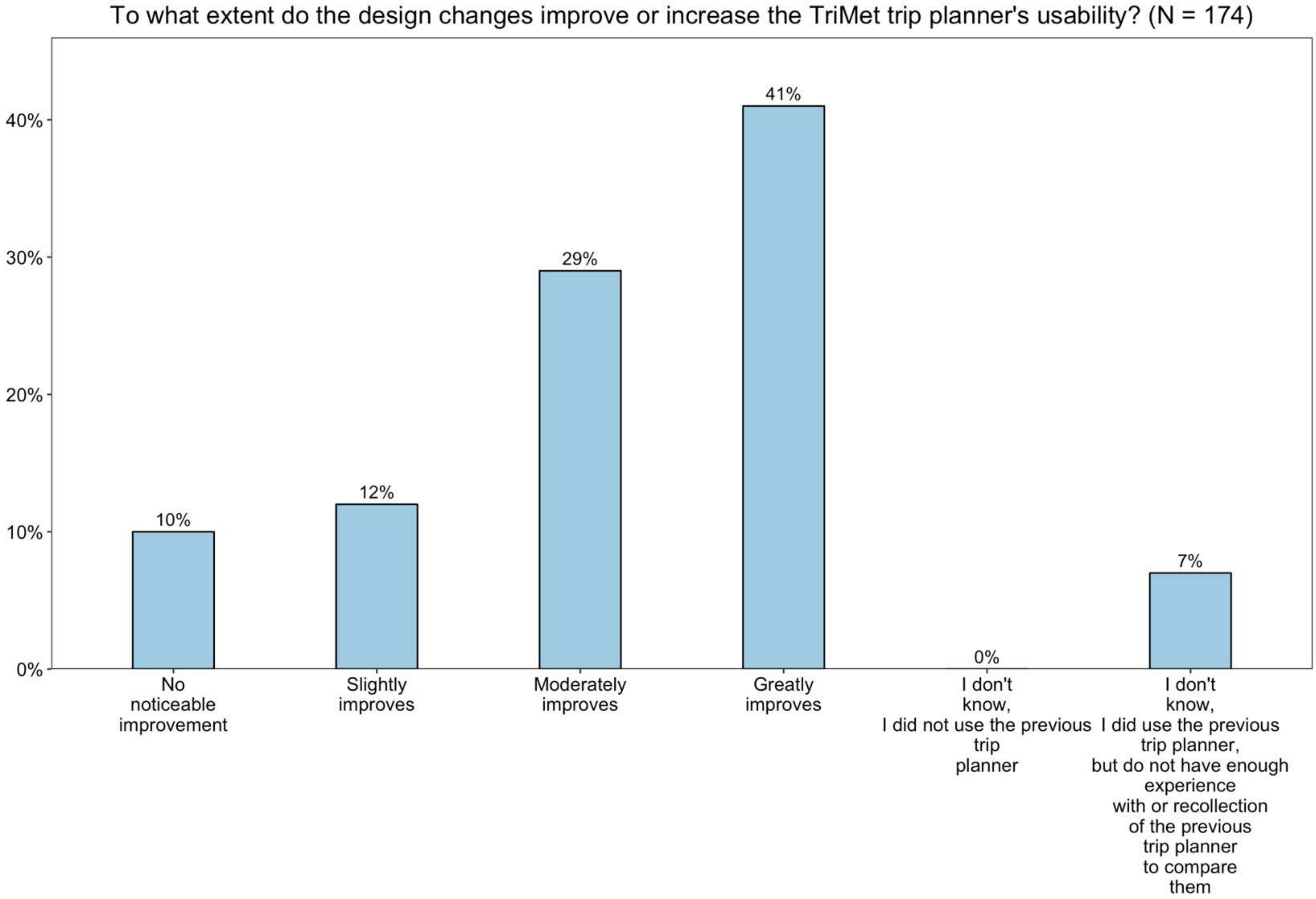


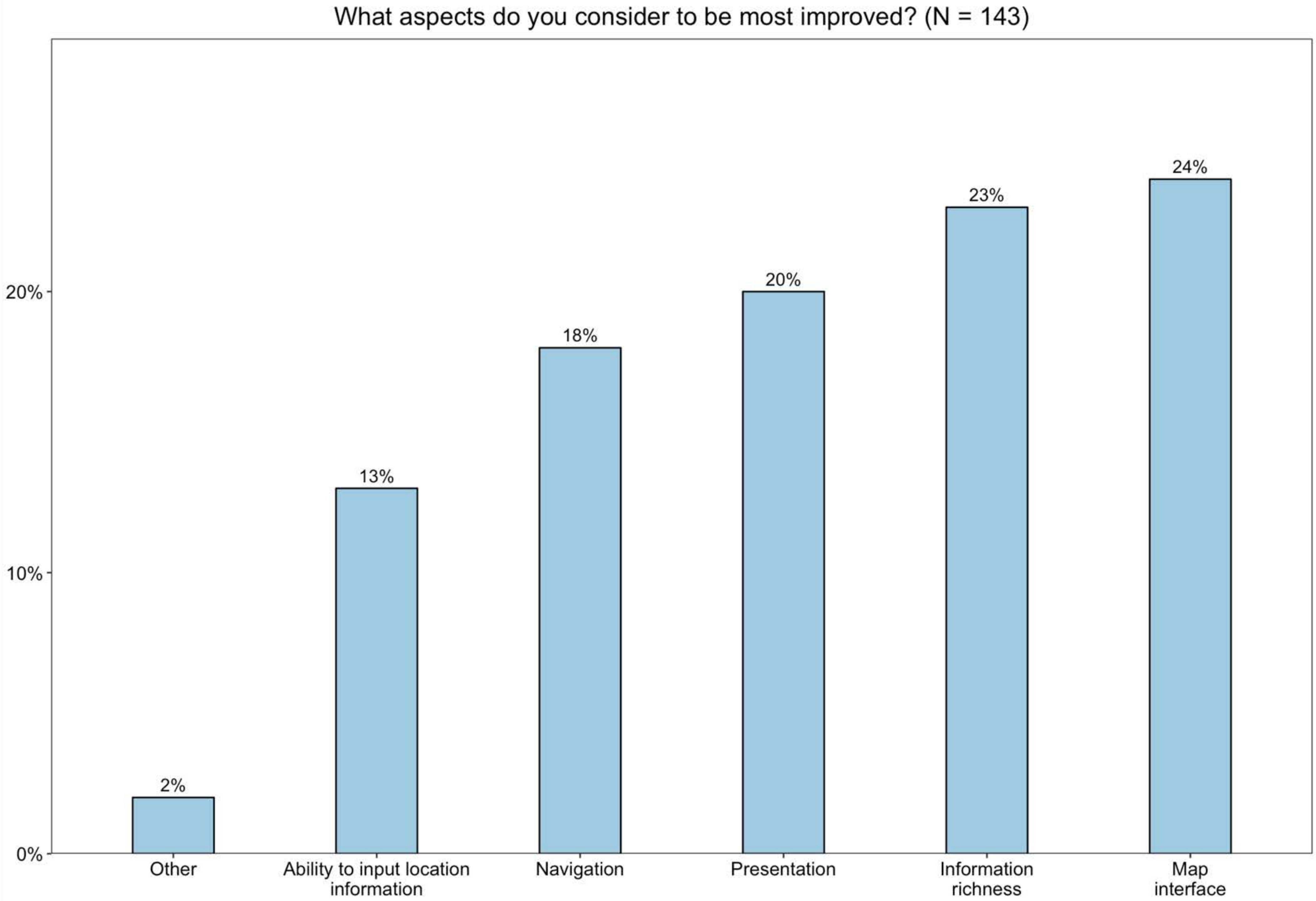
To what extent do you feel that having access to shared mobility options will increase your mobility and accessibility? (N = 185)
34%
20%
21%
20%
5%
30%
20%
10%
0%
Not impact my mobility too much
Slightly improve my mobility
Moderately improve my mobility
Greatly improve my mobility
I don't know

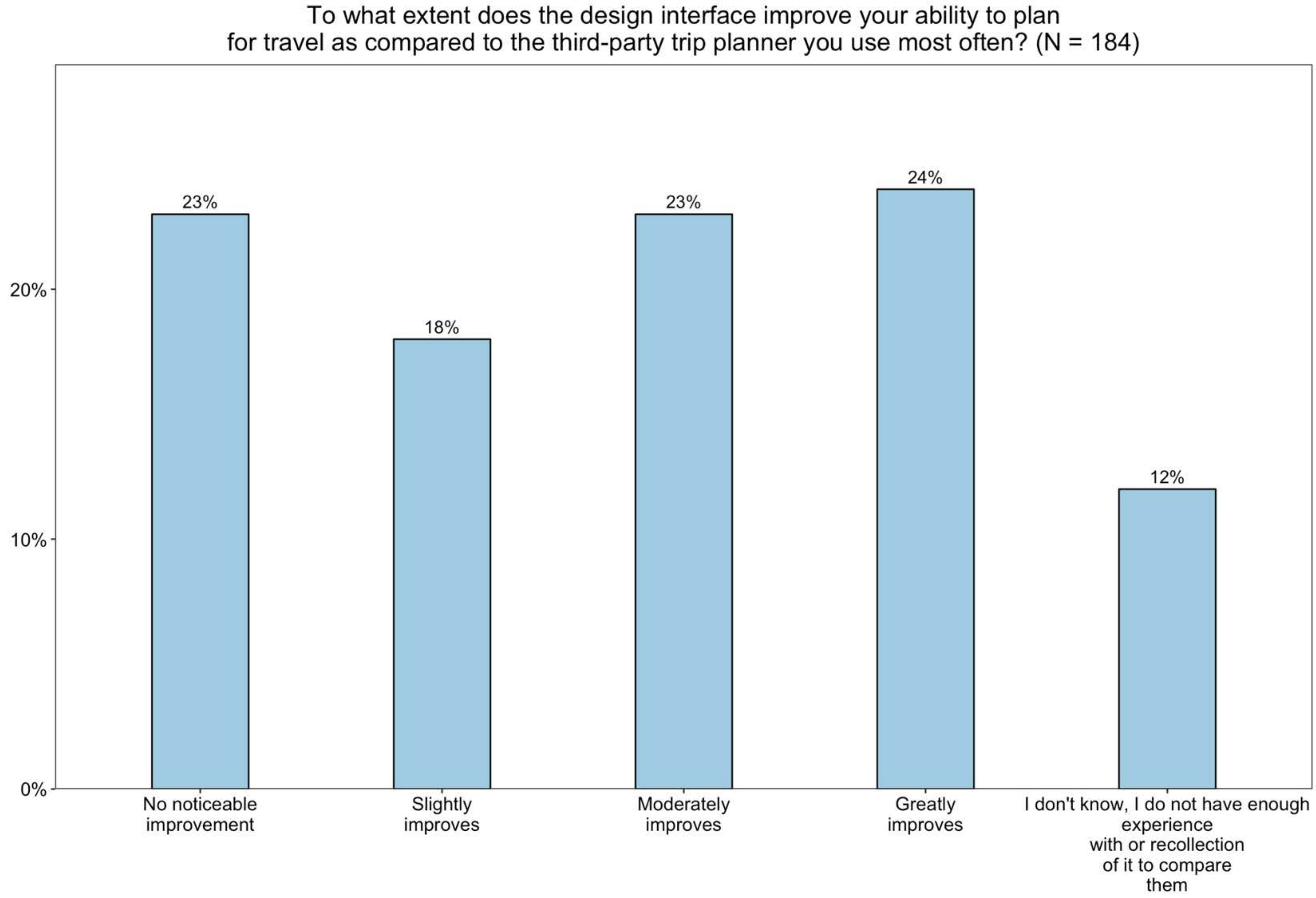


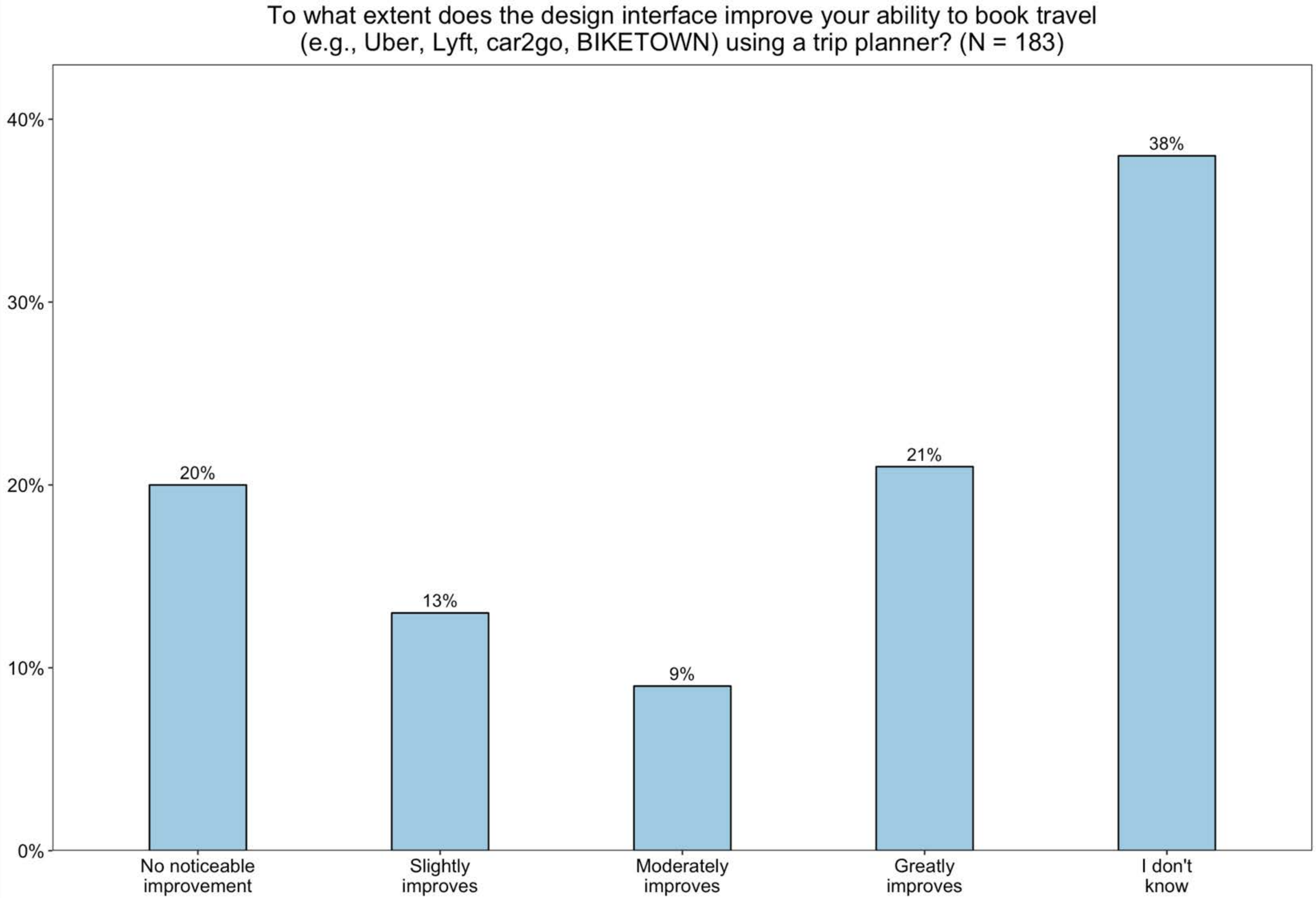
Overall, how would you rate the overall design interface of the trip planner? (N = 186)
25%
20%
15%
10%
5%
0%
3%
1%
3%
4%
4%
6%
18%
22%
15%
19%
4%
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know


To what extent does the design interface improve your ability to plan for travel as compared to the TriMet Trip Planner (the one currently available on trimet.org, not the one tested with the survey)? (N = 175)
40%
30%
20%
10%
0%
10%
11%
31%
39%
0%
9%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I did not use the previous trip planner
I don't know, I did use the previous trip planner, but do not have enough experience with or recollection of the previous trip planner to compare them

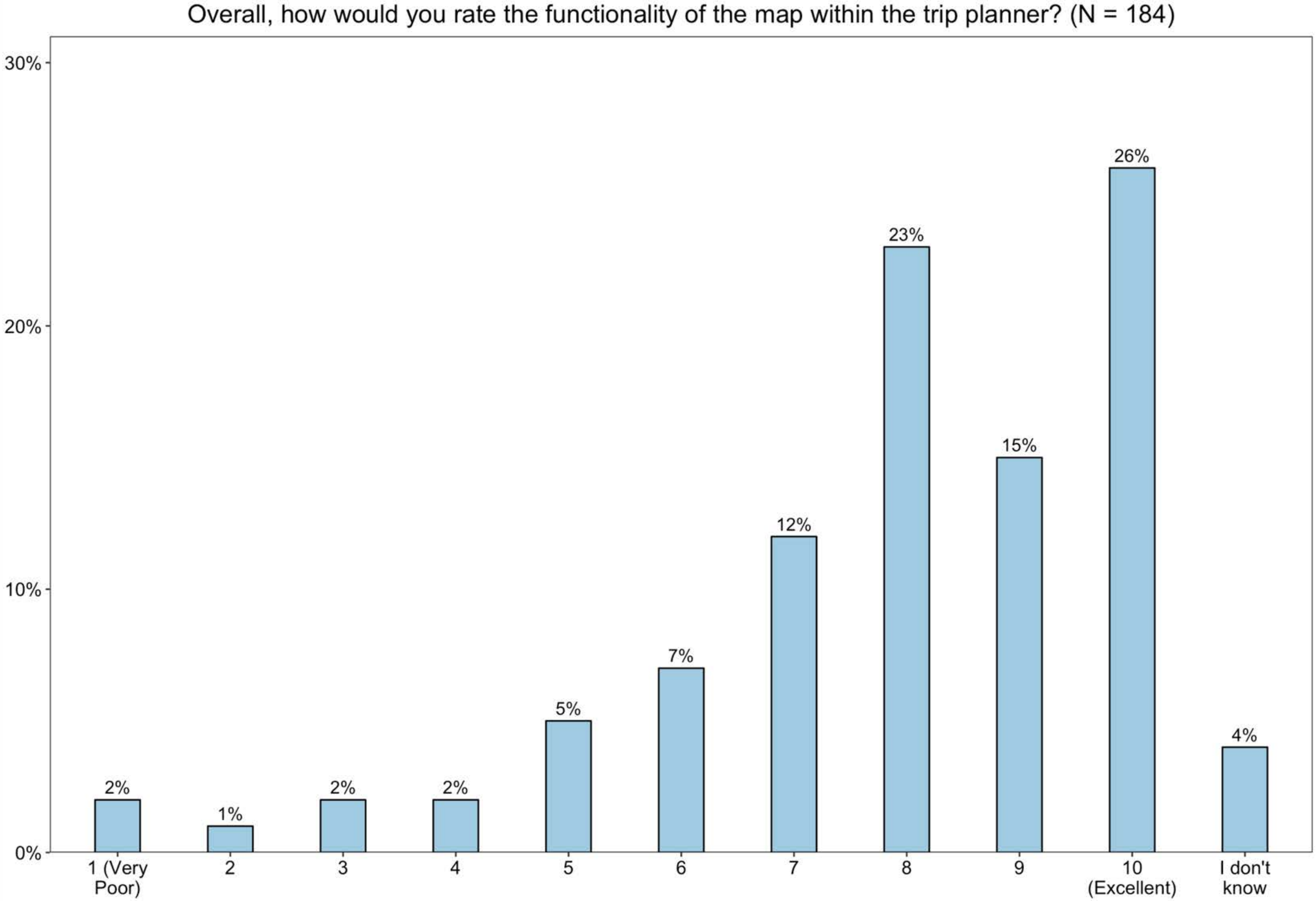

To what extent do the design changes improve or increase the TriMet trip planner's usability? (N = 174)
40%
30%
20%
10%
0%
10%
12%
29%
41%
0%
7%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I did not use the previous trip planner
I don't know, I did use the previous trip planner, but do not have enough experience with or recollection of the previous trip planner to compare them


What aspects do you consider to be most improved? (N = 143)
20%
10%
0%
2%
13%
18%
20%
23%
24%
Other
Ability to input location information
Navigation
Presentation
Information richness
Map interface

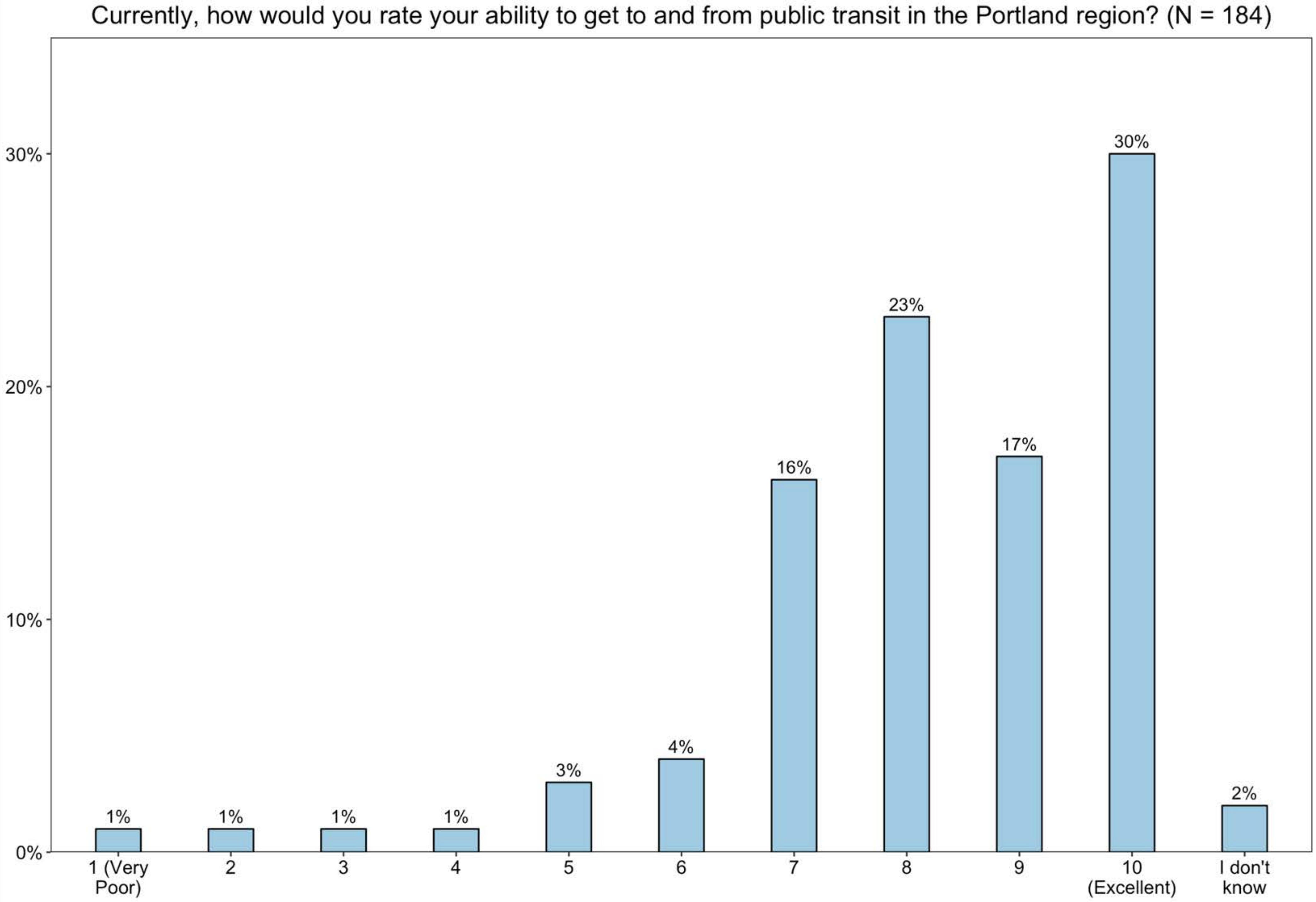

To what extent does the design interface improve your ability to plan
for travel as compared to the third-party trip planner you use most often? (N = 184)
23%
18%
23%
24%
12%
20%
10%
0%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I do not have enough experience with or recollection of it to compare them

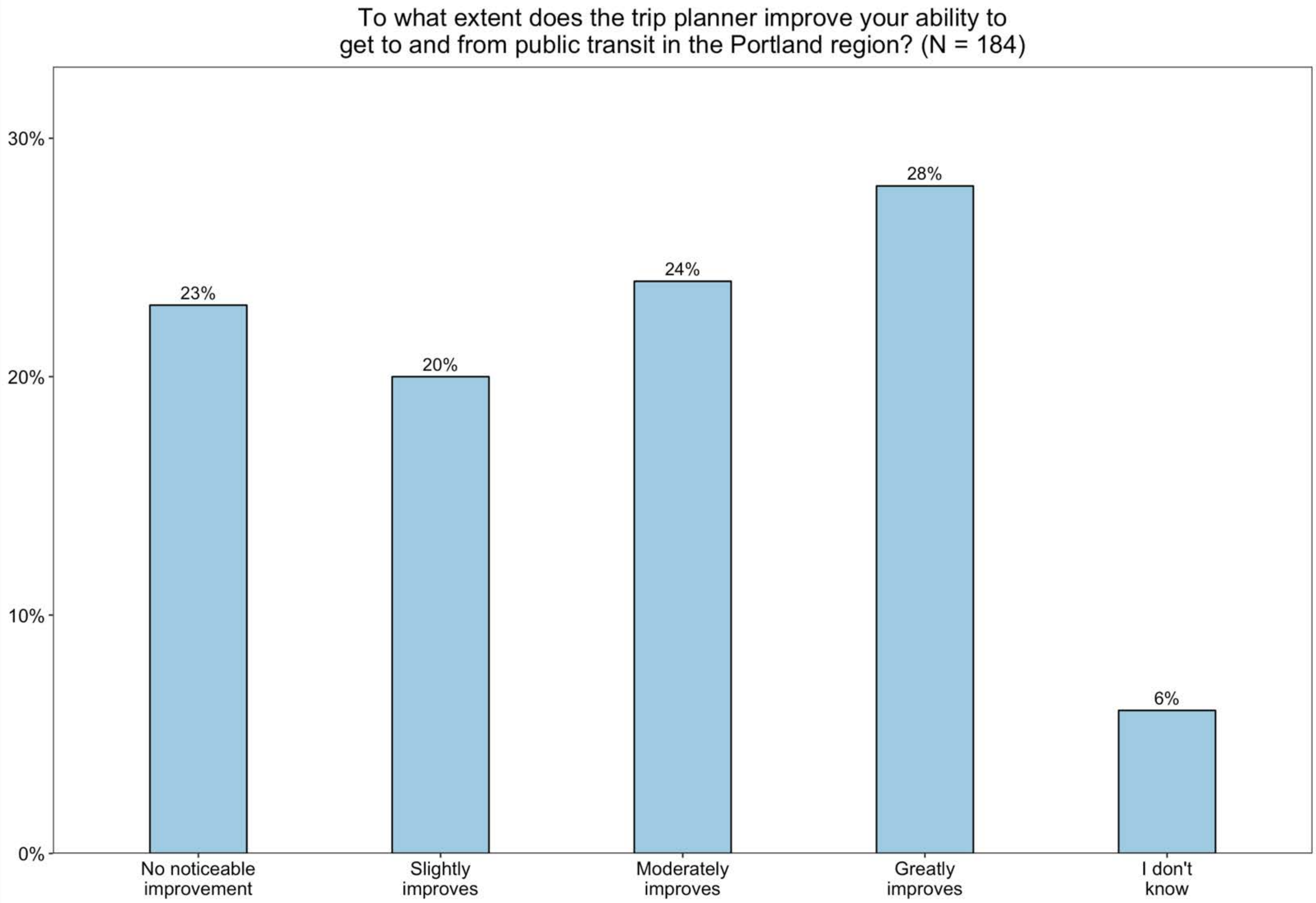


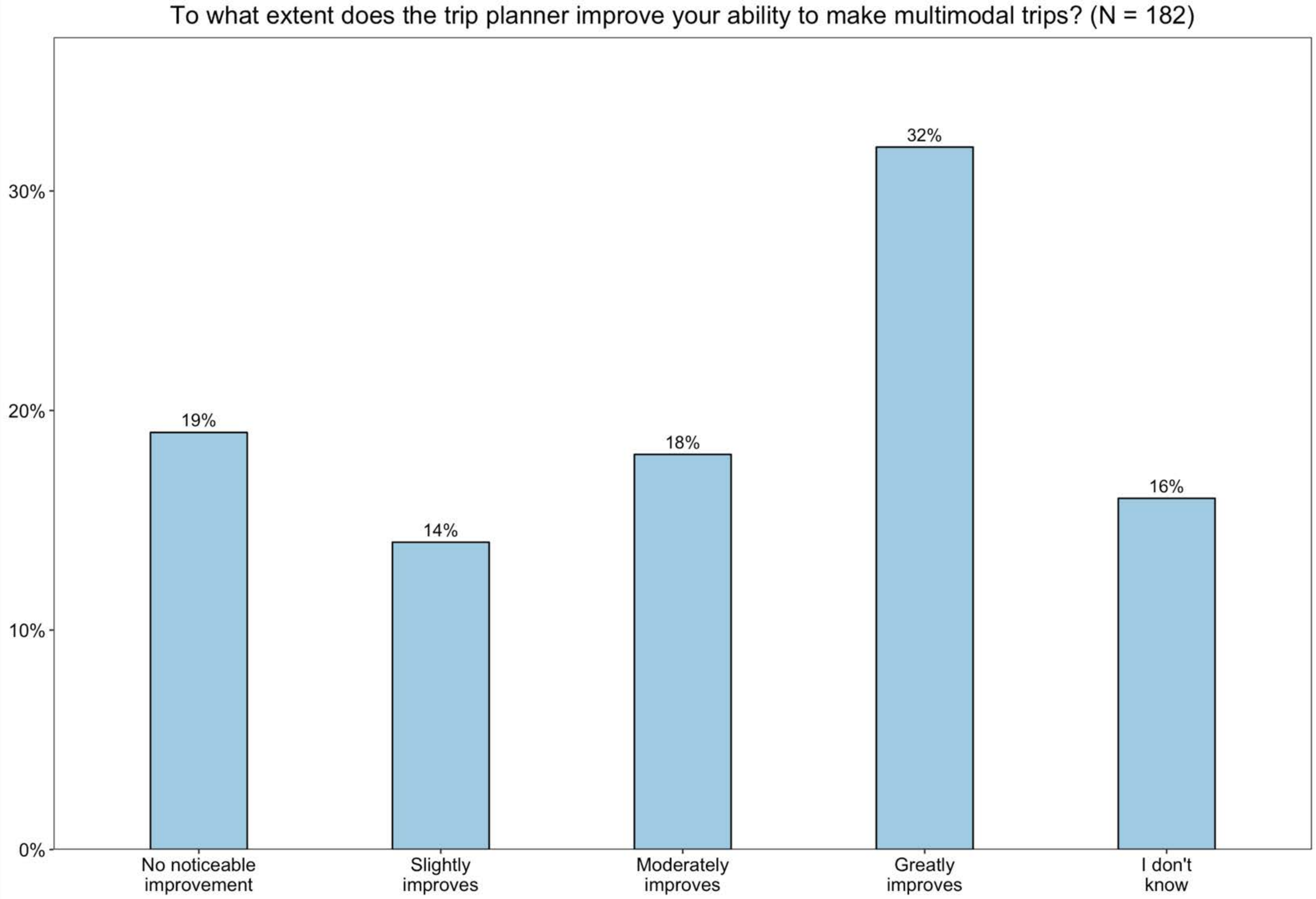
To what extent does the design interface improve your ability to book travel
(e.g., Uber, Lyft, car2go, BIKETOWN) using a trip planner? (N = 183)
40%
30%
20%
10%
0%
20%
13%
9%
21%
38%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know



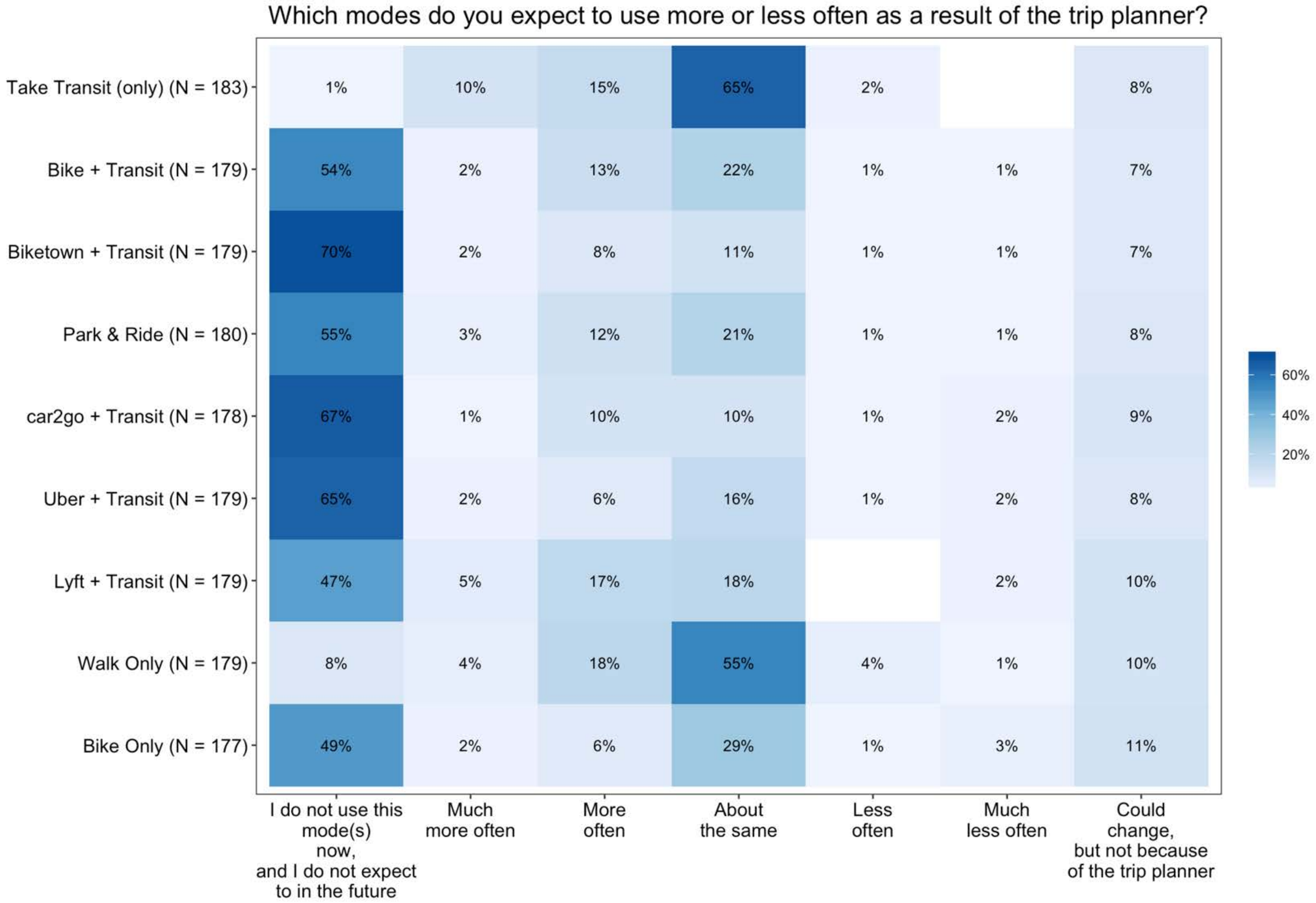
Overall, how would you rate the functionality of the map within the trip planner? (N = 184)
30%
20%
10%
0%
2%
1%
2%
2%
5%
7%
12%
23%
15%
26%
4%
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know


Currently, how would you rate your ability to get to and from public transit in the Portland region? (N = 184)
30%
20%
10%
0%
1%
1%
1%
1%
3%
4%
16%
23%
17%
30%
2%
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know

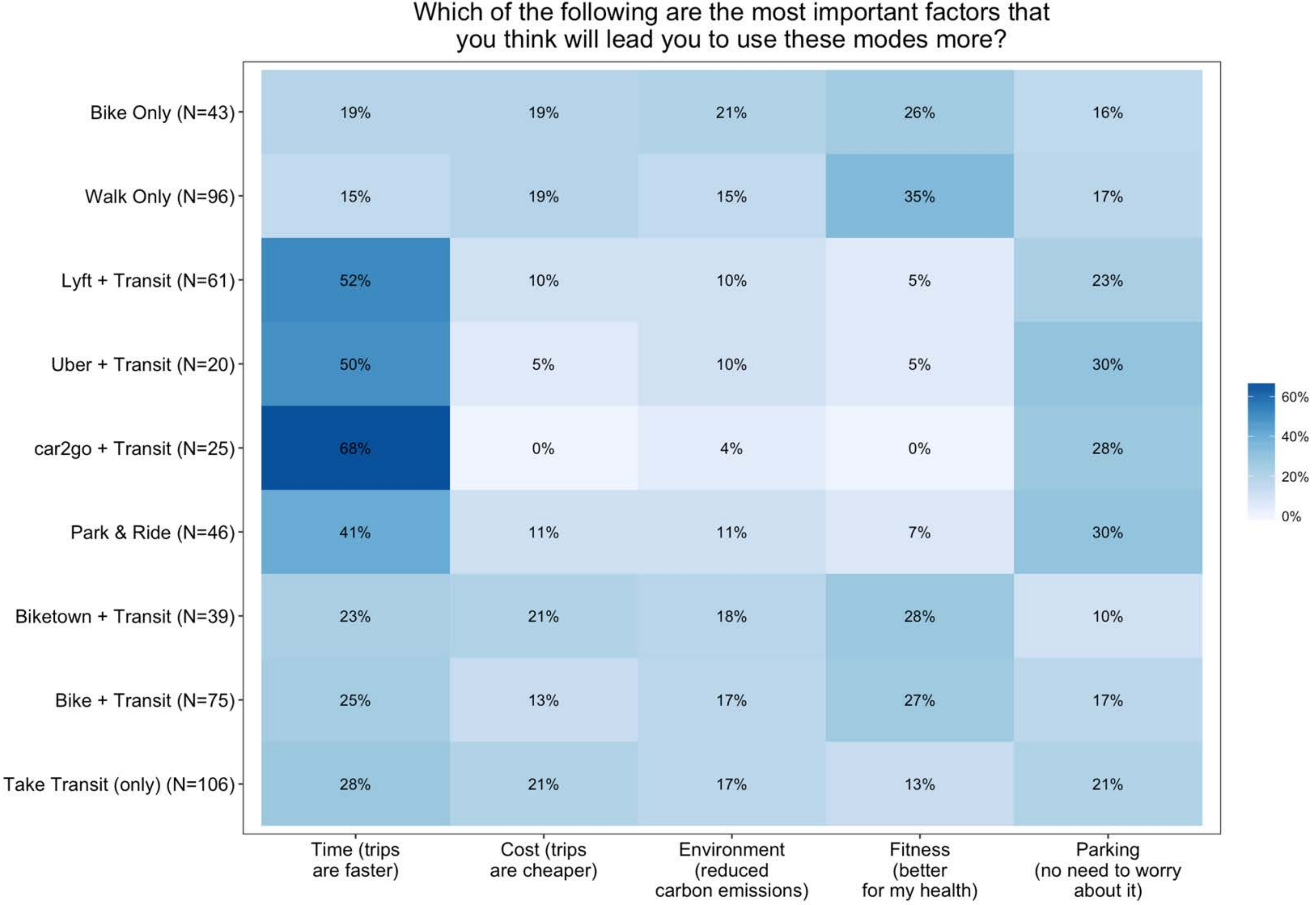

To what extent does the trip planner improve your ability to get to and from public transit in the Portland region? (N = 184)
30%
20%
10%
0%
23%
20%
24%
28%
6%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know

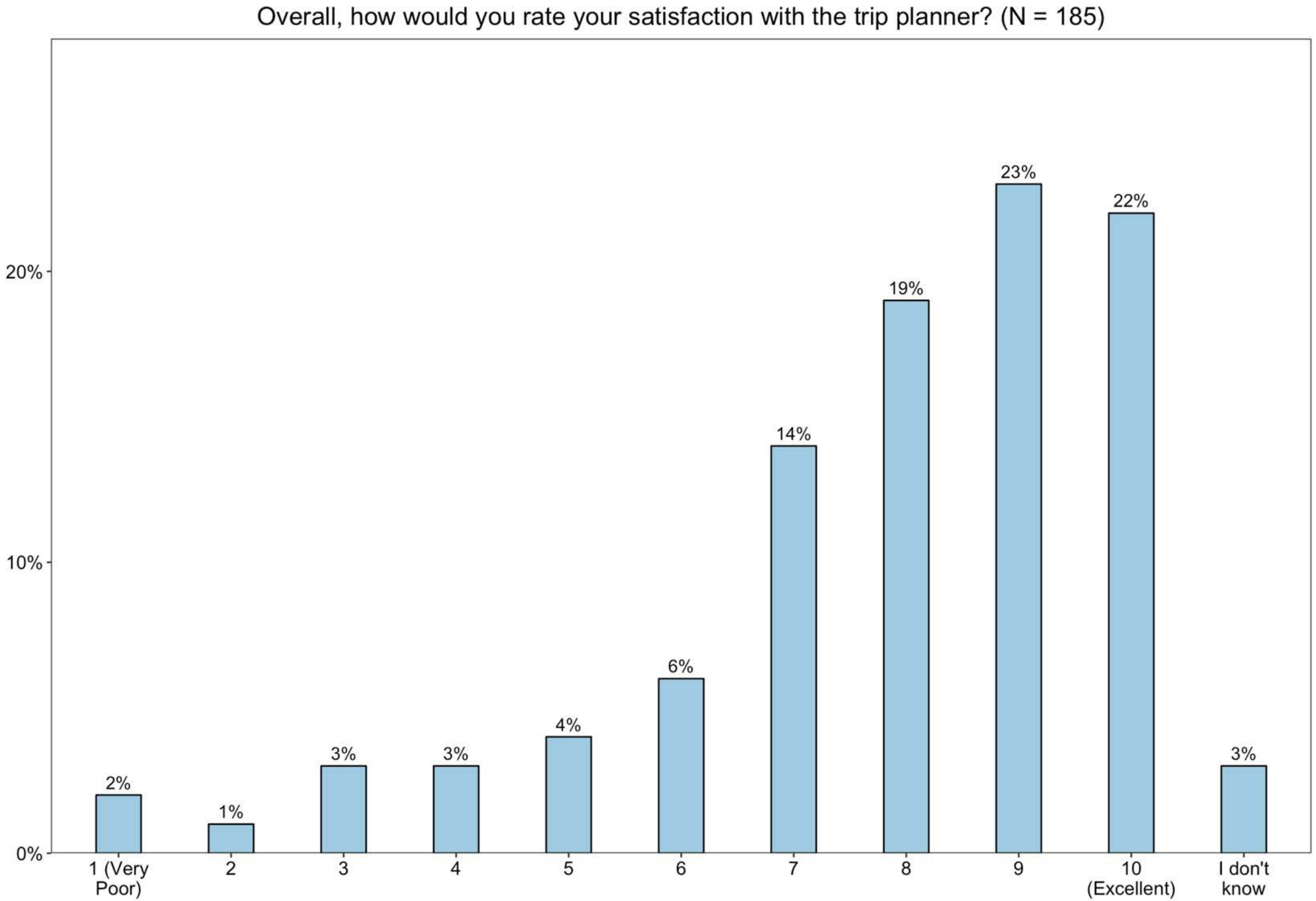


To what extent does the trip planner improve your ability to make multimodal trips? (N = 182)
30%
20%
10%
0%
19%
14%
18%
32%
16%
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know

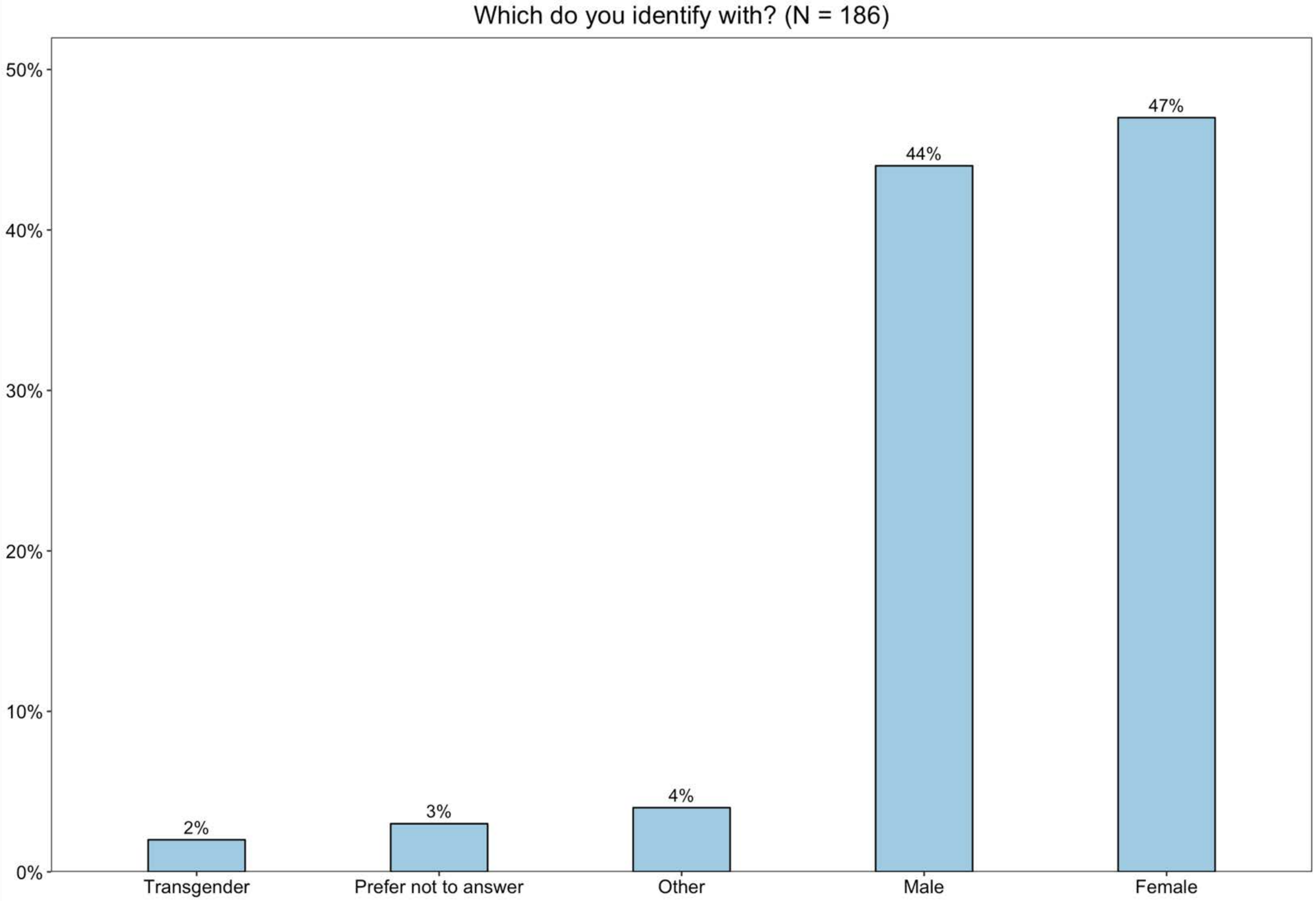


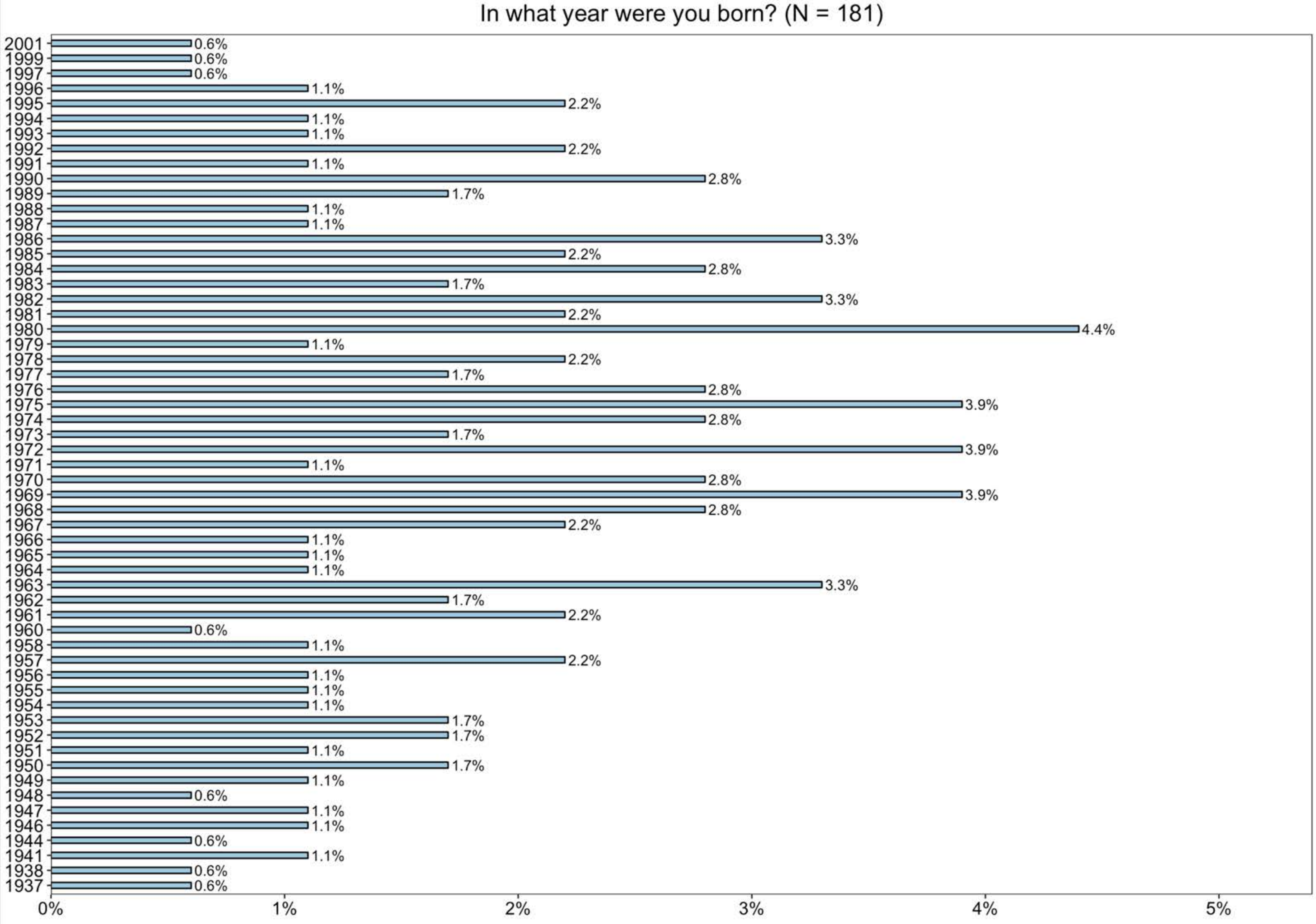
Which modes do you expect to use more or less often as a result of the trip planner?
Take Transit (only) (N = 183)
Bike + Transit (N = 179)
Biketown + Transit (N = 179)
Park & Ride (N = 180)
car2go + Transit (N = 178)
Uber + Transit (N = 179)
Lyft + Transit (N = 179)
Walk Only (N = 179)
Bike Only (N = 177)
1% 10% 15% 65% 2% 8%
54% 2% 13% 22% 1% 1% 7%
70% 2% 8% 11% 1% 1% 7%
55% 3% 12% 21% 1% 1% 8%
67% 1% 10% 10% 1% 2% 9%
65% 2% 6% 16% 1% 2% 8%
47% 5% 17% 18% 2% 10%
8% 4% 18% 55% 4% 1% 10%
49% 2% 6% 29% 1% 3% 11%
I do not use this mode(s) now, and I do not expect to in the future
Much more often
More often
About the same
Less often
Much less often
Could change, but not because of the trip planner
60%
40%
20%

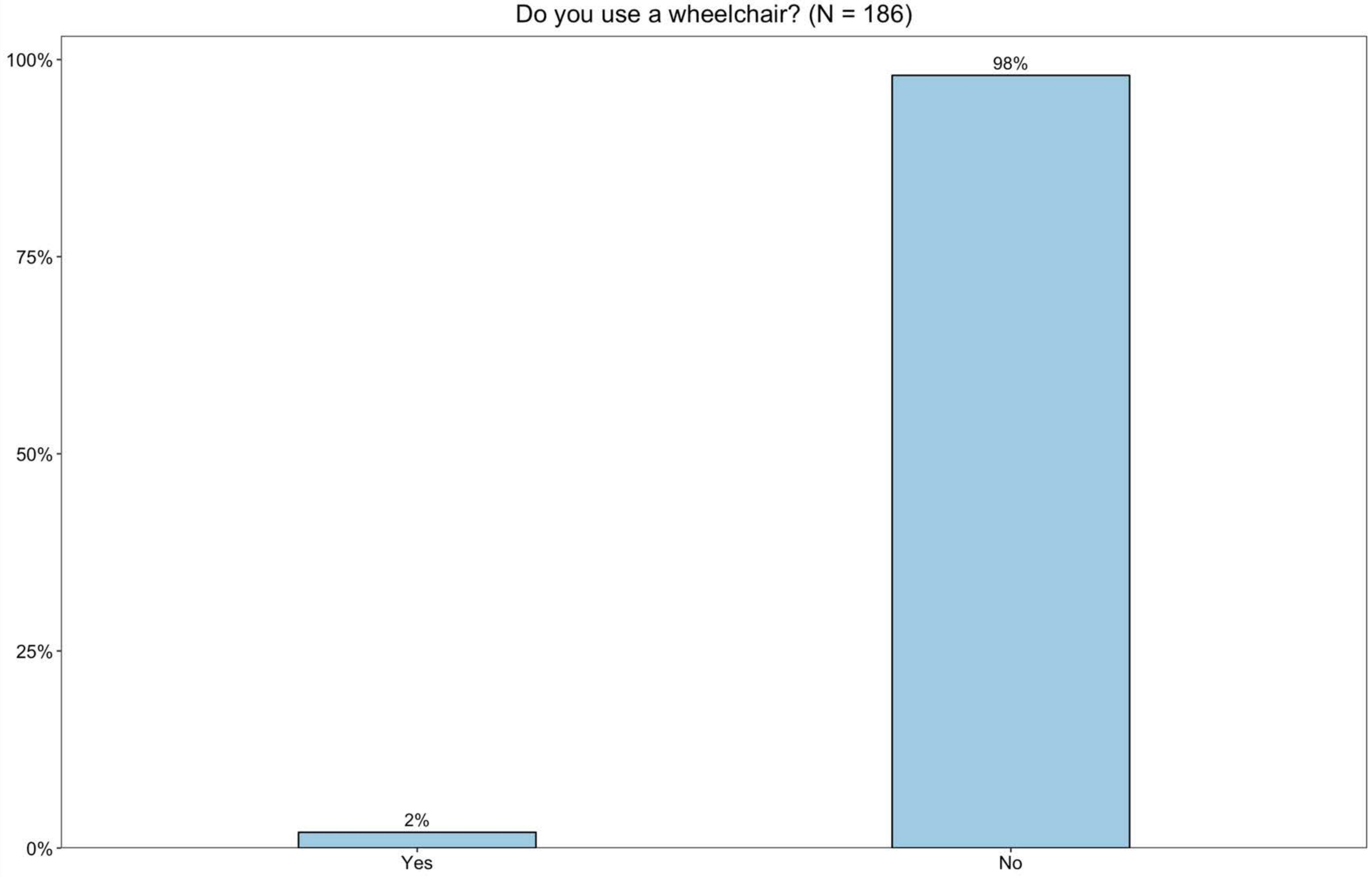

Which of the following are the most important factors that
you think will lead you to use these modes more?
Bike Only (N=43)
Walk Only (N=96)
Lyft + Transit (N=61)
Uber + Transit (N=20)
car2go + Transit (N=25)
Park & Ride (N=46)
Biketown + Transit (N=39)
Bike + Transit (N=75)
Take Transit (only) (N=106)
Time (trips are faster)
Cost (trips are cheaper)
Environment (reduced carbon emissions)
Fitness (better for my health)
Parking (no need to worry about it)
19% 19% 21% 26% 16%
15% 19% 15% 35% 17%
52% 10% 10% 5% 23%
50% 5% 10% 5% 30%
68% 0% 4% 0% 28%
41% 11% 11% 7% 30%
23% 21% 18% 28% 10%
25% 13% 17% 27% 17%
28% 21% 17% 13% 21%
60%
40%
20%
0%

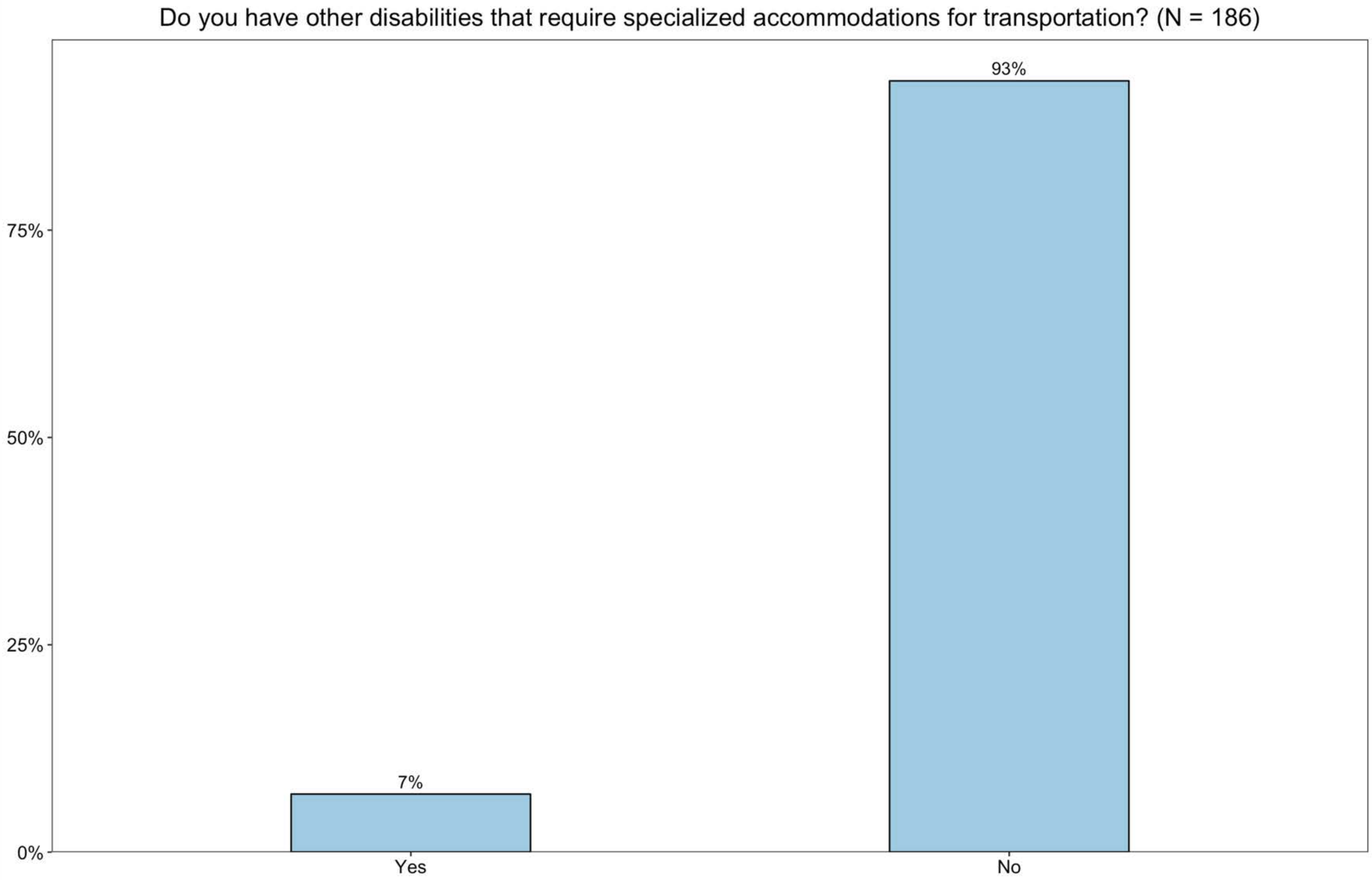


Overall, how would you rate your satisfaction with the trip planner? (N = 185)
20%
10%
0%
2%
1%
3%
3%
4%
6%
14%
19%
23%
22%
3%
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know

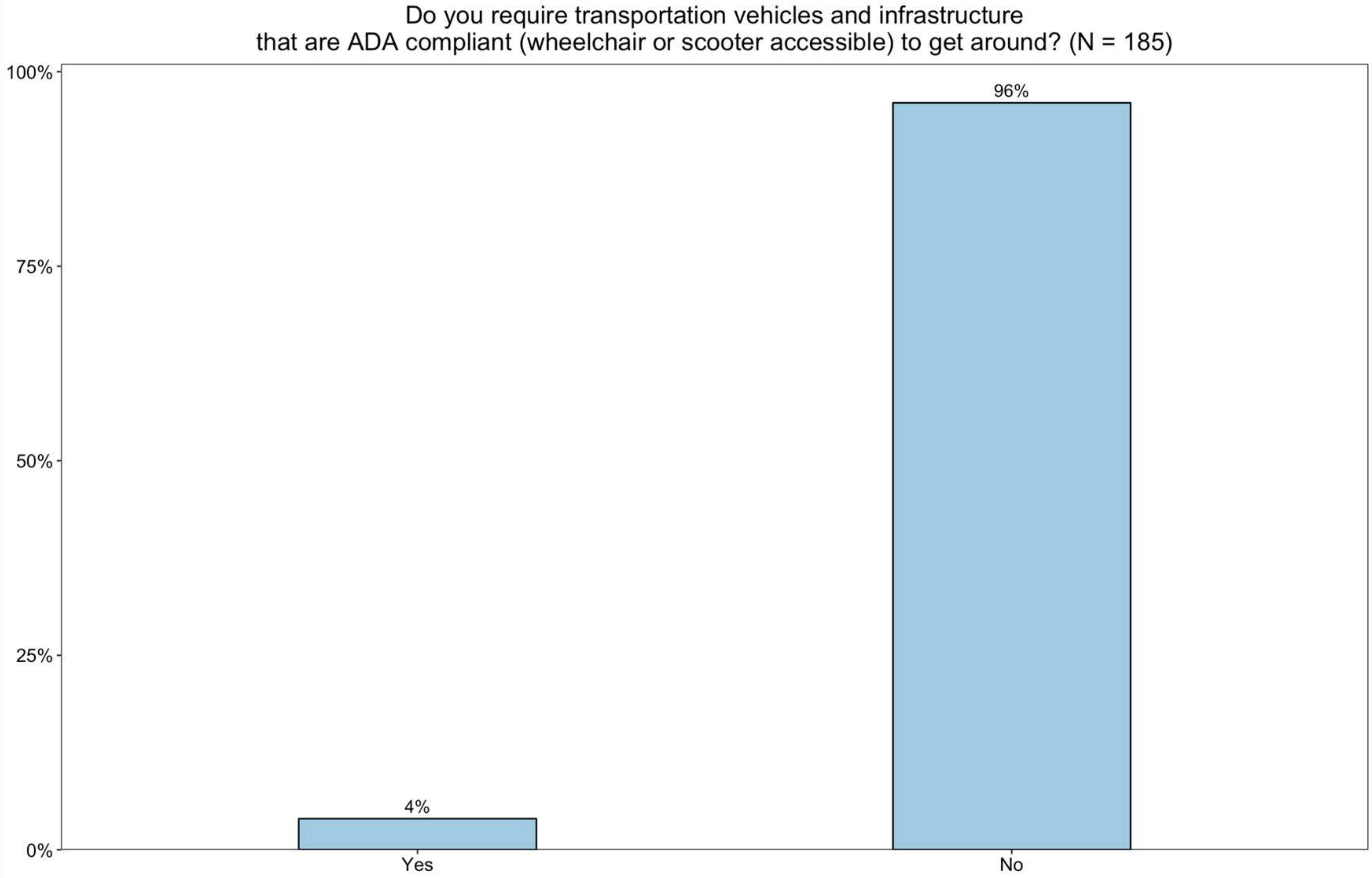

Which do you identify with? (N = 186)
50%
40%
30%
20%
10%
0%
2%
3%
4%
44%
47%
Transgender
Prefer not to answer
Other
Male
Female

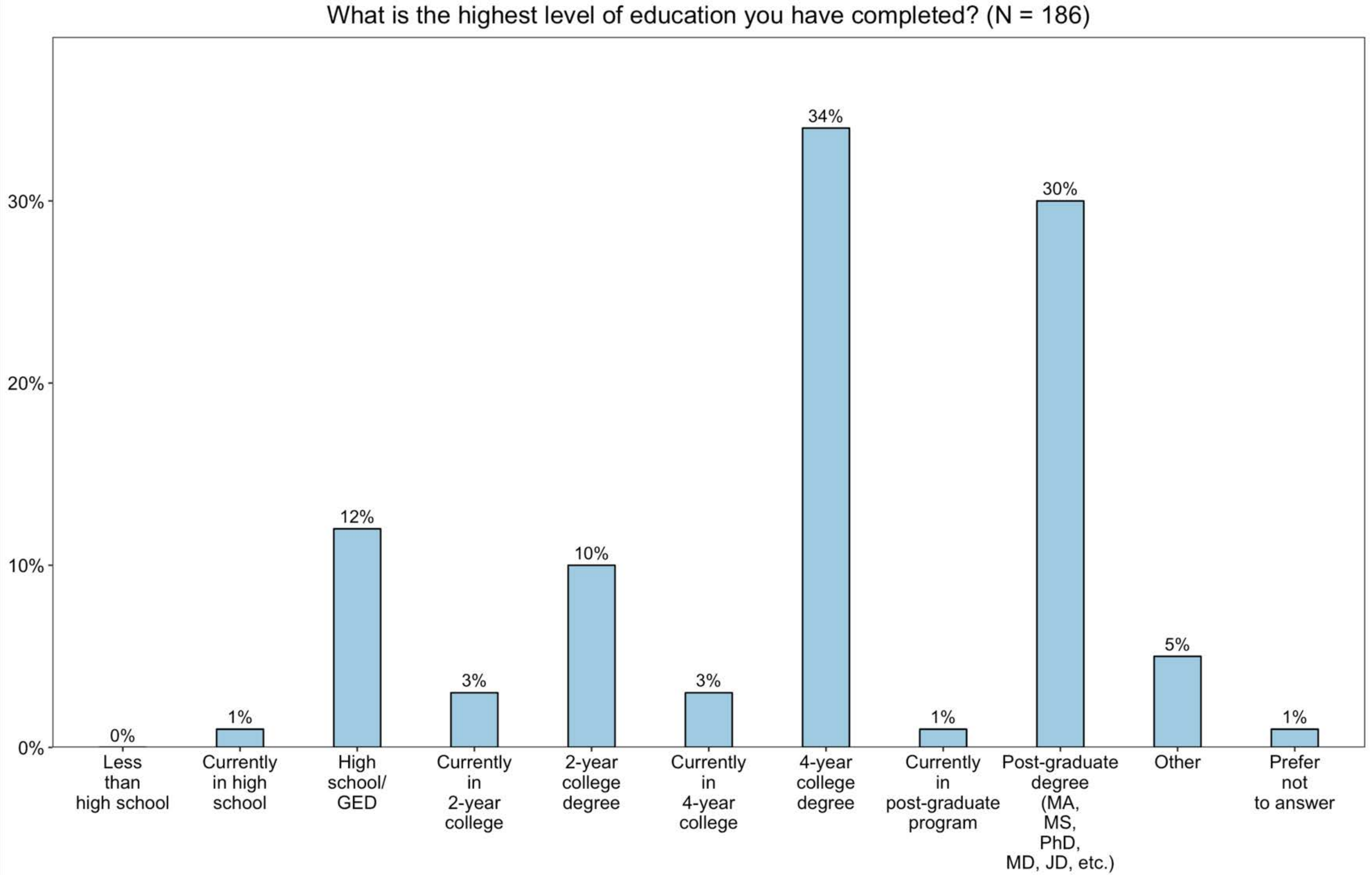

In what year were you born? (N = 181)
2001 0.6%
1999 0.6%
1997 0.6%
1996 1.1%
1995 2.2%
1994 1.1%
1993 1.1%
1992 2.2%
1991 1.1%
1990 2.8%
1989 1.7%
1988 1.1%
1987 1.1%
1986 3.3%
1985 2.2%
1984 2.8%
1983 1.7%
1982 3.3%
1981 2.2%
1980 4.4%
1979 1.1%
1978 2.2%
1977 1.7%
1976 2.8%
1975 3.9%
1974 2.8%
1973 1.7%
1972 3.9%
1971 1.1%
1970 2.8%
1969 3.9%
1968 2.8%
1967 2.2%
1966 1.1%
1965 1.1%
1964 1.1%
1963 3.3%
1962 1.7%
1961 2.2%
1960 0.6%
1958 1.1%
1957 2.2%
1956 1.1%
1955 1.1%
1954 1.1%
1953 1.7%
1952 1.7%
1951 1.1%
1950 1.7%
1949 1.1%
1948 0.6%
1947 1.1%
1946 1.1%
1944 0.6%
1941 1.1%
1938 0.6%
1937 0.6%
0% 1% 2% 3% 4% 5%

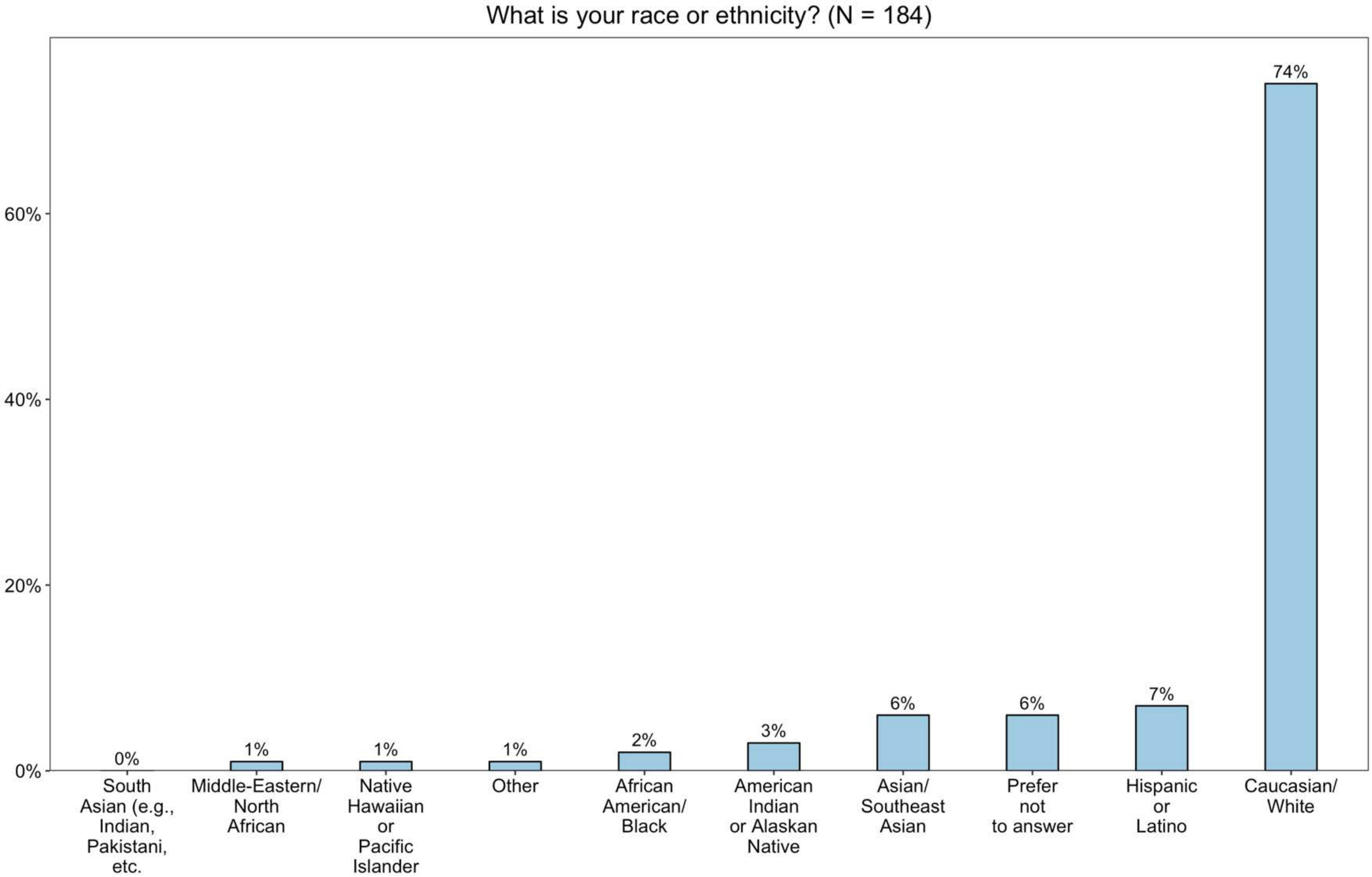

Do you use a wheelchair? (N = 186)
100%
75%
50%
25%
0%
98%
2%
Yes
No



Do you have other disabilities that require specialized accommodations for transportation? (N = 186)
93%
7%
75%
50%
25%
0%
Yes
No

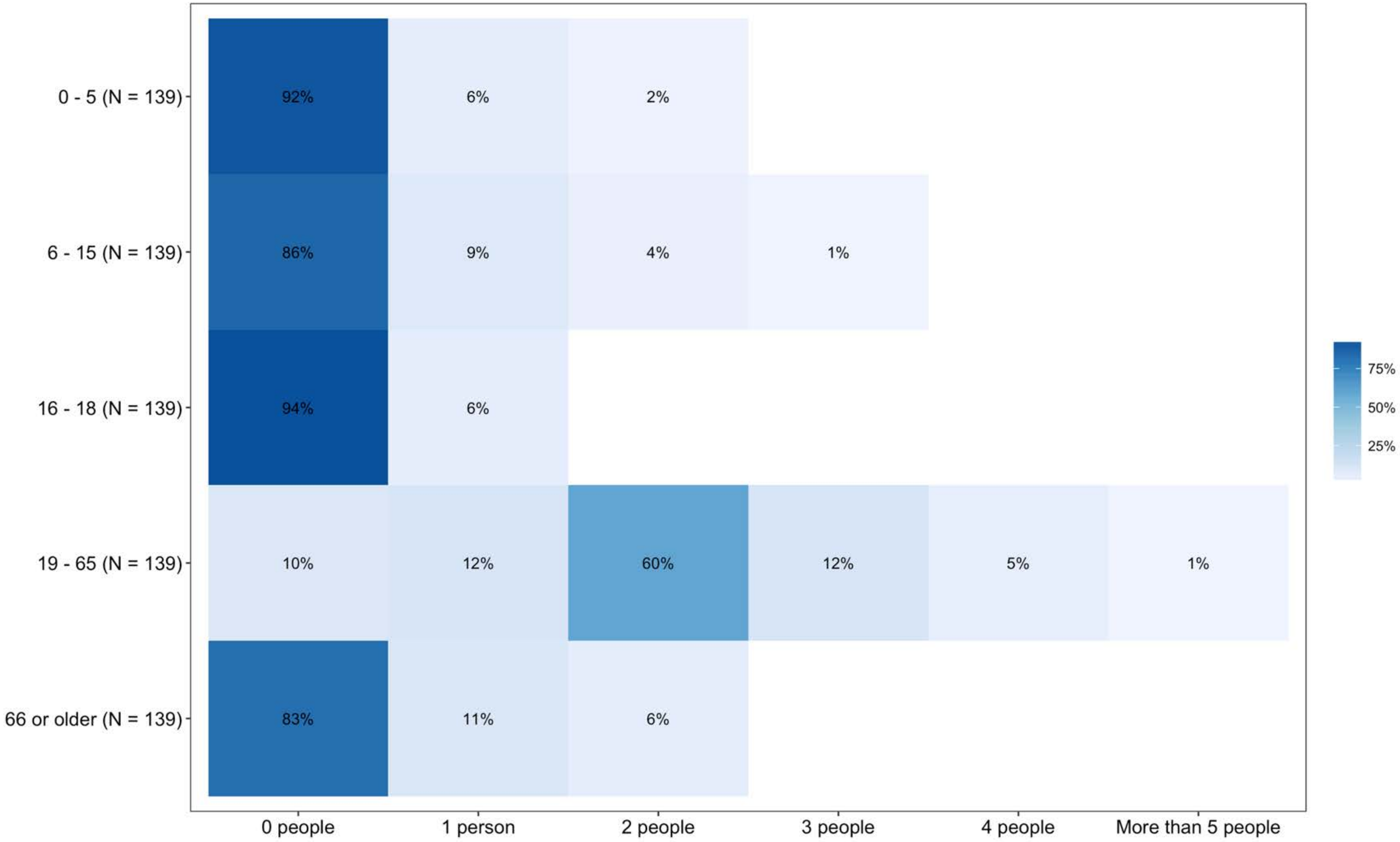

Do you require transportation vehicles and infrastructure
that are ADA compliant (wheelchair or scooter accessible) to get around? (N = 185)
100%
75%
50%
25%
0%
4%
96%
Yes
No

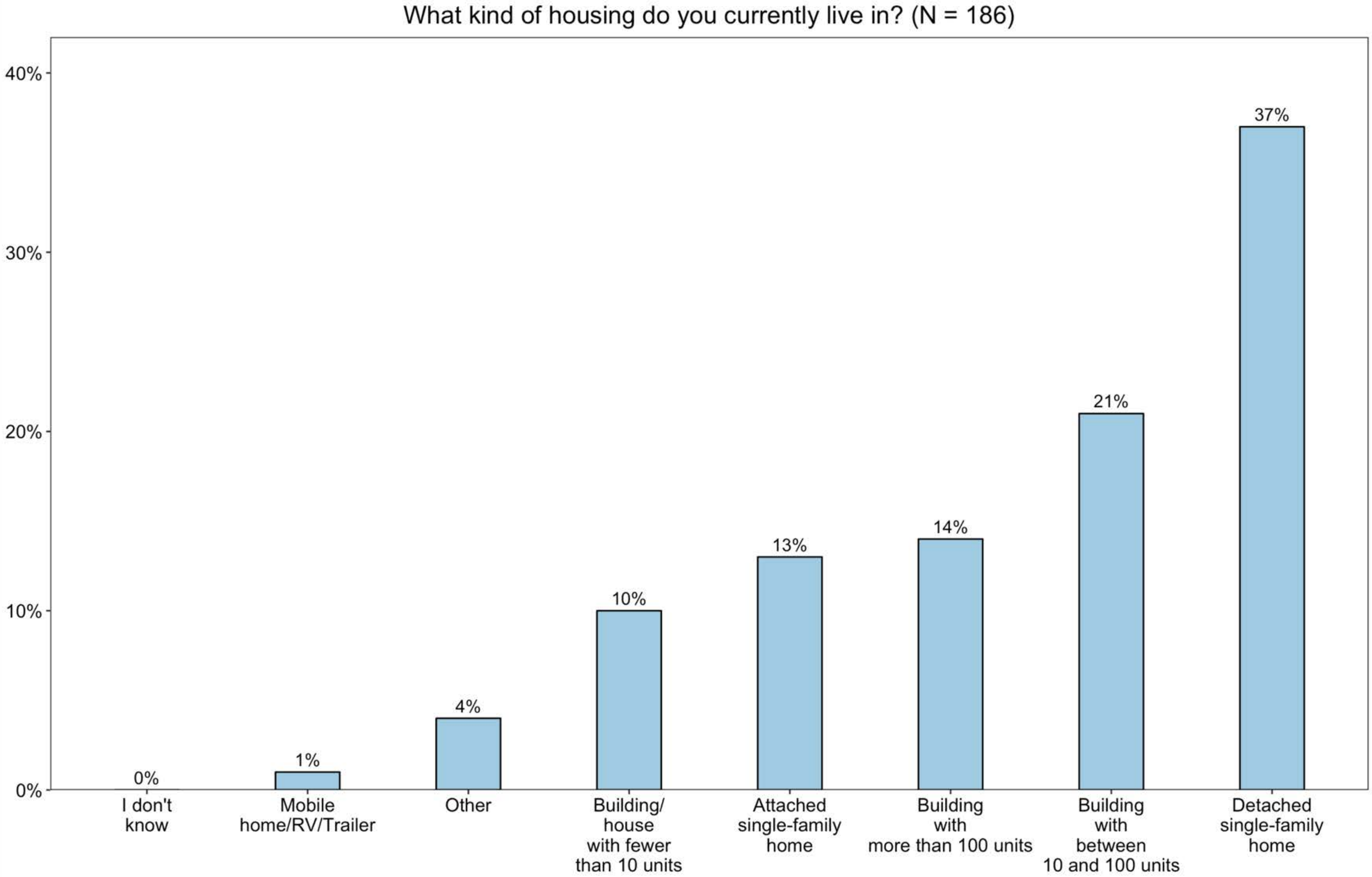

What is the highest level of education you have completed? (N = 186)
0%
10%
20%
30%
0%
1%
12%
3%
10%
3%
34%
1%
30%
5%
1%
Less than high school
Currently in high school
High school/ GED
Currently in 2-year college
2-year college degree
Currently in 4-year college
4-year college degree
Currently in post-graduate program
Post-graduate degree (MA, MS, PhD, MD, JD, etc.)
Other
Prefer not to answer

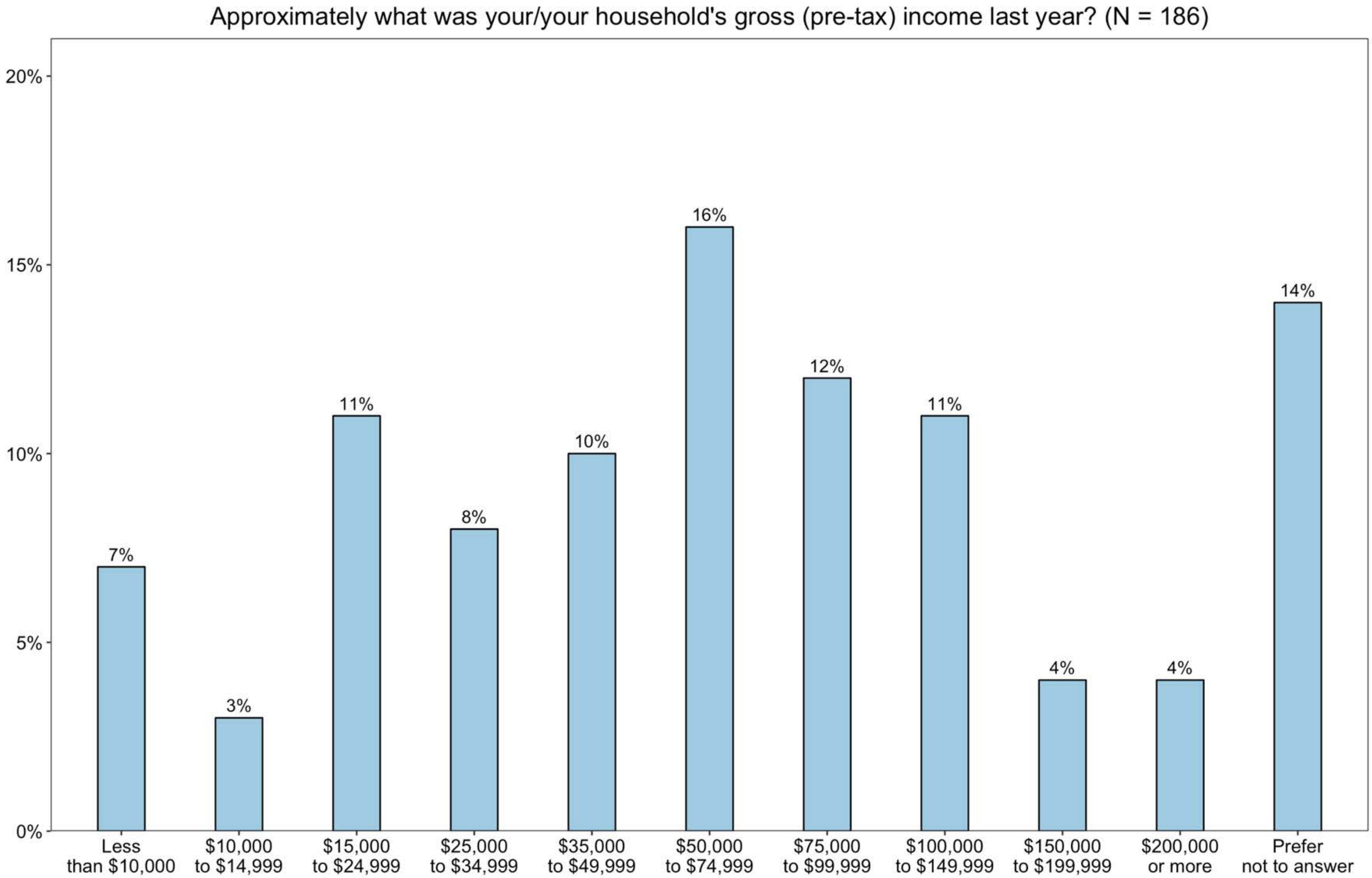


What is your race or ethnicity? (N = 184)
60%
40%
20%
0%
0%
1%
1%
1%
2%
3%
6%
6%
7%
74%
South Asian (e.g., Indian, Pakistani, etc.
Middle-Eastern/ North African
Native Hawaiian or Pacific Islander
Other
African American/ Black
American Indian or Alaskan Native
Asian/ Southeast Asian
Prefer not to answer
Hispanic or Latino
Caucasian/ White

Please indicate the number of household members (including yourself)
that fall into the different age groups listed below




What kind of housing do you currently live in? (N = 186)
40%
30%
20%
10%
0%
0%
1%
4%
10%
13%
14%
21%
37%
I don't know
Mobile home/RV/Trailer
Other
Building/ house with fewer than 10 units
Attached single-family home
Building with more than 100 units
Building with between 10 and 100 units
Detached single-family home


Approximately what was your/your household's gross (pre-tax) income last year? (N = 186)
20%
15%
10%
5%
0%
7%
3%
11%
8%
10%
16%
12%
11%
4%
4%
14%
Less than $10,000
$10,000 to $14,999
$15,000 to $24,999
$25,000 to $34,999
$35,000 to $49,999
$50,000 to $74,999
$75,000 to $99,999
$100,000 to $149,999
$150,000 to $199,999
$200,000 or more
Prefer not to answer

APPENDIX

K

One-on-One Field Shadowing

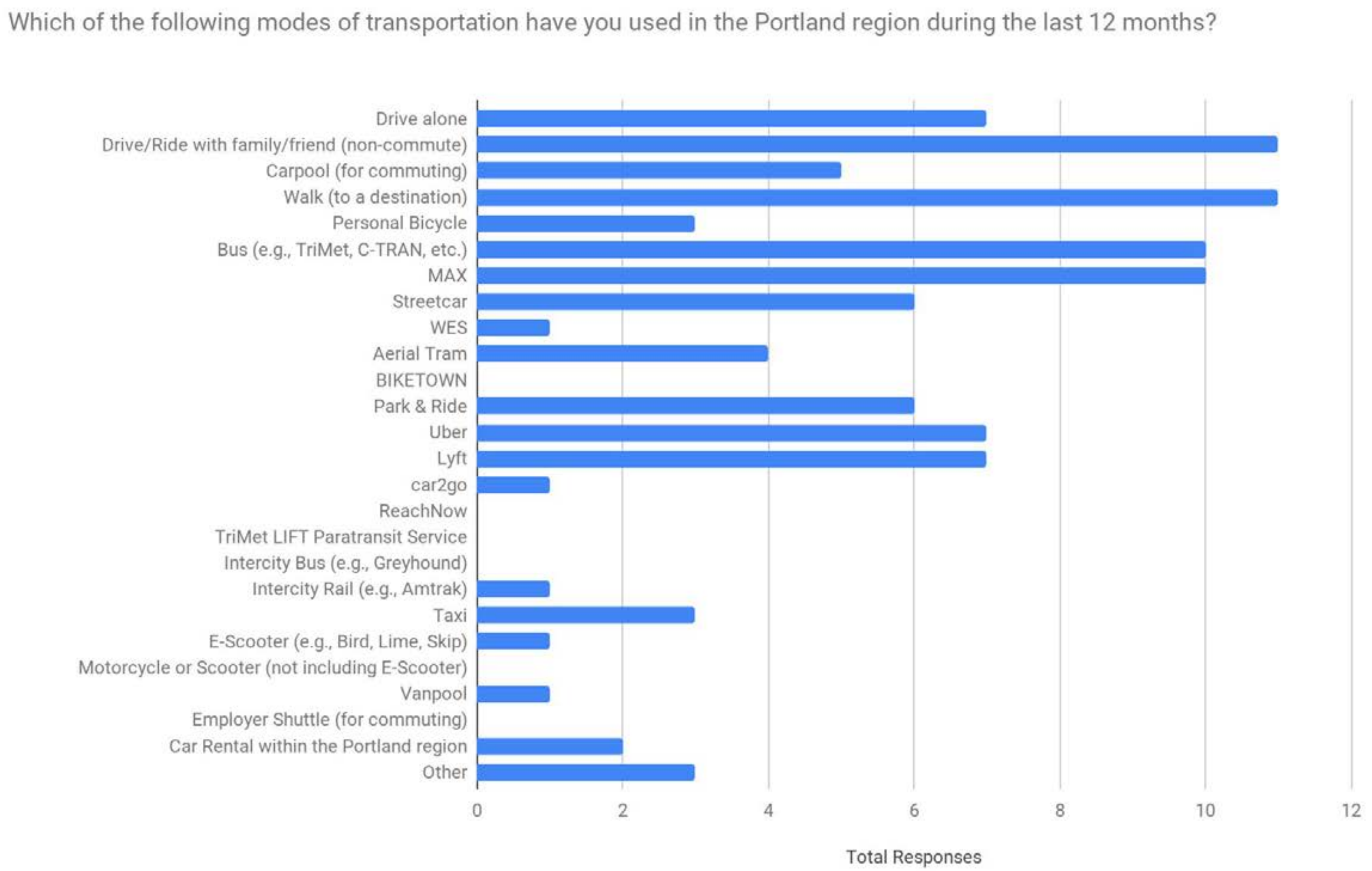
User Observations via Field Shadowing

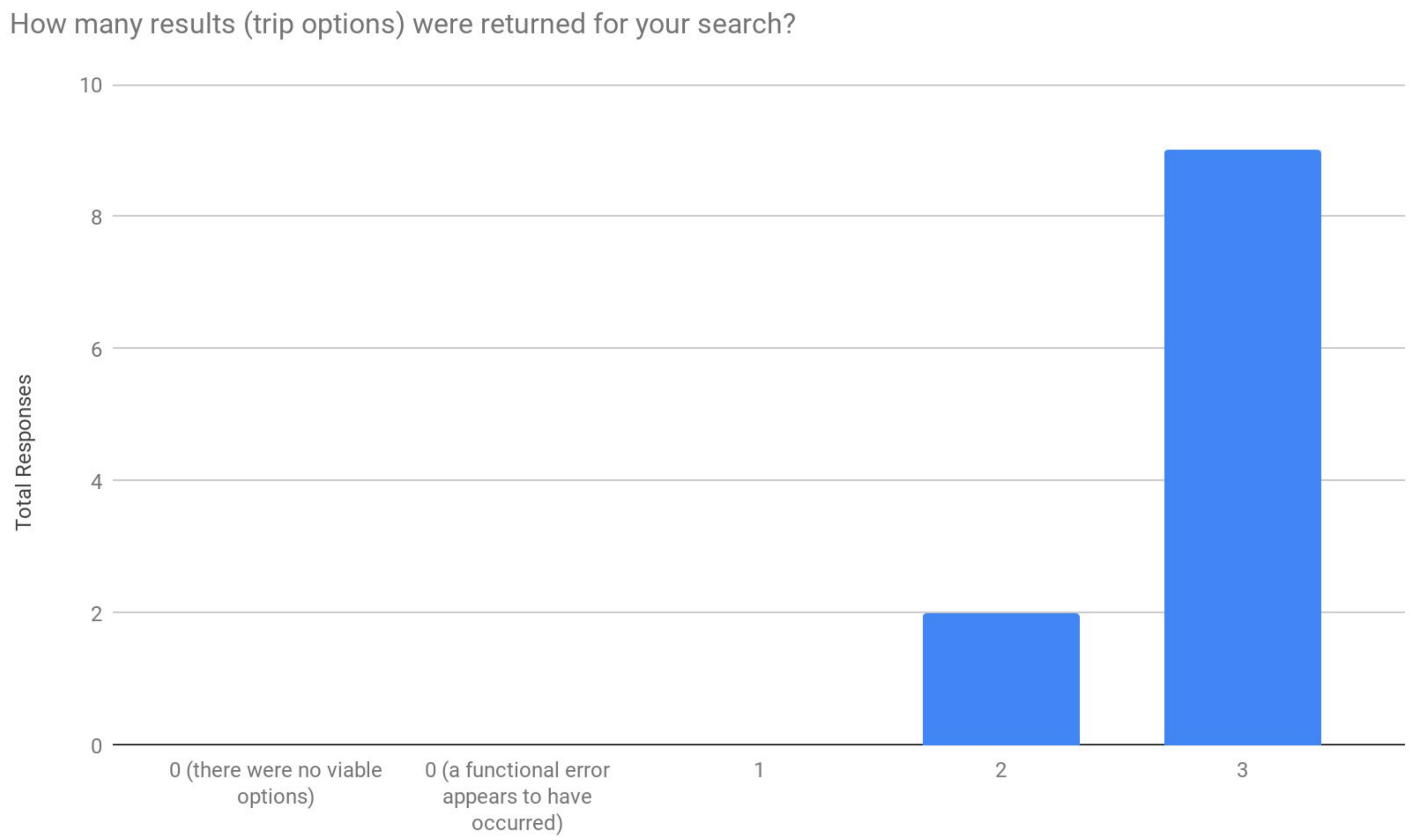
Meredith Rider
Cassadi Willey

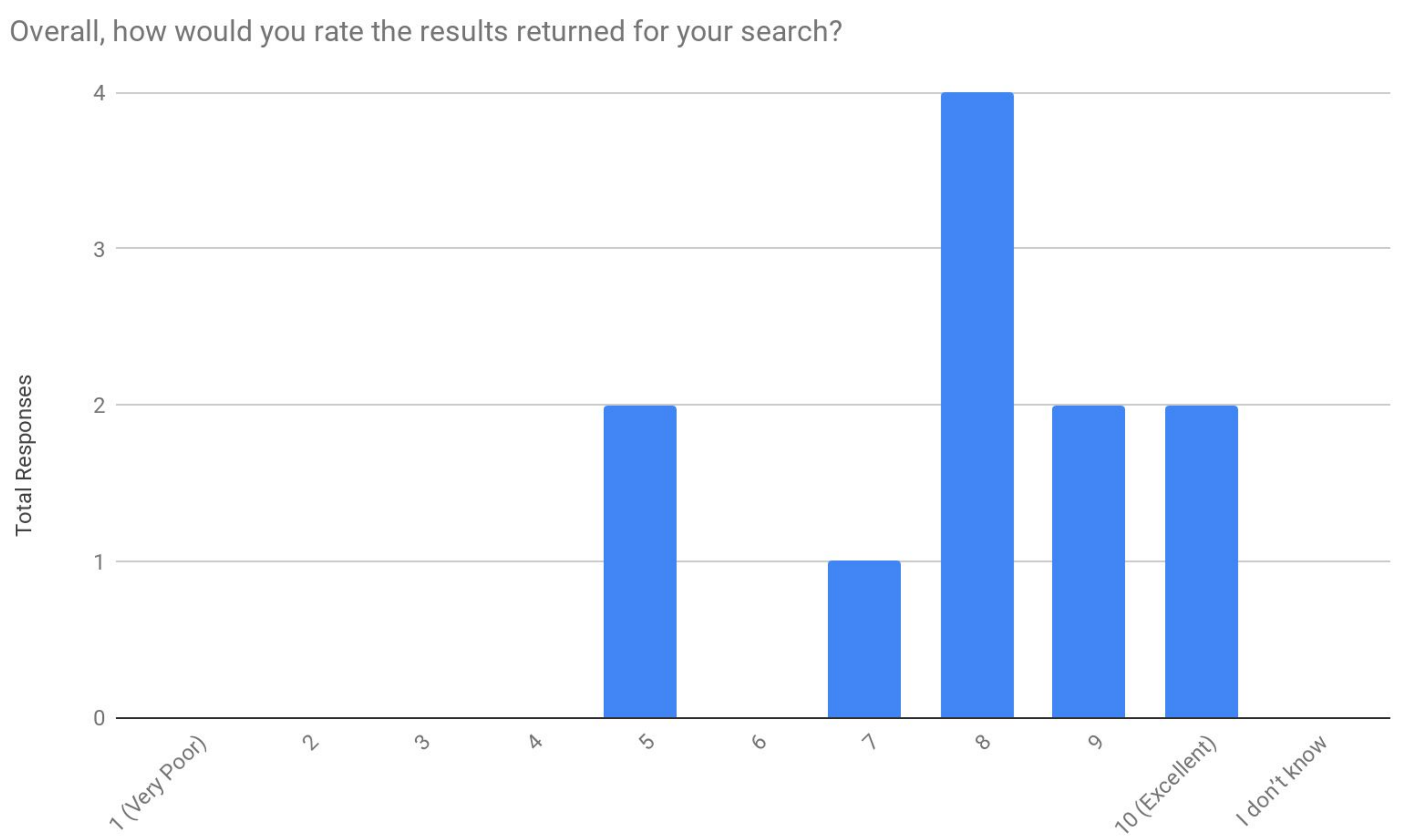
January 2019

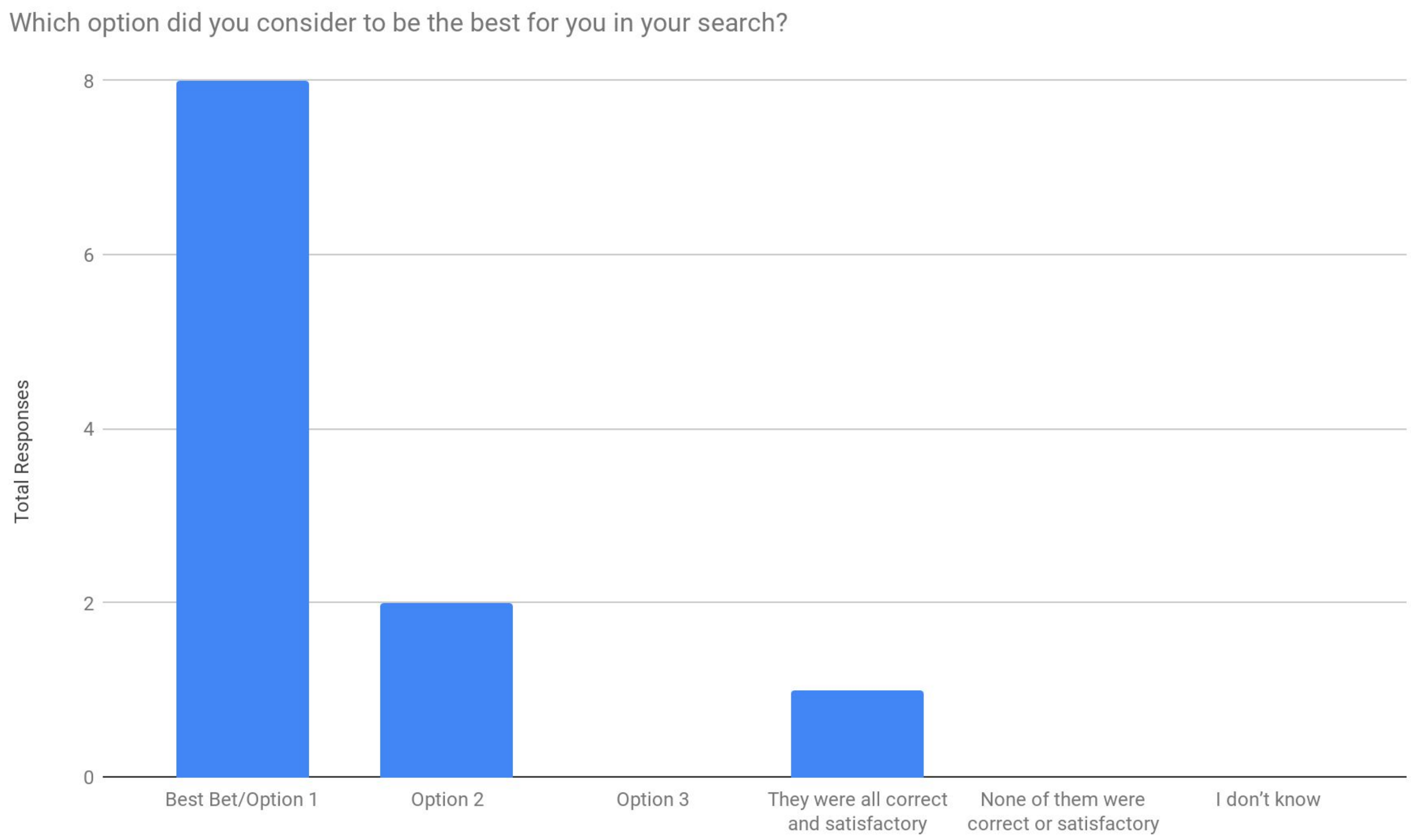
One-on-One Field Shadowing Participant Profile

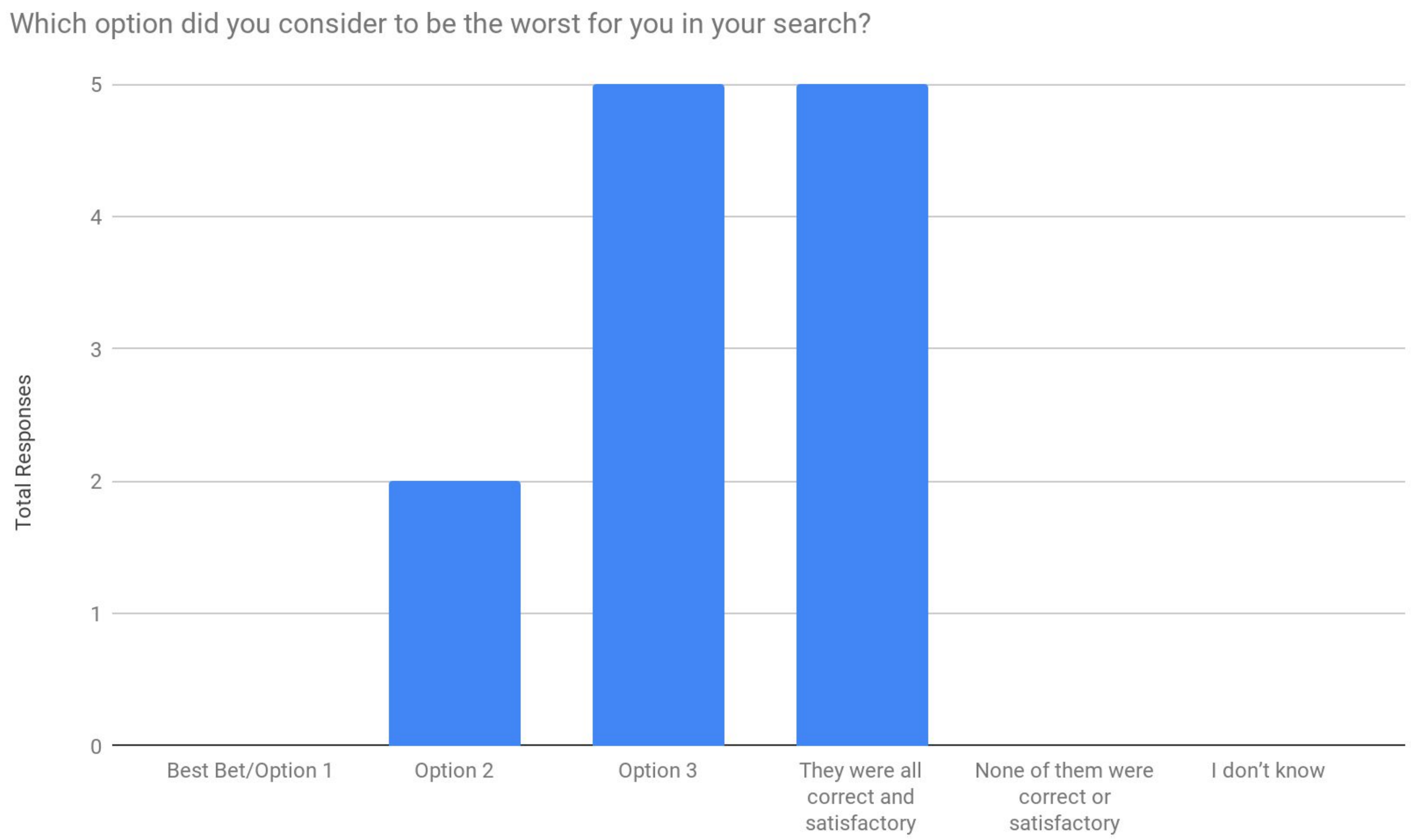
	Gender	Age Range	Race/Ethnicity	Frequency of Public Transit Use	Low Income (150% FPL)
Respondent 1	Female	65 or more	Caucasian/White	Frequent rider, I ride almost every day	No
Respondent 2	Female	65 or more	Caucasian/White	Regular rider, I ride several times a week	Yes
Respondent 3	Female	25-34	Caucasian/White	Occasional rider, I ride a couple of times a month	Yes
Respondent 4	Male	25-34	Caucasian/White	Infrequent rider, I ride less than once a month	No
Respondent 5	Female	55-64	Caucasian/White	Frequent rider, I ride almost every day	No
Respondent 6	Female	65 or more	Caucasian/White	Regular rider, I ride several times a week	No
Respondent 7	Female	25-34	Caucasian/White	Frequent rider, I ride almost every day	No
Respondent 8	Female	25-34	Asian/Asian American	Occasional rider, I ride a couple of times a month	Yes
Respondent 9	Female	45-54	Asian/Asian American	Infrequent rider, I ride less than once a month	No
Respondent 10	Female	55-64	Caucasian/White	Regular rider, I ride several times a week	No
Respondent 11	Male	25-34	Caucasian/White	Regular rider, I ride several times a week	No

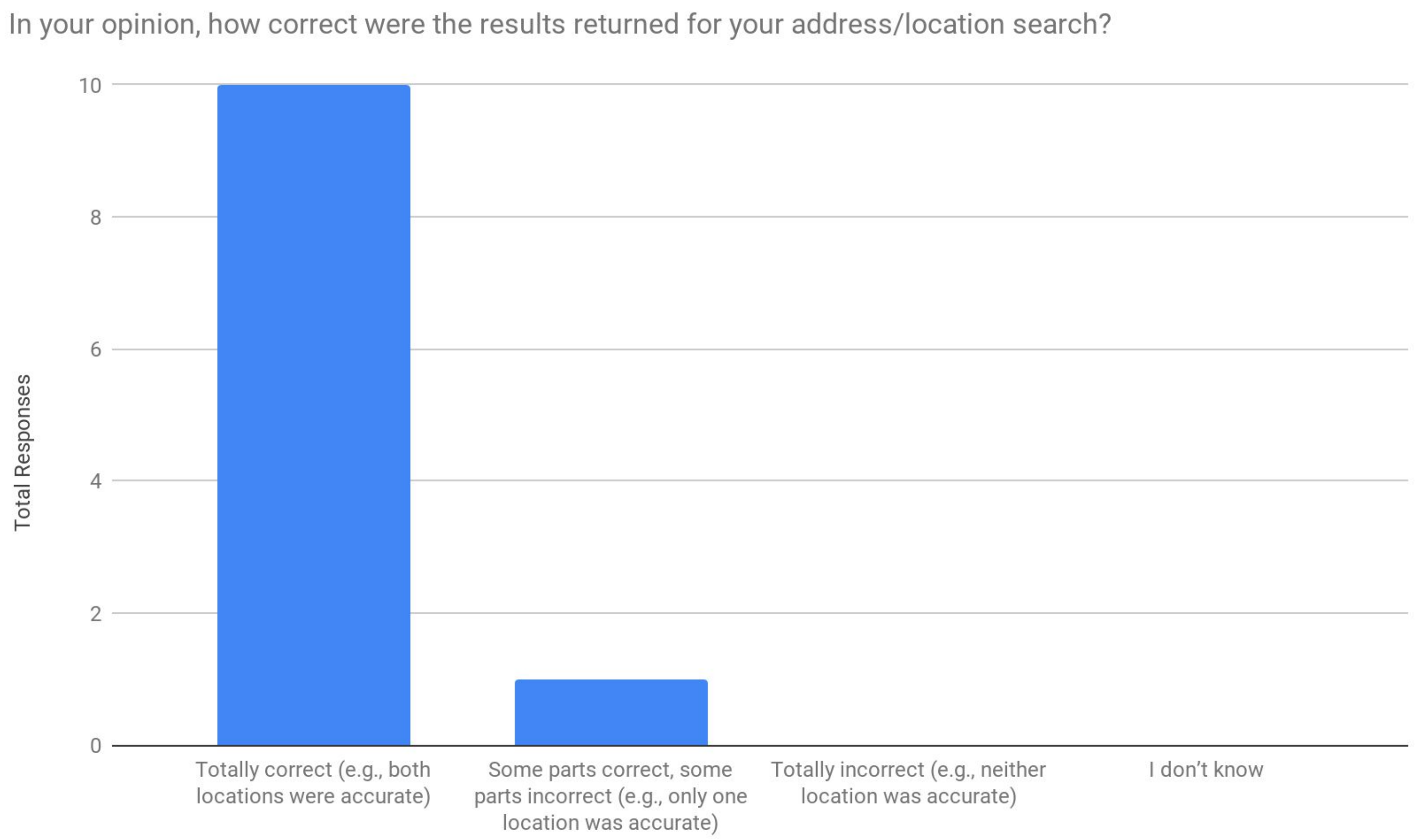

Which of the following modes of transportation have you used in the Portland region during the last 12 months?
Drive alone
Drive/Ride with family/friend (non-commute)
Carpool (for commuting)
Walk (to a destination)
Personal Bicycle
Bus (e.g., TriMet, C-TRAN, etc.)
MAX
Streetcar
WES
Aerial Tram
BIKETOWN
Park & Ride
Uber
Lyft
car2go
ReachNow
TriMet LIFT Paratransit Service
Intercity Bus (e.g., Greyhound)
Intercity Rail (e.g., Amtrak)
Taxi
E-Scooter (e.g., Bird, Lime, Skip)
Motorcycle or Scooter (not including E-Scooter)
Vanpool
Employer Shuttle (for commuting)
Car Rental within the Portland region
Other
0
2
4
6
8
10
12
Total Responses

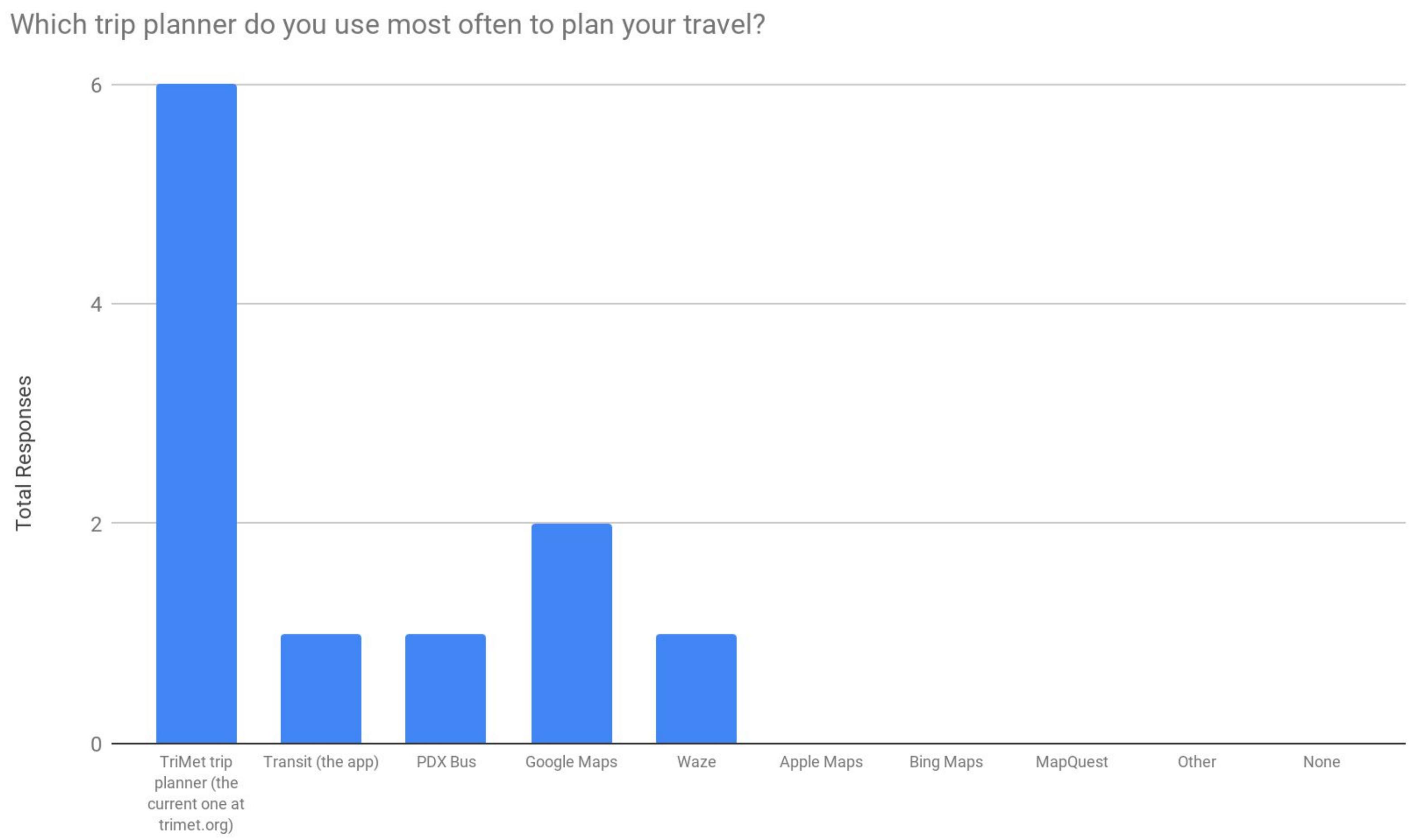

How many results (trip options) were returned for your search?
Total Responses
10
8
6
4
2
0
0 (there were no viable options)
0 (a functional error appears to have occurred)
1
2
3

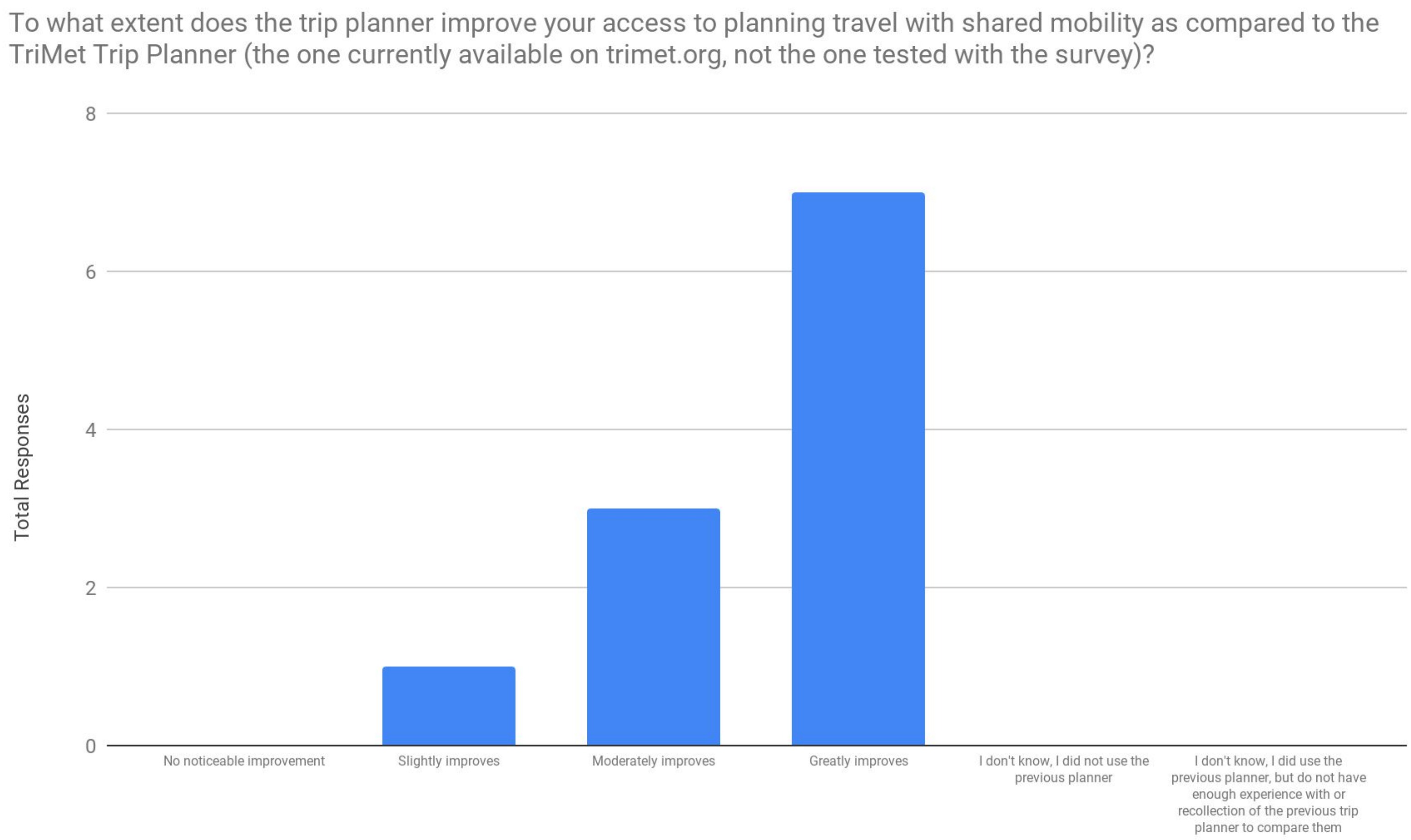

Overall, how would you rate the results returned for your search?
Total Responses
4
3
2
1
0
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know

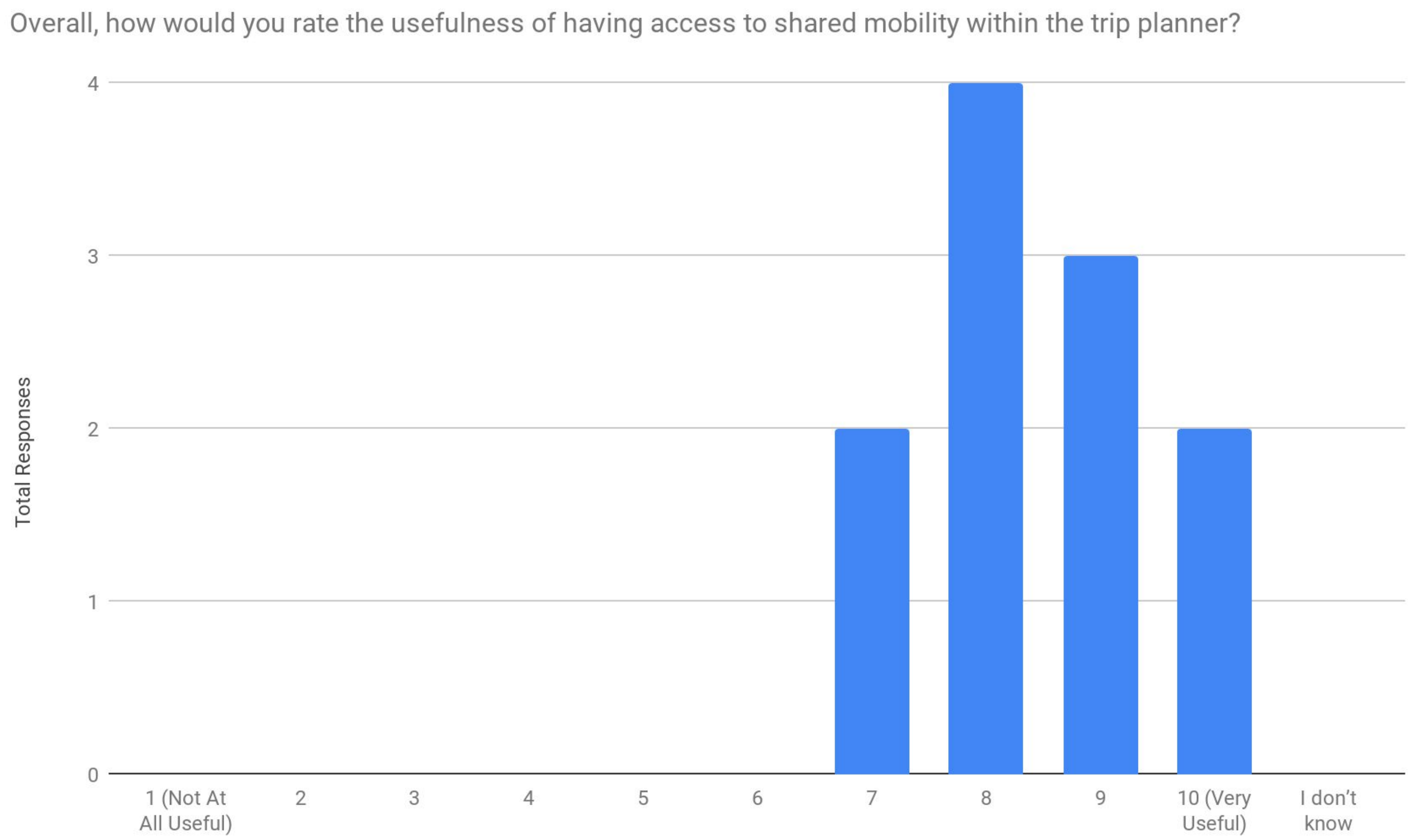

Which option did you consider to be the best for you in your search?
Total Responses
8
6
4
2
0
Best Bet/Option 1
Option 2
Option 3
They were all correct and satisfactory
None of them were correct or satisfactory
I don't know

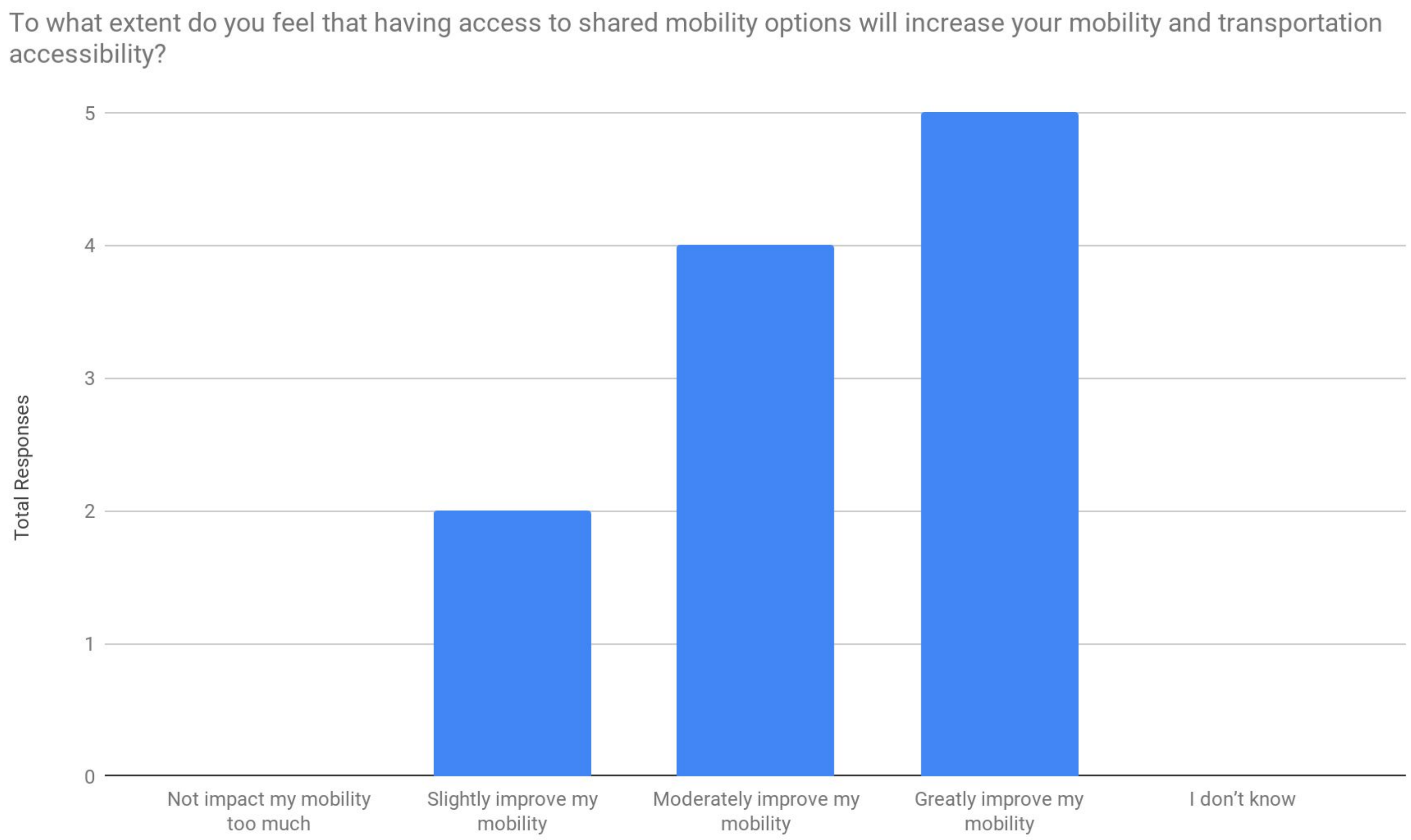

Which option did you consider to be the worst for you in your search?
Total Responses
0
1
2
3
4
5
Best Bet/Option 1
Option 2
Option 3
They were all correct and satisfactory
None of them were correct or satisfactory
I don't know

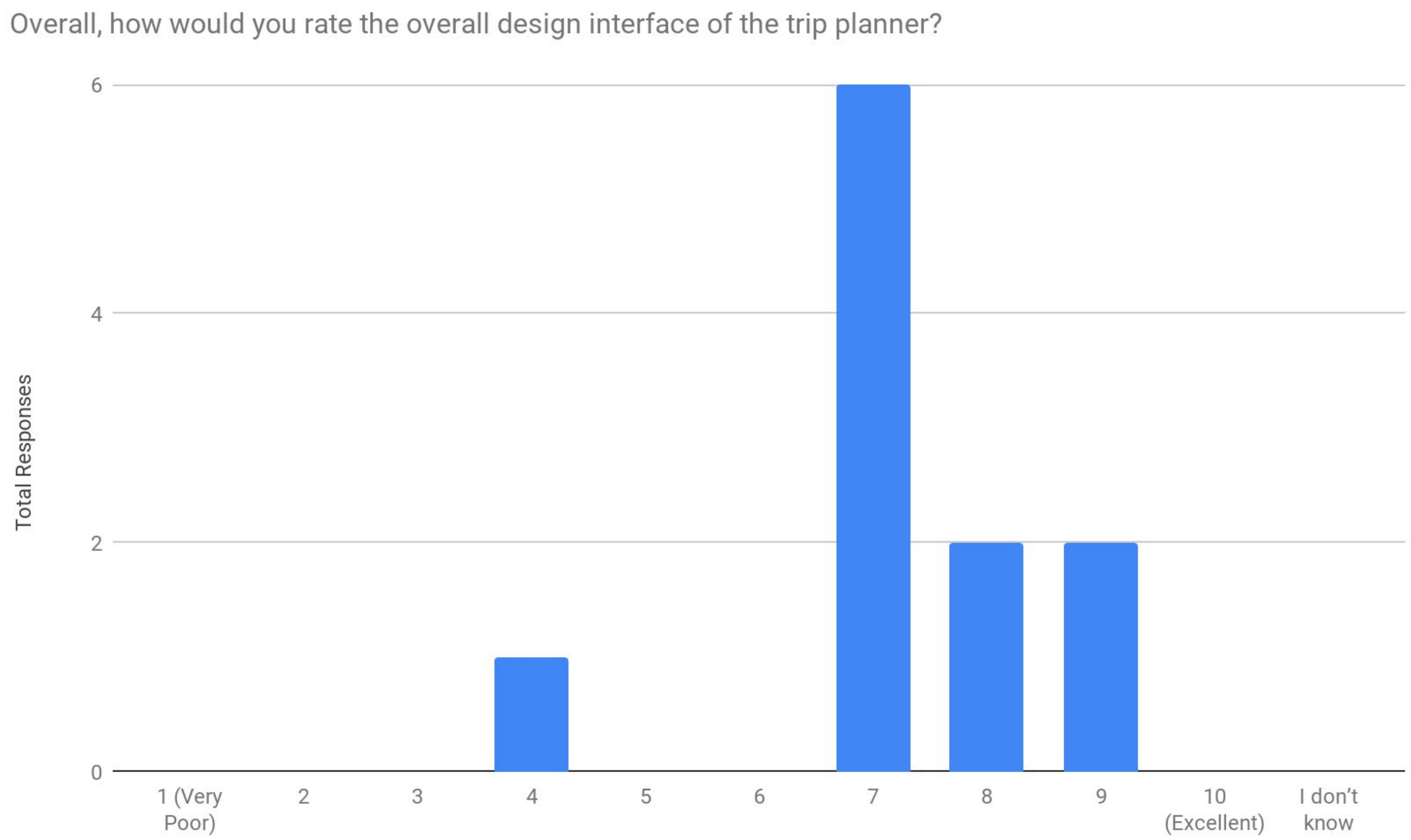

In your opinion, how correct were the results returned for your address/location search?
Total Responses
10
8
6
4
2
0
Totally correct (e.g., both locations were accurate)
Some parts correct, some parts incorrect (e.g., only one location was accurate)
Totally incorrect (e.g., neither location was accurate)
I don't know


Which trip planner do you use most often to plan your travel?
Total Responses
6
4
2
0
TriMet trip planner (the current one at trimet.org)
Transit (the app)
PDX Bus
Google Maps
Waze
Apple Maps
Bing Maps
MapQuest
Other
None

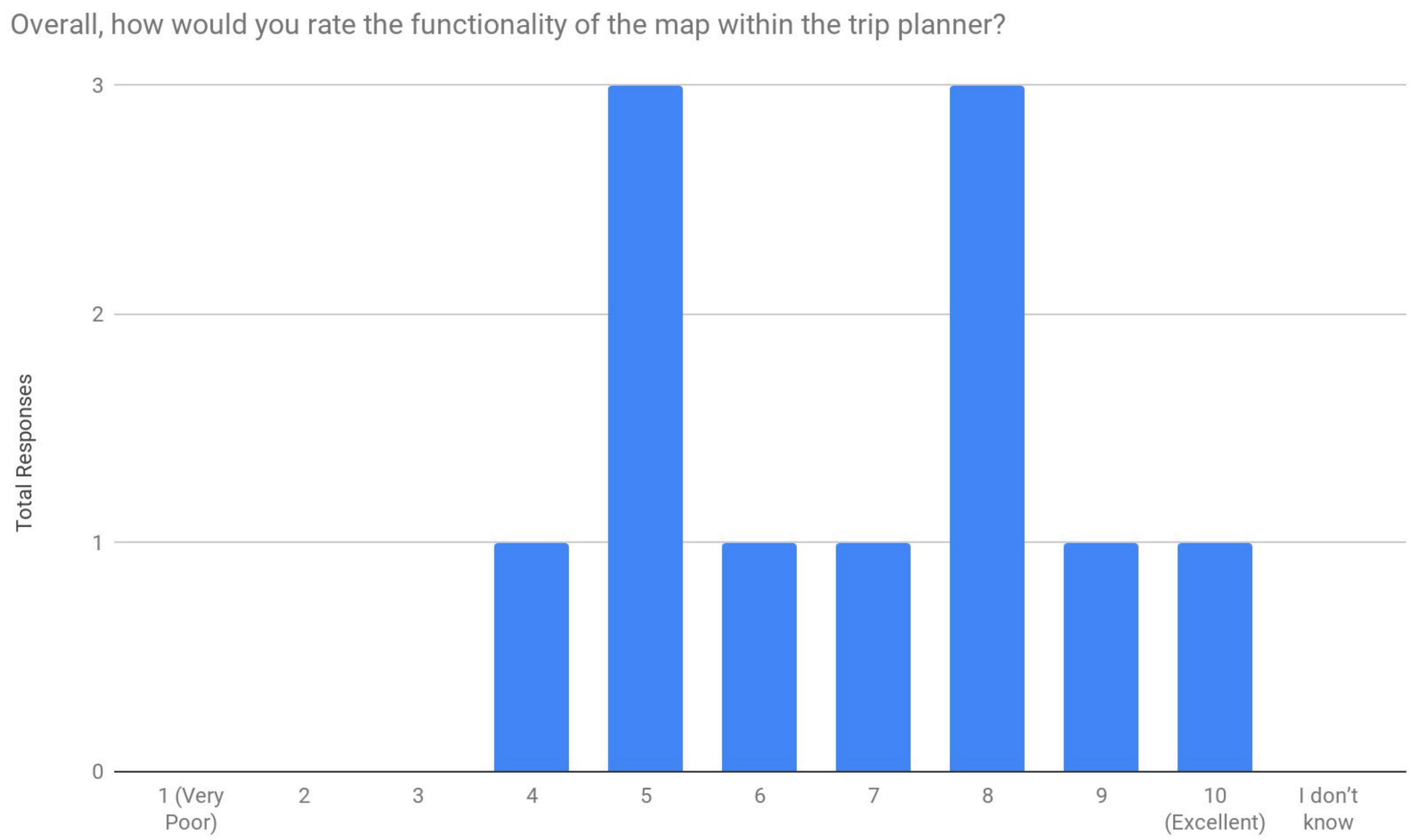

To what extent does the trip planner improve your access to planning travel with shared mobility as compared to the TriMet Trip Planner (the one currently available on trimet.org, not the one tested with the survey)?
Total Responses
8
6
4
2
0
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know, I did not use the previous planner
I don't know, I did use the previous planner, but do not have enough experience with or recollection of the previous trip planner to compare them

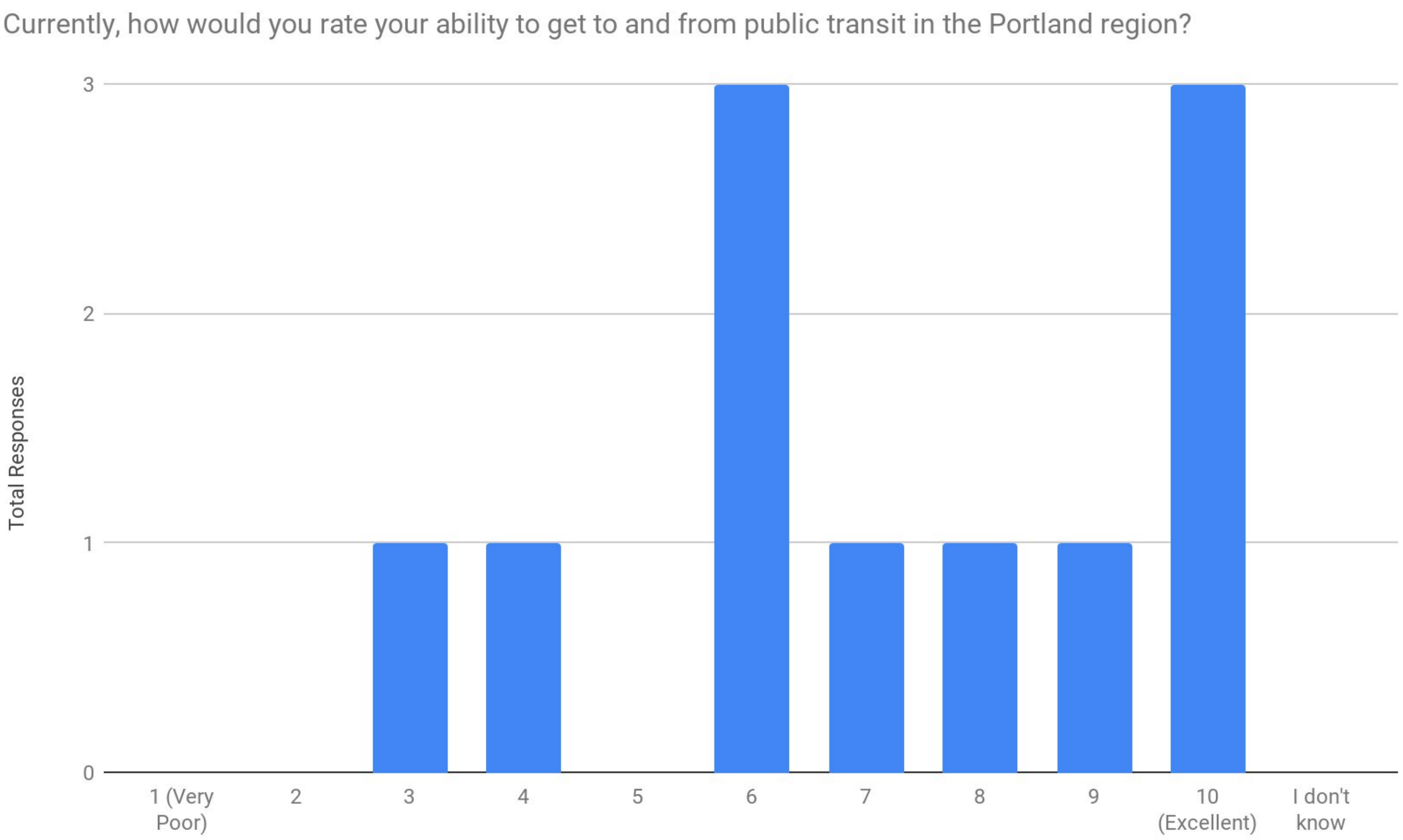

Overall, how would you rate the usefulness of having access to shared mobility within the trip planner?
Total Responses
0
1
2
3
4
1 (Not At All Useful)
2
3
4
5
6
7
8
9
10 (Very Useful)
I don't know

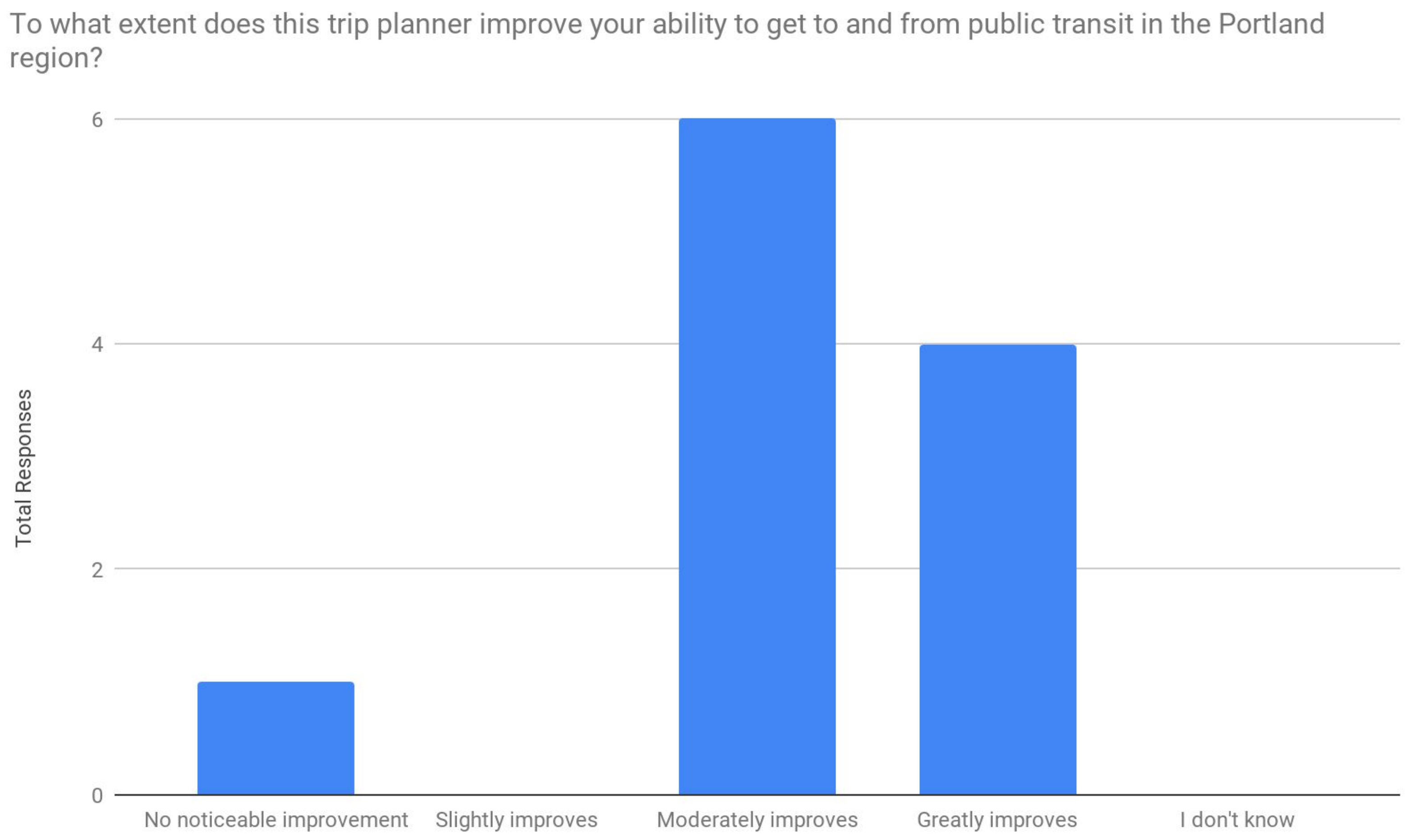

To what extent do you feel that having access to shared mobility options will increase your mobility and transportation accessibility?
Total Responses
0
1
2
3
4
5
Not impact my mobility too much
Slightly improve my mobility
Moderately improve my mobility
Greatly improve my mobility
I don't know

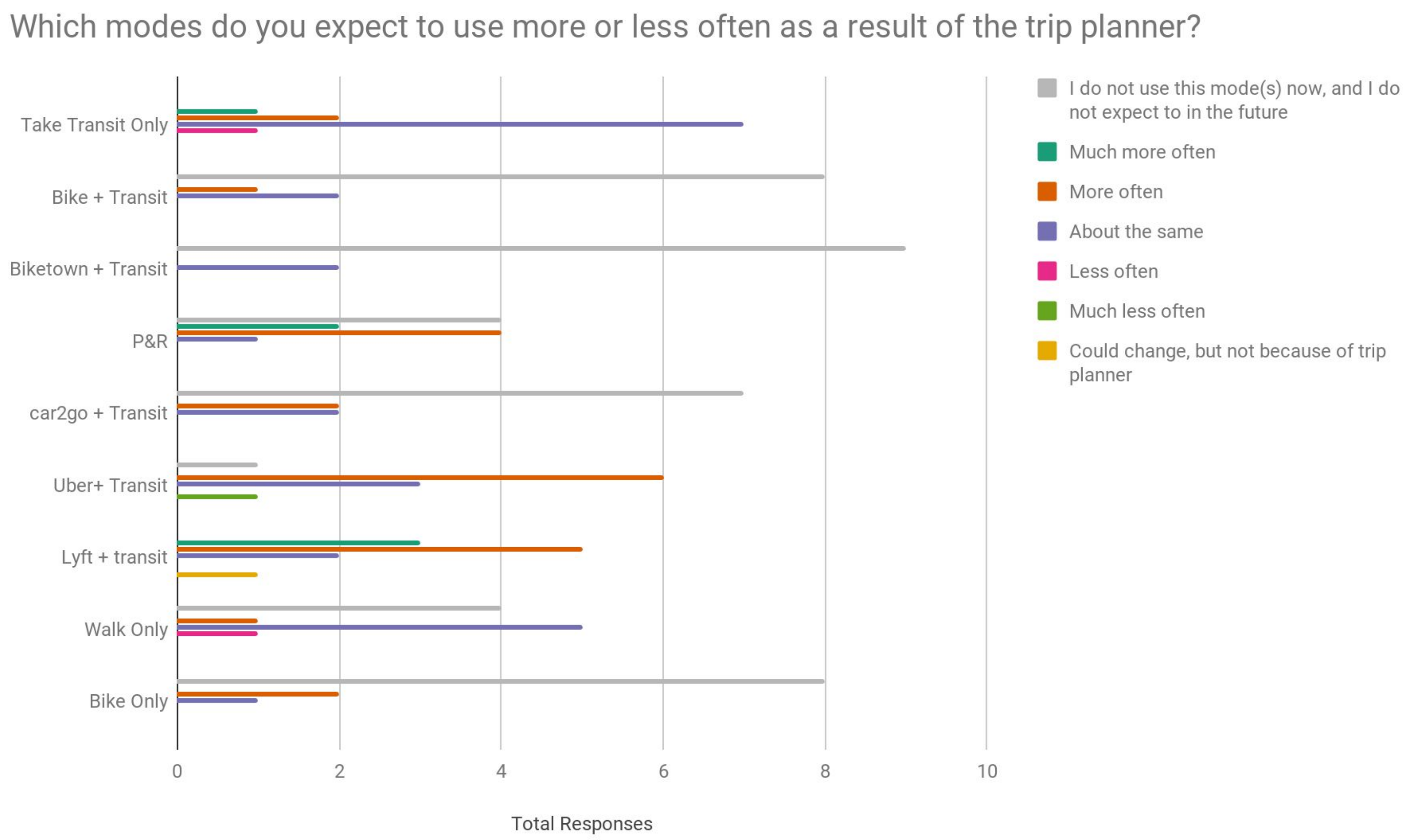


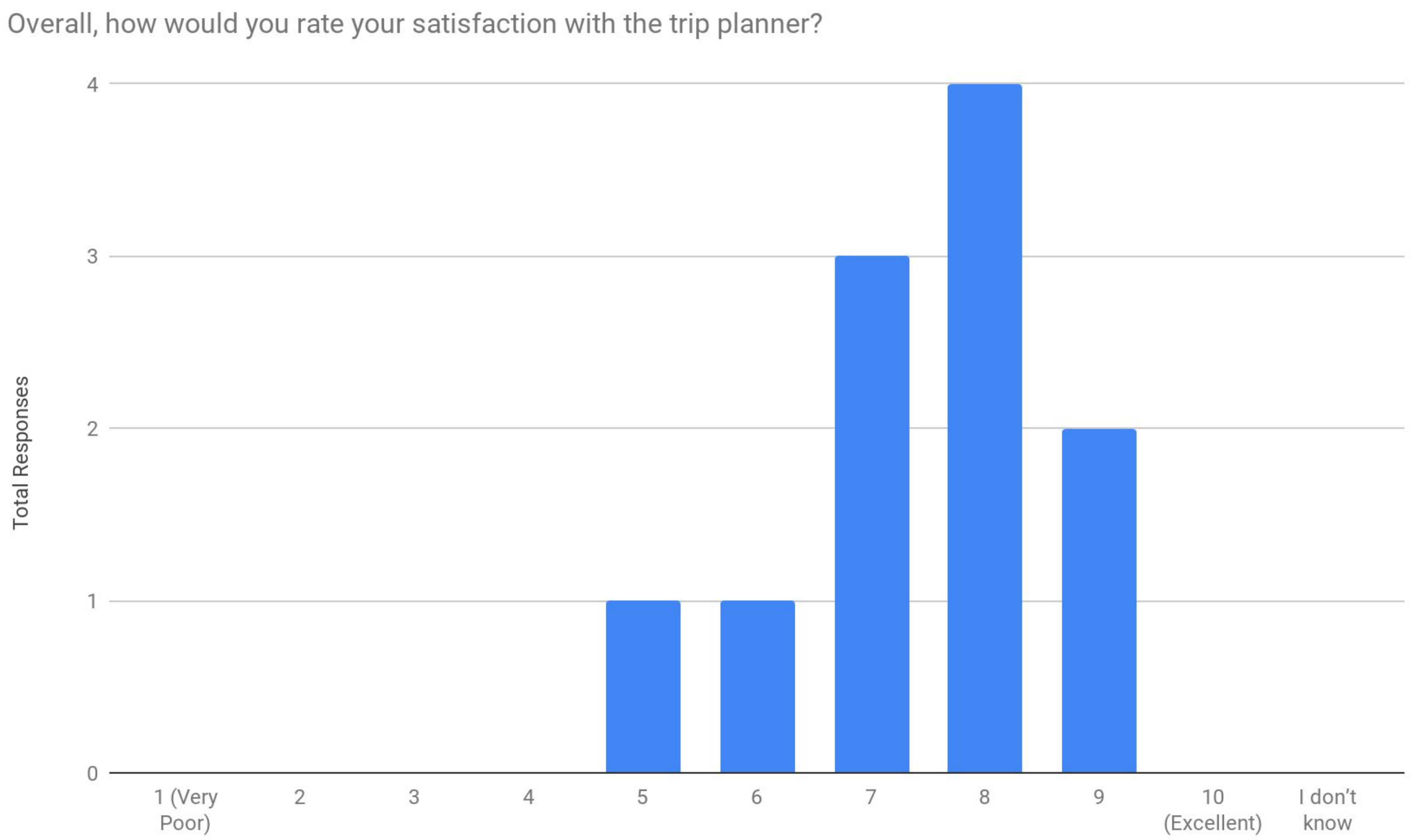
Overall, how would you rate the overall design interface of the trip planner?
Total Responses
6
4
2
0
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know


Overall, how would you rate the functionality of the map within the trip planner?
Total Responses
3
2
1
0
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know


Currently, how would you rate your ability to get to and from public transit in the Portland region?
Total Responses
3
2
1
0
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don't know


To what extent does this trip planner improve your ability to get to and from public transit in the Portland region?
Total Responses
6
4
2
0
No noticeable improvement
Slightly improves
Moderately improves
Greatly improves
I don't know


Which modes do you expect to use more or less often as a result of the trip planner?
Take Transit Only
Bike + Transit
Biketown + Transit
P&R
car2go + Transit
Uber+ Transit
Lyft + transit
Walk Only
Bike Only
0
2
4
6
8
10
Total Responses
I do not use this mode(s) now, and I do not expect to in the future
Much more often
More often
About the same
Less often
Much less often
Could change, but not because of trip planner


Overall, how would you rate your satisfaction with the trip planner?
Total Responses
0
1
2
3
4
1 (Very Poor)
2
3
4
5
6
7
8
9
10 (Excellent)
I don’t know

ACRONYMS & ABBREVIATIONS

API	Application Programming Interface
FTA	Federal Transit Administration
GBFS	General Bikeshare Feed Specification
GTFS	General Transit Feed Specification
GTFS-RT	General Transit Feed Specification realtime update extension
GTFS-flex	General Transit Feed Specification flexible-service extension
MaaS	Mobility as a Service
MAF	Master Address File
MOD	Mobility on Demand
OA	OpenAddresses
OSM	OpenStreetMap
OSS	Open Source Software
OTP	OpenTripPlanner
PLC	Project Leadership Committee
POI	Point of interest
RLIS	Regional Land Information System
SUM	Shared Use Mobility
UI	User Interface
UX	User Experience
WAV	Wheelchair-accessible vehicle

Transit Agencies

AC Transit	Alameda-Contra Costa Transit District (East Bay area, CA)
BART	Bay Area Rapid Transit Authority (San Francisco Bay area, CA)
LA Metro	Los Angeles County Metropolitan Transportation Authority (Los Angeles, CA)
RTD	Regional Transportation District of Denver (Denver, CO)
VTA	Santa Clara Valley Transit Authority (San Jose, CA)
VTrans	Vermont Agency of Transportation (Montpelier, VT)

U.S. Department of Transportation
Federal Transit Administration

U.S. Department of Transportation
Federal Transit Administration
East Building
1200 New Jersey Avenue, SE
Washington, DC 20590
https://www.transit.dot.gov/about/research-innovation