Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety

CVI UTC

CONNECTED VEHICLE/INFRASTRUCTURE UNIVERSITY TRANSPORTATION CENTER (CVI-UTC)

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Connected Vehicle/Infrastructure UTC

The mission statement of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) is to conduct research that will advance surface transportation through the application of innovative research and using connected-vehicle and infrastructure technologies to improve safety, state of good repair, economic competitiveness, livable communities, and environmental sustainability.

The goals of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) are:

- Increased understanding and awareness of transportation issues
- Improved body of knowledge
- Improved processes, techniques and skills in addressing transportation issues
- Enlarged pool of trained transportation professionals
- Greater adoption of new technology

Abstract

Many transit agencies provide real-time operational information and trip-planning tools through phone, Web, and smartphone applications. These services utilize a one-way information flow from transit agencies to transit users. Current smartphone technology and connected vehicle infrastructure (CVI), however, can allow a two-directional information flow from users to transit agencies and back.

This report provides a literature review on the state of current transit apps; proposes a system architecture for a smartphone app that allows for dynamic flexible routing and increased transit user safety; and presents the results of a survey conducted on the perception and acceptability of the model app.

Survey results were analyzed in terms of safety, efficiency, and privacy for different demographic, travel behavior, and geographic characteristics. Results showed that users did not significantly consider the privacy issues (7.1 on a scale from 1 [least acceptable] to 10 [most acceptable]) but believed that it could improve nighttime safety (7.3/10.0). Users believed that the app could improve nighttime pedestrian safety if it were connected to the police department (7.8/10.0). This app was also expected to improve transit efficiency and increase ridership, and is eventually recommendable (7.3/10.0). The least expected improvement was daytime safety (6.4/10.0), which is reasonable and expectable.

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Table of Contents

List of Figures

List of Tables

Introduction

Background

In urban areas, public transportation is often viewed as a means of reducing congestion. In rural areas, public transportation is viewed as a "lifeline," providing access to jobs, stores, and medical services in larger, nearby communities. However, approximately 38% of the rural population has no access to public transportation. Existing service is sometimes restricted to weekdays, with service often operating only from 8 a.m. to 4 p.m., or even fewer hours per day (Intelligent Transportation Systems Joint Program Office, RITA, USDOT, 2013).

Transit and private transportation provide different benefits. The advantage of transit is that its users do not need to own and maintain a car, or even need to be able to drive. But transit also has disadvantages. Transit is usually operated on a fixed route to a preset schedule, forcing users to be at a defined point by a set time, giving them less control over their schedules than owners of private vehicles. In addition, transit users sometimes need to transfer (Lee, Analysis and Optimization of Transit Network Design with Integrated Routing and Scheduling, 1998), which can result in longer travel times.

In order to minimize the disadvantages of transit service, a great deal of research regarding transit planning, operation, and design has been conducted. Intelligent transportation systems (ITS) have been actively utilized as a part of those efforts in recent years in the following categories (Intelligent Transportation Systems Joint Program Office, RITA, USDOT, 2013).

- Fleet Operations and Management – To facilitate transit operations and provide input to senior management
- Traveler Information – To provide customer-facing technologies such as trip-planning and real-time operational information
- Safety and Security – To improve the safety and security of transit staff and passengers
- Automated Fare Payment – To provide fare collection and payment technologies
- Maintenance – To facilitate maintenance activities
- Other – Other technologies and systems, such as data management and the use of open data

The use of ITS in transit operations has increased dramatically in recent years to identify vehicle locations using automatic vehicle location (AVL), manage and dispatch transit vehicles using computer-aided dispatch (CAD), and disseminate transit information through a real-time information system, such as a transit app and display system. Figure 1 shows the deployment trends for some of the most prevalent transit technologies from 1997 to 2010. Four major trends are displayed in this figure: the percentage of fixed-route vehicles equipped with AVL, the percentage of fixed-route buses with electronic real-time monitoring of system components, the percentage of demand responsive vehicles that operate using CAD, and the percentage of transit stops with an electronic display of dynamic traveler information to the public (Intelligent Transportation Systems Joint Program Office, RITA, USDOT, 2013).

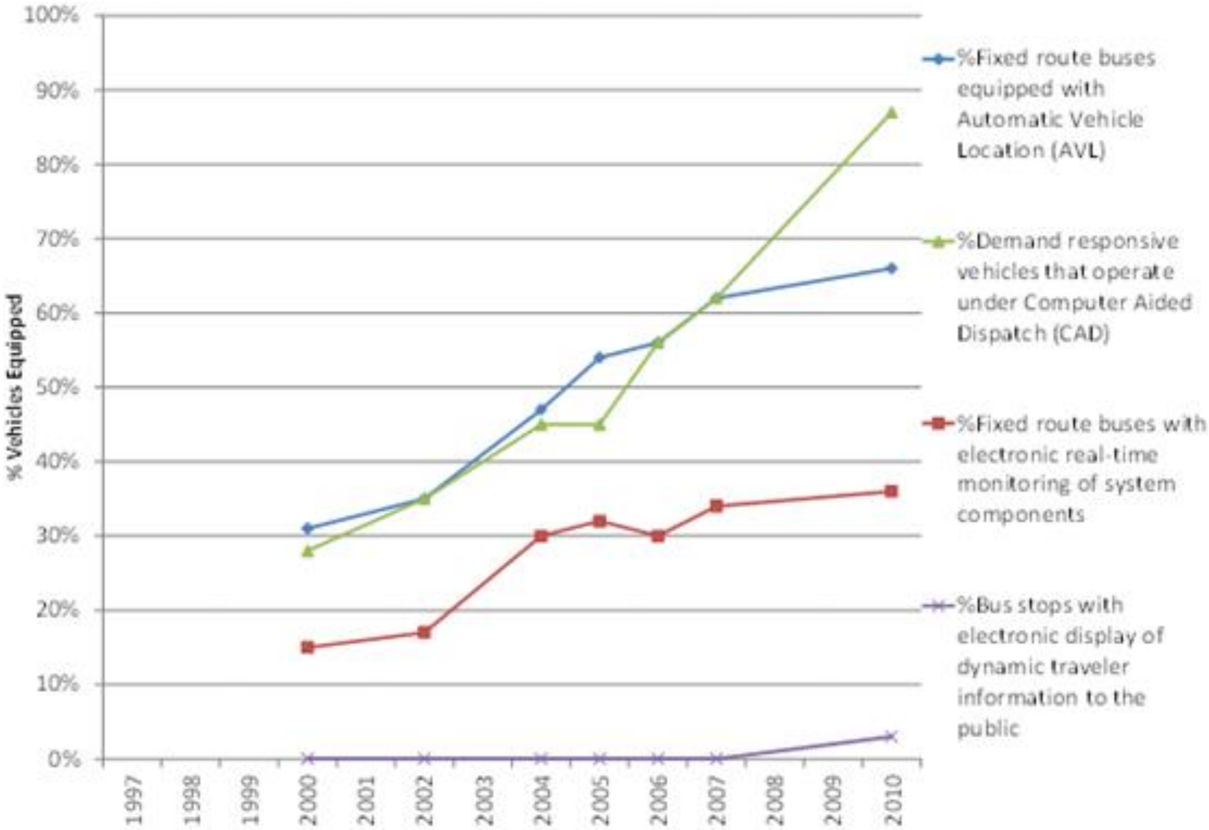


Figure 1. Deployment trends for some of the most prevalent transit technologies from 1997 to 2010 (Intelligent Transportation Systems Joint Program Office, RITA, USDOT, 2013).

Figure 2 shows an example of the relationships among various transit ITS technologies at a central dispatch location.

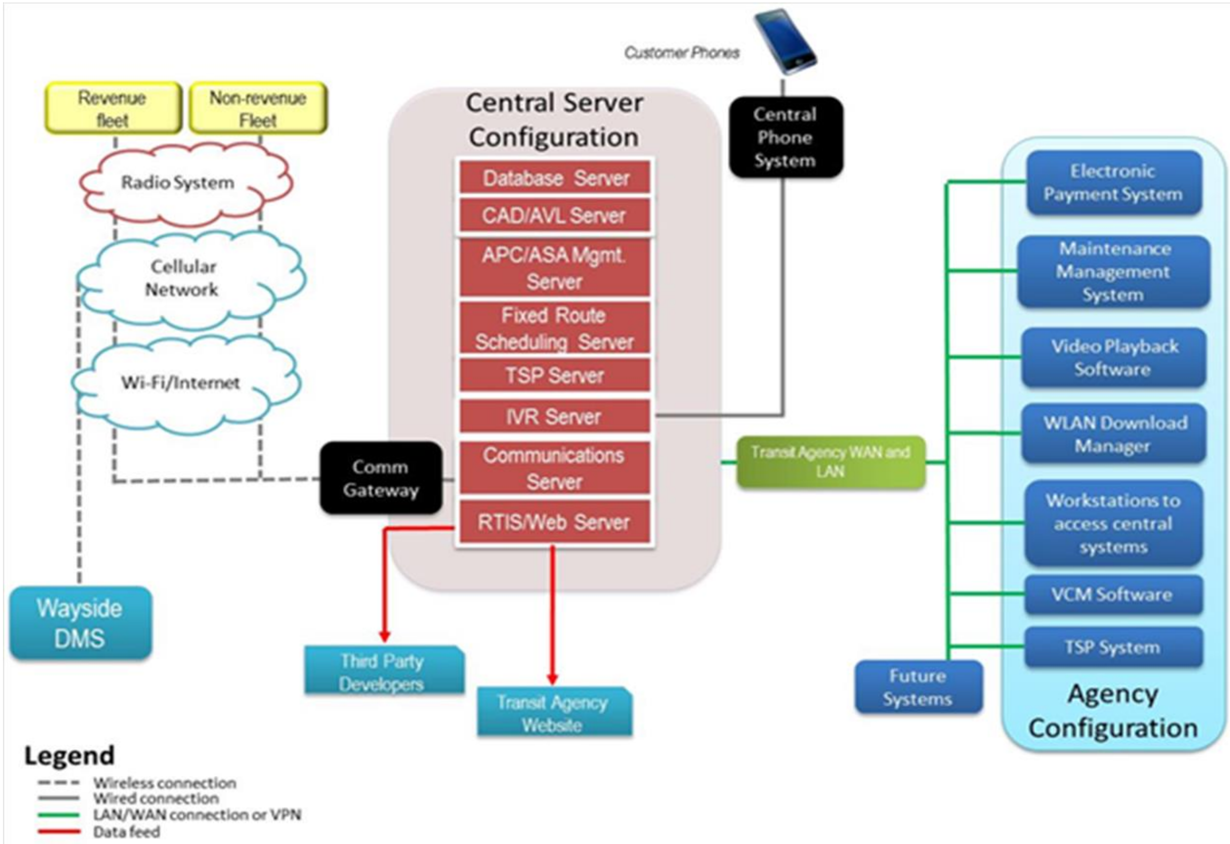


Figure 2. Relationships among various transit ITS technologies at a central dispatch location (Intelligent Transportation Systems Joint Program Office, RITA, USDOT, 2013).

Most ITS technologies utilize a one-directional information flow from transit agencies to transit users. However, the development of connected vehicle (CV) technology in recent years can allow a two-directional information flow, which includes information from users to transit agencies (Intelligent Transportation Systems Joint Program Office, RITA, USDOT). In addition to Dedicated Short Range Communication (DSRC) devices, smartphones are considered a potential candidate due to their popularity and powerful and versatile functionality.

Numerous smartphone applications (apps) related to transportation and transit are coming to the market, and these apps increasingly rely on open data (Wikipedia, the free encyclopedia, 2014). Many transit apps provide real-time operational information, including routing and scheduling through Web, phone, and smartphone applications. They also provide a trip-planning tool for a given origin and destination. Table 1 shows major U.S. cities that have transit apps available, the total ridership, and the number of transit apps (as of April 2014).

Despite the obvious benefits of transit, apps some problems have emerged. Many apps have proven to be inaccurate in predicting real-time information during congested traffic conditions (Wikipedia, the free encyclopedia, 2014; Raschke, What's wrong with the Nextbus API?, 2013; Raschke, Transit Agencies Must Improve Service Through Technology, 2013; Bad App Reviews, 2014; German, 2012; The Marketing People, 2012; Cohan, 2012). Apps can also be potentially harmful and risky for users' information. The security situation is complicated by the number of players in the market. Very few apps are developed by transportation agencies themselves; most have been developed by non-agency, third-party developers. And despite the proliferation of the technology, there are no standards for monitoring and evaluating the performance of transit apps.

Table 1. Major U.S. Cities with Transit Apps (Massachusetts Bay Transportation Authority, 2014; Tri-County Metropolitan Transportation District of Oregon , 2014; King County Metro, 2014; Washington Metropolitan Area Transit Authority (Washington DC), 2014; APTA, 2012; Chicago Transit Authority (CTA), 2014; Metropolitan Transportation Authority (MTA), 2014)

City	Boston, MA	Chicago, IL	New York, NY	Portland, OR	Seattle, WA	Washington, DC
Agency	MBTA	CTA	MTA	TriMed	King County Metro	WMATA
2012 Total Ridership (000s)	406,801	1,518,450	4,114,454	113,365	196,621	479,576
Number of Apps	70	41	199	56	7	42
First Year of Data Release	2008	2009	2010	2007	2009	2009

The majority of transit apps are still one-directional and do not utilize two-way communication. Two-way communication, however, could enable a more-flexible, efficient, and safe transit system. For example, users could send their origin and destination information to the agency, and the agency could use that information for demand-responsive transit routing and scheduling in rural transit operation. A smartphone's Global Positioning System (GPS) could provide user locations to the agency, which could help a flexible-route transit vehicle pick up passengers more efficiently (especially when they are not at the transit stop when expected) and save travel time. Knowledge of user location could also contribute to passenger safety at nighttime.

User input could also be beneficial for fixed-route, mass transit operation and passenger safety during the nighttime. If a bus driver can identify the locations of passengers who are late to the bus stop, the bus driver can wait a short time for passengers, eliminating the chance that they will miss the bus and have to wait for the next bus, which may not come until 20–30 minutes later.

Research Objectives

This project developed a rudimentary architectural framework for two connected vehicle/infrastructure (CVI) applications: a dynamic routing tool (DRT) and an enhanced traveler safety application that allows individuals to notify a transit vehicle that they are within a specified distance of the vehicle's current stop. The architecture is conceptual and designed to generically map communications and linkages between the components that make up the two applications.

This research consisted of the following tasks.

1. Conduct an extensive literature review on current cutting-edge smartphone apps for transit service.
2. Develop a framework for a handheld mobile app for users, a mobile app for transit drivers, and a management server program with functions such as person-to-infrastructure (P2I), vehicle-to-infrastructure (V2I), and person-to-vehicle (P2V) connections among transit users, transit agency, transit vehicles, and transit stops as follows:
   - P2I – Origin-destination information from passengers to agency, and route information from agency to passengers
   - V2I – Routing information and passenger information from agency to vehicle, and vehicle location from vehicle to agency
   - P2V – GPS location from passengers to vehicle, and vehicle location information from vehicle to passengers
3. Develop a smartphone application for transit users that supports Task 2.
4. Develop a database for transit agencies that supports Task 2.
5. Develop a mobile onboard application for a transit vehicle that supports Task 2.
6. Conduct a survey to find out user perceptions as to whether this kind of user location-based transit mobile app can improve ridership and safety (especially during the nighttime).
7. Document potential improvements to transit efficiency and safety using smartphone and CVI technologies.

Literature Review

Transit has seen a growth in usage in recent years. One of the reasons attributed to the increase in ridership has been the availability of transit apps that rely on open data. Open data is based on the idea that certain data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents, or other mechanisms of control. Transit open data can be defined as access to the public internal data of a transit agency. Transit open data is a usable format for both interested individuals, professionals (application programmers), and experts (for analysis).

The main benefits of providing transit apps based on open data are as follows (Fleet Beat, 2010):

- Free development of mobile applications
- Increased ridership
- Improved customer service
- Time saved by agencies in developing customized applications
- More accurate applications
- Positive image for agencies
- App centers on agencies' webpages

The General Transit Feed Specification (GTFS), which defines a common format for public transportation schedules and associated geographic information, is the most popular and important open data format for transit. GTFS, first conceived by Bibiana McHugh, an IT Manager at the TriMet transit agency in the Portland metropolitan area (Oregon), was developed by Google and Portland TriMet in 2005, and originally known as the Google Transit Feed Specification. A GTFS feed is a collection of CSV files (with extension .txt) that model a public transit system's schedules, usually contained within a zip file. The files are sufficient to provide trip-planning functionality, and to a greater extent power additional applications such as real-time information systems and service analysis (Wikipedia, the free encyclopedia, 2014).

Various regional, national, and global transit apps are available. Several transit apps are available for large cities such as New York, Chicago, and Washington, D.C., and there are new apps with different formats, data, and prices being prepared. To illustrate the diversity of apps available, Table 2 shows currently available transit apps in Maryland (in particular, those for the Baltimore metropolitan area).

Table 2. Transit Apps Covering the State of Maryland

#	App Name	App Developer	Covering Area in MD	Platform	Payment Type	Developer's Website
1	HopStop	HopStop	Baltimore & BWI	iPhone & Android Apps, Website	Free	https://www.hopstop.com/mobile , https://baltimore.hopstop.com/
2	SmartTransit	Microjects	Baltimore	Android App	Free	https://play.google.com/store/apps/details?id=com.transit.client.main
3	TripGo	Skedgo Pty	Baltimore	iPhone & Android Apps	Free	https://itunes.apple.com/au/app/tripgo/id533630842?mt=8
4	RailBandit	Barry Engel	Baltimore	BB, iPhone & Android Apps	Paid ($7.89)	http://www.railbandit.com/mobile-train-schedule.htm
5	Smart Ride	Codemass, Inc.	Baltimore	iPhone App	Free	http://www.smartrideapp.com/
6	Mapiz	Mapiz	Baltimore	iPhone & Android Apps	Free	http://home.mapiz.com/
7	TransiCast	Joa	Baltimore	Android App	Free	http://www.transicast.com/
8	AnyStop	MTA	Baltimore	Android App	Free	http://anystopapp.com/baltimore-transit/
9	Baltimore Transit	Miguel Carrasco Enterprises	Baltimore	Windows App	Free	http://apps.microsoft.com/windows/en-us/app/baltimore-transit/28a5934d-8d55-46cf-86f5-66dde330dad2

#	App Name	App Developer	Covering Area in MD	Platform	Payment Type	Developer's Website
10	Charm City Circulator	Apps Now Mobile RedBit Developmt	Baltimore	Windows App	Paid ($1.99)	http://apps.microsoft.com/windows/en-us/app/charm-city-circulator/95c07831-b4f0-4f2f-bae5-de378e08bb83
11	ECG MARC	MTRC llc	Baltimore	iPhone App	Paid ($0.99)	https://itunes.apple.com/us/app/ecg-marc/id860193821?mt=8
12	AnyStop	Charm City Circulator	Baltimore	iPhone & Android Apps, Website	Free	http://www.charmcitycirculator.com/mobileapps/next-bus?device=desktop
13	allSchedules	J.Carvalho, L. Certo	Baltimore, MD City	iPhone App	Paid ($1.99)	http://www.allschedulesapp.com/
14	Stopango	Stopango sp. z o.o.	Cumberland	iPhone App, Website	Free	http://stopango.com/
15	Buzz Stop	Designing Webs, Inc	Global	iPhone App	Paid ($0.99)	https://itunes.apple.com/us/app/buzz-stop/id415852246?mt=8&ls=1
16	Transit App	Samuel Vermette	Global	iPhone & Android Apps	Free	http://www.thetransitapp.com/
17	Moovit	TranzMate	Global	iPhone App, Android App	Free	http://www.moovitapp.com/
18	Google Maps	Google, Inc.	Global	iPhone & Android Apps, Website	Free	https://maps.google.com
19	RocketMan Transit	Avisinna	Global	iPhone, Android & BB Apps	Free	http://rocketmanapp.com/
20	TransitTim+ Trip Planner	Zervaas Enterprises	Global	iPhone App, Android App	Paid ($2.99)	http://transittimesapp.com/baltimore-public-transit-app.html

As mentioned in the Background section, some problems have emerged with the proliferation of apps. Many apps have proven to be inaccurate in predicting real-time information during congested traffic conditions (Wikipedia, the free encyclopedia, 2014; Raschke, What's wrong with the Nextbus API?, 2013; Raschke, Transit Agencies Must Improve Service Through Technology, 2013; Bad App Reviews, 2014; German, 2012; The Marketing People, 2012; Cohan, 2012). Apps can also be potentially harmful and risky for users' information. Due to such risks, the majority of transit agencies have added notes and disclaimers on their app centers (examples are shown in Table 3).

Table 3. Notes/Disclaimers of App Centers/Galleries of Major U.S. Cities with Transit Apps (Massachusetts Bay Transportation Authority, 2014; Tri-County Metropolitan Transportation District of Oregon , 2014; King County Metro, 2014; Washington Metropolitan Area Transit Authority (Washington DC), 2014; Chicago Transit Authority (CTA), 2014; Metropolitan Transportation Authority (MTA), 2014)

Cities	Note/Disclaimer
Boston, MA (MBTA)	*App Disclaimer* These apps are not made by MBTA, and MBTA does not sell or license the apps. They are written by third parties unless otherwise noted. MBTA shall not be held responsible for the content of third party websites or any issue arising from the use of third party applications. MBTA neither endorses any third party products listed here nor makes any guarantees or representations as to accuracy or reliability. Proceed with care and understand any usage charges that may apply to you. MBTA reserves the right to remove/add applications listings without notice.
Chicago, IL (CTA)	*Important note* These apps (unless otherwise noted) are not made by CTA, and CTA does not sell or license the apps. They are written by third parties. CTA shall not be held responsible for the content of third party websites or any issue arising from the use of third party applications. CTA neither endorses any third party products listed here nor makes any guarantees or representations as to accuracy or reliability. Proceed with care and understand any usage charges that may apply to you. CTA reserves the right to remove/add applications listings without notice.
New York, NY (MTA)	Beginning in a few weeks, all MTA data feeds will become accessible only through issuance of an API key. App developers must agree to the terms and conditions of this access and complete and submit an Online Registration Form. Once that form is reviewed and accepted, the developer will be issued a Developer's API key. The key will enable the developer to access the MTA's data feeds.
Portland, OR (TriMed)	*Transit tools for the web and mobile devices* Below are some of the free and commercial applications that are available from third-party developers using TriMet's open data.
Seattle, WA (King County Metro)	King County provides links to third-party applications and sites that use King County data for informational purposes to the general public. King County does not warrant or support these applications or sites. King County does not endorse or sponsor these sites. King County is not affiliated with or associated with these organizations. The content and views expressed on these sites are not those of King County's. You access these links and applications at your own risk, and neither King County nor any of its employees or agents shall be liable for your use of these links and applications nor shall be liable for the accuracy of the information or any actions taken as a result.
Washington, D.C. (WMATA)	*Note*: WMATA provides these links as a convenience and cannot be held responsible for the content of third party websites. This listing is provided "as is" without express or implied warranty. WMATA makes no representations as to accuracy, reliability or completeness.

User complaints about accuracy and critical security issues point to the need to monitor and evaluate the performance of the numerous apps available in the marketplace. Figure 3 shows efforts to develop data and file standards for transit public and open data, but there are not any similar efforts for monitoring and evaluating the apps that use transit open data.

	Champion	Where it's used	Applicable data sets	Examples	More information[11]
Data Standards					
GTFS	Google	Worldwide	Schedule data	Train line schedule	https://developers.google.com/transit/gtfs/
GTFS-realtime	Google	Select US & European cities	Real-time data	"Train arriving in 3 min"	https://developers.google.com/transit/gtfs-realtime/
SIRI	European Committee for Standardization	European cities	Real-time data	"Train arriving in 3 min"	http://bustime.mta.info/wiki/Developers/SIRIIntro
TransXchange	UK Gov	UK Buses	Bus schedules & data	Bus route schedule	http://www.dft.gov.uk/transxchange/
DATEX 2	European Commission	European Cities	Traffic data & Management	Delays on Route 4	http://www.datex2.eu/content/datex-background
File Formats					
CSV	Many	Worldwide	Data tables	Historic on-time data	http://www.ehow.com/how_5091077_use-csv-files.html
TXT	Many	Worldwide	Text	Textual information	http://en.wikipedia.org/wiki/Text_file
GIS	Many	Worldwide	Geographic mapping	Subway station entrances	http://en.wikipedia.org/wiki/GIS_file_formats
KML	Google	Worldwide	Google Maps & Earth	GIS road outlines	https://developers.google.com/kml/documentation/
XML	Many	Worldwide	Large data sets	Traffic numbers	http://www.w3schools.com/xml/xml_whatis.asp

Figure 3. Transit open data standards (Kaufman, 2012).

Catalog of CV Applications

There are many CV applications, at either the concept or development stage, covering a variety of transportation components. Nearly 100 different CV applications have been identified by Connected Vehicle Reference Implementation Architecture (CVRIA), as shown in Table 4. There are four main application types: Environmental, Mobility, Safety, and Support, which are further subdivided into 18 groups. Mobility has 36 applications (37.1%) in 11 groups, followed by Safety with 30 applications (30.9%) in 3 groups, and 22 Environmental applications (22.7%) in 2 groups.

Table 4. Connected Vehicle Applications

Type	Group	#	%	#	%
Environmental	AERIS/ Sustainable Travel	16	16.5%	22	22.7%
	Road Weather	6	6.2%		
Mobility	Border	1	1.0%	36	37.1%
	Commercial Vehicle Fleet Operations	5	5.2%		
	Commercial Vehicle Roadside Operations	2	2.1%		
	Electronic Payment	2	2.1%		
	Freight Advanced Traveler Information Systems	2	2.1%		
	Planning and Performance Monitoring	1	1.0%		

Type	Group	#	%	#	%
	Public Safety	4	4.1%		
	Traffic Network	4	4.1%		
	Traffic Signals	5	5.2%		
	Transit	8	8.2%		
	Traveler Information	2	2.1%		
Safety	Transit Safety	3	3.1%	30	30.9%
	V2I Safety	13	13.4%		
	V2V Safety	14	14.4%		
Support	Core Services	8	8.2%	9	9.3%
	Security	1	1.0%		
Total		***97***	***100.0%***	***97***	***100.0%***

Source: (Iteris, Inc., 2016)

There are also currently nine applications in the Support category that were designed and developed for internal purposes and facilitating other applications, such as:

- Core authorization
- Data distribution
- Infrastructure management
- Location and time
- Map management
- Object registration and discovery
- Privacy protection
- System monitoring
- Security and credentials management

Current Research and Practices for Transit, Bicycles, and Pedestrians Using CVI

Two application groups in Table 4 are explicitly identified as being related to transit: the Transit group under Mobility and the Transit Safety group under Safety. No groups directly refer to bicycles and pedestrians, but there are a few applications targeting these road users that will be reviewed in the following sections.

Transit

Table 5 summarizes transit-related CV applications. There are 14 transit-related applications that account for 14.4% of all CV applications. The majority of transit applications are categorized under Mobility (10 out of 14; more than 70%), while there are three Transit Safety applications (around 21%) and, finally, one Environmental application.

The definitions of the following transit applications are provided in Table 5.

Table 5. Transit-Related CV Applications

Type	Group	Application	#	%	#	%
Environmental	AERIS/ Sustainable Travel	Eco-Transit Signal Priority	1	1.0%	1	1.0%
Mobility	Traffic Signals	Transit Signal Priority	1	1.0%	10	10.3%
	Transit	Dynamic Ridesharing	8	8.2%		
		Dynamic Transit Operations				
		Integrated Multi-Modal Electronic Payment				
		Intermittent Bus Lanes				
		Route ID for the Visually Impaired				
		Smart Park and Ride System				
		Transit Connection Protection				
		Transit Stop Request				
	Traveler Information	Advanced Traveler Information Systems	1	1.0%		
Safety	Transit Safety	Transit Pedestrian Indication	3	3.1%	3	3.1%
		Transit Vehicle at Station/Stop Warnings				
		Vehicle Turning Right in Front of a Transit Vehicle				
Subtotal (Transit Applications)			*14*	*14.4%*	*14*	*14.4%*
Total (All CV Applications)			***97***	***100.0%***	***97***	***100.0%***

Source: (Iteris, Inc., 2016)

Bicycles

Table 6 summarizes bicycle-related CV applications. There are only four bicycle-related applications, accounting for only 4.1% of all CV applications. Some of the identified applications are shared among bicyclists and pedestrians (i.e., pedestrian mobility applies to bicyclists as well). The study team also assumes that some applications for other vehicles (like motorcycles and slow vehicles) may also be applicable for bicycles, either directly or with some modifications.

The definitions of the following bicycle applications are provided in Table 6.

Table 6. Bicycle-Related CV Applications

Type	Group	Application	#	%	#	%
Mobility	Traffic Signals	Pedestrian Mobility	1	1.0%	2	2.1%
	Traveler Information	Advanced Traveler Information Systems	1	1.0%		
Safety	V2V Safety	Motorcycle Approaching Indication	2	2.1%	2	2.1%
		Slow Vehicle Warning				
Subtotal (Bicycle Applications)			*4*	*4.1%*	*4*	*4.1%*
Total (All CV Applications)			***97***	***100.0%***	***97***	***100.0%***

Source: (Iteris, Inc., 2016)

Pedestrians

Table 7 summarizes pedestrian-related CV applications. There are six pedestrian-related applications, accounting for 6.2% of all CV applications. The main application type is Mobility (3 out of 6; 50%), followed by Safety (2 out of 6; 33.3%).

The definitions of the following pedestrian applications are provided in Table 7.

Table 7. Pedestrian-Related CV Applications

Type	Group	Application	#	%	#	%
Environmental	AERIS/ Sustainable Travel	Eco-Traffic Signal Timing	1	1.0%	1	1.0%
Mobility	Traffic Signals	Intelligent Traffic Signal System	2	2.1%	3	3.1%
		Pedestrian Mobility				
	Traveler Information	Advanced Traveler Information Systems	1	1.0%		
Safety	Transit Safety	Transit Pedestrian Indication	1	1.0%	2	2.1%
	V2I Safety	Pedestrian in Signalized Crosswalk Warning	1	1.0%		
Subtotal (Pedestrian Applications)			*6*	*6.2%*	*6*	*6.2%*
Total (All CV Applications)			***97***	***100.0%***	***97***	***100.0%***

Source: (Iteris, Inc., 2016)

Transit Apps

Most transit apps rely on open data in standardized formats.

Introduction to Open Data

Open data is based on the idea that certain data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents, or other mechanisms of control.

Figure 4 shows the open data movement since 2006. Notable application programming interfaces (APIs) associated with the open data movement are Google Maps, Wikipedia, Facebook, and Twitter (introduced in 2006); YouTube and Yelp (2007); N.Y. Times (2008); and Netflix and LinkedIn (2009).

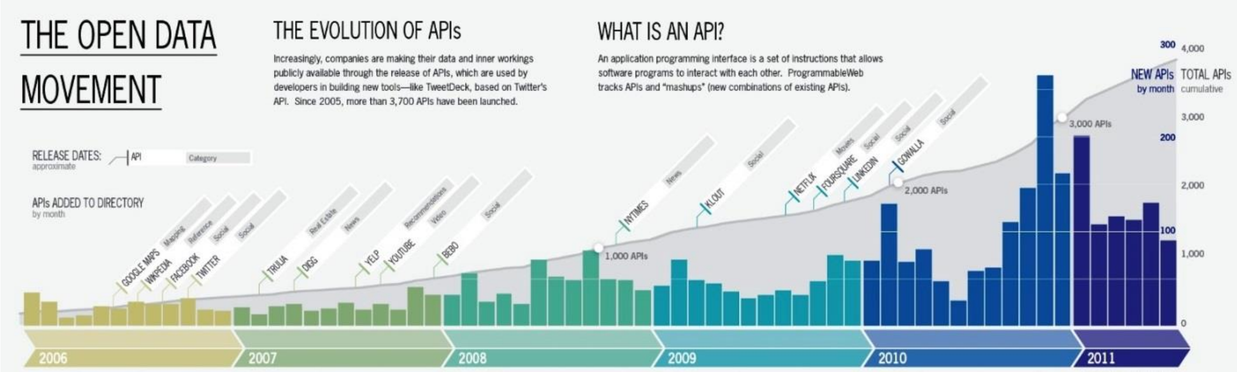


Figure 4. The open data movement (Source: (Visually, 2011)).

Although open data is free, there are costs for the application and provision, including (a) converting data to mainstream formats, (b) Web service for hosting data, (c) personnel time to update and maintain data as needed, and (d) personnel time to liaise with data users (Kaufman, 2012).

Transit Open Data

Transit open data is the availability of access to the public internal data made available by a transportation organization. Transit open data is a usable format for both interested individuals, professionals (application programmers), and experts (for analysis) (Kaufman, 2012).

The "must-have" data items are schedules, routes, and infrastructure locations (stations, roadways and landmarks, and networks) (Kaufman, 2012). Desirable data items are real-time data, budgetary data, performance data, ridership data, and origin-destination data (Kaufman, 2012). The desirable data can enhance operating and planning processes for a transit agency.

The standards for transit open data are shown in Figure 3, presented earlier in this report.

GTFS

The GTFS is a common format for public transportation schedules and associated geographic information that was developed by Google. GTFS is an open data format for public transportation schedules and associated geographic information. GTFS uses a .txt file format. The required data items are agency.txt, stops.txt, routes.txt, trips.txt, stop_times.txt, and calendar.txt. Optional data items are calendar_dates.txt, fare_attributes.txt, fare_rules.txt, shapes.txt, frequencies.txt, transfers.txt, and feed_info.txt (Google Developers, 2016).

GTFS Realtime

GTFS realtime is a feed specification that allows public transportation agencies to provide real-time updates about their fleet to application developers. It is an extension to GTFS. The GTFS realtime data exchange format is based on Protocol Buffers (Google Developers, 2016).

The current supported information includes (Google Developers, 2016):

- Trip updates – Delays, cancellations, and changed routes

- Example: “*Bus X is delayed by 5 minutes.*”
- Service alerts – Stop moved, unforeseen events affecting a station, route, or the entire network
  - Example: “*Station Y is closed due to construction.*”
- Vehicle positions – Information about the vehicles, including location and congestion level
  - Example: “*This bus is at position X at time Y.*”

Notable U.S. transit agencies employing open data are shown in Table 1. The following summarizes New York’s and Chicago’s status.

New York City – Metropolitan Transportation Authority (MTA): Currently (summer 2016) there are 247 apps cited on the MTA website (iPhone/iPod: 91; iPad: 56; Android: 57; Blackberry: 7; Windows: 10; Mobile/Web: 19; SMS/email: 4; telephone: 3). Most of these apps are free, and some are officially licensed by MTA (Metropolitan Transportation Authority (MTA), 2016).

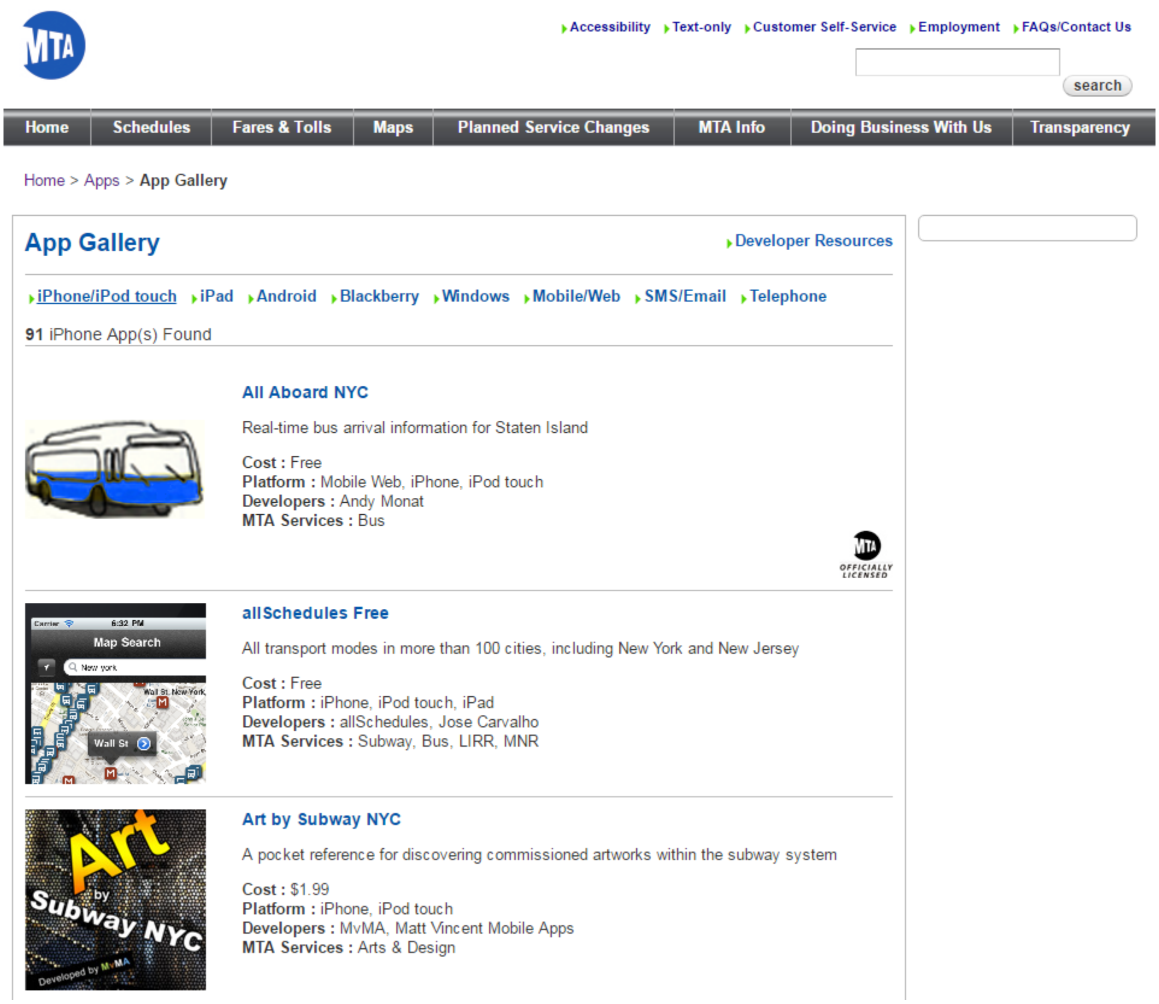


Figure 5. New York MTA App Center website (Source: (Metropolitan Transportation Authority (MTA), 2016)).

Chicago – Chicago Transit Authority (CTA): Currently (summer 2016) there are 50 apps cited on the CTA website (Web/computer apps: 7; Android: 18; iPhone & iPad: 22; Windows phone: 2;

dial-in applications: 1). Most of the apps are free, and one of them is made officially by CTA (Chicago Transit Authority (CTA), 2016).

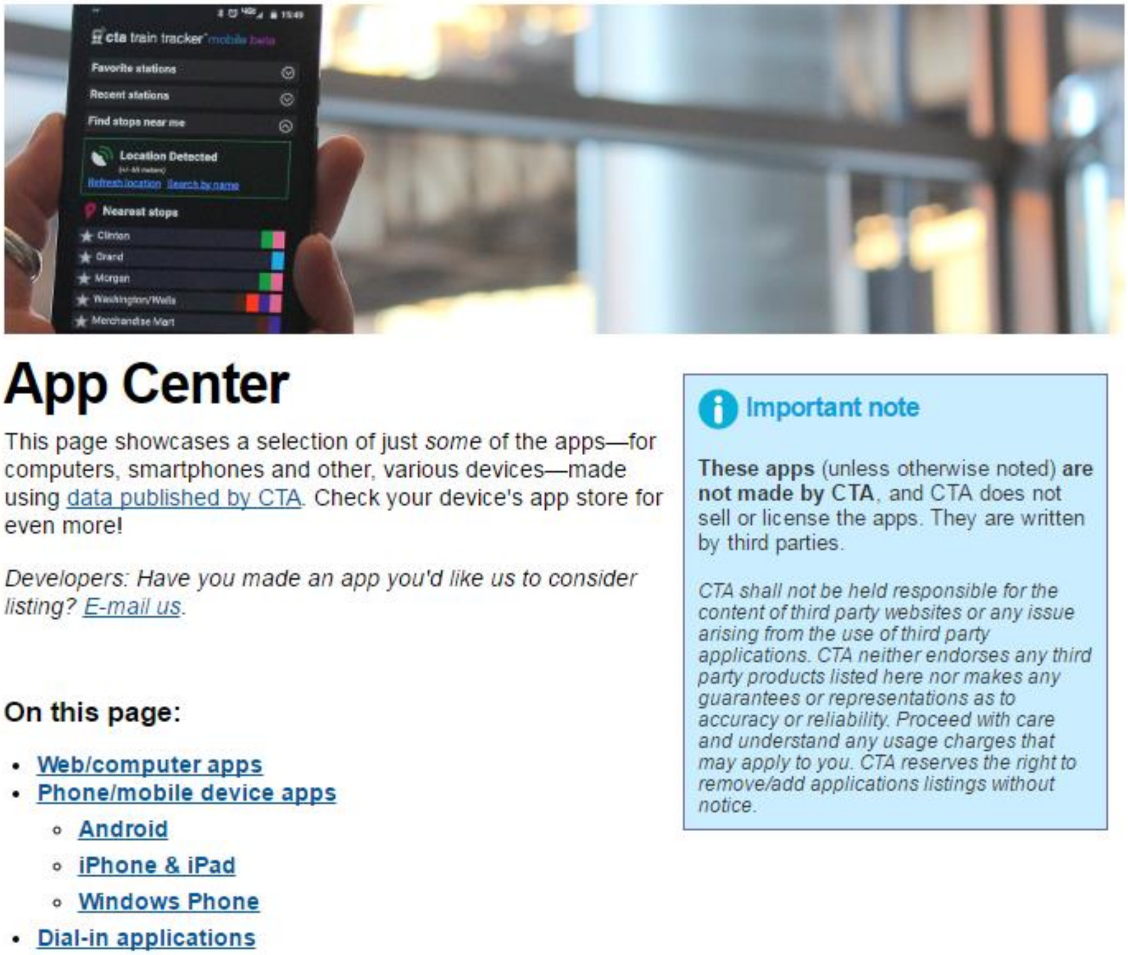


Figure 6. Chicago CTA App Center website (Source: (Chicago Transit Authority (CTA), 2016)).

Benefits and Impact of Open Data

The main transportation-related benefits of open data are the following (Kaufman, 2012):

- More-efficient travel (with an enhanced ability to find optimal routes while on the go)
- Greater understanding of finance and administration (possibly promoting improved funding)
- Crowd-sourced analysis capabilities (potentially helping detect schedule improvements or errors in stop locations or names, for instance)

The typical transportation-related benefits of open data are summarized in Figure 7.

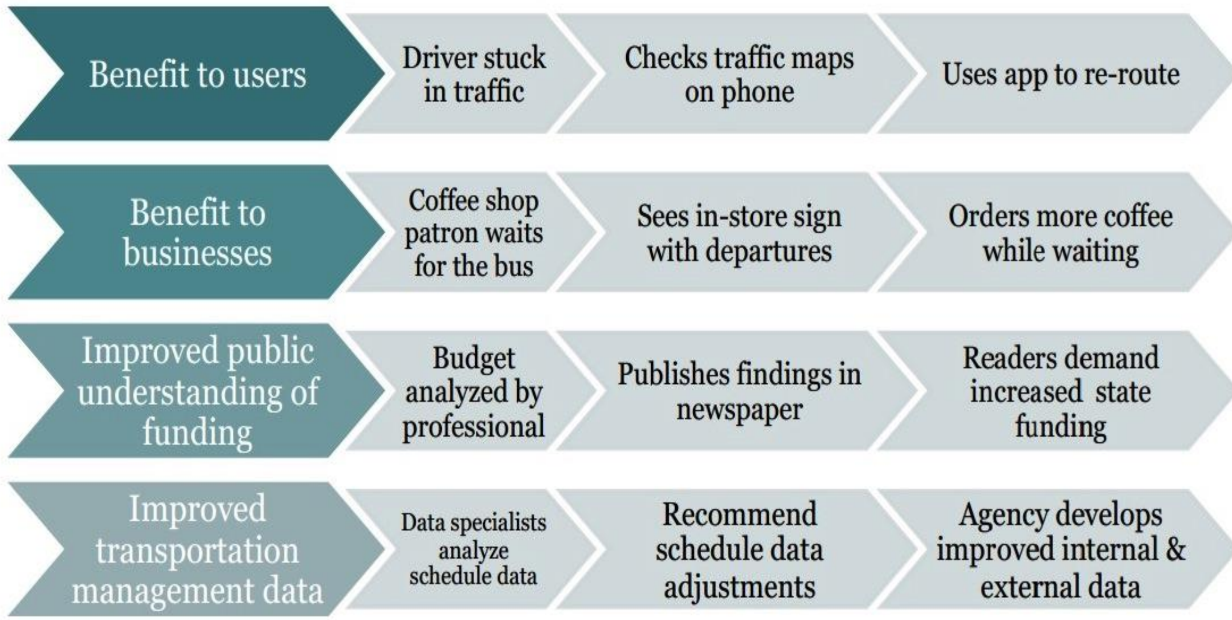


Figure 7. Typical Transportation Benefits of Open Data

Source: (Kaufman, 2012)

The transit benefits of open data are (The Fleet Beat, 2010)

- Free development of mobile applications;
- Increased ridership;
- Improved customer service;
- Time saved by agencies in developing customized applications;
- More-accurate applications;
- Positive image for agencies.

Studies have investigated the possible impacts of open data on transit ridership. A Seattle study (Rutherford, Wang, Watkins, & Malinovskiy, 2012) on real and perceived wait times revealed that users of real-time apps had 2.4-minute shorter perceived wait times and 2-minute shorter actual wait times. A study by the University of Iowa (Visser, 2012) showed that real-time bus info displays increased ridership by 5%. A City of Chicago real-time bus data impact study (Tang & Thakuriah, 2012) showed a 1.8% to 2.2% ridership increase attributed to real-time data over the study period (2002–2010).

Current Transit Apps

A few examples of existing transit apps are provided in the following figures.

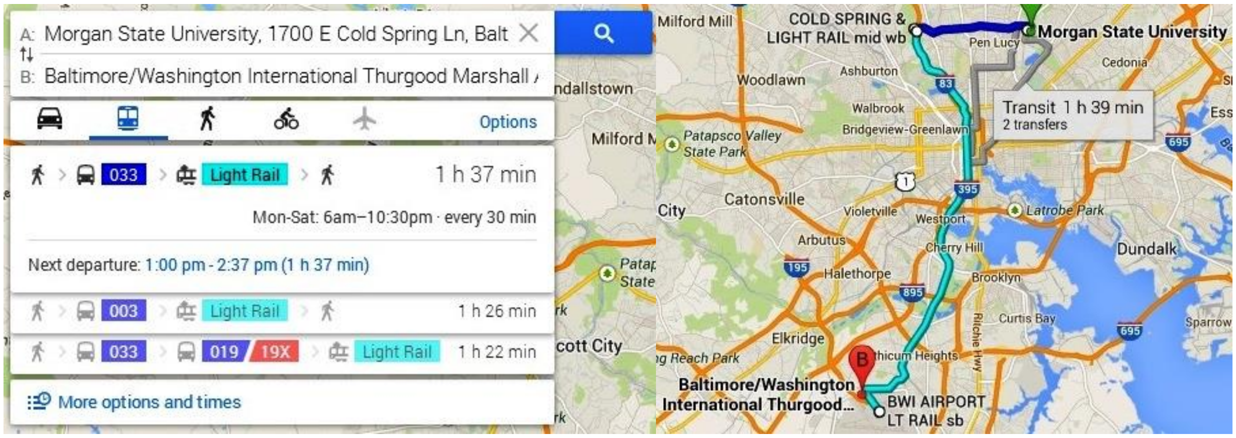


Figure 8. Point-to-point trip planning: Google Maps (Source: (Google Inc., 2016)).

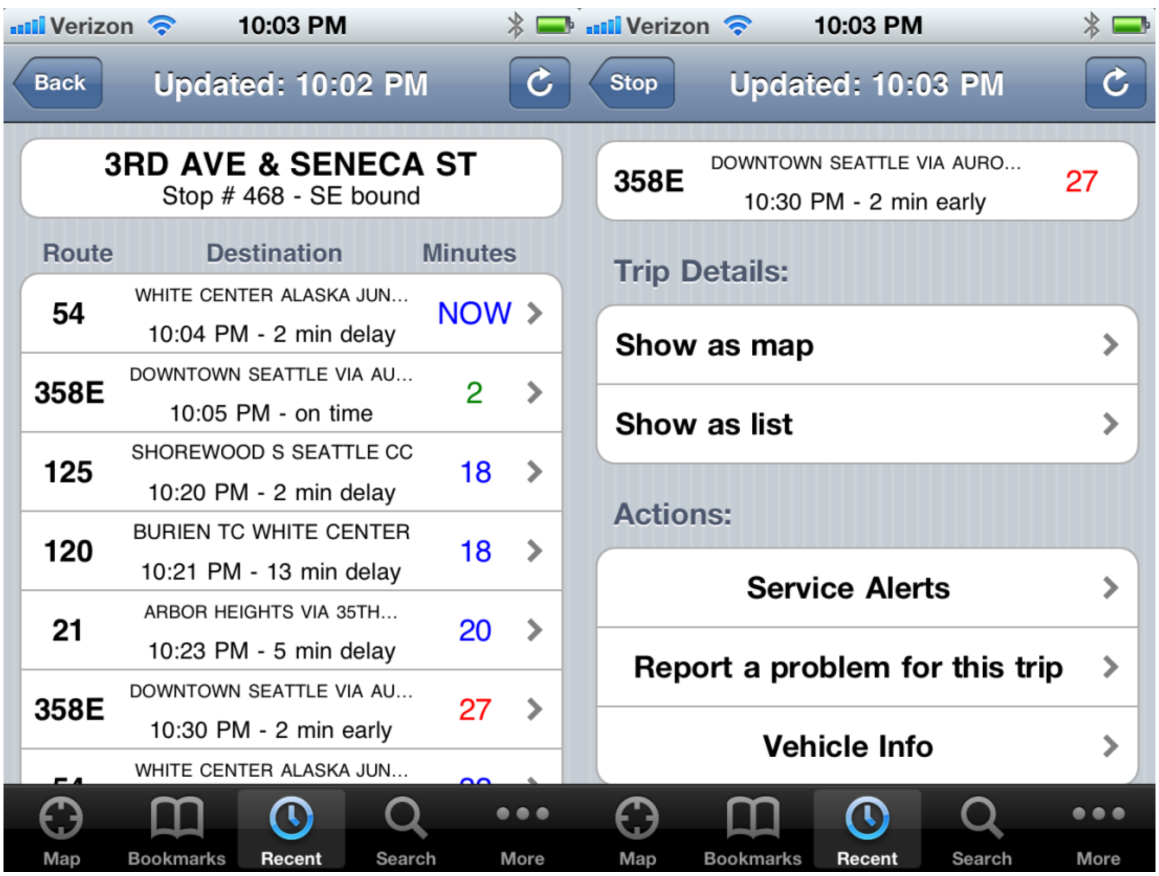


Figure 9. Real-time schedule app: One Bus Away (Source: (Ferris, One Bus Away, 2016)).

Figure 10. Seoul: Above the streets: "Seoul Bus" app with real-time info (Source: (Kakao Corporation, 2016)).

Figure 11. Seoul: Below the streets: "Jihachul" (Subway) app (Source: (Malang Studio Co. Ltd., 2016)).

Figure 12. 乗換案内 (Norikae Annai) for Tokyo (Source: (Jorudan Co., Ltd., 2016)).

Four broad categories of apps concern transportation. These categories can be categorized by the apps' primary function (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016):

1. Mobility apps
2. Vehicle connectivity apps
3. Smart parking apps
4. Courier network services (CNS) apps

The mobility apps that are of interest to this study are those with the primary function of assisting users in planning and understanding their transportation choices and those that may enhance access to alternative modes. They can be categorized in the following eight sub-categories (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016):

- Business-to-consumer (B2C) sharing
- Mobility trackers
- Peer-to-peer (P2P) sharing
- Public transit
- Real-time information
- Ridesourcing/transportation network companies (TNCs)
- Taxi e-hailing
- Trip aggregators

The majority of these apps are free.

Other important applications of transit apps are for operation, performance, planning, and so on. The Florida Department of Transportation considered and studied an expansion to the Google transit data to support operations and planning. They found that GTFS data could be employed in service planning efforts. In addition, they "identified opportunities to supplement the GTFS with performance-related information and developed a prototype application that integrated GTFS data with an automatic passenger counter (APC). (Catalá, Downing, & Hayward, 2011)

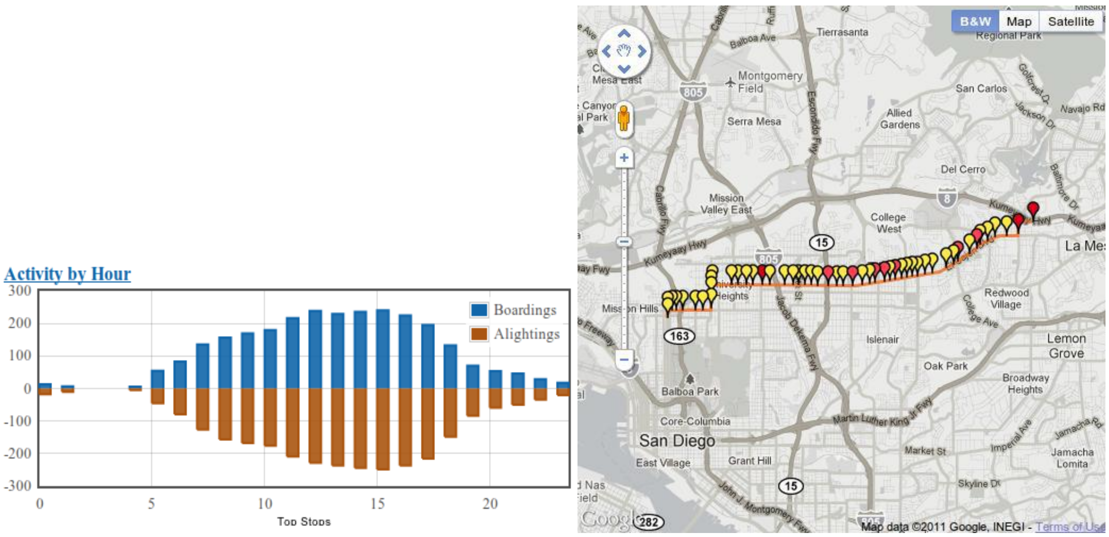


Figure 13. Route-level activity by hour & trip-level boarding activity (Source: (Catalá, Downing, & Hayward, 2011)).

Evaluation of Impact of Transit Apps on Ridership

To assess the impact of open data and transit apps, data analysis was performed on the available transit (2002–2012) data from the American Public Transportation Association (APTA) (American Public Transportation Association (APTA), 2013) . The following analyses were performed and are shown in Figure 14 through Figure 21:

- Ridership impact on six U.S. cities with open data (Boston, Chicago, New York and Newark, Portland, Seattle, and Washington, DC)
- Ridership impact with open data on the New York rail system
- Ridership of six U.S. cities without open data (Charlotte, Jacksonville, Memphis, New Orleans, Oklahoma City, and Phoenix)
- U.S. transit data (2002–2012)
- U.S. transit vs. six U.S. cities with open data
- The effect of open data release (total of six U.S. cities with open data [based on open data release year])

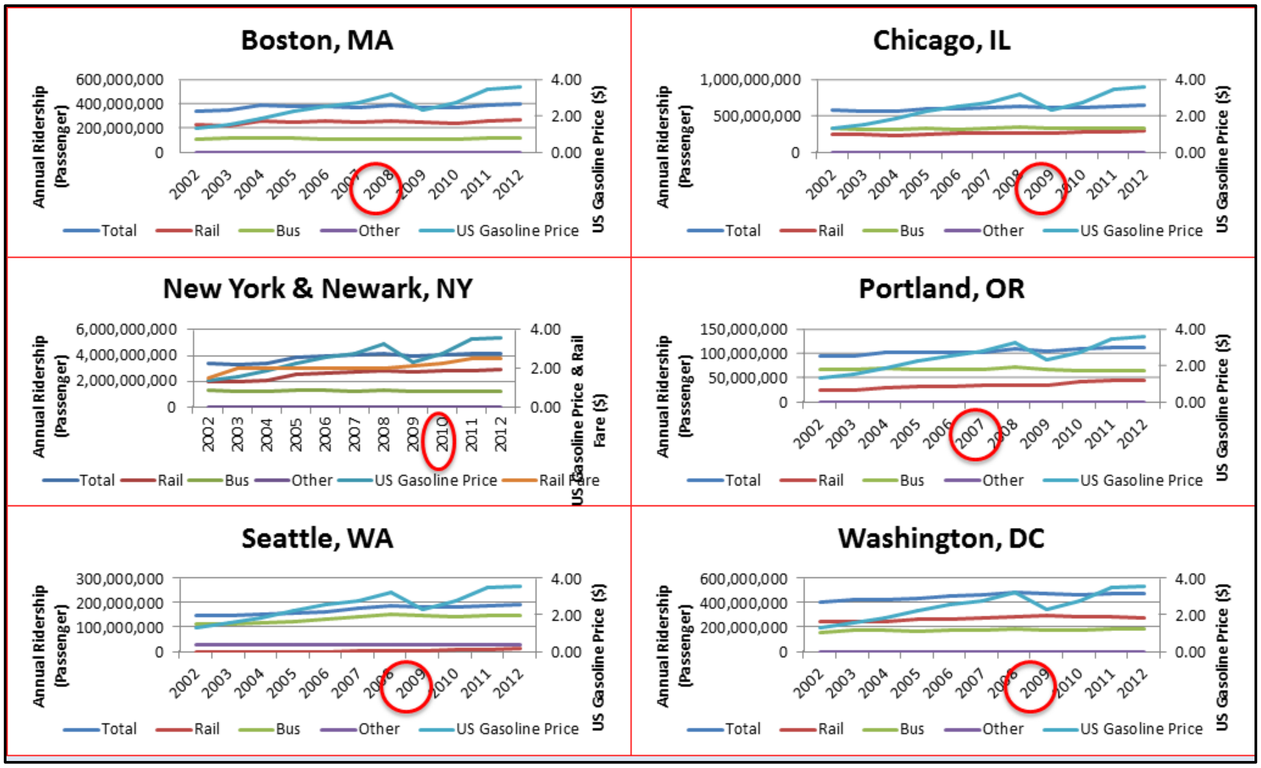


Figure 14. Ridership impact with open data on six U.S. cities.

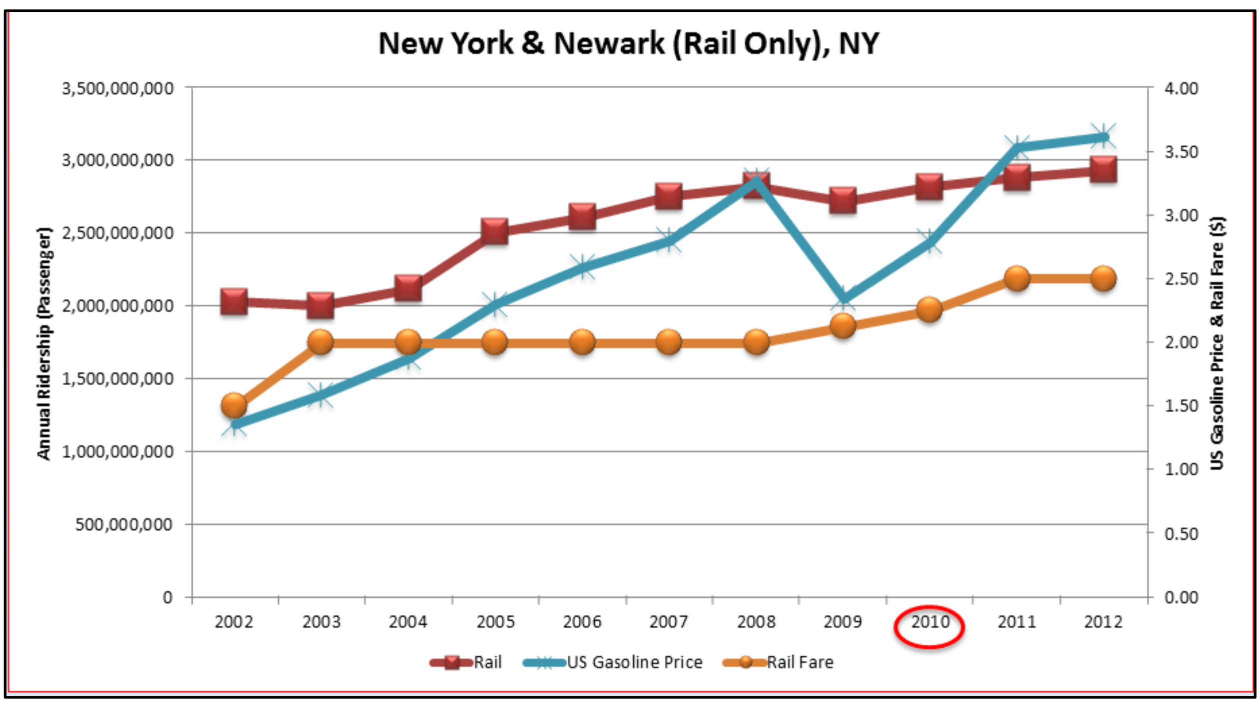


Figure 15. Ridership impact with open data on New York rail system.

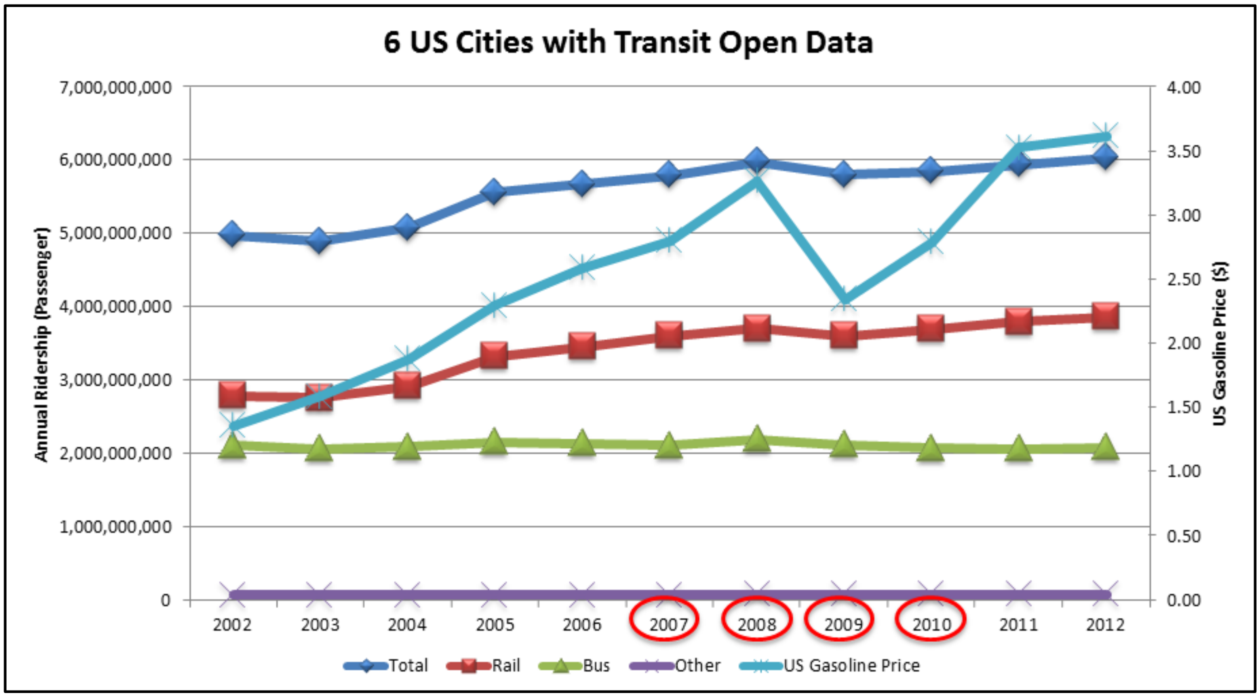


Figure 16. Ridership impact with open data on six U.S. cities.

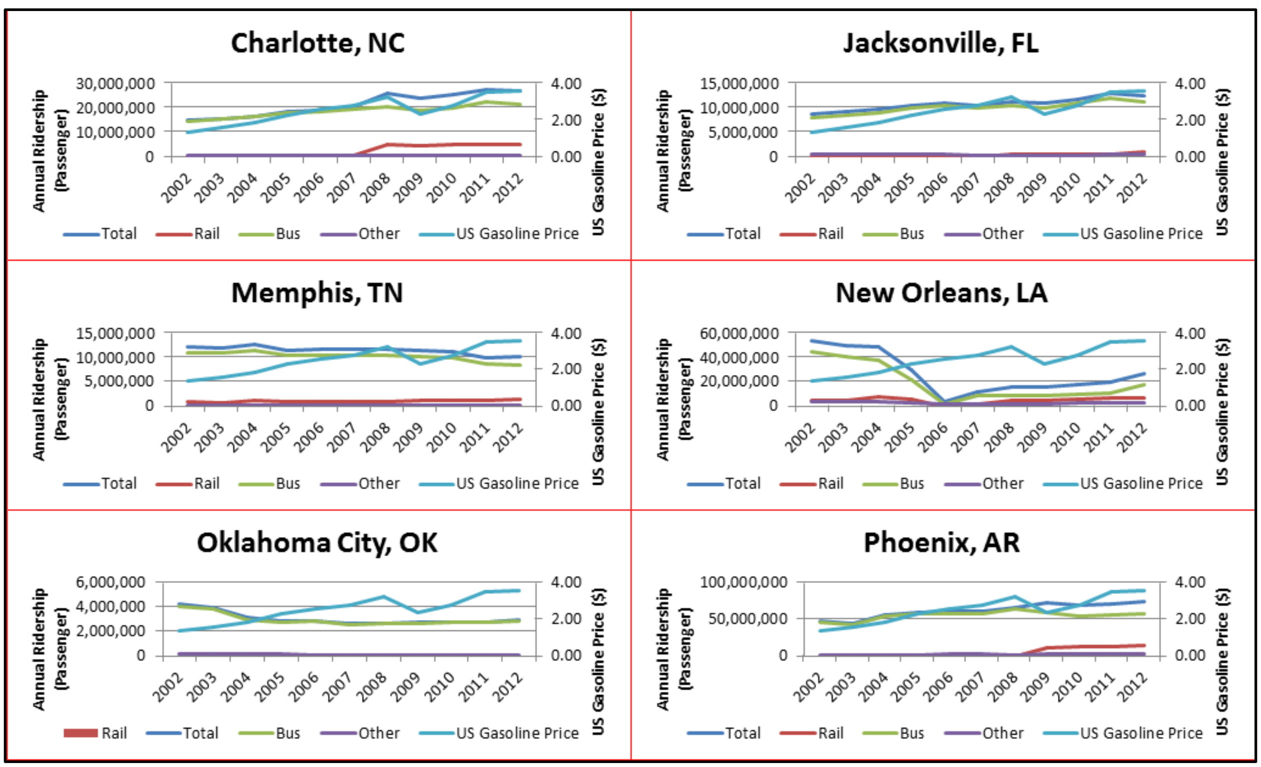


Figure 17. Ridership of six U.S. cities without open data.

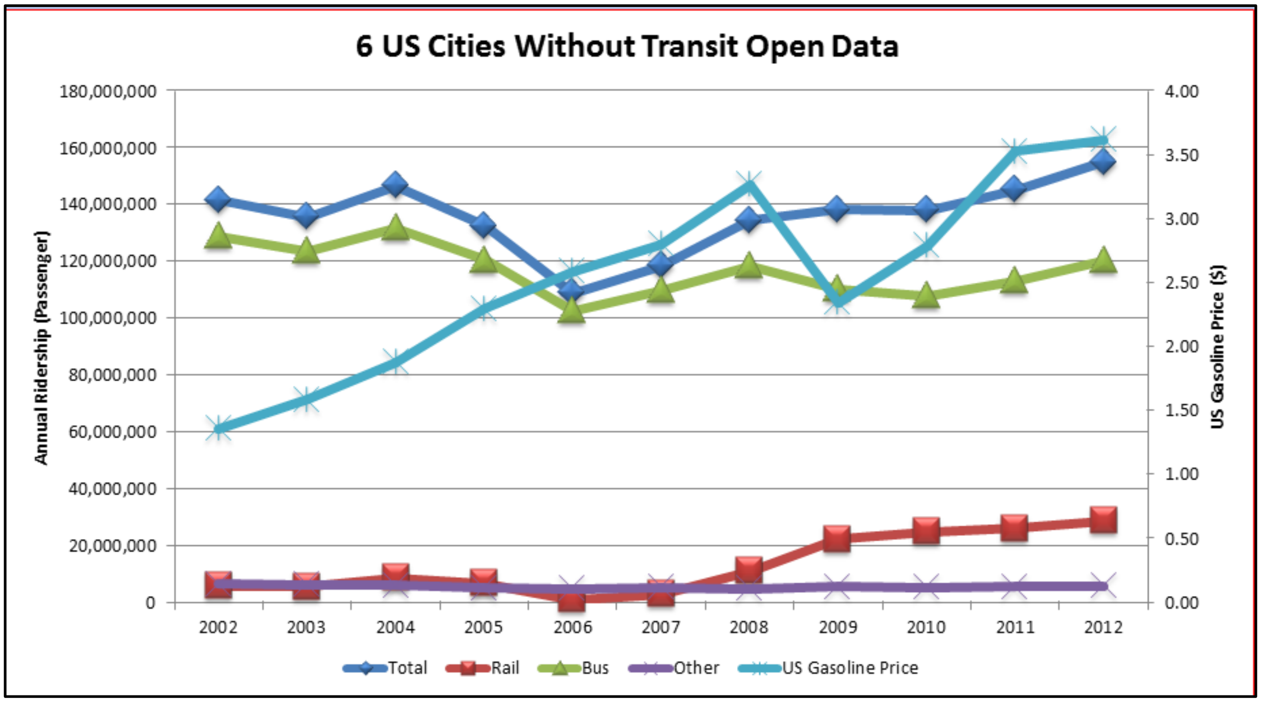


Figure 18. Ridership of six U.S. cities without open data.

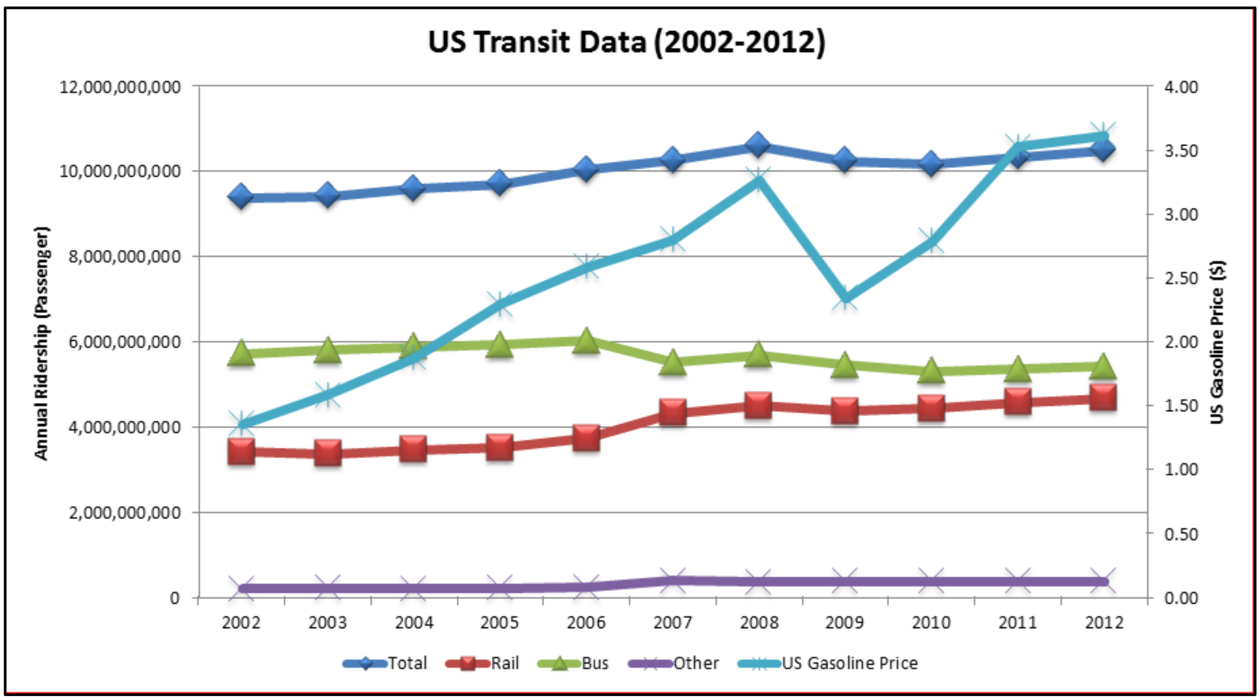


Figure 19. U.S. transit data (2002–2012).

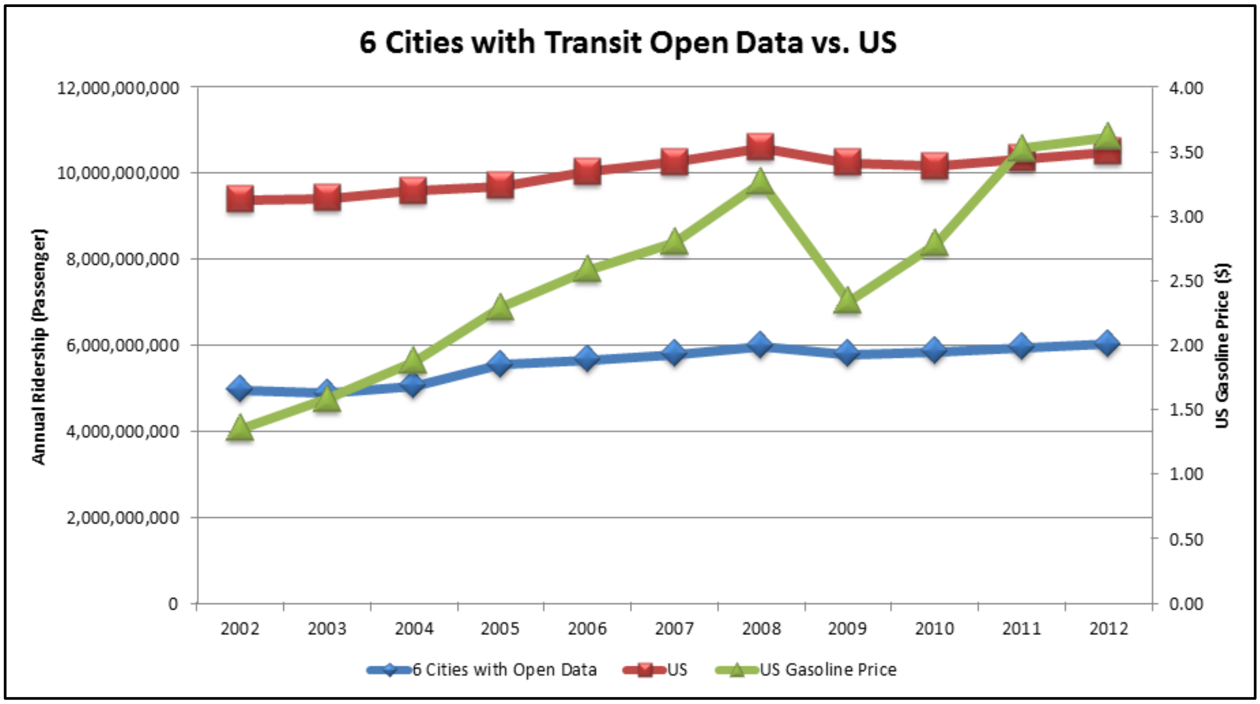


Figure 20. U.S. transit vs. six U.S. cities with open data.

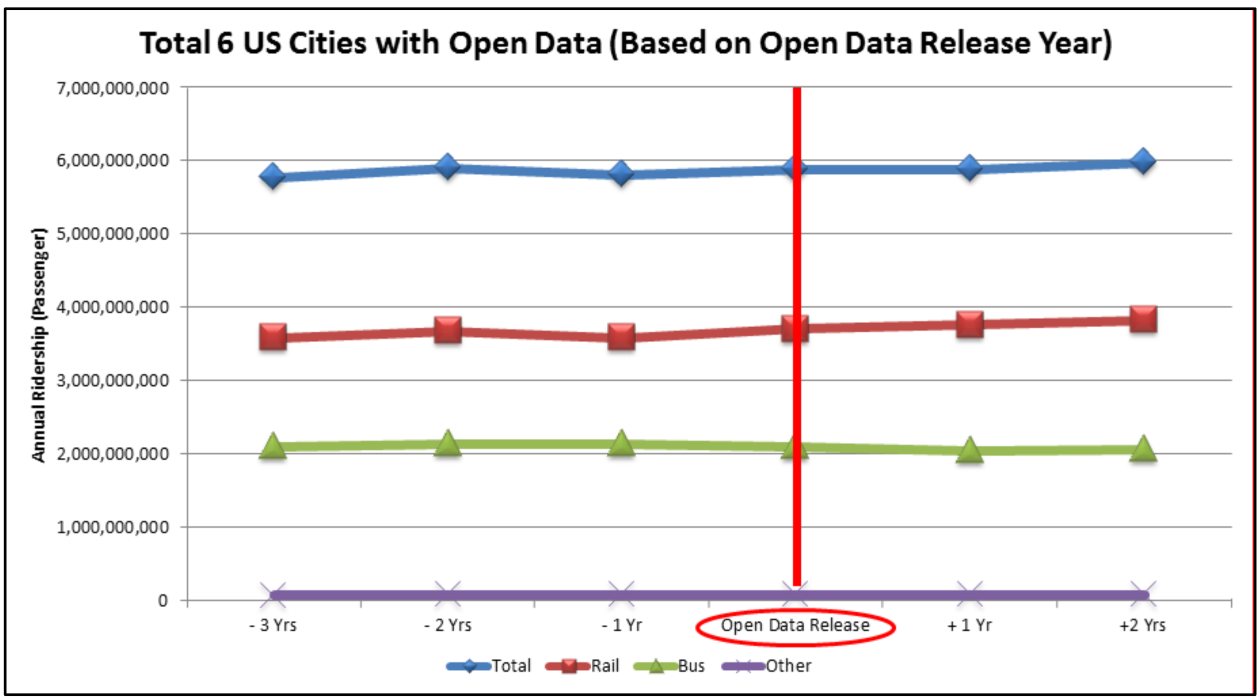


Figure 21. The effect of open data release.

Ridership Evaluation Results

Various factors may affect transit ridership, such as gasoline prices, unemployment levels, and local weather conditions in addition to transit open data and transit information apps.

Cities with open data have many more transit apps. Currently, however, there is not a strong relationship between ridership and transit apps. However, it is too premature to conclude that transit apps will have no impact on ridership.

Comprehensive Evaluation of Transit Apps

Some users have complained that a few transit apps do not work correctly. Apps may function poorly due to the effect of traffic, not using real-time information, and perhaps bugs and errors in the coding. Moreover, transit apps can be potentially harmful and risky for users' information. Consequently, as mentioned earlier, some means of evaluating apps is essential.

One solution to this problem is City-Go-Round, a website with the mission "to help make public transit more convenient" (City-Go-Round, 2016). City-Go-Round provides users' ratings for different apps. Two examples are shown in Figure 22.

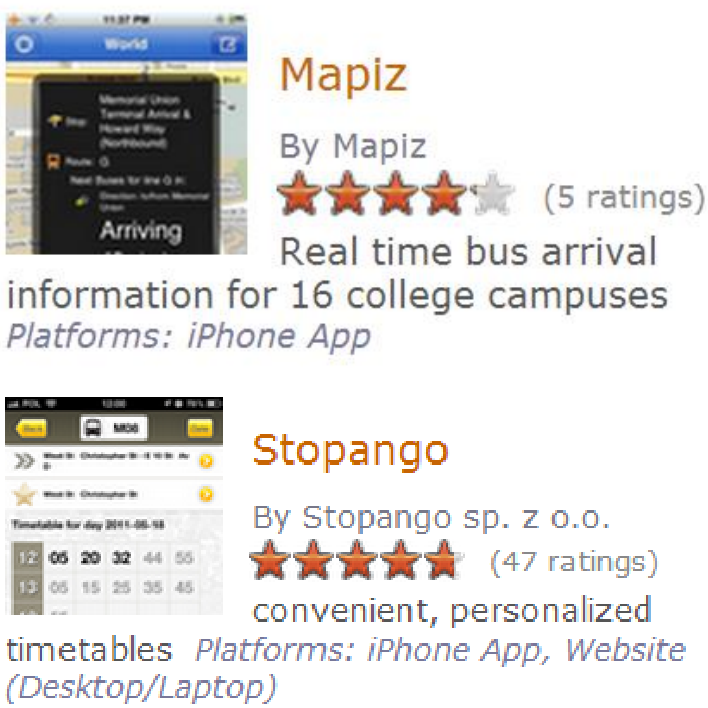


Figure 22. Two examples of app ratings in City-Go-Round (Source: (City-Go-Round, 2016)).

App Development Competition

The MTA and AT&T have collaborated to hold an ongoing series of "App Quest" competitions for individuals, teams, and organizations to develop applications utilizing MTA's publicly available data and APIs. The goal of these competitions is to use "global competition to solicit development of new mobile solutions designed to help improve commutes for millions of subway, bus and rail riders…." This type of competition, as well as the judging criteria, (MTA & AT&T, 2013) as follows, could be used in developing apps for other transit systems:

- Quality of idea – Creativity and originality of the idea, and potential to improve the travel experience for MTA riders.
- Implementation of idea – How well the idea was executed by the developer and how well the app integrates with the MTA public data and APIs.
- Potential impact – The extent to which the submission will impact MTA customers and their travel experience.

The best overall winner in 2013 was Citymapper App, which offers point-to-point journey planning with real-time information for subways, buses, and bikes for New York City and London.

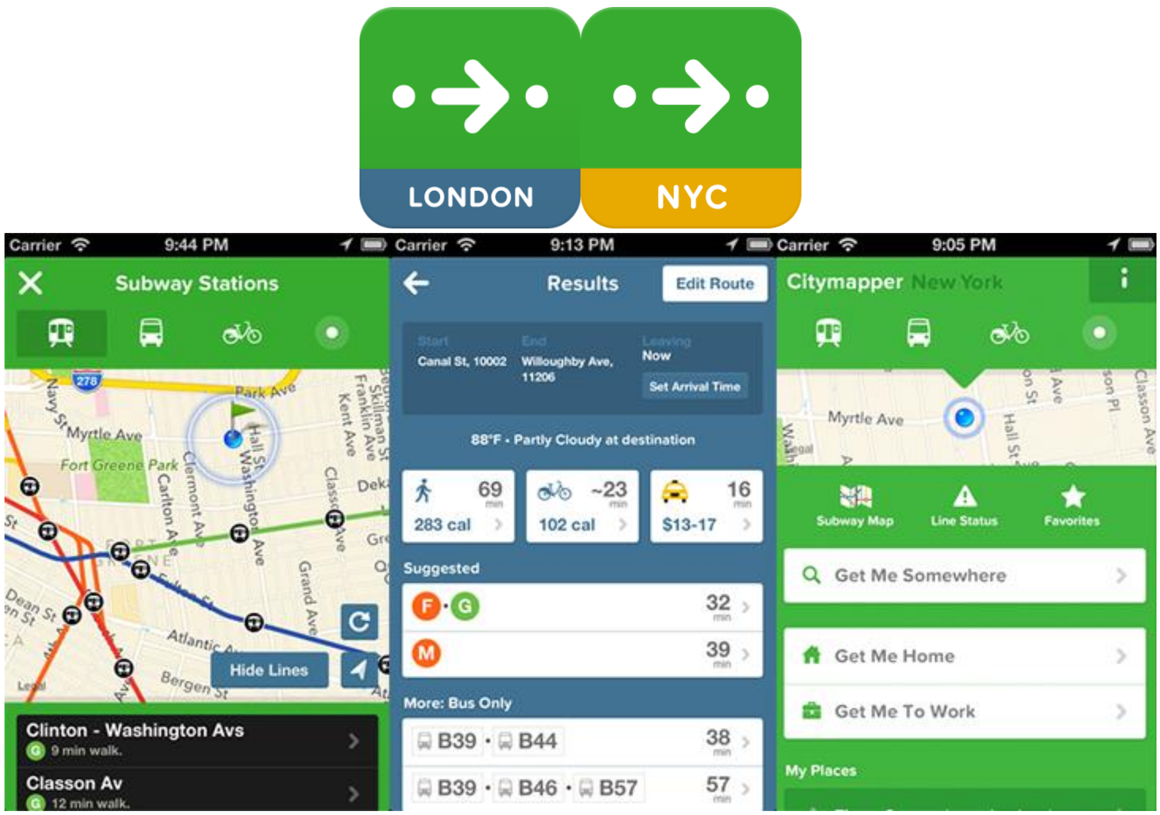


Figure 23. Citymapper: MTA AT&T App Quest winner preview (Source: (MTA & AT&T, 2013)).

Transit Apps Review Summary

Based on the findings and analysis, the opportunities and needs for future efforts include:

- Next target: Real-time transit open data for all cities
- Developing a methodology to evaluate transit apps' accuracy, security, and currency
- Establishing a committee (maybe in each related agency or independently) regarding a transit apps database

- Creating a comprehensive website for transit apps (current implementations are not comprehensive)
- Enhancing transit agencies' planning, operation, and performance levels by using transit apps (transit apps can send back or collect users' preferences and service-related information.)

Flexible Routing and User Location-based Transit Apps

A review of relevant U.S. patents revealed information regarding the emergence, acceptance, and usage of the technologies and systems underlying flexible routing and user location-based systems. Table 8 summarizes some of these U.S. patents.

The features that can be traced via reviewing these patents can be categorized as follows:

- Communication network and systems
- Improvements for real-time mapping and navigation
- Location information services
- User location driven services
- Improvements for fixed-route transport
- Introduction of flexible-route transport
- Decentralized transportation

Competitors in the industry include AT&T, the Institute for Information Industry, Uber (founded as UberCab in 2009), Curb, Didi Chuxing, Flywheel, Grab, Hailo, Kabbee, Lyft, Ola Cabs, and Shuddle (Parnell, 2016; Johnson, 2016).

Table 8. Summary of Selected U.S. Patents Related to Flexible Routing and User Location-Based Transportation

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
1	US4350969 A	William H. Greer	Greer William H	Vehicle identification and position signalling system in a public transportation system	September 21, 1982	Each vehicle of a transportation system is provided with a radio transmitter providing electable and different sequences of signals, one part of the signal identifying the vehicle, and another changing sequence of signals, either under operator control or automatically by attachment to the odometer, to indicate the present position of the vehicle on a scheduled route. The home of a passenger desirous of meeting a particular vehicle at a particular pickup point is provided with a radio receiver with selectable detectors which can be set to detect the signals from a particular vehicle transmitter, and provide a visual or audible indication of the present position of the vehicle on the scheduled route. Pre-specified settings of the receiver, and corresponding detectable signals, inform a passenger of no service or delayed service.
2	US4360875 A	Robert W. Behnke	Behnke Robert W	Automated, door-to-door, demand-responsive public transportation system	November 23, 1982	A flexible-route transportation system, primarily utilizing privately-owned vehicles to provide ridesharing transportation for the public, is described. Interactive communications terminals are provided through which drivers of the vehicles may rapidly transmit ride offers via a telecommunications network to a central operations coordinating station, equipped with a general-purpose programmable computer. Rider interactive communications terminals, located at public and private facilities, are also connected by the telecommunications network with the central coordinating station, permitting eligible members of the public to quickly request rides from one location to another. The central coordinating station matches the ride requests with the ride offers, on a trip-by-trip basis, comparing the driver's indicated origin,

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
						destination, seating requirements and time with the rider's requested origin, destination, seat availability and time. If a ride offer and ride request can be matched within reasonable limits of space and time, the central coordinating station transmits to the driver the rider's identity and location and transmits to the rider the description and identity of the vehicle, so that the driver can pick up and drop off the rider en route to his or her destination. The system includes security features for preventing unauthorized access to the system by either drivers or riders, accounting features for properly billing riders and reimbursing vehicle owners for transportation services, and special terminals for entering trip information quickly and accurately.
3	US5168451 A	John G. Bolger	Bolger John G	User responsive transit system	December 1, 1992	A transit system includes a number of service request terminals located at frequent placement intervals in local areas served by the transit system. Transit vehicles flow throughout the local service area without predetermined routes or schedules. Movement of the vehicles is determined solely by the dispatches assigned to them in real time in response to service request. Passengers use the service request terminals to transmit a service request to a central dispatch controller that receives the request and automatically dispatches the most efficient vehicle to service the request. The central computer determines the most efficient vehicle by calculating the total added travel distance to service the request and destination in relation to the dispatches previously assigned to each vehicle. The service request is dispatched to the vehicle which would have the minimum added travel distance. The dispatched vehicle has a terminal that receives the dispatch command

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
						that was transmitted by the central dispatch controller and enters it on a graphical display of a map of the local area for convenient viewing by the vehicle operator. The order in which dispatches are serviced and the path traveled by the vehicle between dispatch locations is determined by the vehicle operator, so as to allow continuous modification in response to new dispatches, prevailing traffic conditions, etc.
4	US5799263 A	Russell D. Culbertson	Bct Systems	Public transit system and apparatus and method for dispatching public transit vehicles	August 25, 1998	A public transit system uses a plurality of intracell vehicles to service transit requests in individual transit cells, and the transit cells are connected by intracell vehicles which travel between cell terminals located within the respective transit cells. The intracell vehicles are automatically dispatched by a dispatching system (12) which assigns each transit request to an intracell vehicle servicing a matching transit route or soft route comprising a geographical area and a route travel direction. The dispatching system (12) uses a process for selecting the most appropriate vehicle to handle a transit request where no prior route matches the request. This initial transit request then defines a new soft route for the vehicle to which it is assigned. Transit requests are preferably communicated to the dispatching system via a local telephone system and locations within the transit cell are defined by telephone numbers or other suitable identifiers.

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
5	US6756913 B1	Mourad Ben Ayed	Mourad Ben Ayed	System for automatically dispatching taxis to client locations	June 29, 2004	A system and method for dispatcher free vehicle allocation. A client requesting taxi service calls a taxi dispatch center using a cellular phone equipped with a location identification device. The location identification device provides the current location information to the dispatch center. The taxi dispatch center keeps track of available taxis and their locations and stores them in a database. After determining the client location data, a processor searches the available taxis database for a taxi whose location matches the client's location. The client location data is converted to an address and sent to the assigned taxi. The address is displayed on a mobile data terminal in the taxi.
6	US20060217885 A1	Mark Crady et al.	Mark Crady et al.	User location driven identification of service vehicles	September 28, 2006	A vehicle position aggregation system receives position information for service vehicles from various fleet management systems, and maintains the current location of the vehicles in a database, including information identifying each vehicle's associated fleet and related contact information. End users can query the vehicle position aggregation system to obtain information about service vehicles in the vicinity of the user's input location.
7	US7181225 B1	Robert T. Moton, Jr. et al.	Bellsouth Intellectual Property Corporation	System and method for surveying wireless device users by location	February 20, 2007	The present invention is a system and method for conducting survey using wireless devices. The system architecture of the present invention comprises a location server and a location system. The location server can receive a survey request from a subscriber, delineate a survey area for the survey, broadcast a query containing the survey to a plurality of wireless devices, process responses received from the wireless devices, and delivers a result of the survey to the subscriber. The location system can generate location information for each of the wireless devices that received the query. The location

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
						system may be a network-based unit or a portable unit provisioned at each of the wireless devices. In the preferred embodiment, the location system is a GPS receiver that generates the longitude and the latitude of the wireless device at which it is provisioned.
8	US7245925 B2	Samuel N. Zellner	At&T Intellectual Property, Inc.	System and method for using location information to execute an action	July 17, 2007	Provided are methods for executing an action in response to a request for a service using location information in conjunction with service-specific parameters. A user may request a provider of a specified service (e.g., taxi, plumber, pharmacist, etc.). In evaluating the request, providers may be evaluated based on the location information in addition to service-specific parameters. An action in response may include merely displaying selected service provider(s) in response to the request, or acting on behalf of the user by communicating with a selected service provider.
9	US7391341 B2	Ian Keaveny, Brad Heide	Trapeze Software Inc.	System and method of optimizing a fixed-route transit network	June 24, 2008	According to an aspect of the invention there is provided a method of optimizing a fixed route on a transit network, comprising the steps of: a) permitting a vehicle providing service on the fixed route to make deviations from the fixed route based on passenger requests; b) tracking the deviations and number of passenger requests corresponding to each deviation; c) submitting information from tracking step b) into a decision-making algorithm; and d) modifying the fixed route to include new stops based on results from the decision-making algorithm, as well as a system for implementing this method.
10	US20090192851 A1	Paul L. Bishop	Bishop Paul L	Location-Based	July 30, 2009	Various implementations of a location based transportation management system and methods are disclosed, including a device for

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
				Transportation Management		visually communicating with drivers in a variety of environments.
11	US20120123894 A1	Frank Chee-Da Tsai et al.	Institute For Information Industry	Decentralized Transportation Dispatching System and Method for Decentralized Transportation Dispatching	May 17, 2012	A method for decentralized transportation dispatching is disclosed. The method bypasses utilizing a centralized dispatch call center and includes announcing a transportation requirement via broadcasting directly by at least one user, and replying to the transportation requirement with a plurality of competitive bidding information directly from a plurality of transportation providers who are capable of providing a passenger-carrying service or providing a goods-carrying service. The method further includes selecting one transportation provider from the transportation providers according to a request from the user, in which the selecting is performed through referencing the bidding information replied to by the transportation providers.
12	US20130132246 A1	Shalin Amin et al.	Uber Technologies, Inc.	Providing a summary or receipt for on-demand services through use of portable computing devices	May 23, 2013	A method for providing a service summary or receipt on a computing device is provided. One or more processors determine information for a service rendered for a user. The information includes a cost for the service, a type of service performed, and a person who performed the service. A summary receipt panel is provided on a display of the computing device and includes the information for the service rendered. The one or more processors provide, on the summary receipt panel, a map that identifies a location relevant to the service rendered and a feedback feature that enables the user to rate the service received.

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
13	US20130132140 A1	Shalin Amin, Mina Radhakrishnan	Uber Technologies, Inc.	Determining a location related to on-demand services through use of portable computing devices	May 23, 2013	A method for determining a location relating to an on-demand service on a computing device is provided. One or more processors receiving a transport request from a user. The transport request specifies at least one of a pick-up region or a drop-off region. One or more locations of interests within the at least one of the pick-up region or the drop-off region are determined. Based on the at least one of the pick-up region or the drop-off region, one or more historical locations related to the user is determined. A likely location is determined based on the determined one or more locations of interest and the one or more historical locations.
14	US20140244412 A1	Jesse H. Davis et al.	Creative Mobile Technologies, LLC	Passenger information module	August 28, 2014	A method and system utilizes an interface for the blind and low vision passengers in a touch screen passenger information module (PIM). The PIM is enabled to operate in at least two modes. A low vision mode provides different user input framework on the touch screen as well as appropriate audio prompting. The interface enables a blind or low vision person to interact with the PIM easily, including using the PIM to pay for the fare. The low vision mode can be initiated by the passenger.
15	US20150161564 A1	Matthew Sweeney et al.	Uber Technologies, Inc.	System and method for optimizing selection of drivers for transport requests	June 11, 2015	A computing system operates to process multiple transport requests at one time, each of the multiple transport request specifying a pickup location that is within a geographic region. During a given interval when each of the multiple transport request are open, a pool of candidate drivers is determined within the geographic region that can fulfill one or more of the transport requests within a threshold duration of time. A driver is selected for each of the multiple transport requests. In selecting the driver, the computer system implements an optimization process to minimize an estimated time to pick up for

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
						at least one of the multiple transport requests.
16	US9082144 B2	Russell Jones et al.	Cargo Chief	Transportation service matching with arrival estimation adjusted for external factors	July 14, 2015	Matches for load or transportation services with transportation service providers (TSPs) are established, and estimated arrival times are provided. A transportation service request is provided and a received bid is received. An estimate of time of arrival is made based on an estimation of a time for performing a delivery of the load or provide the transportation service, and the time of arrival estimate is adjusted by at least one external factor expected to affect transit time. An anticipated turn-around time for availability of the TSP is made for a subsequent leg or backhaul and the adjusted time of arrival estimate and the anticipated turn-around time are used to estimate a time of availability of the TSP for the subsequent leg or backhaul. An accepted bid for the subsequent leg or backhaul is made based on an estimated time of availability.
17	WO2015175030 A1	Travis Kalanick et al.	Uber Technologies, Inc.	User-configurable indication device for use with an on-demand service	November 19, 2015	A system and method for configuring an indication device is described. An on-demand service system arranges a transport service for a user to be provided by a driver. The system determines whether the user has specified an output configuration for an indication device in an account of the user. In response to determining that the user has specified an output configuration for the indication device, the system identifies data corresponding to the output configuration and transmits the data to a driver device of the driver to enable the driver device to control the indication device of the driver based on the data.

#	Patent Number	Inventor	Original Assignee	Title	Publication Date	Description
18	US9230292 B2	Shalin Amin et al.	Uber Technologies, Inc.	Providing on-demand services through use of portable computing devices	January 5, 2016	A method for requesting an on-demand service on a computing device is provided. One or more processors determine the current location of the computing device. A multistate selection feature of a plurality of service options for providing the on-demand service is presented on the display of the computing device. The multistate selection feature enables a user to select a service option that is available within a region that includes the current location to provide the on-demand service. In response to the user selecting one of the plurality of service options, a summary user interface is presented on the display to provide region-specific information about the on-demand service based on the selected service option.

Source: (Google Inc., 2016)

Location-Aware Transportation Tools

Many transportation tools work based on the known location information of the involved parties. The following section reviews some of these location-aware apps.

OneBusAway (http://onebusaway.org) (Ferris, One Bus Away, 2016), a suite of transit traveler information tools that was developed at the University of Washington, provides real-time arrival information, a trip planner, a schedule and route browser, and a transit-friendly destination finder for the Seattle area (early effort) and other major urban areas like Atlanta, Tampa, and New York City. The app uses the user's location to provide information about nearby buses and schedules; moreover, it can help the user to plan a trip. Figure 24 shows the app's interface.

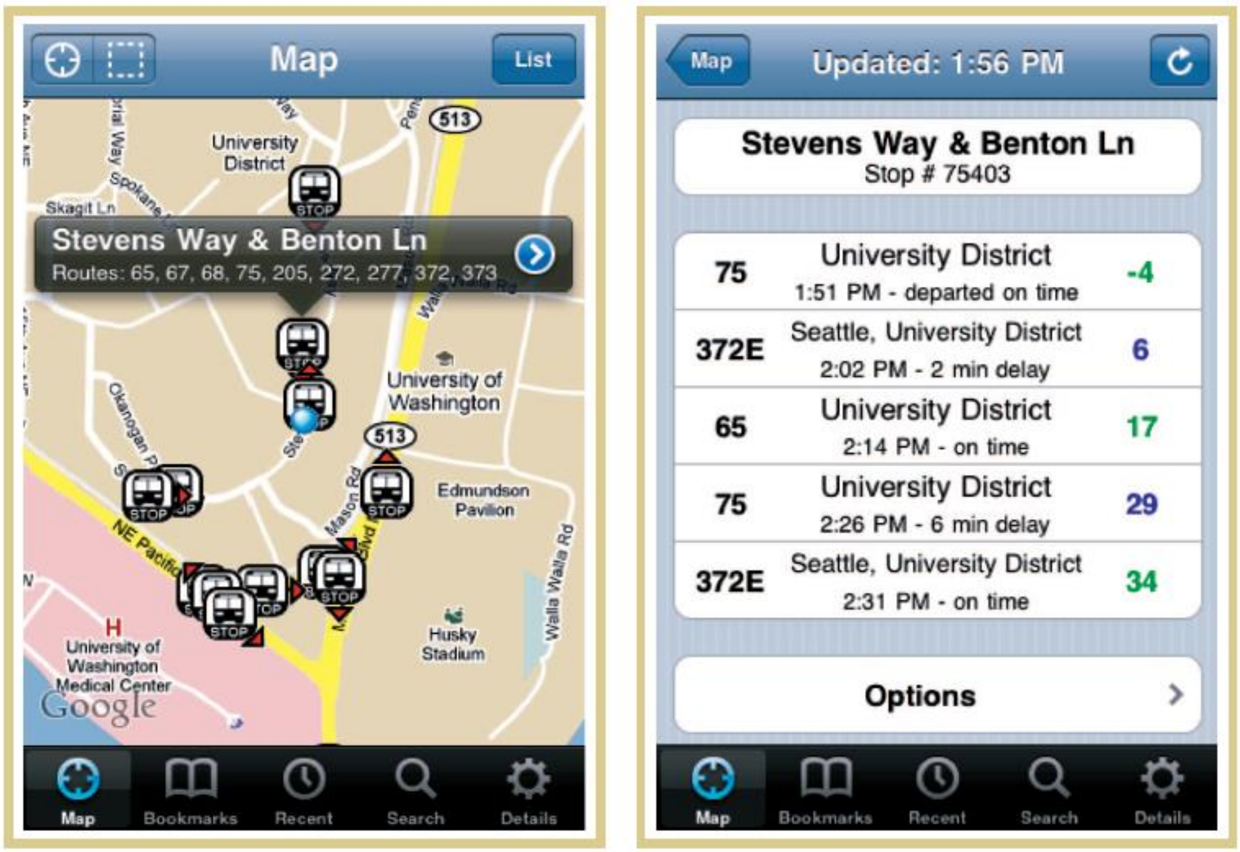


Figure 24. The OneBusAway iPhone application (Source: (Ferris, One Bus Away, 2016)).

The sharing economy has also had an effect on transportation tools. According to Shaheen et al., "Advancements in social networking, location-based services, the Internet, and mobile technologies have contributed to a sharing economy (also referred to as peer-to-peer sharing, the mesh economy, and collaborative consumption) (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016)."

In recent years, many sharing models have emerged, such as P2P marketplaces (e.g., Airbnb), crowdfunding (e.g., Kickstarter), and shared mobility (e.g., Getaround) (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016):

- In April 2011, Zipcar, a car-sharing company providing short-term (e.g., hourly) vehicle rentals, raised $174 million in its initial public offering, giving it a valuation of $1.2 billion. The Avis Budget Group acquired Zipcar for $500 million in January 2013.
- By December 2014, Uber, the ride-sourcing platform that provides door-to-door, for-hire vehicle services, was valued at $41.2 billion. Between mid-2012 through 2014, the company grew to more than 160,000 drivers. Just one year later, Uber was valued at $70 billion.

Shared mobility includes ride-sourcing (sometimes referred to as transportation network companies or TNCs), such as Lyft and Uber; ride-splitting (e.g., UberPOOL and Lyft Line) in which passengers split a fare and ride; and e-Hail (app-enabled taxis) (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016). Figure 25 shows existing, developing, and future shared mobility services.

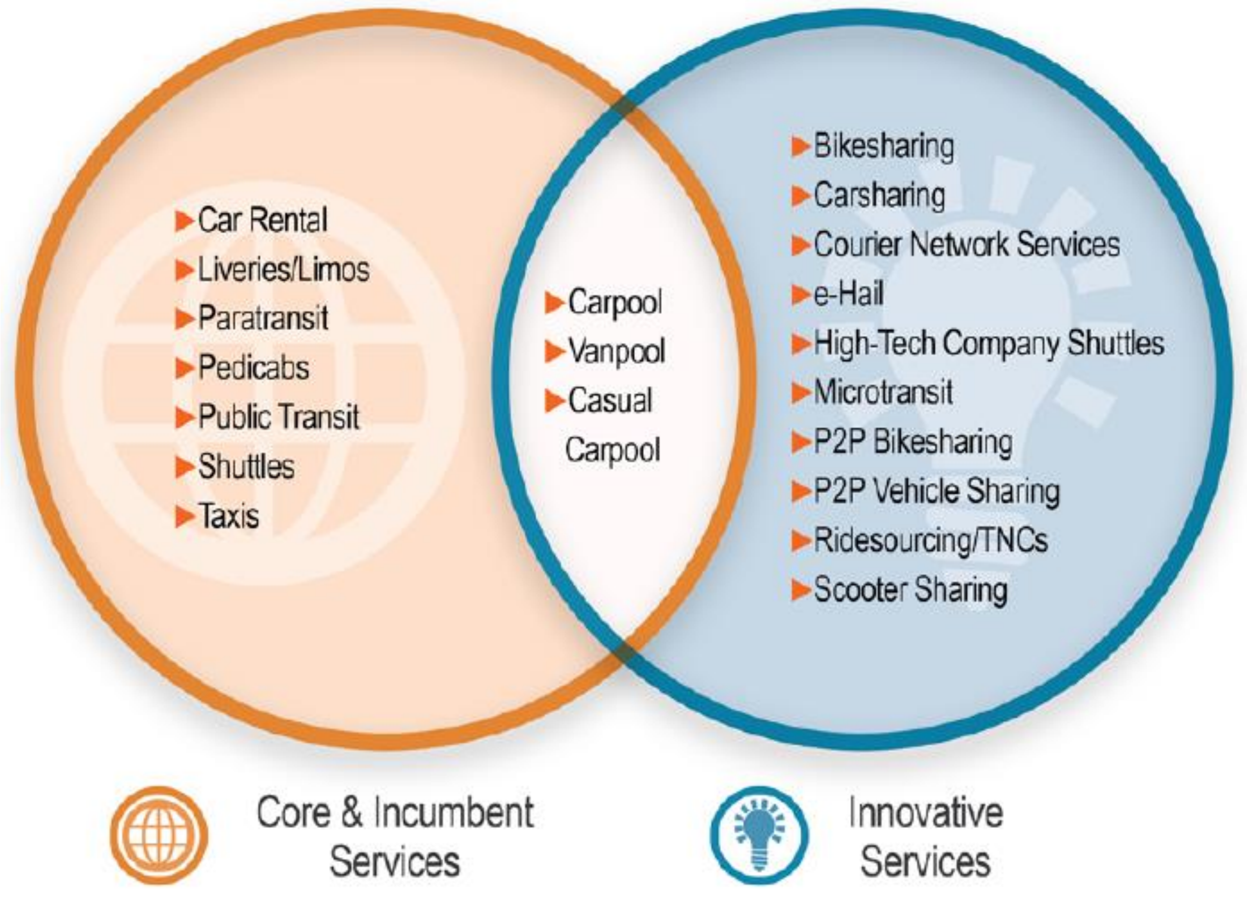


Figure 25. Shared mobility service models (Source: (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016)).

While both the number and usage of transit apps using user location information are rising, numerous studies indicate that people are either unaware of what private information they are exposing or they do not understand what information they are consenting to share (Shaheen, Cohen, Zohdy, & Kock, Smartphone Applications to Influence Travel Choices: Practices and Policies, 2016).

Literature Review Summary

In recent years—due to concurrent developments in communication network and systems (including CV technology and smartphones), improvements for real-time mapping and navigation, and location information services—many different transportation-related apps have been developed for different purposes and users.

The introduction of open data, which was followed by Big Data, revolutionized practices. Aided by new methods of computation and analysis, new systems emerged, such as user location-driven services, improvements for fixed-route transport, the introduction of flexible-route transport, and decentralized transportation.

Utilizing GPS-enabled mobile devices, many social network services, including Facebook, provide some kind of user location-based services, such as finding friends or locations. Shared mobility services, such as Uber and Lyft, also use location-based service to make their services more convenient. App services such as Waze utilize user locations to share traffic information. Location-based services are now familiar to many users, and there is a clear need for user location-based services for public transportation. Yet, to the best of the authors' knowledge, currently there is no user location-based app for public transit service.

System Architecture

Task 2 of the research objectives calls for the development of a framework for a handheld mobile app for transit users, a mobile app for transit drivers, and a management server program. This architecture takes advantage of two-way connectivity to enable dynamic routing and improved safety. The connectivity is managed by stored persistence of unique mobile identification numbers. Continuous sampling of GPS, accelerometer, magnetometer, and other sensors in a mobile device such as a smartphone is used to infer accurate locations. Velocity, acceleration, and orientation data from the mobile device can then be used to correlate modes of travel. Transportation modes are computed from GPS coordinates and sensor data. The system is appropriate for a variety of transportation applications, including autonomous navigation, routing, and tracking.

The research evaluates algorithms to filter noisy sensor measurements and detect motion changes. Sensor signal processing will enhance accuracy and precise measurements. The filters will include both low-pass and high-pass filters. The low-pass filters will consist of weighted smoothing, moving average, moving median, and others. Band and high-pass filters are also explored. Kalman filtering is of particular interest. Group travel modes are inferred from collaborative data. Sensor sharing will also provide collaboration between applications. Developers may write tools that consume sensor data to incorporate information into their applications.

The mobile and Web interface will allow users to send their origin and destination information to the transit agency application server. Then, the agency software will use that information for demand-responsive transit routing and scheduling. The GPS location of the mobile device will provide the tracking information corresponding to the mobile users, which can facilitate transit software to pick up passengers more efficiently. The transit application will eliminate chances for a passenger to miss the transit vehicle, and therefore increase efficiency and effectiveness.

Sensor and GPS sharing can also create a social network for collaboration. The tracking system is capable of tracking the location of "travel friends." A travel friend connection is established via a "friend request." Once a friend connection is established, all corresponding mobile device locations become available. Sharing GPS coordinates would allow a cluster of mobile devices to be tracked. If the request is accepted, then the corresponding identification is added to the list.

The connected sensor tracking system consists of mobile devices, Internet servers, and data storage systems. Each device has a mobile application for transmitting GPS coordinates and sensor data to the application server. The application servers are capable of HTTP, UDP, Datagrams, and other TCP/IP protocols. The application server accepts the multiple connections from the mobile devices. The data storage system is a database management application. The database management system consists of entities which relate the mobile device with the associated tracking data. The DBS can be used to log sensor data, track history, and provide real-time location.

The programming technologies include standard programming languages such as Java, Javascript, and other Internet tools. The database engine is scripted with Structured Query Language (SQL). SQL defines a common language for database access. The framework is composed of a network of mobile devices, Internet application, and database management system. SQL is based on relational algebra and therefore provides effective means to select, join, and manipulate data. The database entities are defined to reflect the attributes of the sensors and GPS receiver. The technical challenges will include memory requirements, concurrent devices, bandwidth, data storage space, and real-time security.

The connected sensor network is a management tool for optimization in transportation. The traveling buddy social network is applied to the design of a flexible route.

Composition of the User Location-Based Transit App System

The roles of the transit user, the transit agency's server, and driver's tablet are as follows:

1. Functions of a mobile user
    - Sending a travel request (origin, destination, preferred departure time or arrival time)
    - Receiving a potential travel route, modified by the agency
    - Confirming the modified route acceptance (yes or no)
    - Reviewing provided map of the travel route, including stop locations, bus location, driver information, etc.

2. Functions of an agency’s server
    - Collecting users’ travel requests
    - Making groups with similar travel requests
    - Creating travel routes from the modified travel requests (stops, stop sequences, departure and arrival times, driver information)
    - Sending the modified travel requests to users
    - Receiving final travel confirmations from the users
    - Finalizing travel routes
    - Creating a travel route map
3. Functions of a driver’s tablet device
    - Viewing a route map with stop locations, user locations, user information, vehicle locations, stop sequence, departure and arrival times for each stop
    - Possibly communicating with a passenger when the passenger is not at the stop on time

The usual process envisioned for this architecture would proceed in the following sequence:

1. User submits the travel request.
2. Agency collects the travel requests.
3. Agency groups the travel requests.
4. Agency creates a route with potentially modified travel requests.
5. Agency disseminates the route information with modified travel requests.
6. User confirms acceptance of the travel route.
7. Agency finalizes the travel routes.
8. Agency submits the route information to users and the driver.
9. The driver uses a travel map to drive and collect passengers.
10. In case a passenger is not at the bus stop, the driver can communicate with the passenger.

The user location-based transit app consists of three elements: server database, the user’s mobile app, and the driver’s app.

1. User mobile app – The basic functions of the user mobile app are to send the user’s travel requests and receive travel information. Users can also view real-time transit operational information, including the bus’s location and arrival times at origins and destinations. Figure 1 shows a tentative user interface for the mobile application.

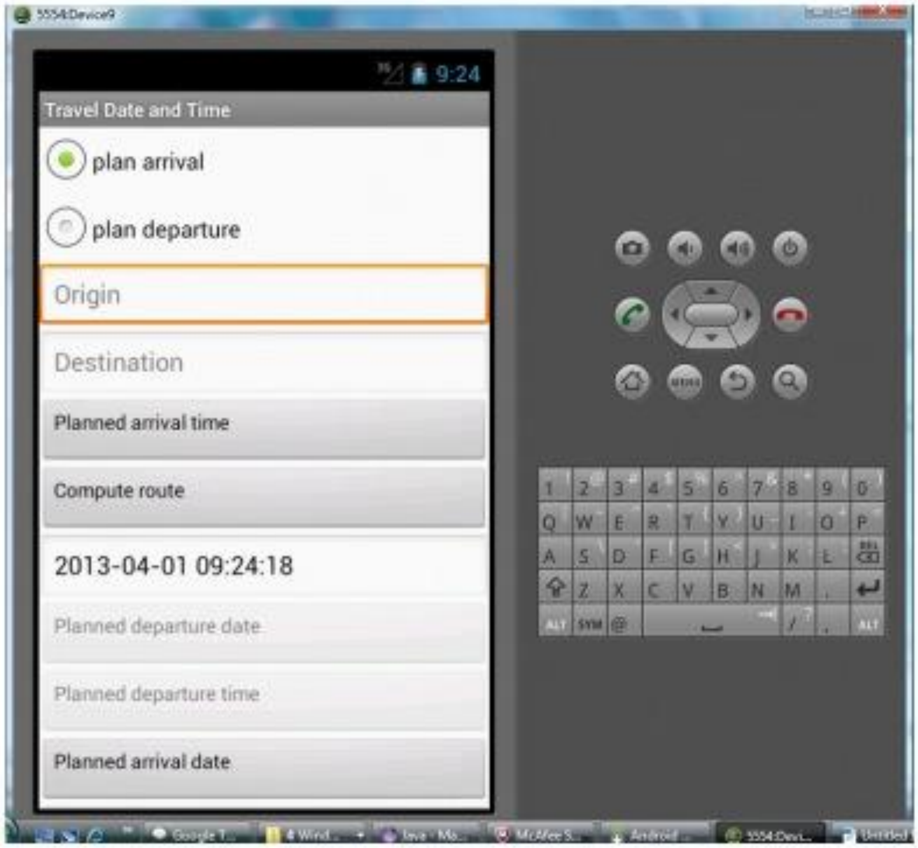
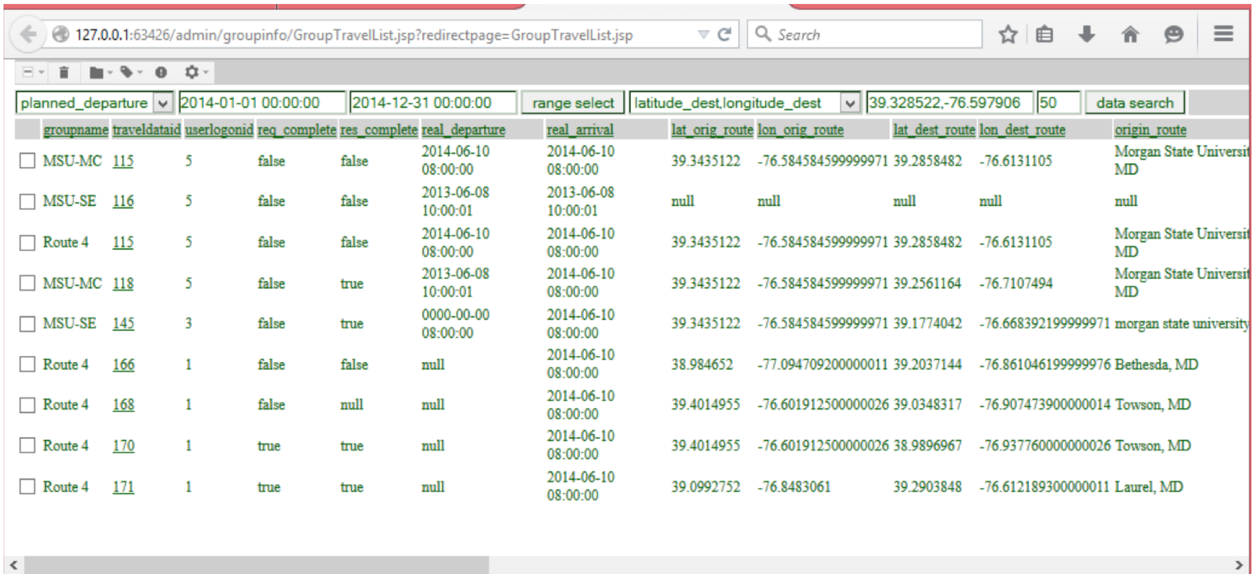


Figure 26. Example of user interface of the smartphone application for transit users.

2. Server database – The transit agency receives multiple travel requests from mobile app users and stores those requests in the server database as shown in Figure 2. Those requests can be modified in terms of origin and destination locations and departure and arrival times at the database. They are then sent back to users for confirmation.


127.0.0.1:63426/admin/groupinfo/GroupTravelList.jsp?redirectpage=GroupTravelList.jsp

planned_departure | 2014-01-01 00:00:00 | 2014-12-31 00:00:00 | range select | latitude_dest,longitude_dest | 39.328522,-76.597906 | 50 | data search

groupname	traveldataid	userlogonid	req_complete	res_complete	real_departure	real_arrival	lat_orig_route	lon_orig_route	lat_dest_route	lon_dest_route	origin_route
MSU-MC	115	5	false	false	2014-06-10 08:00:00	2014-06-10 08:00:00	39.3435122	-76.584584599999971	39.2858482	-76.6131105	Morgan State Universit MD
MSU-SE	116	5	false	false	2013-06-08 10:00:01	2013-06-08 10:00:01	null	null	null	null	null
Route 4	115	5	false	false	2014-06-10 08:00:00	2014-06-10 08:00:00	39.3435122	-76.584584599999971	39.2858482	-76.6131105	Morgan State Universit MD
MSU-MC	118	5	false	true	2013-06-08 10:00:01	2014-06-10 08:00:00	39.3435122	-76.584584599999971	39.2561164	-76.7107494	Morgan State Universit MD
MSU-SE	145	3	false	true	0000-00-00 08:00:00	2014-06-10 08:00:00	39.3435122	-76.584584599999971	39.1774042	-76.668392199999971	morgan state university
Route 4	166	1	false	false	null	2014-06-10 08:00:00	38.984652	-77.094709200000011	39.2037144	-76.861046199999976	Bethesda, MD
Route 4	168	1	false	null	null	2014-06-10 08:00:00	39.4014955	-76.601912500000026	39.0348317	-76.907473900000014	Towson, MD
Route 4	170	1	true	true	null	2014-06-10 08:00:00	39.4014955	-76.601912500000026	38.9896967	-76.937760000000026	Towson, MD
Route 4	171	1	true	true	null	2014-06-10 08:00:00	39.0992752	-76.8483061	39.2903848	-76.612189300000011	Laurel, MD

Figure 27. Example of a database for transit agencies' servers.

Once flexible routes are generated at the database, the map—which indicates the route information, bus stop information, and passenger information—is automatically created as shown in Figure 28 to Figure 31.

3. App for the driver – The driver's app will provide bus stop information, arrival and departure times, and real-time passenger location as shown in Figure 6. However, personal passenger information will not be provided to the driver due to privacy concerns.

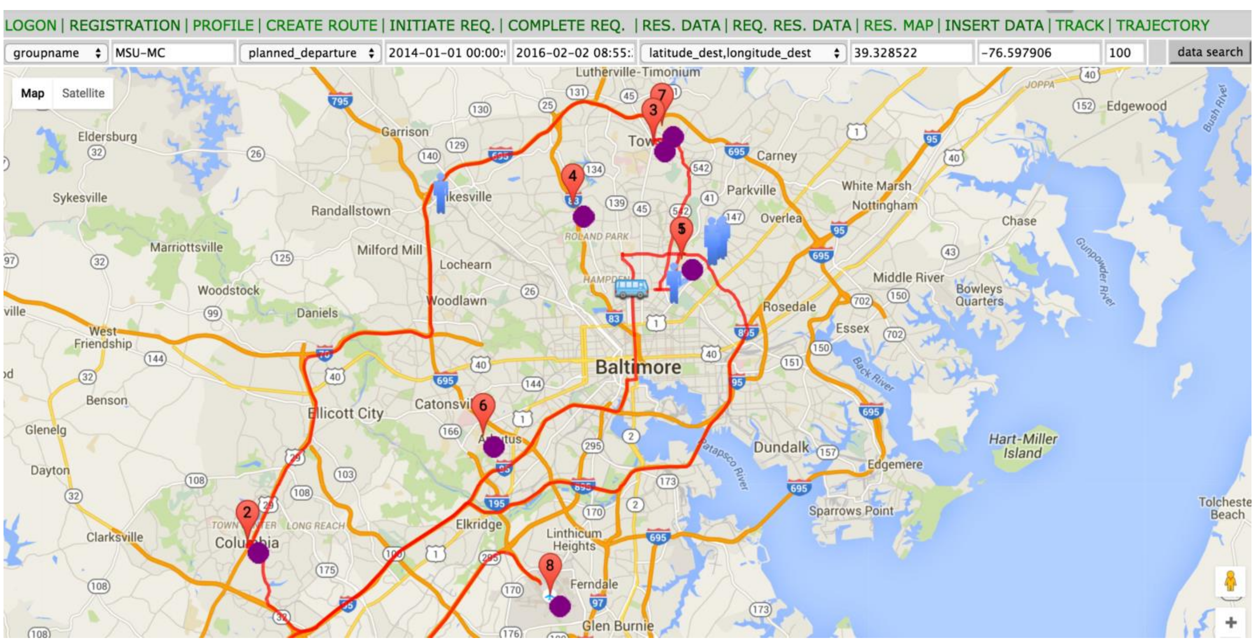


Figure 28. Passenger locations and potential bus stops created at the database.

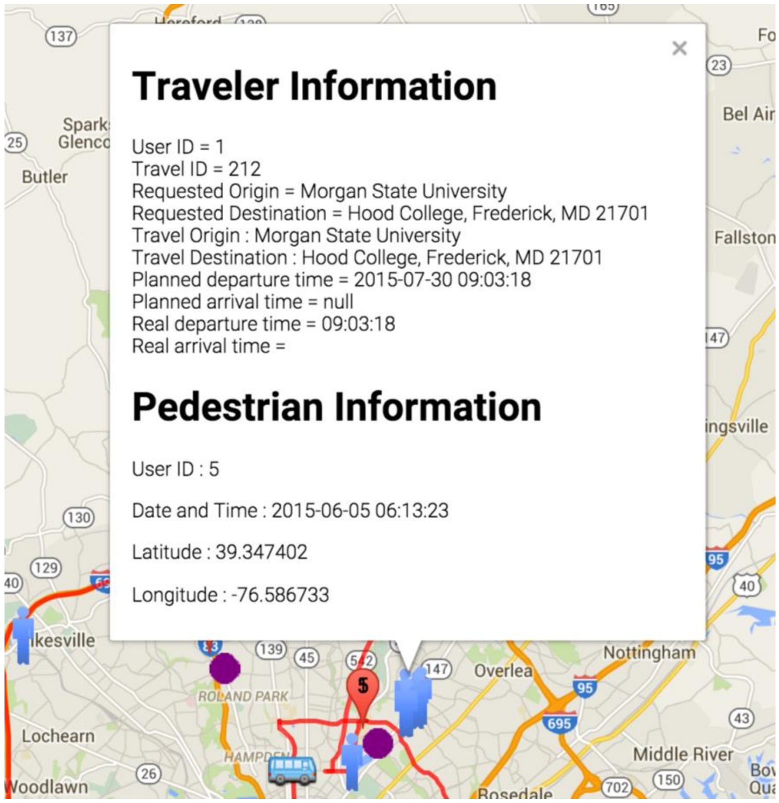


Figure 29. Passenger's original travel request and modified travel information.

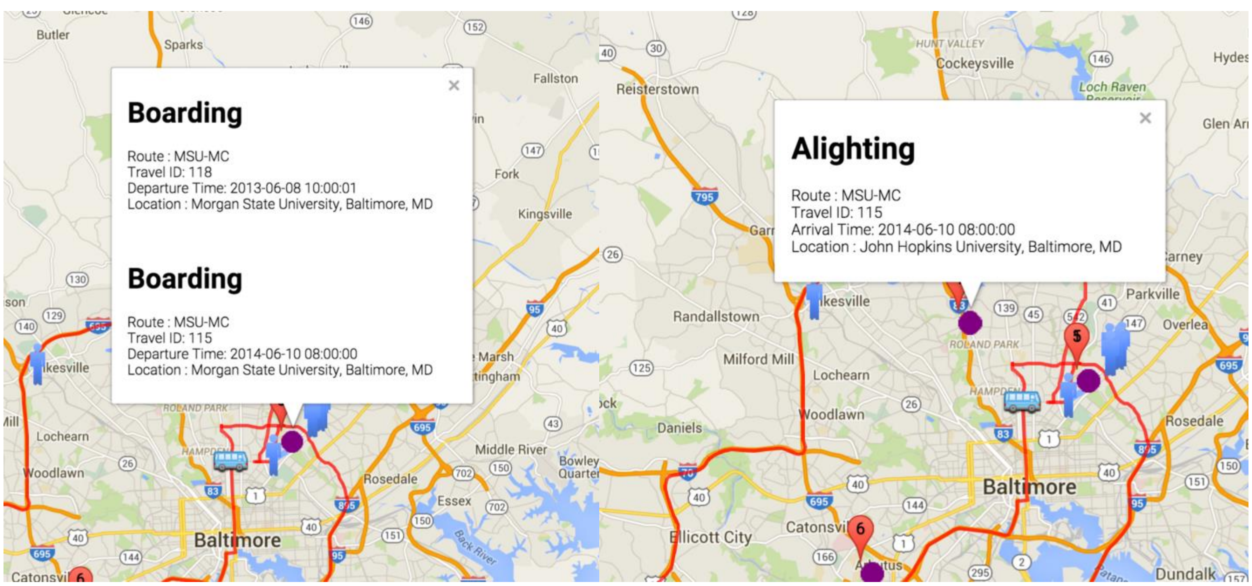


Figure 30. Potential bus stop information created at the database.

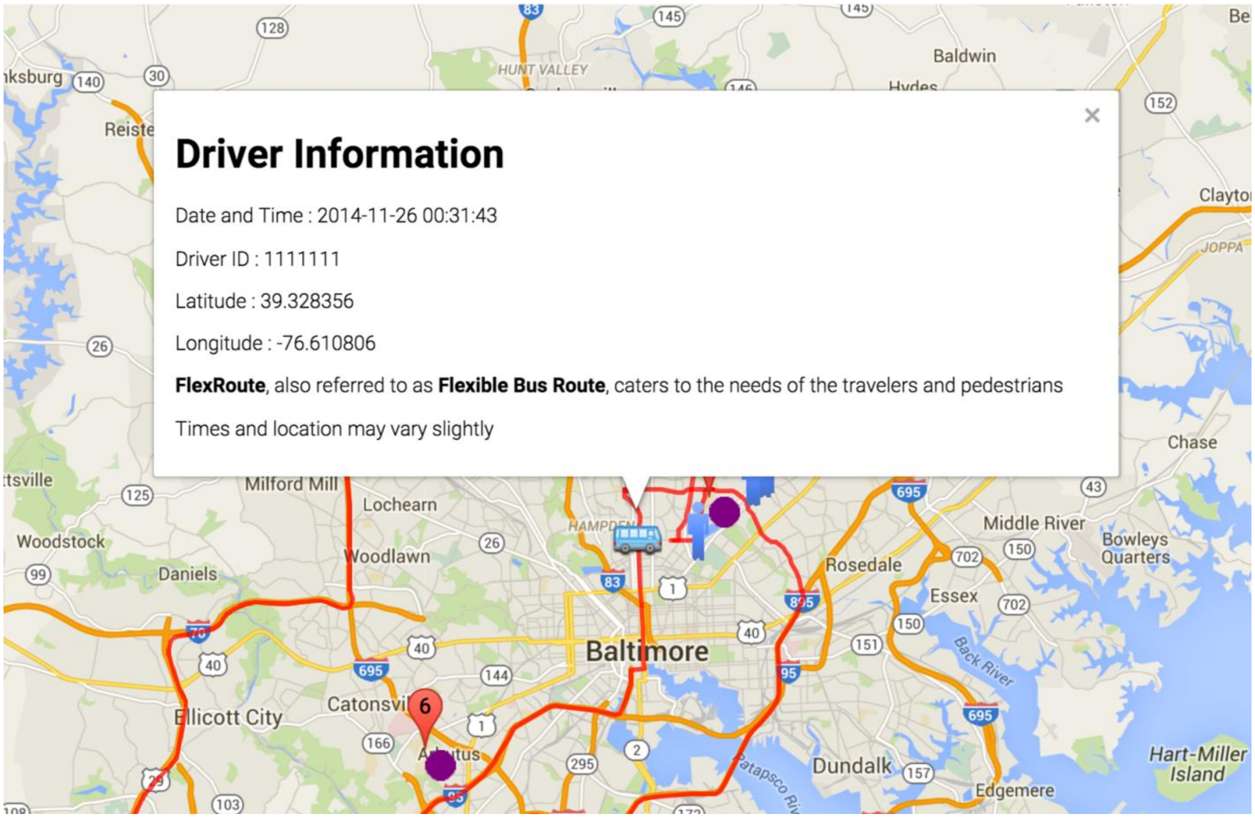


Figure 31. Example of a bus driver information app.

Expected Benefits

Some of the benefits expected from this system architecture are as follows:

1. More efficient shuttle bus operation (especially, during low-demand nighttime hours).
2. Accurate information for the shuttle service through the mobile app.
3. Improved passenger safety during nighttime by ensuring pickup.
4. Pedestrian safety at night (pedestrians can provide their location to the police department).

HTTP protocol is utilized to transmit parameters from mobile devices. The application server receives these parameters, and then submits values to the database management system. The transmission intervals are approximately 120 seconds. A slower rate is required as the number of mobile devices increases due to constraints within the application and database server. A transmission interval of 300 seconds is recommended. The application server limits the HTTP request/response rate, and the database management system limits the maximum number of simultaneous connections. The application and database congestion is alleviated with the utilization of additional network protocols and storage systems.

The following is a sample of the transmitted parameters:

- z acceleration: zacclrtn = 6.2114563

- x acceleration: xacclrtn = 1.5124054
- y acceleration: yacclrtn = 6.9717865
- z axis rotation: zrotation = −0.26365373
- y axis rotation: yrotation = −0.23883891
- x rotation: xrotation = −0.8286834
- date and time: datetime = 2016-04-09+07%3A47%3A56
- longitude: longitude = −76.60806427
- latitude: latitude = 39.47141771
- user logon ID: userlogonid = 103

An additional column will indicate travel mode. The real-time data will be displayed on a map. Devices within the same social network will have the privilege of viewing each other's locations.

Survey

An online survey was designed and distributed to capture public opinion about user app described in the system architecture. This chapter summarizes survey data collection and analysis. The survey was titled, "Survey for the User Location-based Transit Mobile App," and a copy is provided in Appendix C.

Data Collection

The survey was open online from April 25, 2016, to July 8, 2016, and 92 usable responses were collected. The survey mainly recruited in Baltimore, Maryland, and southern Virginia. Advertising on some online websites like Craigslist was also among the methods of survey recruitment. Table 9 to Table 11 summarize demographics, travel behavior, and geographic characteristics, respectively. The demographics table includes gender, age, marital status, household annual income, race/ethnicity, education, and occupation. There were more male participants than females, 56.5% to 43.5%. Two age categories, 25–34 (34.8%) and 45–64 (31.5%), covered more than 65% of participants. The majority of participants, more than 60%, were married or in a domestic partnership. Almost half of participants had an annual income between $50,000 and $100,000. Due to survey recruitment, the majority of participants were White, followed by Black or African-American. Similar reasons caused the level of education to be a little bit skewed, and 75% of participants had at least a bachelor's degree. Finally, about 75% of participants were employed, and the rest were students (undergraduate and graduate).

The majority of participants drive regularly (80%); however, almost 30% of participants use transit to commute at least once per week. More than half of the participants either commute less than 20 minutes or live in walking distance; however, around 20% of participants had commuting times of more than 40 minutes. The maximum number of transfer points when commuting by transit was two (for 7.6% of participants). Using transit to commute requires extra time for the majority of participants; however, 38% of participants did not know since they have probably never tried transit to commute in the past. Almost half of the participants were familiar with transit apps (in general) and have used at least one in the past.

Due to the survey recruitment, the majority of participants lived in suburban areas (81%), mainly from Virginia (53%) and Maryland (37%), with a few participants from Connecticut, New Jersey, Pennsylvania, and Washington, D.C. (all together about 10%). The main type of commute for participants was suburban to suburban (more than 66%), followed by suburban to city (15%). The full list of the cities/urban areas where participants live and work/study is provided in Appendix D.

Table 9. Summary of Participants' Demographic Characteristics

Demographic Characteristics		Count	%
Gender	Male	52	56.5%
	Female	40	43.5%
Age	18-24	12	13.0%
	25-34	32	34.8%
	35-44	18	19.6%
	45-64	29	31.5%
	65 and over	1	1.1%
Marital Status	Single	36	39.6%
	In domestic partnership	3	3.3%
	Married	52	57.1%
Annual Income	Less than $25,000	12	13.2%
	$25,000 – $50,000	7	7.7%
	$50,000 – $75,000	23	25.3%
	$75,000 – $100,000	20	22.0%
	$100,000 – $200,000	18	19.8%
	More than $200,000	4	4.4%
	Prefer not to answer	7	7.7%
Race/Ethnicity	White (non-Hispanic)	51	55.4%
	Hispanic	4	4.3%
	Black or African-American	23	25.0%
	Asian	11	12.0%
	American Indian or Alaska Native	0	0.0%
	Native Hawaiian or other Pacific Islander	0	0.0%
	Other	2	2.2%
	Prefer not to answer	1	1.1%
Education	Some high school	1	1.1%
	High school diploma or GED	9	9.8%
	Associate's degree	13	14.1%
	Bachelor's degree	23	25.0%
	Master's degree	31	33.7%
	Doctoral or higher	15	16.3%
Occupation	Undergraduate student	11	12.1%
	Graduate student	9	9.9%
	Employed	69	75.8%
	Not Employed	1	1.1%
	Other	1	1.1%

N = 92

Table 10. Summary of Participants' Travel Behavior Characteristics

Travel Behavior Characteristics		Count	%
Driving Pattern (Regularly)	Yes	72	79.1%
	No	19	20.9%
Transit Use Frequency	None	64	69.6%
	1-3	12	13.0%
	4-6	6	6.5%
	7 and more	10	10.9%
Commute Time	Walking distance	6	6.5%
	Less than 20 minutes	47	51.1%
	Less than 40 minutes	19	20.7%
	Less than an hour	11	12.0%
	More than an hour	9	9.8%
# Transfer(s)	I do not use transit to commute	52	56.5%
	No transfer required	13	14.1%
	1 transfer	14	15.2%
	2 transfers	7	7.6%
	3 or more transfers	0	0.0%
	I do not know	6	6.5%
Transit Extra Time	Almost the same	8	9.2%
	Less than 20 minutes more	18	20.7%
	Less than 40 minutes more	8	9.2%
	Less than an hour more	5	5.7%
	More than an hour more	15	17.2%
	I do not know	33	37.9%
Transit App Familiarity	Yes	48	52.7%
	No	43	47.3%
Transit App Use	Yes	46	50.0%
	No	46	50.0%

N = 92

Data Analysis

Prior to the analysis, some variable recoding efforts were performed because, based on Table 9 to Table 11, some of the participant characteristic cohorts had an insufficient number of participants (e.g., age 65 and over with just one participant, or marital status in domestic partnership with only three participants). After variable recoding, questions from the online survey associated with the proposed transit app were analyzed with regard to participant characteristics.

Variable Recoding

The following tables (Table 15 – Table 25) summarize the recoding efforts for age, marital status, annual income, race/ethnicity, education, occupation, transit use frequency, commute time, number of transfers, transit extra times, and commute type, respectively. The recoding procedure was carried out to make sure the modified cohorts included a reasonable number of participants that would not bias the analyses.

Table 11. Summary of Participants' Geographic Characteristics

Geographic Characteristics		Count	%
Home Location Category	City (>=50,000)	17	18.9%
	Suburban (<50,000)	73	81.1%
State (Home)	CT	1	1.1%
	DC	1	1.1%
	MD	33	36.7%
	NJ	1	1.1%
	PA	6	6.7%
	VA	48	53.3%
Work/Study Location Category	City (>=50,000)	23	27.7%
	Suburban (<50,000)	60	72.3%
State (Work/Study)	CT	1	1.2%
	DC	1	1.2%
	MD	30	36.1%
	NJ	0	0.0%
	PA	7	8.4%
	VA	44	53.0%
Commute Category (4 groups)	City-City	11	13.3%
	City-Suburban	5	6.0%
	Suburban-City	12	14.5%
	Suburban-Suburban	55	66.3%

N = 92

Table 12. Recoding Age

Age		#	%
Age (original)	18-24	12	13.0%
	25-34	32	34.8%
	35-44	18	19.6%
	45-64	29	31.5%
	65 and over	1	1.1%
	Total	**92**	**100.0%**
Age (3 groups)	18-34	44	47.8%
	35-44	18	19.6%
	45 and over	30	32.6%
	Total	**92**	**100.0%**
Age (2 groups)	18-34	44	47.8%
	35 and over	48	52.2%
	Total	**92**	**100.0%**

Table 13. Recoding Marital Status

Marital Status		#	%
Marital Status (original)	Single	36	39.1%
	In domestic partnership	3	3.3%
	Married	52	56.5%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**
Marital Status (2 groups)	Single	36	39.1%
	Married or in domestic partnership	55	59.8%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**

Table 14. Recoding Annual Income

Annual Income		#	%
Annual Income (original)	Less than $25,000	12	13.0%
	$25,000 – $50,000	7	7.6%
	$50,000 – $75,000	23	25.0%
	$75,000 – $100,000	20	21.7%
	$100,000 – $200,000	18	19.6%
	More than $200,000	4	4.3%
	Prefer not to answer	7	7.6%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**
Annual Income (3 groups)	Less than $50,000	19	20.7%
	$50,000 – $100,000	43	46.7%
	More than $100,000	22	23.9%
	Subtotal	*84*	*91.3%*
Missing		8	8.7%
Total		**92**	**100.0%**

Note: “Prefer not to answer” was excluded in recoding.

Table 15. Recoding Race/Ethnicity

Race/Ethnicity		#	%
Race/Ethnicity (original)	White (non-Hispanic)	51	55.4%
	Hispanic	4	4.3%
	Black or African-American	23	25.0%
	Asian	11	12.0%
	Other	2	2.2%
	Prefer not to answer	1	1.1%
	Total	**92**	**100.0%**
Race/Ethnicity (3 groups)	White (non-Hispanic)	51	55.4%
	Black or African-American	23	25.0%
	Other	17	18.5%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**

Table 16. Recoding Education

Education		#	%
Education (original)	Some high school	1	1.1%
	High school diploma or GED	9	9.8%
	Associate's degree	13	14.1%
	Bachelor's degree	23	25.0%
	Master's degree	31	33.7%
	Doctoral or higher	15	16.3%
	Total	**92**	**100.0%**
Education (3 groups)	Associate's degree or lower	23	25.0%
	Bachelor's degree	23	25.0%
	Master's degree or higher	46	50.0%
	Total	**92**	**100.0%**

Table 17. Recoding Occupation

Occupation		#	%
Occupation (original)	Undergraduate student	11	12.0%
	Graduate student	9	9.8%
	Employed	69	75.0%
	Not Employed	1	1.1%
	Other	1	1.1%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**
Occupation (2 groups)	Student or not employed or other	22	23.9%
	Employed	69	75.0%
	Subtotal	*91*	*98.9%*
Missing		1	1.1%
Total		**92**	**100.0%**

Table 18. Recoding Transit Use Frequency

Transit Use Frequency		#	%
Transit Use Frequency (original)	None	64	69.6%
	1-3	12	13.0%
	4-6	6	6.5%
	7 and more	10	10.9%
	Total	**92**	**100.0%**
Transit Use Frequency (3 groups)	None	64	69.6%
	Few	12	13.0%
	Many	16	17.4%
	Total	**92**	**100.0%**
Transit Use Frequency (2 groups)	No	64	69.6%
	Yes	28	30.4%
	Total	**92**	**100.0%**

Table 19. Recoding Commute Time

Commute Time		#	%
Commute Time (original)	Walking distance	6	6.5%
	Less than 20 minutes	47	51.1%
	Less than 40 minutes	19	20.7%
	Less than an hour	11	12.0%
	More than an hour	9	9.8%
	Total	**92**	**100.0%**
Commute Time (2 groups)	Less than 20 minutes	53	57.6%
	More than 20 minutes	39	42.4%
	Total	**92**	**100.0%**

Table 20. Recoding Number of Transfers

# Transfer(s)		#	%
# Transfer(s) (original)	I do not use transit to commute	52	56.5%
	No transfer required	13	14.1%
	1 transfer	14	15.2%
	2 transfers	7	7.6%
	I do not know	6	6.5%
	Total	92	100.0%
Transfer	Yes	21	22.8%
	No	13	14.1%
	Subtotal	*34*	*37.0%*
Missing		58	63.0%
Total		**92**	**100.0%**

Note: “I do not use transit to commute” and “I do not know” were excluded in recoding.

Table 21. Recoding Transit Extra Time

Transit Extra Time		#	%
Transit Extra Time (original)	Almost the same	8	8.7%
	Less than 20 minutes more	18	19.6%
	Less than 40 minutes more	8	8.7%
	Less than an hour more	5	5.4%
	More than an hour more	15	16.3%
	I do not know	33	35.9%
	Subtotal	*87*	*94.6%*
Missing		5	5.4%
Total		**92**	**100.0%**
Transit Extra Time (3 groups)	Less than 20 minutes	26	28.3%
	More than 20 minutes	28	30.4%
	I do not know.	33	35.9%
	Subtotal	*87*	*94.6%*
Missing		5	5.4%
Total		**92**	**100.0%**

Table 22. Recoding Commute Type

Commute Type		#	%
Commute Category (4 groups)	City-City	11	12.0%
	City-Suburban	5	5.4%
	Suburban-City	12	13.0%
	Suburban-Suburban	55	59.8%
	Subtotal	*83*	*90.2%*
Missing		9	9.8%
Total		**92**	**100.0%**
Commute Category (3 groups)	City-City	11	12.0%
	City-Suburban or Suburban-City	17	18.5%
	Suburban-Suburban	55	59.8%
	Subtotal	*83*	*90.2%*
Missing		9	9.8%
Total		**92**	**100.0%**

Analysis of App-related Questions

The last section of the online survey consisted of nine rating questions referring to the “User-based Two-way Mobile App” that was proposed and developed in this study. Figure 32 shows these questions. Participants were asked to rate each of these questions on a scale of 1 (least agree) to 10 (most agree). This section provides a review of responses of each of these questions.

Please rate the following questions from 1 (least agree) to 10 (most agree)

Following questions are referring to the "User-based Two-way Mobile App" that has been developed as part of this research project. In the previous pages, there were few sample screen shots of the mobile app for transit passengers, bus drivers and transit agencies. Please look at them to understand the app and go through the following survey questions.

Q19. Do you think this transit app makes for a safer transit experience during the daytime? (   )

Q20. Do you think this transit app makes for a safer transit experience at night? (   )

Q21. Do you think this transit app can improve safety on the university campus? (   )

Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety? (   )

Q23. Do you think this transit app can be used for school bus operation? (   )

Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation? (   )

Q25. Can you recommend this type of mobile app for transit users? (   )

Q26. Are you willing to use the app and flexible transit service, if it can meet your need? (   )

Q27. Do you think this transit app can increase transit ridership? (   )

Figure 32. Rating questions of "User-based Two-way Mobile App" online survey.

Q19. Do you think this transit app makes for a safer transit experience during the daytime?

The average rating for this question was 6.370, which was the lowest among all nine questions. The average ratings range from 5.604 (for participants whose commute time was "Less than 20 minutes") to 7.410 (of participants whose commute time was "More than 20 minutes"). Cohorts with significantly higher average ratings were as follows:

- Race/Ethnicity: "Black or African-Americans" with an average rating of 7.130 ($p < 0.1$)
- Occupation: "Student or Not employed or Other" with an average rating of 7.227 ($p < 0.05$)
- Commute time: "More than 20 minutes" with an average rating of 7.410 ($p < 0.01$)

Figure 33 shows the distribution (in percent) of the ratings for this question. Figure 34 and Figure 35 depict the average ratings by participant characteristic cohorts.

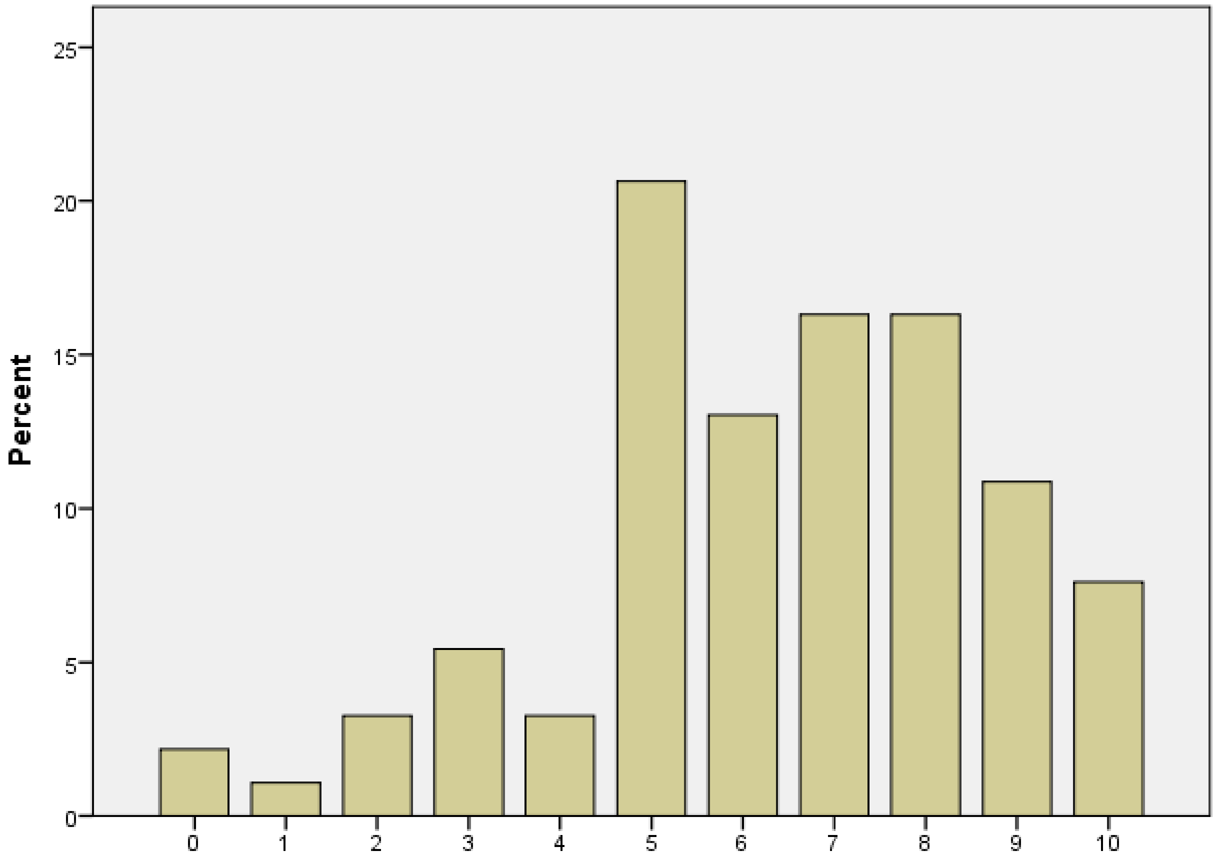


Figure 33. Distribution of ratings for "Q19. Do you think this transit app makes for a safer transit experience during the daytime?"

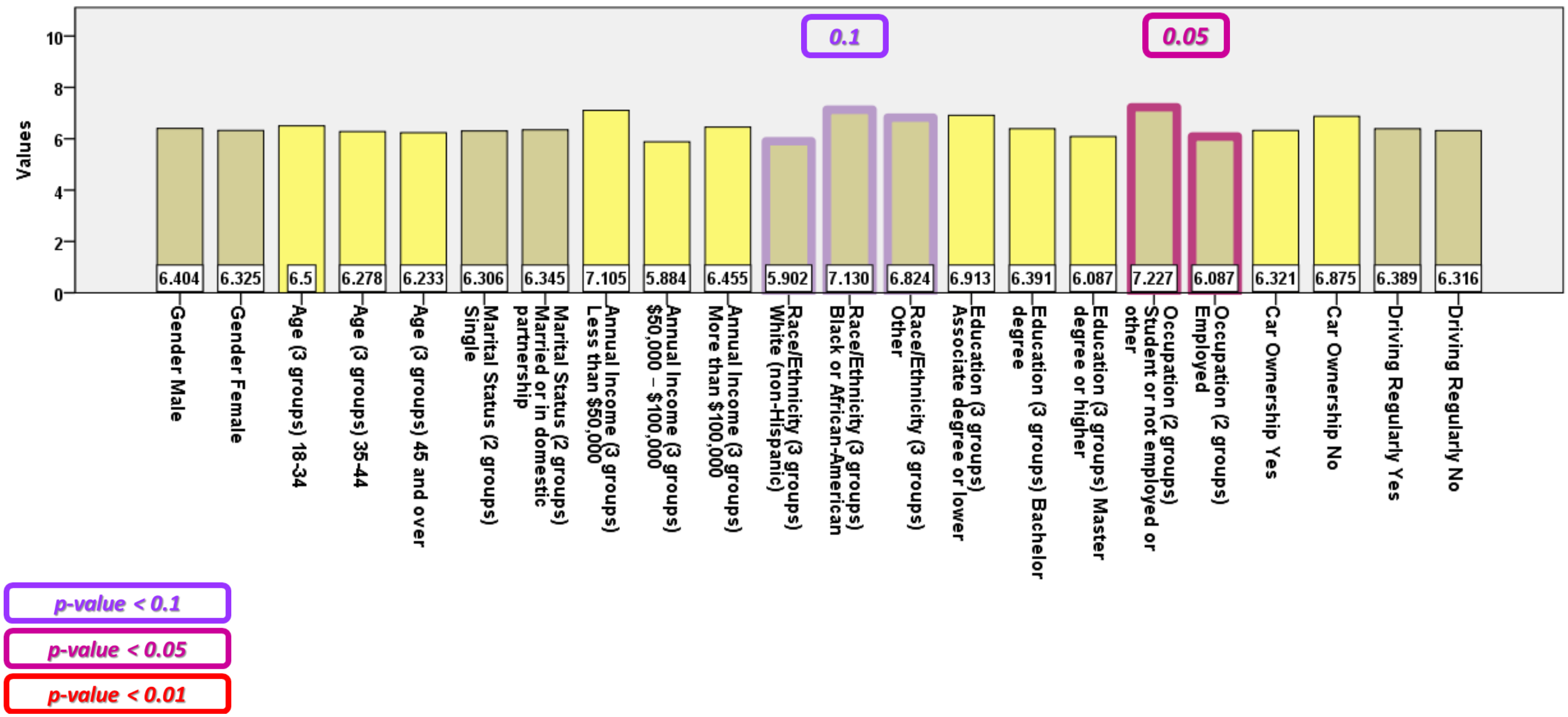


Figure 34. Average rating by participant characteristic for "Q19. Do you think this transit app makes for a safer transit experience during the daytime?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

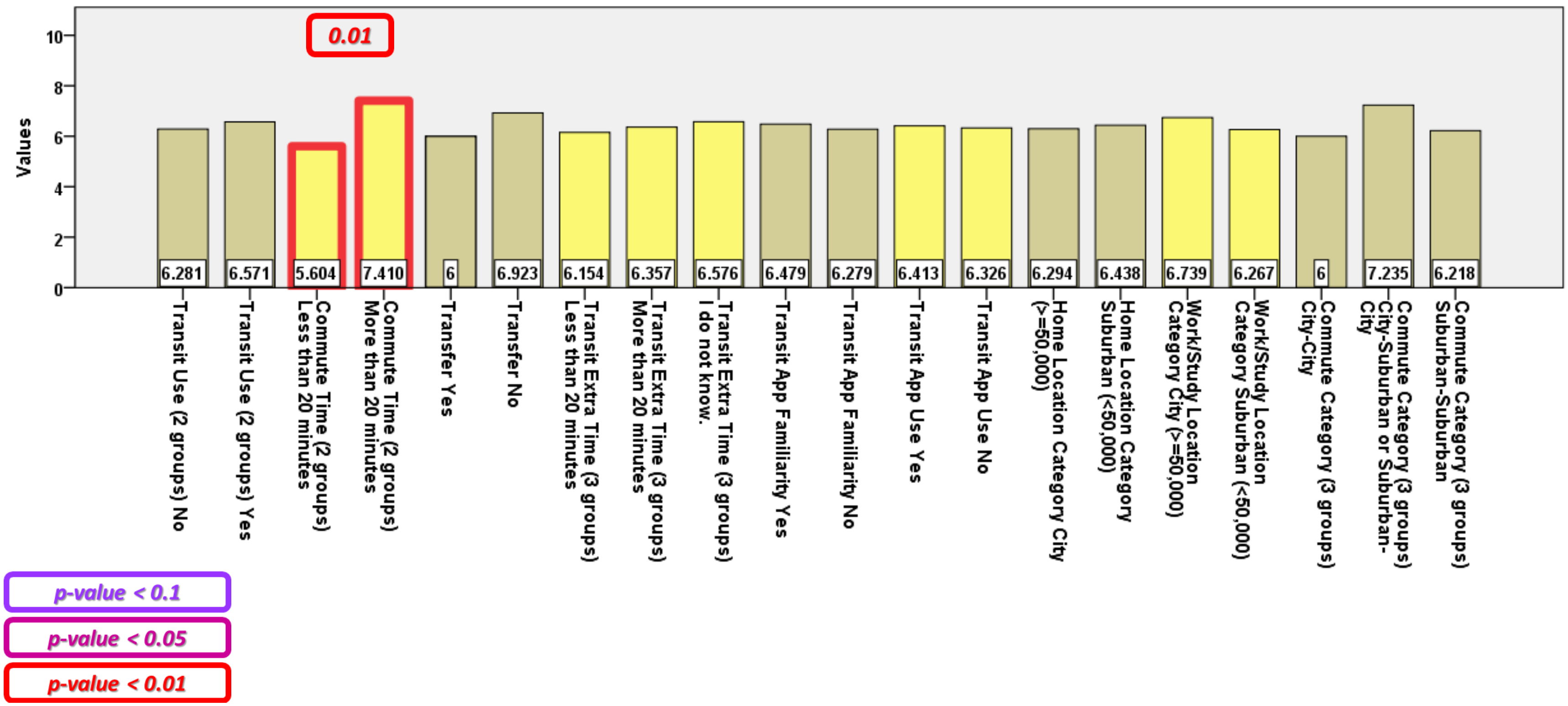


Figure 35. Average rating by participant characteristic for "Q19. Do you think this transit app makes for a safer transit experience during the daytime?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q20. Do you think this transit app makes for a safer transit experience at night?

The average rating for this question was 7.250. Figure 36 shows the distribution (in percent) of the ratings for this question. The average ratings range from 6.767 (for participants whose age was "45 and over") to 8.750 (for participants whose car ownership was "No"). Cohorts with significantly higher average ratings were as follows:

- Car ownership: "No" with an average rating of 8.750 ($p < 0.05$)
- Commute time: "More than 20 minutes" with an average rating of 7.897 ($p < 0.01$)

Figure 37 and Figure 38 depict average ratings by participant characteristic cohorts.

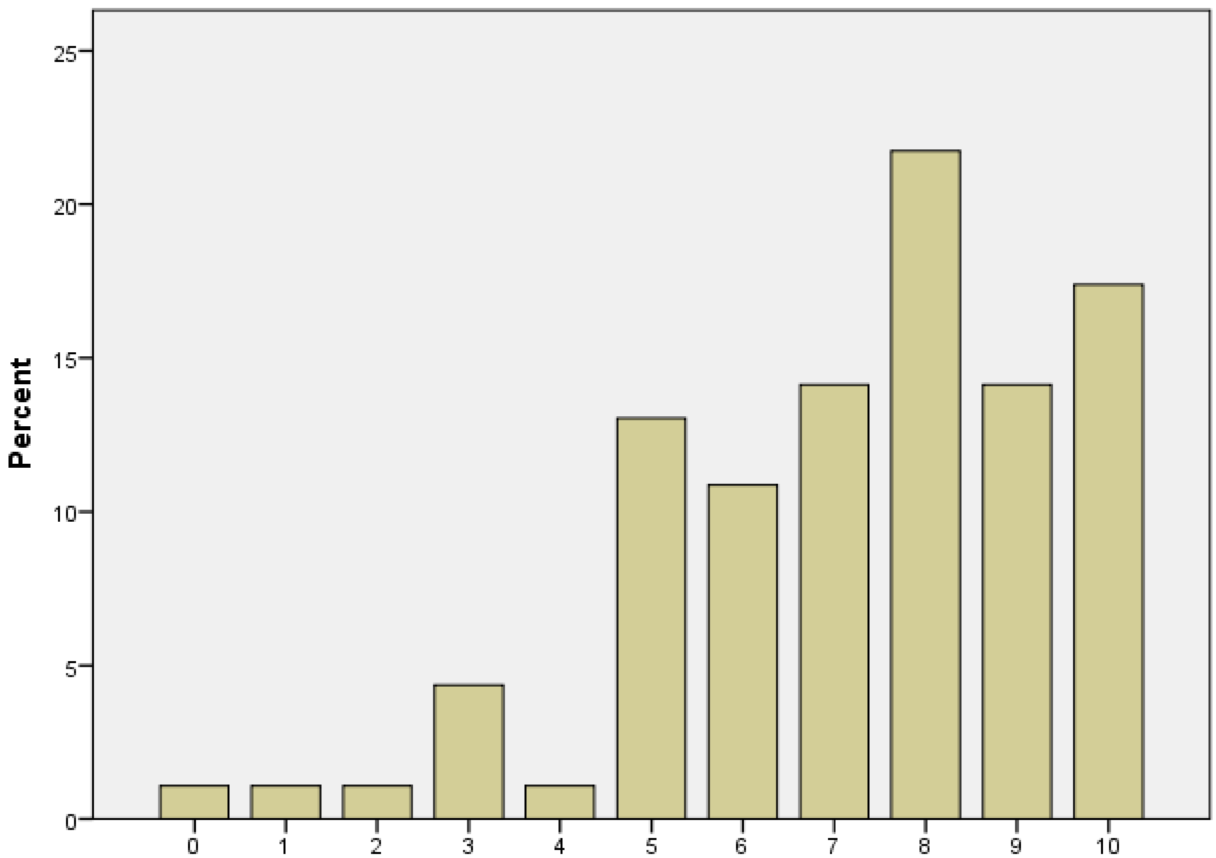


Figure 36**. Distribution of ratings for "Q20. Do you think this transit app makes for a safer transit experience at night?"**

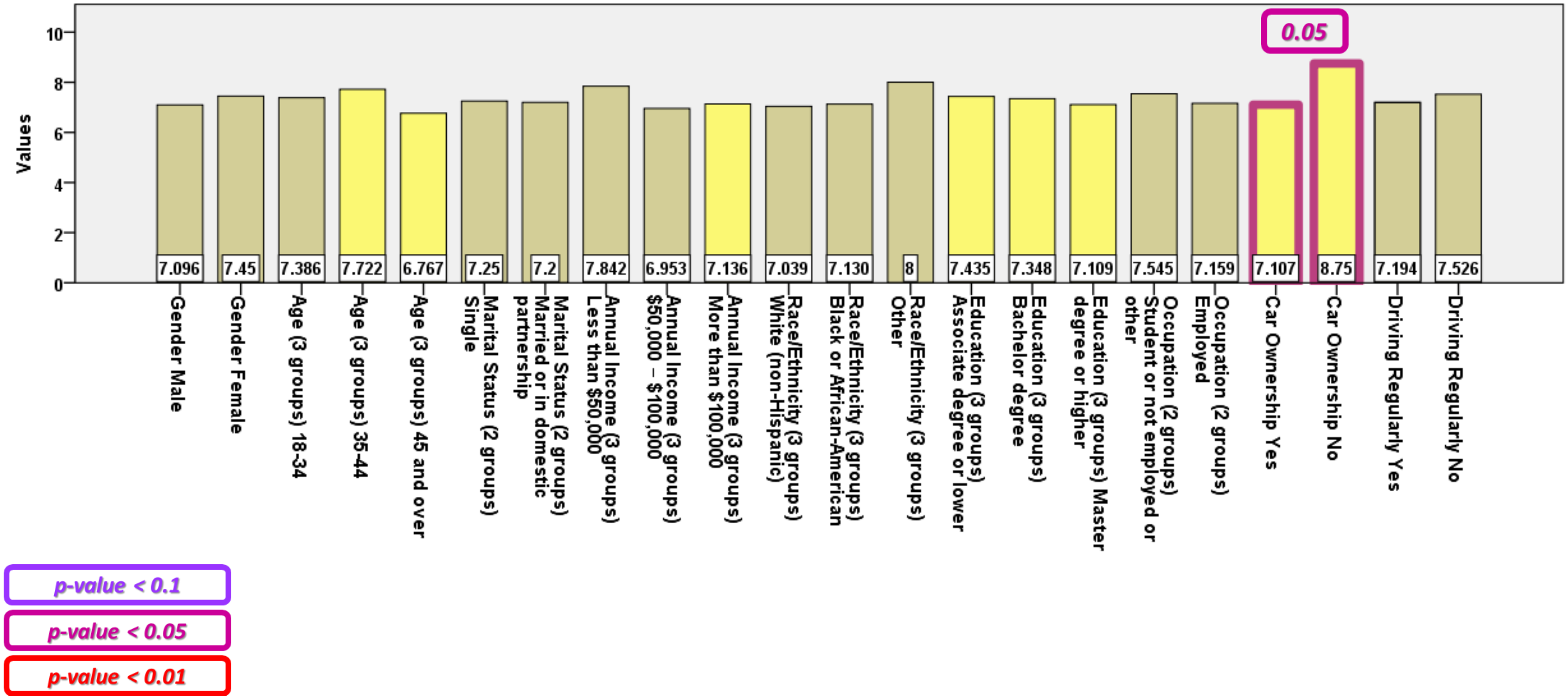


Figure 37. Average rating by participant characteristic for "Q20. Do you think this transit app makes for a safer transit experience at night?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

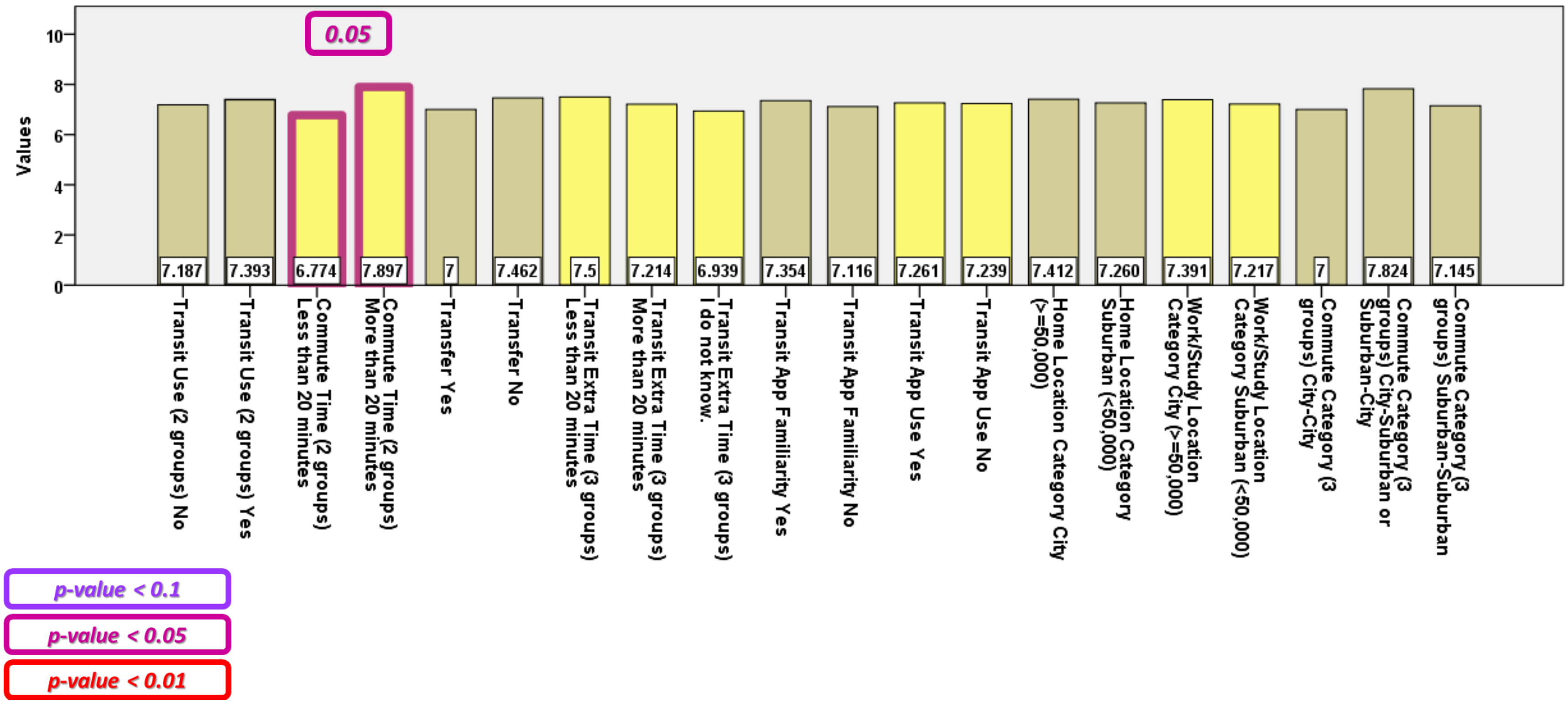


Figure 38. Average rating by participant characteristic for "Q20. Do you think this transit app makes for a safer transit experience at night?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q21. Do you think this transit app can improve safety on the university campus?

The average score for this question was 6.978. Figure 39 shows the distribution (in percent) of the ratings for this question. The average scores range from 6.413 (for participants whose education was "Master's degree or higher") to 8.125 (for participants whose car ownership was "No"). There were five cohorts with significantly higher average ratings for this question, which put it on top of the list with "Q26. Are you willing to use the app and flexible transit service, if it can meet your need?" The cohorts were as follows:

- Education: "Associate's degree or lower" with an average rating of 7.696 ($p < 0.05$)
- Driving pattern (regularly): "No" with an average rating of 7.842 ($p < 0.1$)
- Transit use: "Yes" with an average rating of 7.571 ($p < 0.1$)
- Commute time: "More than 20 minutes" with an average rating of 7.462 ($p < 0.1$)
- Transit transfer: "No" with an average rating of 8 ($p < 0.1$)

Figure 40 and Figure 41 depict average ratings by participant characteristic cohorts.

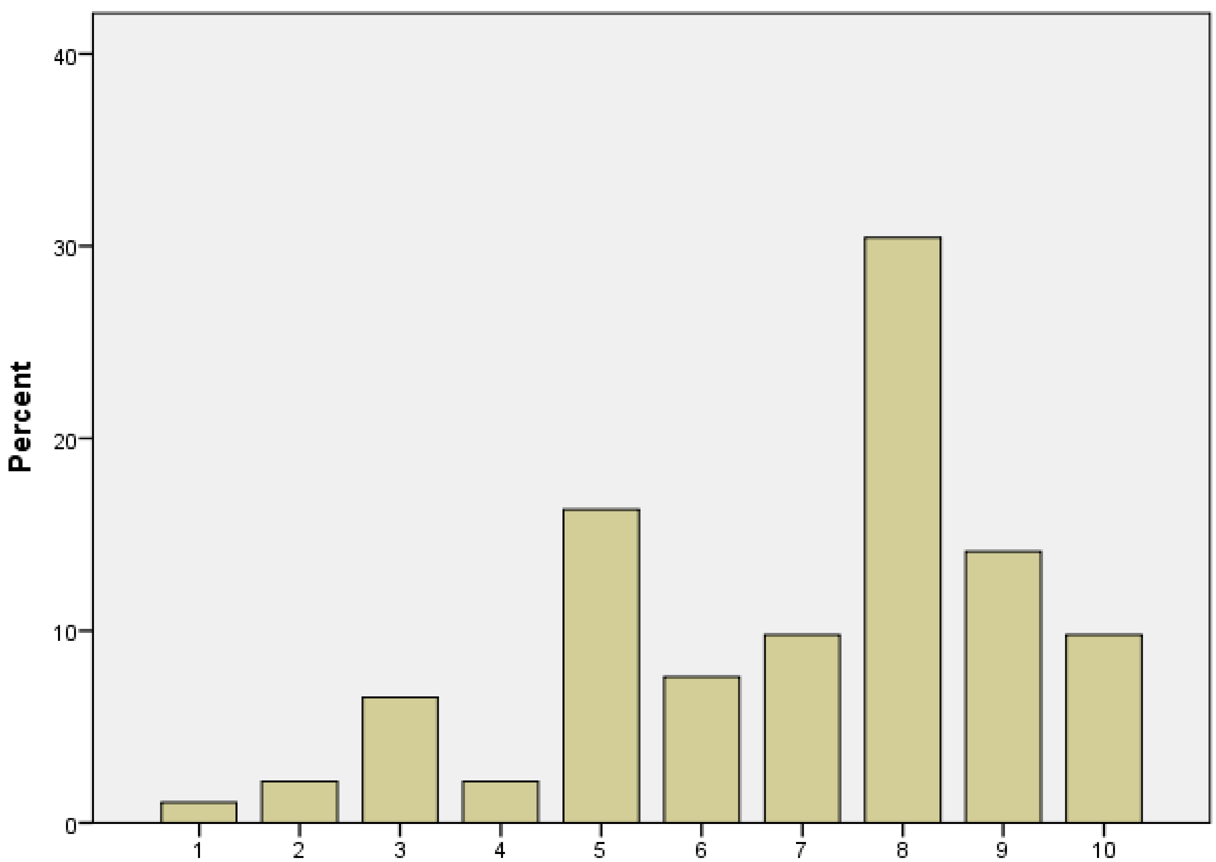


Figure 39. Distribution of ratings for "Q21. Do you think this transit app can improve safety on the university campus?"

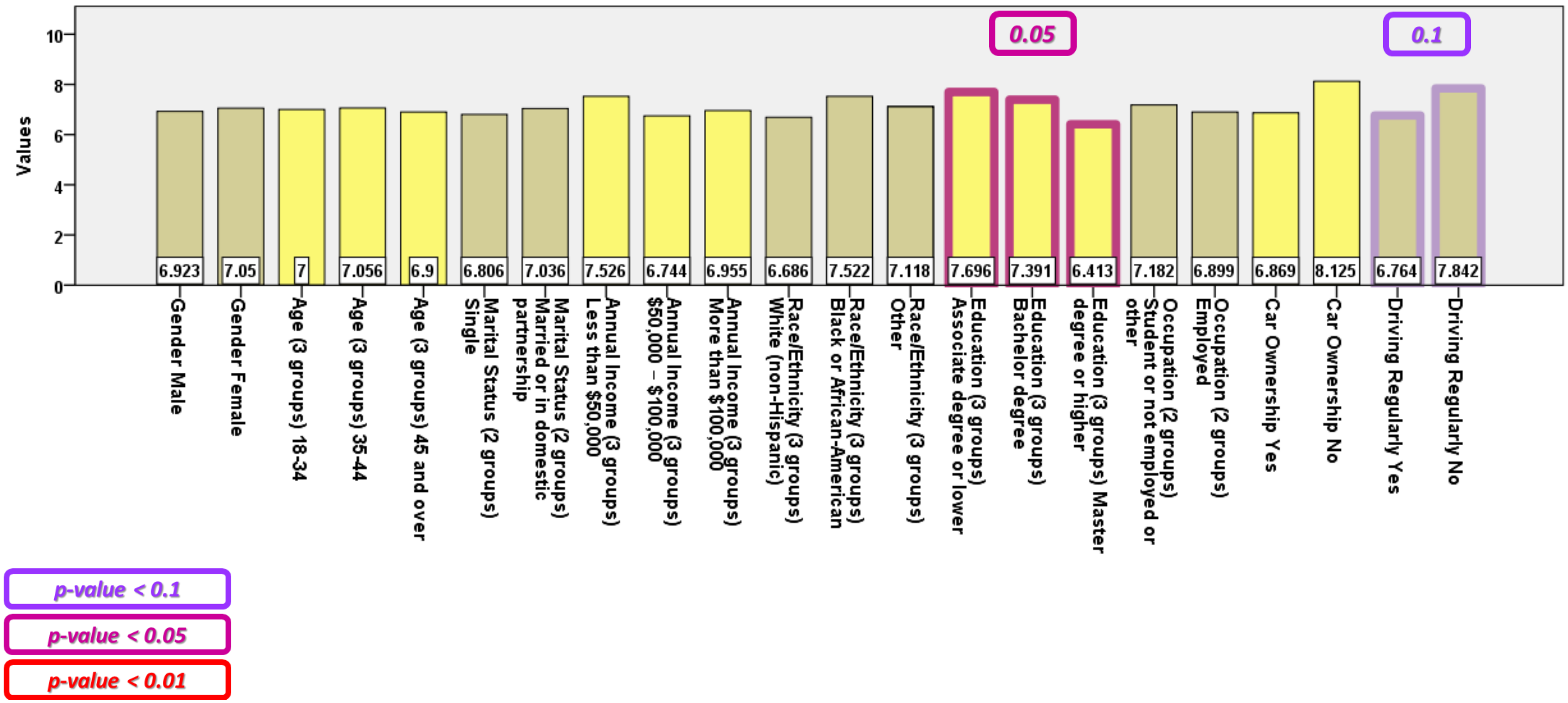


Figure 40. Average rating by participant characteristic for "Q21. Do you think this transit app can improve safety on the university campus?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

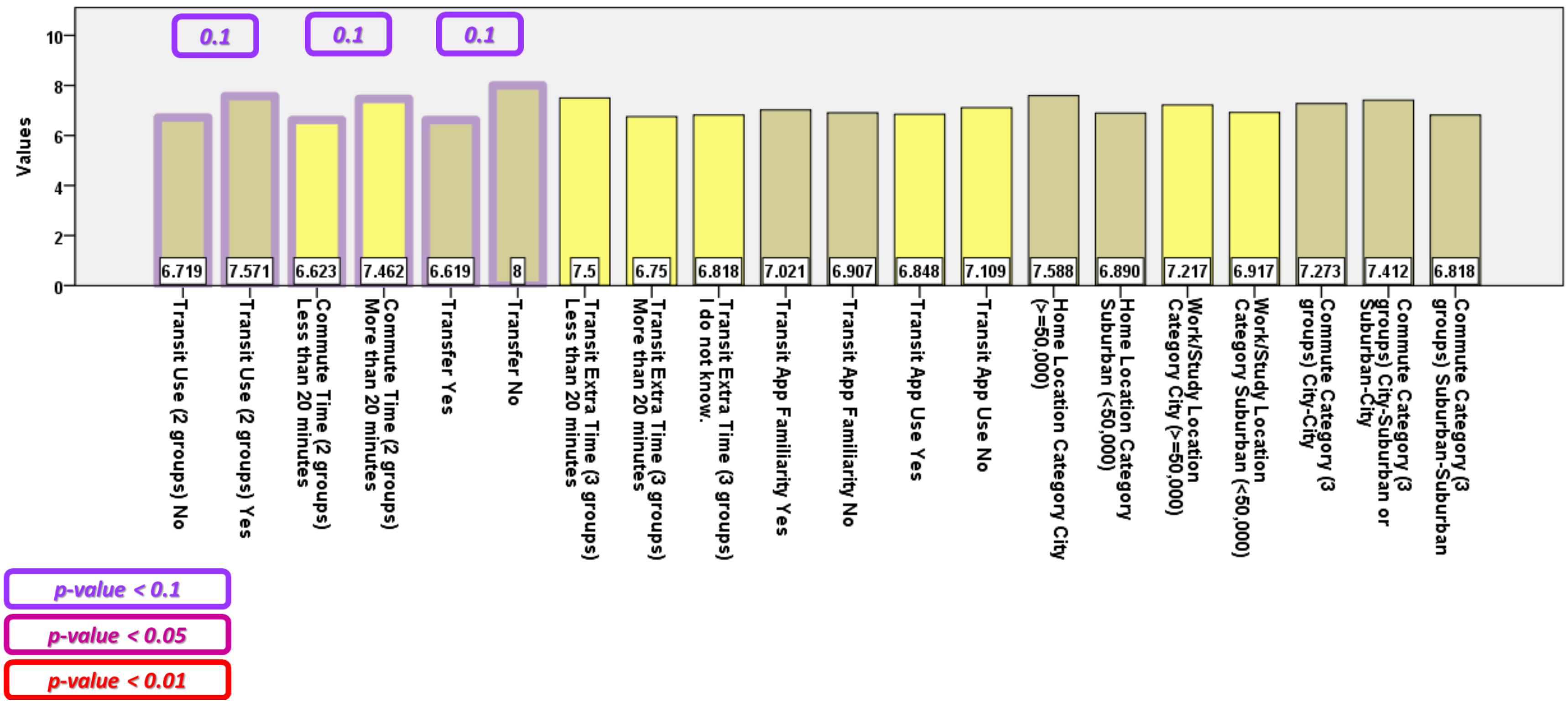


Figure 41. Average rating by participant characteristic for "Q21. Do you think this transit app can improve safety on the university campus?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?

The average rating for this question was 7.804, which was the highest among all nine questions. Figure 42 shows the distribution (in percent) of the ratings for this question. The average ratings range from 6.909 (for participants whose commute type was "City-City") to 8.389 (for participants whose age was 35–44). There was only one cohort with a significantly higher average rating, Commute time: "More than 20 minutes," with an average rating of 8.308 ($p < 0.05$).

Figure 43 and Figure 44 depict average ratings by participant characteristic cohorts.

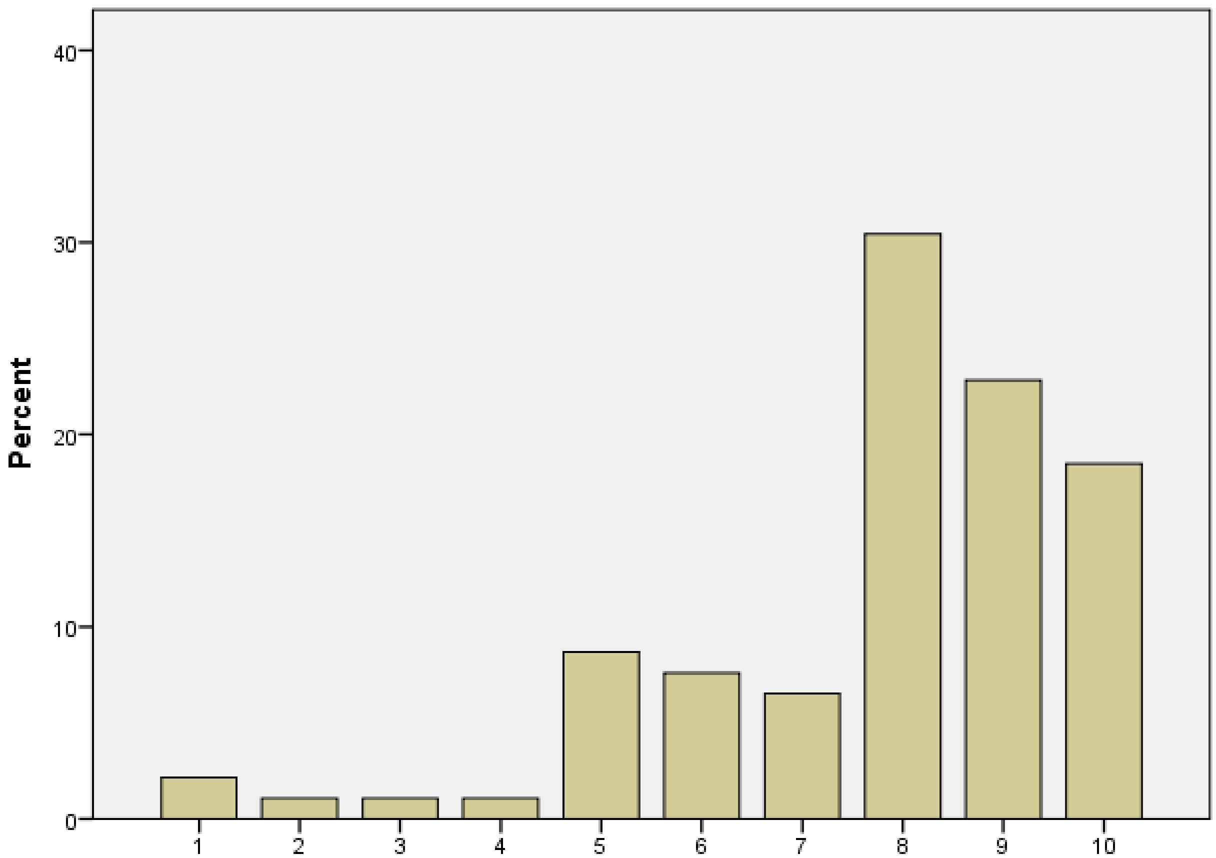


Figure 42. Distribution of ratings for "Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?"

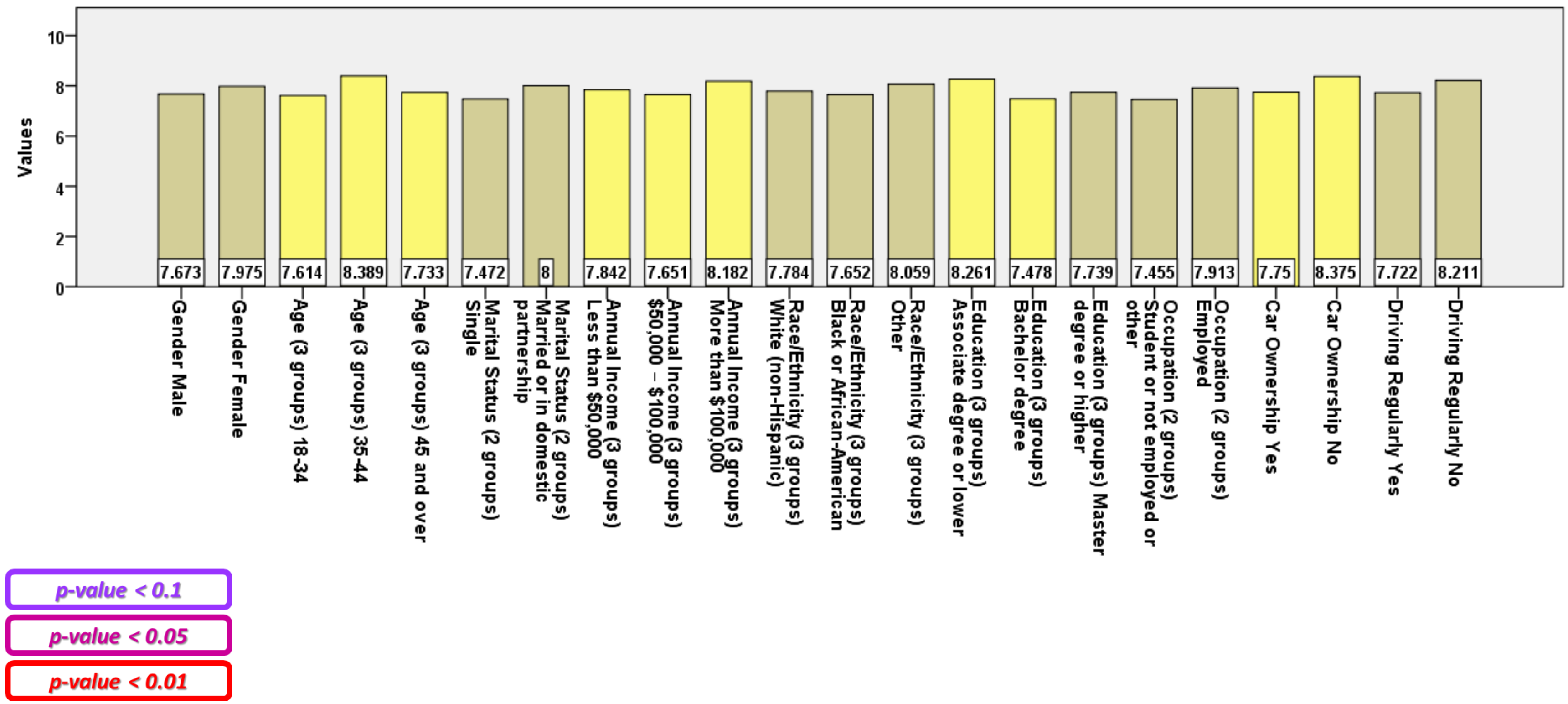


Figure 43. Average rating by participant characteristic for "Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

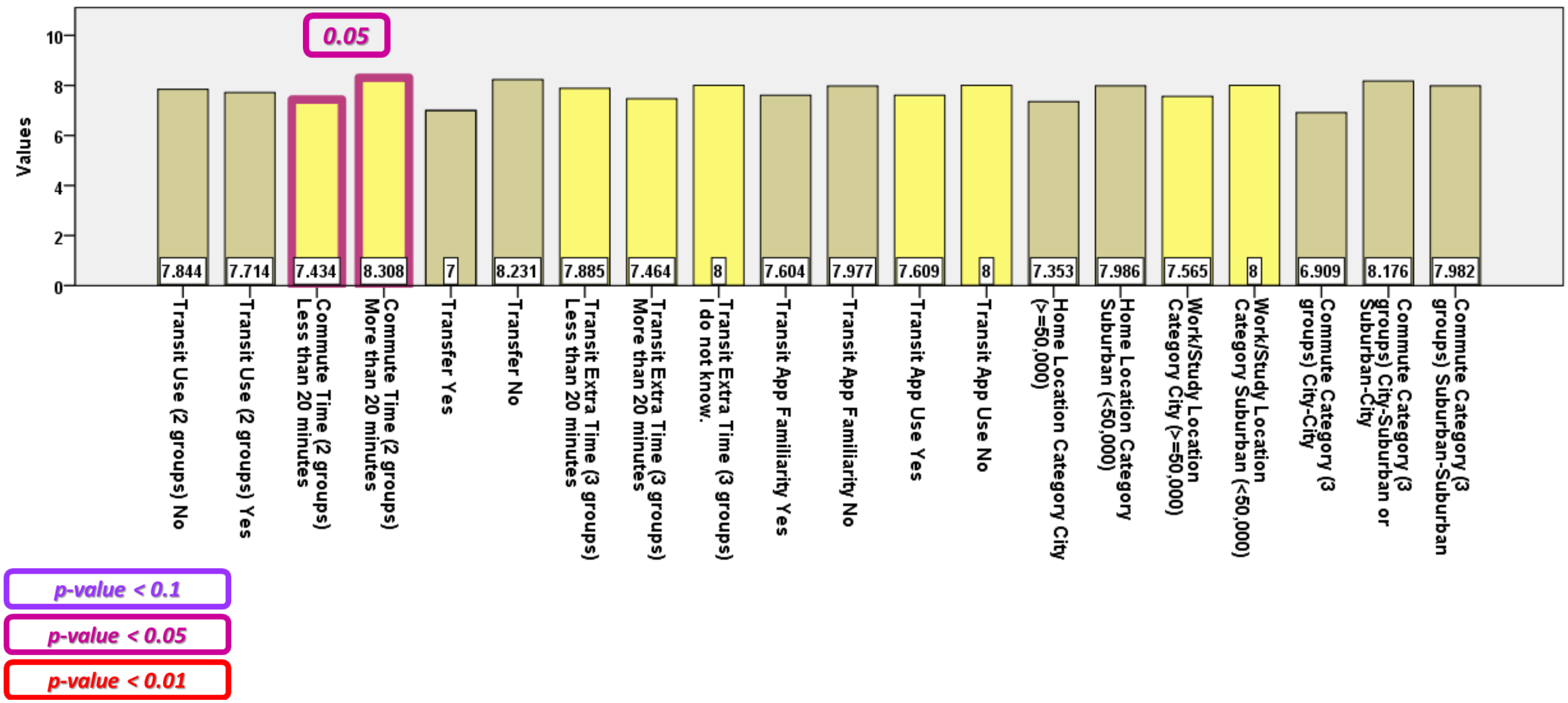


Figure 44. Average rating by participant characteristic for "Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q23. Do you think this transit app can be used for school bus operation?

The average rating for this question was 7.511. Figure 45 shows the distribution (in percent) of the ratings for this question. The average rating ranged from 6.818 (for participants whose commute type was "City-City") to 8.625 (for participants whose car ownership was "No"). Cohorts with significantly higher average ratings were as follows:

- Car ownership: "No" with an average rating of 8.625 ($p < 0.1$)
- Commute time: "More than 20 minutes" with an average rating of 8.103 ($p < 0.05$)

Figure 46 and Figure 47 depict average ratings by participant characteristic cohorts.

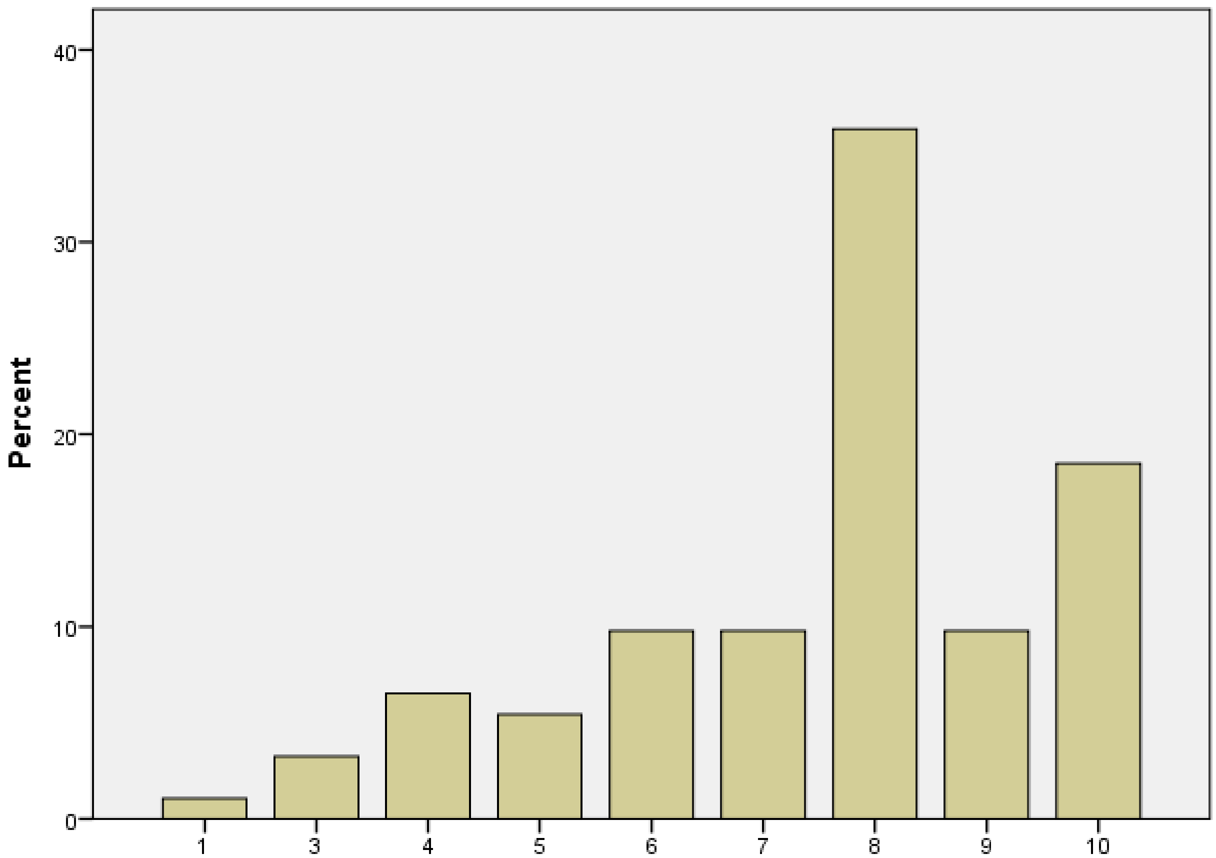


Figure 45. Distribution of ratings for "Q23. Do you think this transit app can be used for school bus operation?"

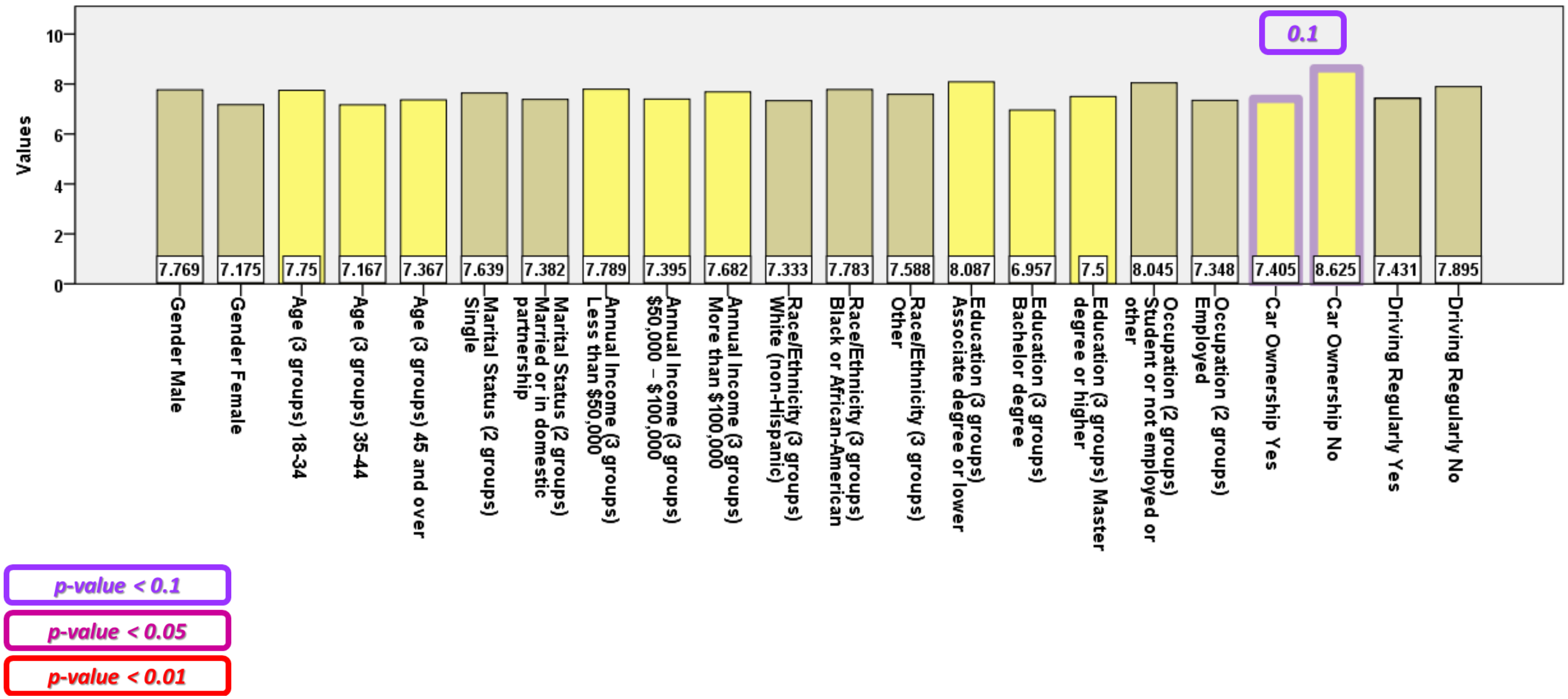


Figure 46. Average rating by participant characteristic for "Q23. Do you think this transit app can be used for school bus operation?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

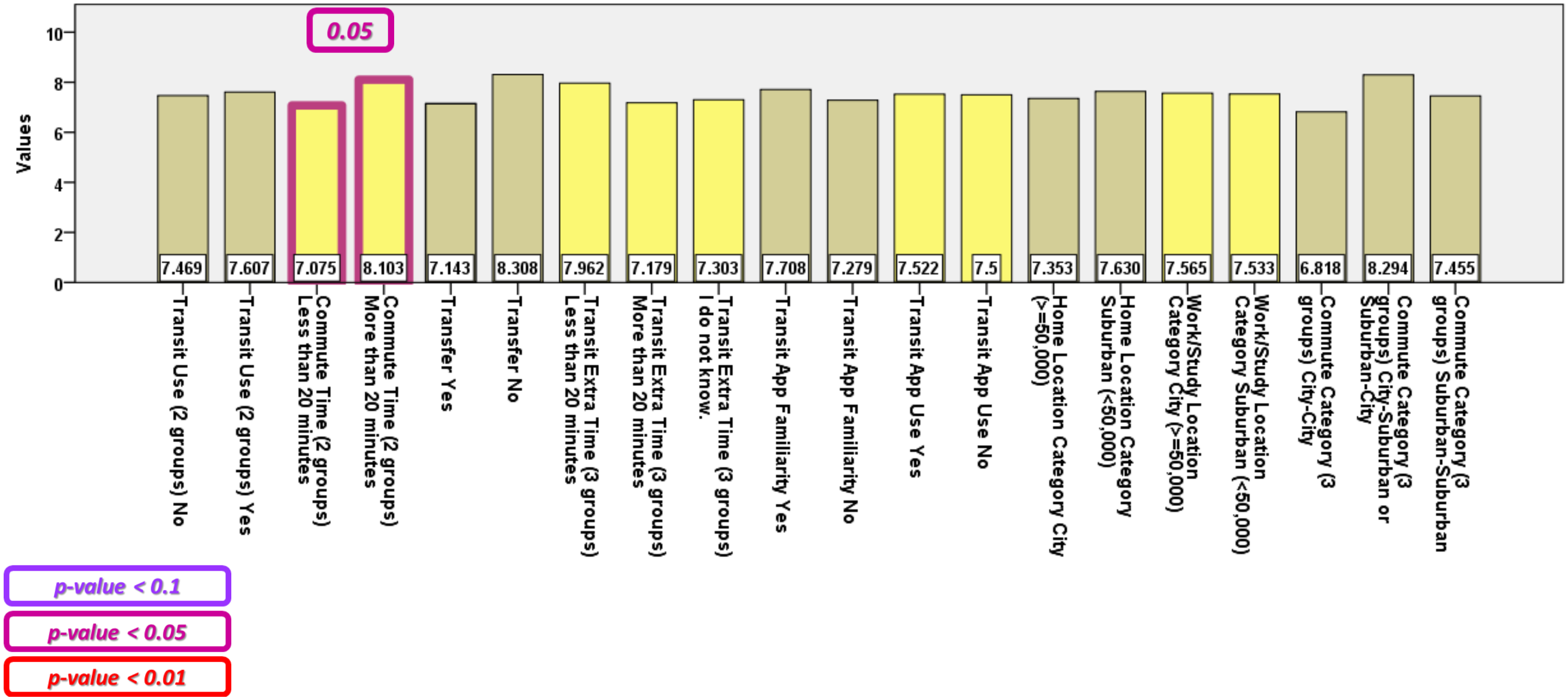


Figure 47. Average rating by participant characteristic for "Q23. Do you think this transit app can be used for school bus operation?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?

The average rating for this question was 7.11. Figure 48 shows the distribution (in percent) of the ratings for this question. The average ratings range from 5.952 (for participants whose transit transfer was "Yes") to 7.957 (for participants whose work/study location category was "City (>=50,000)"). Cohorts with significantly higher average ratings were as follows:

- Transit transfer: "No" with an average rating of 7.923 ($p < 0.05$)
- Work/study location category: "City (>=50,000)" with an average rating of 7.957 ($p < 0.1$)

Figure 49 and Figure 50 depict average ratings by participant characteristic cohorts.

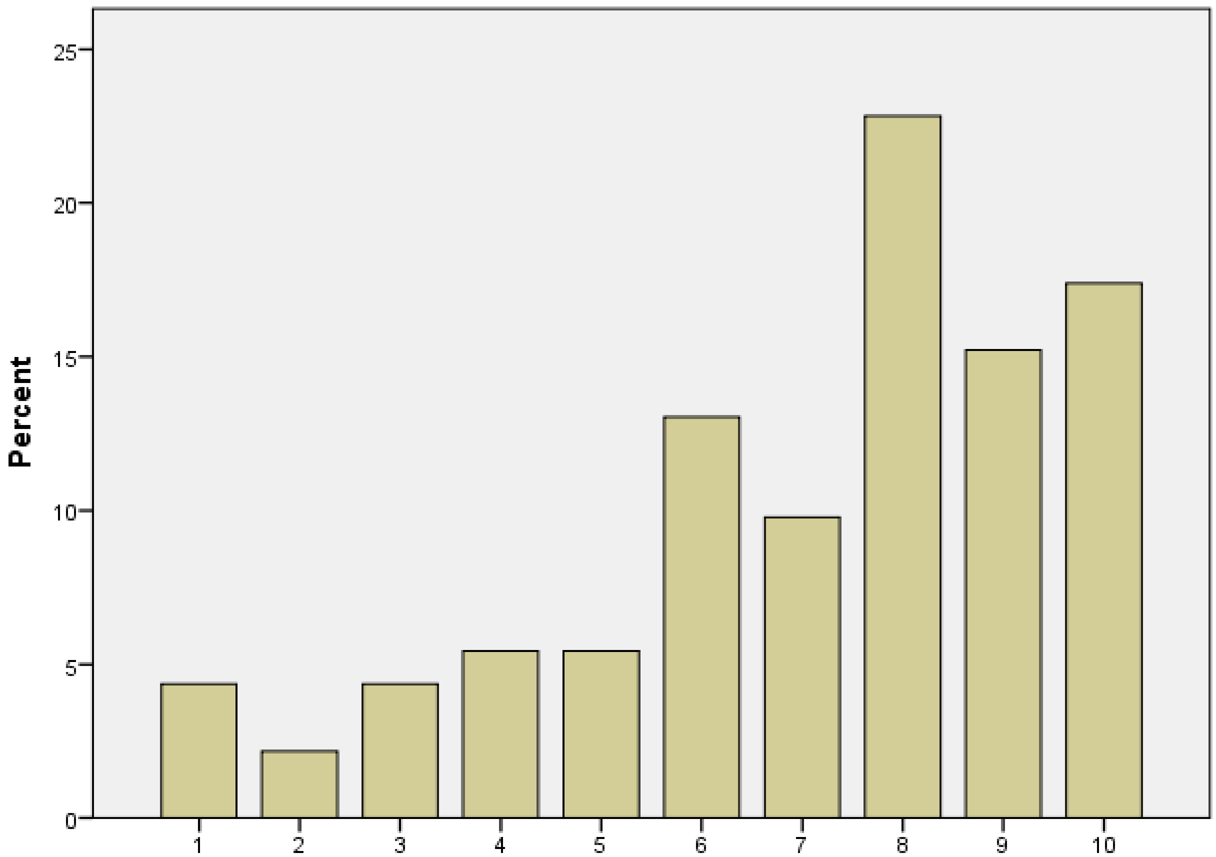


Figure 48. Distribution of ratings for "Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?"

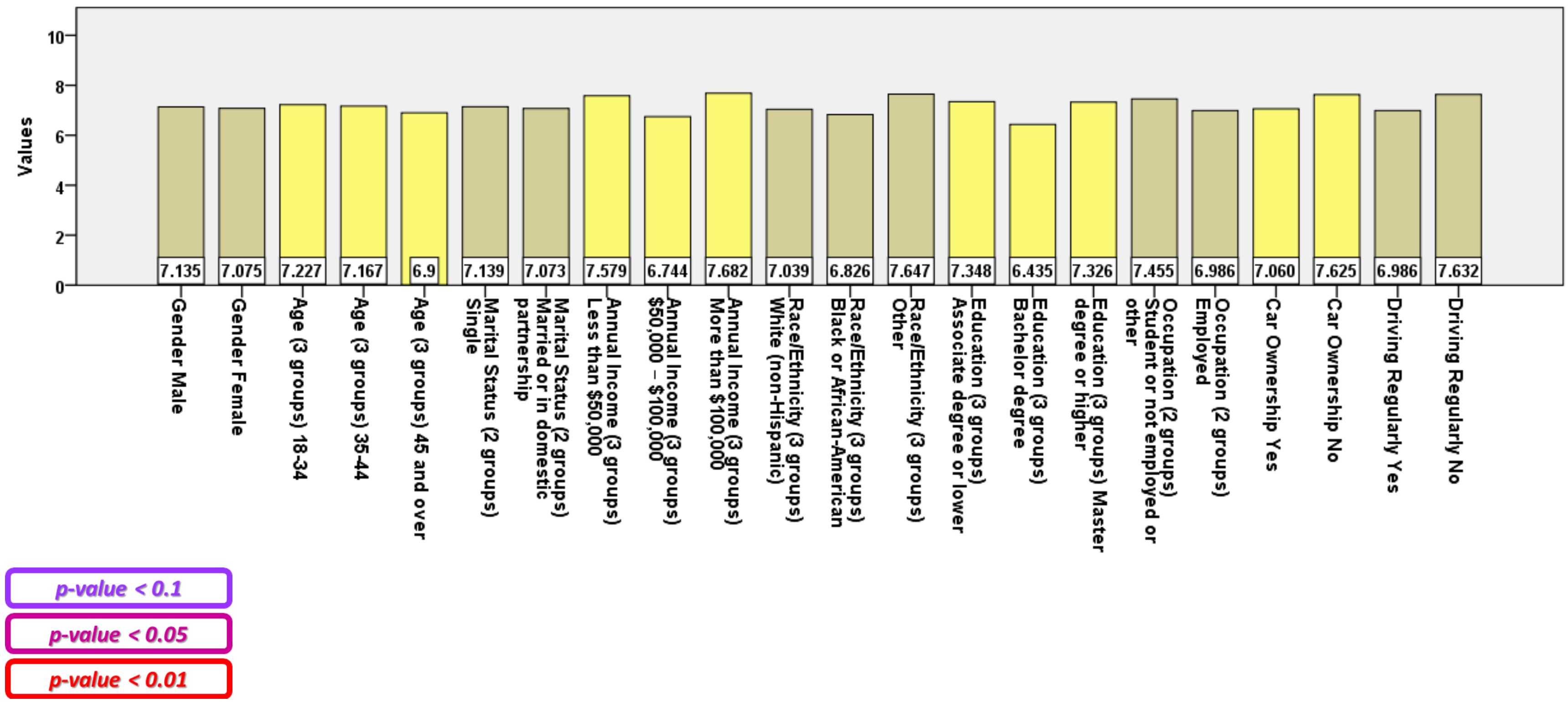


Figure 49. Average rating by participant characteristic for "Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

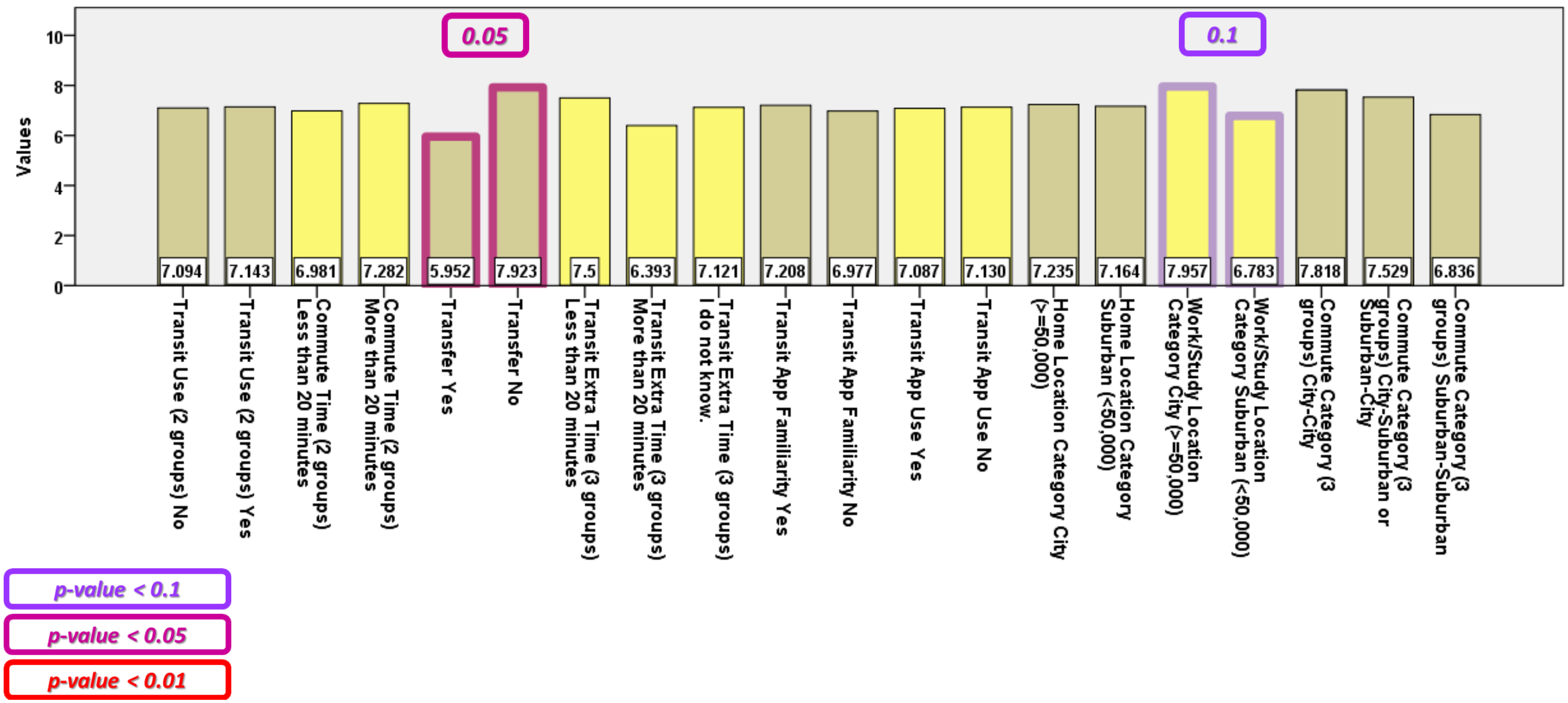


Figure 50. Average rating by participant characteristic for "Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q25. Can you recommend this type of mobile app for transit users?

The average rating for this question was 6.978. Figure 51 shows the distribution (in percent) of the ratings for this question. The average ratings range from 6.095 (for participants whose transit transfer was "Yes") to 8.538 (for participants whose transit transfer was "No"). Cohorts with significantly higher average ratings were as follows:

- Commute time: "More than 20 minutes" with an average rating of 7.615 ($p < 0.05$)
- Transit transfer: "No" with an average rating of 8.538 ($p < 0.01$)

Figure 52 and Figure 53 depict average ratings by participant characteristic cohorts.

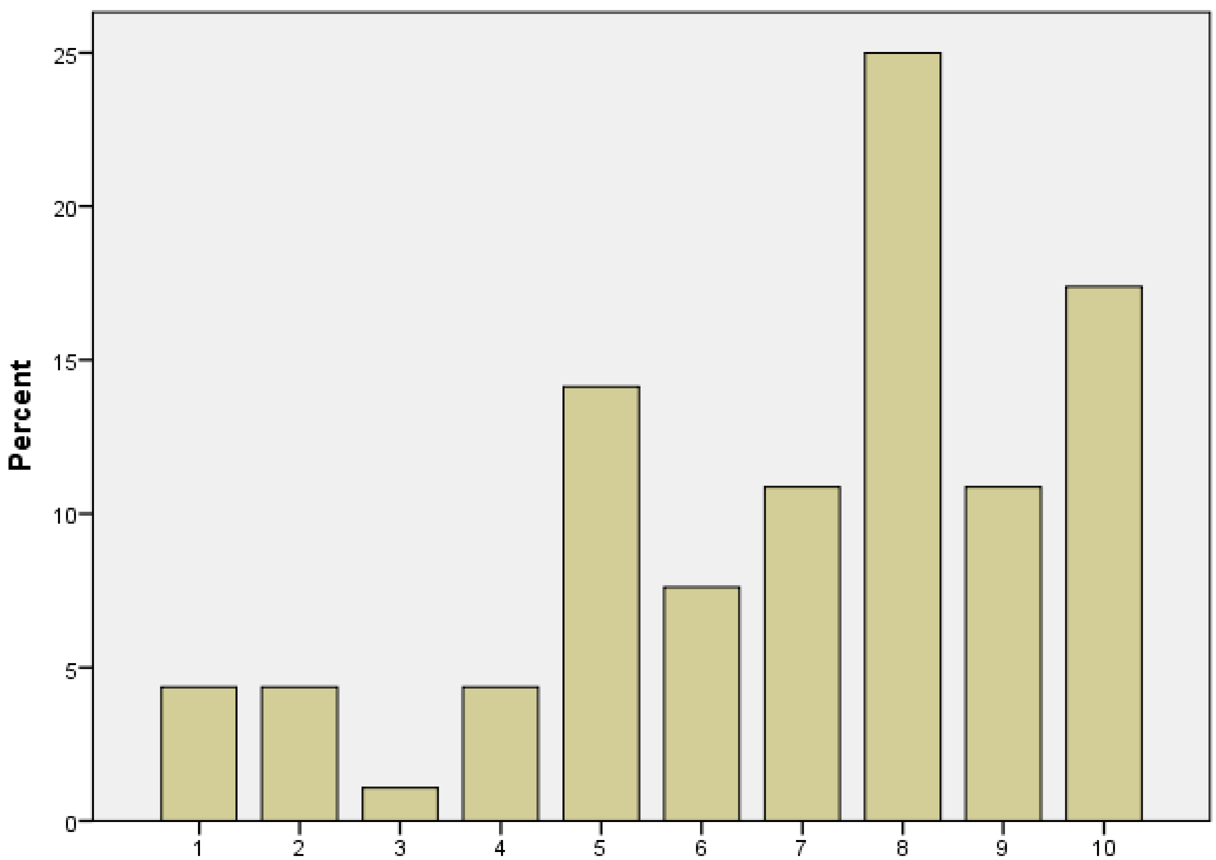


Figure 51. Distribution of ratings for "Q25. Can you recommend this type of mobile app for transit users?"

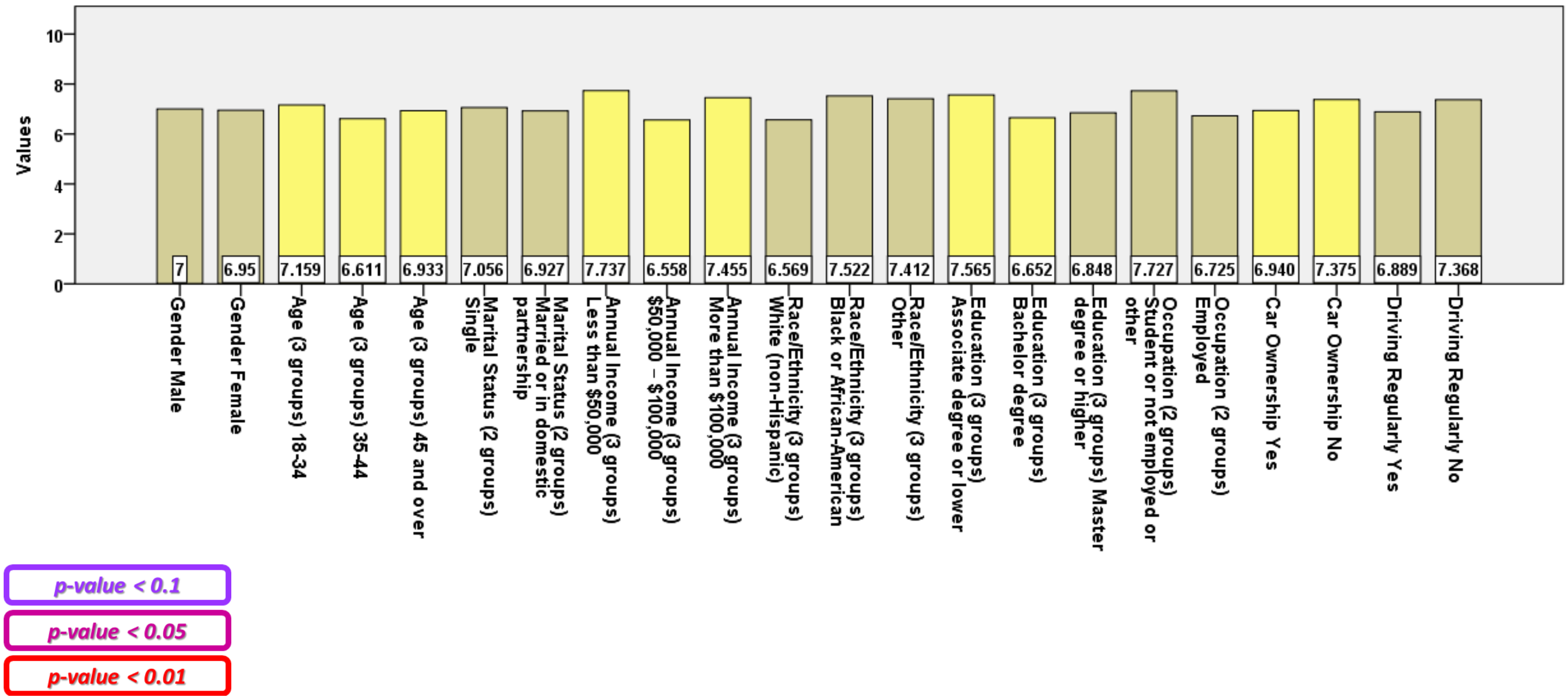


Figure 52. Average rating by participant characteristic for "Q25. Can you recommend this type of mobile app for transit users?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

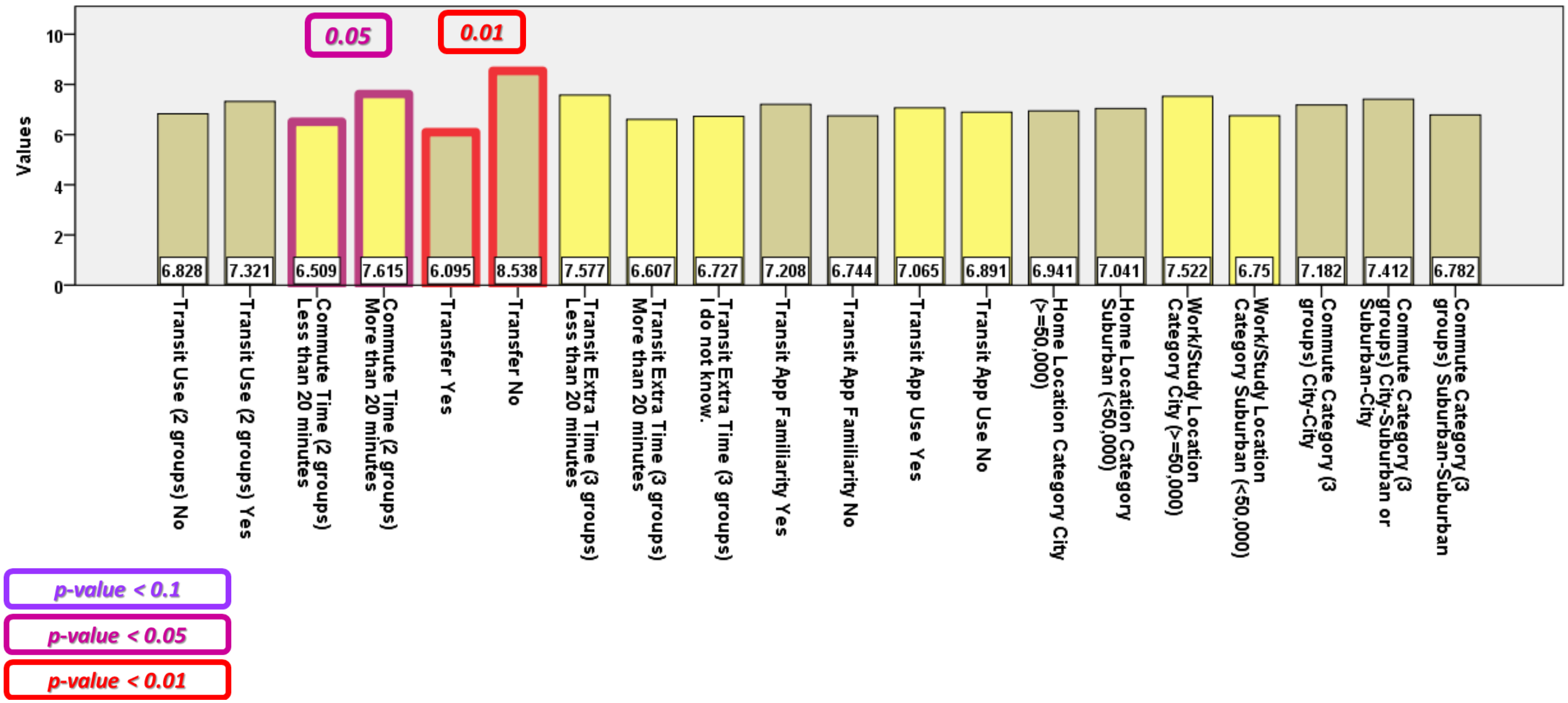


Figure 53. Average rating by participant characteristic for "Q25. Can you recommend this type of mobile app for transit users?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q26. Are you willing to use the app and flexible transit service, if it can meet your need?

The average rating for this question was 7.489. Figure 54 shows the distribution (in percent) of the ratings for this question. The average ratings range from 6.909 (for participants whose transit extra time was "I do not know") to 8.769 (for participants whose transit transfer was "No"). There were five cohorts with significantly higher average ratings for this question, which put it on top of the list with "Q21. Do you think this transit app can improve safety on the university campus?" The cohorts were as follows:

- Annual income: "More than $100,000" with an average rating of 8.227 ($p < 0.1$)
- Driving Pattern (Regularly): "No" with an average rating of 8.474 ($p < 0.05$)
- Transit use: "Yes" with an average rating of 8.143 ($p < 0.1$)
- Transit transfer: "No" with an average rating of 8.769 ($p < 0.1$)
- Transit extra time: "Less than 20 minutes" with an average rating of 8.423 ($p < 0.05$)

Figure 55 and Figure 56 depict average ratings by participant characteristic cohorts.

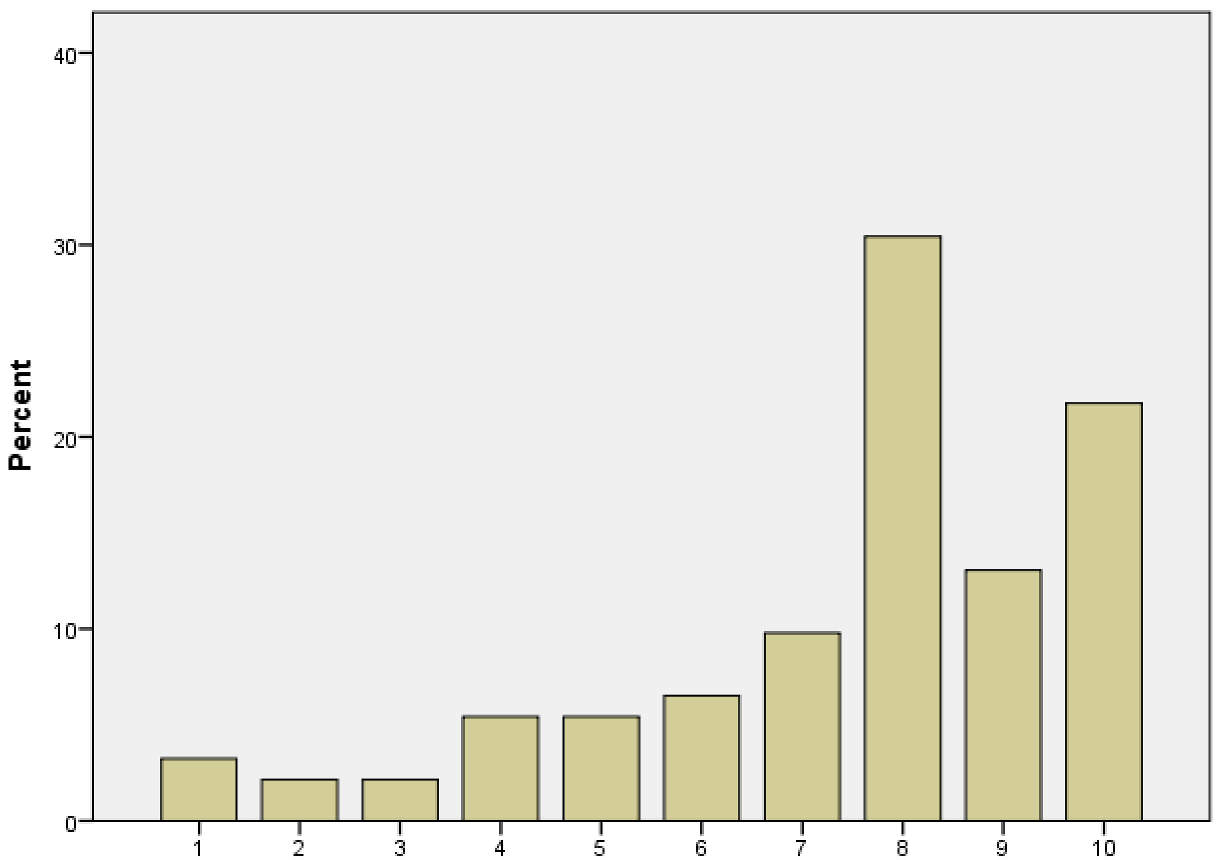


Figure 54. Distribution of ratings for "Q26. Are you willing to use the app and flexible transit service, if it can meet your need?"

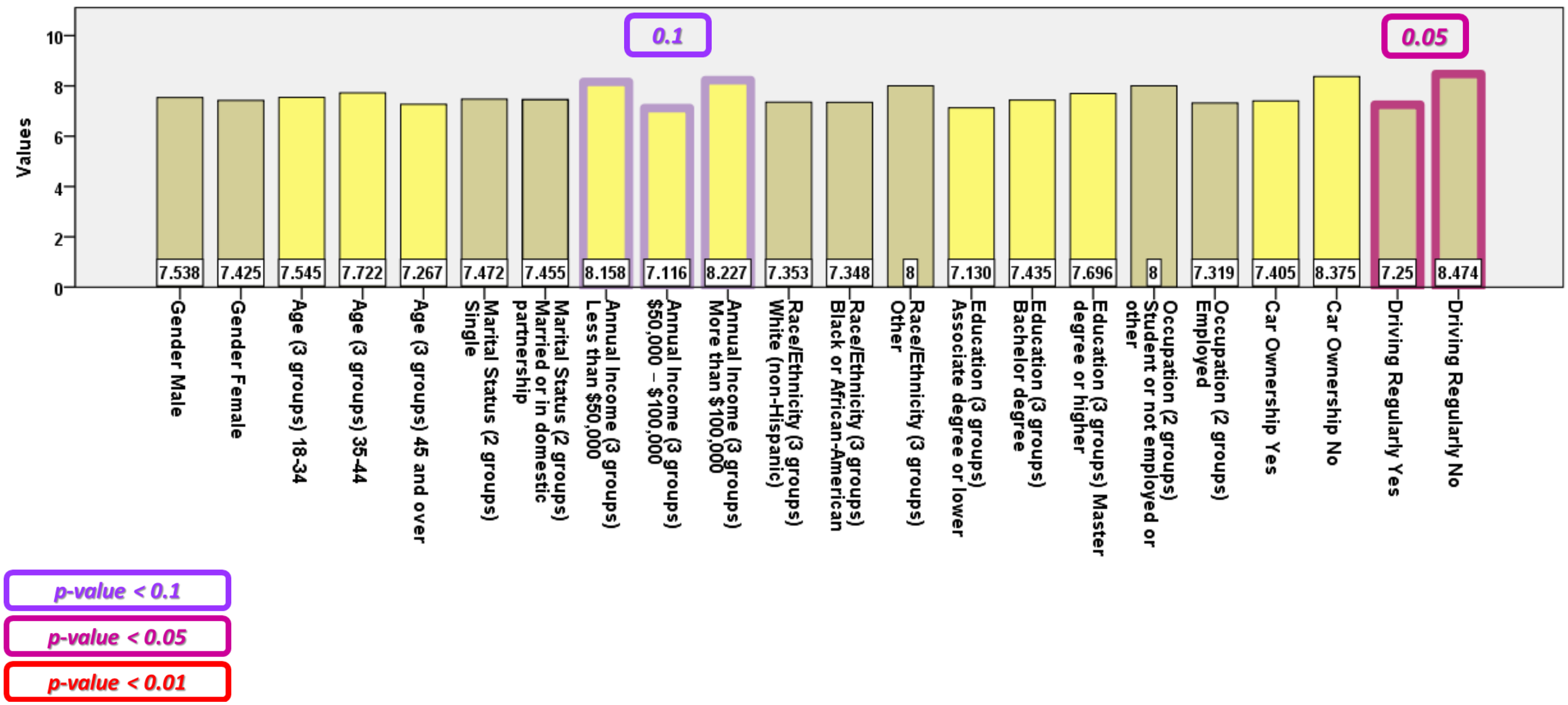


Figure 55. Average rating by participant characteristic for "Q26. Are you willing to use the app and flexible transit service, if it can meet your need?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

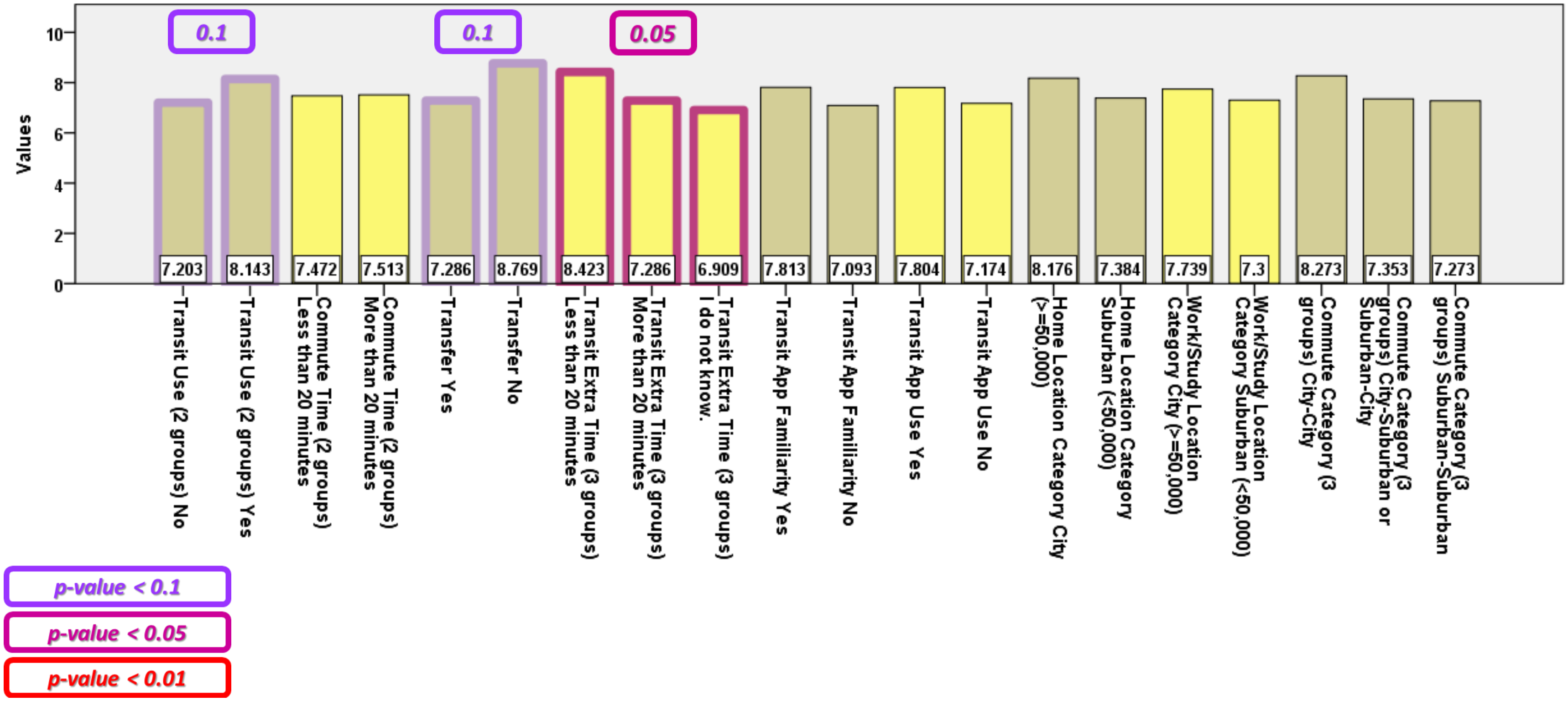


Figure 56. Average rating by participant characteristic for "Q26. Are you willing to use the app and flexible transit service, if it can meet your need?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Q27. Do you think this transit app can increase transit ridership?

The average rating for this question was 7.261. Figure 57 shows the distribution (in percent) of the ratings to this question.

The average ratings range from 6.824 (for participants whose commute category type was "City-Suburban or Suburban-City") to 8 (for participants whose car ownership was "No"). There were no cohorts with significantly higher average ratings.

Figure 58 and Figure 59 depict average ratings by participant characteristic cohorts.

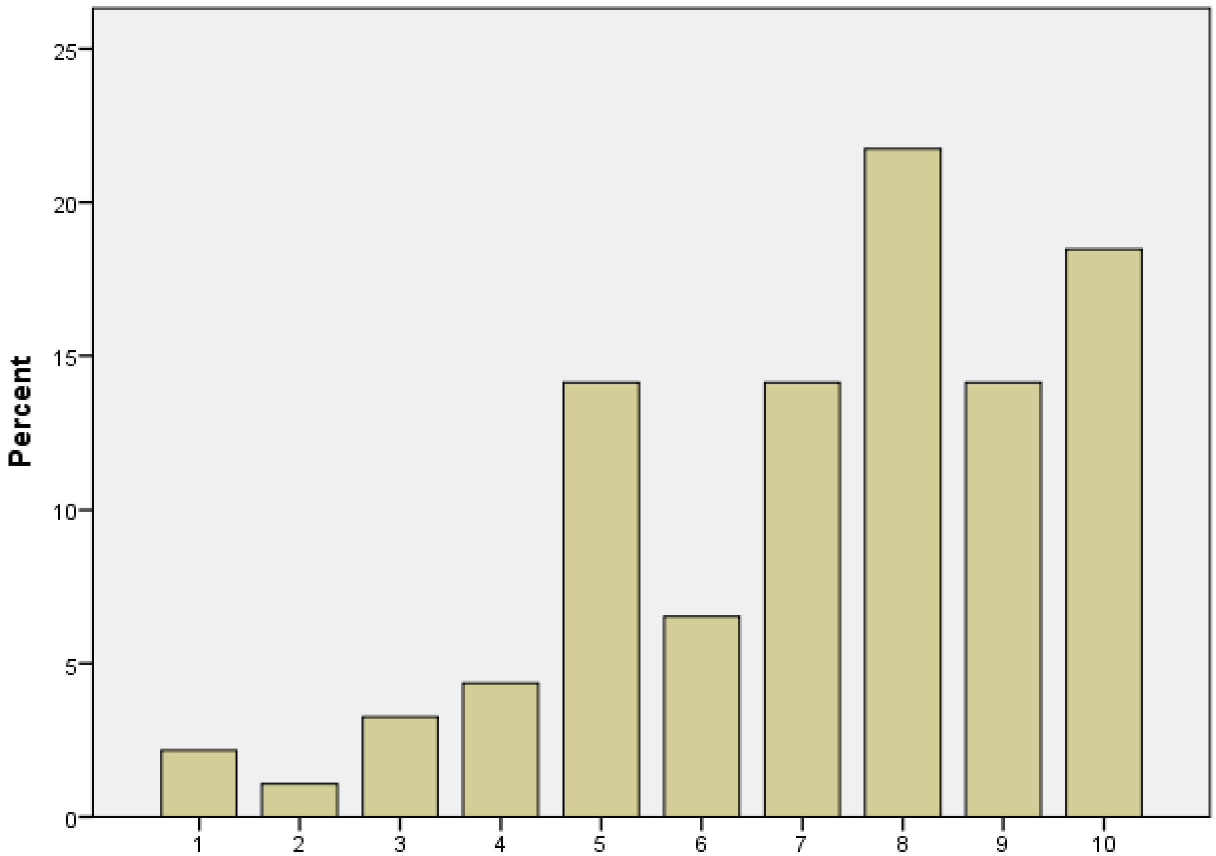


Figure 57. Distribution of ratings for "Q27. Do you think this transit app can increase transit ridership?"

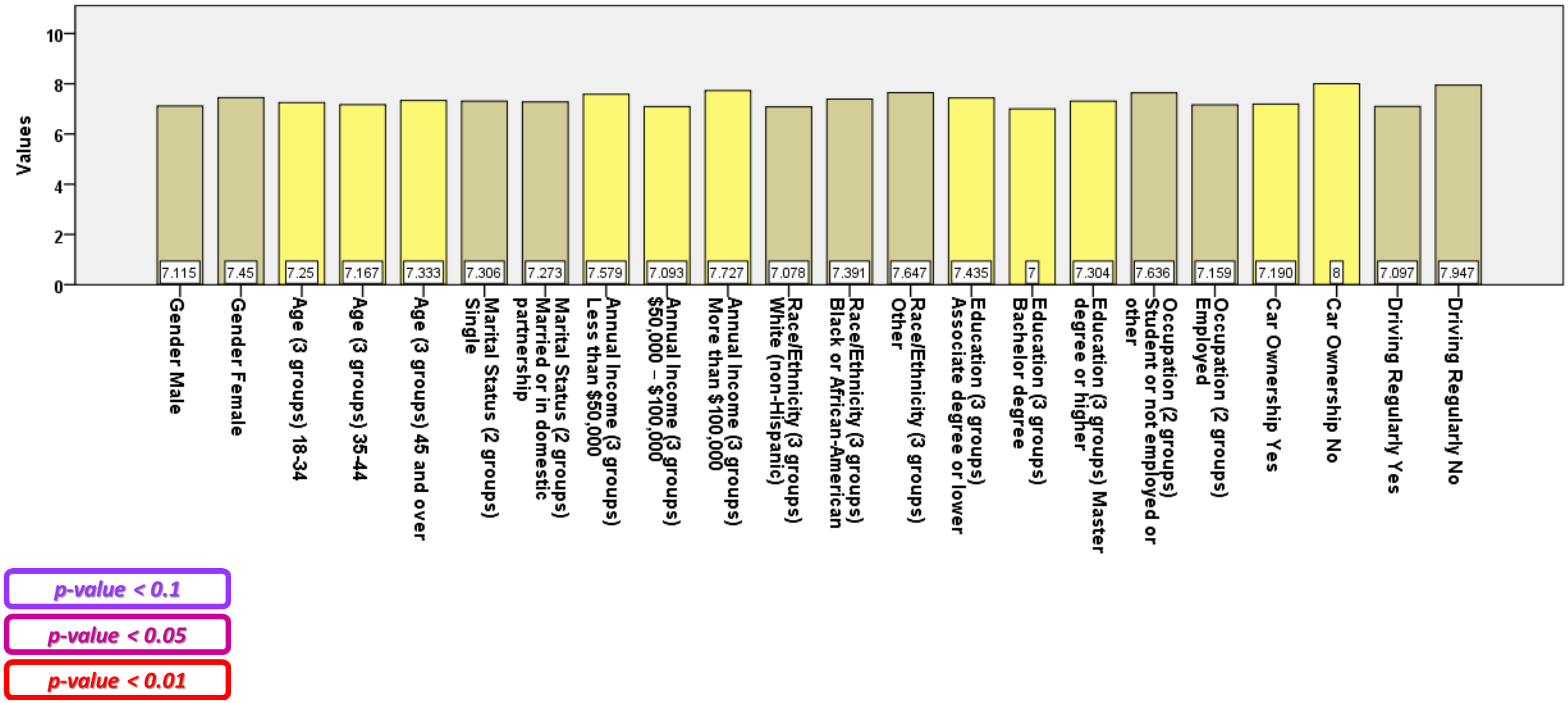


Figure 58. Average rating by participant characteristic for "Q27. Do you think this transit app can increase transit ridership?" (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

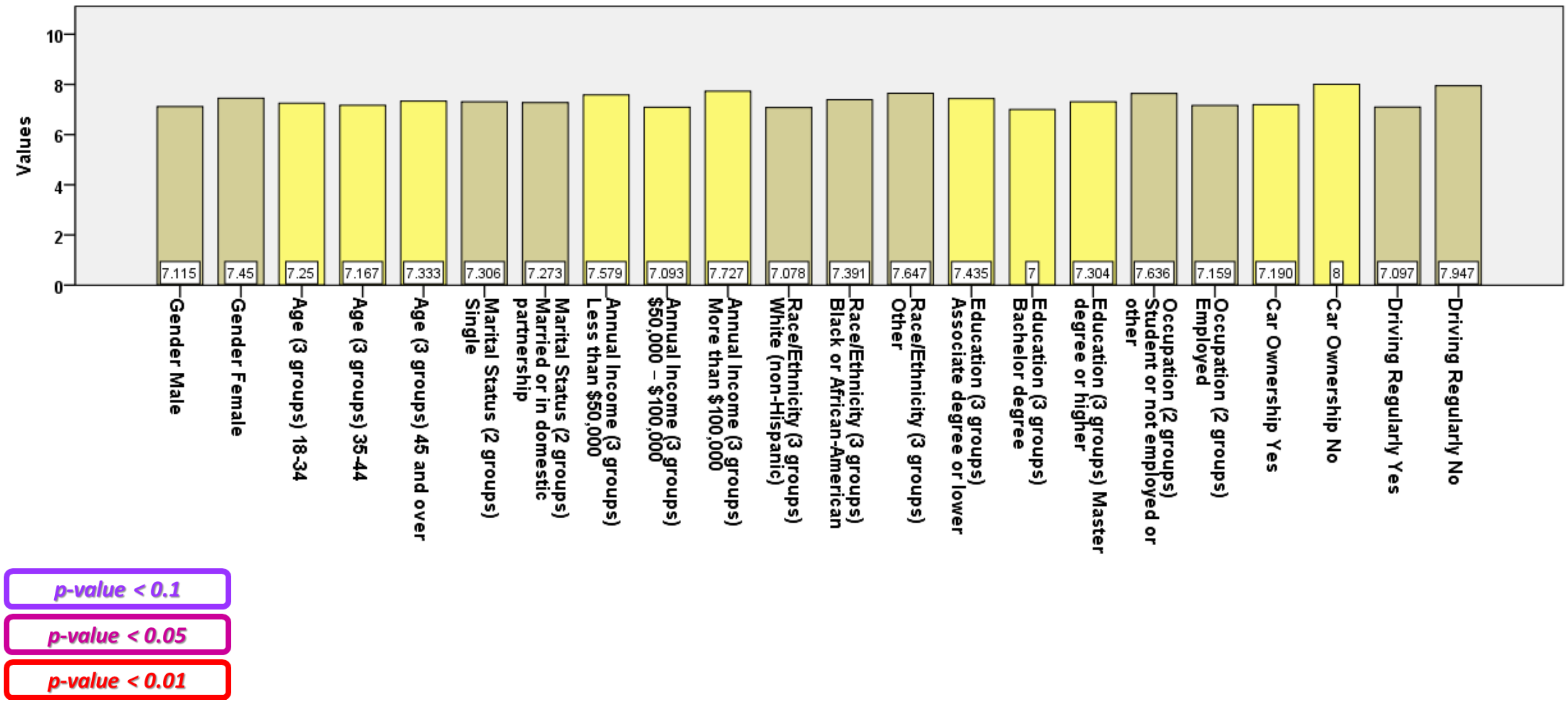


Figure 59. Average rating by participant characteristics for "Q27. Do you think this transit app can increase transit ridership?" (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Comparison of App-related Questions

Table 23 shows the sorted (from maximum to minimum) average ratings for nine different app-related questions (cohort-based); the table also shows the minimum and maximum average ratings by a particular cohort (which vary for different app-related questions). Figure 60 shows a bar chart of the values in the table. "*Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?*" had the highest average rating (7.804), and "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" had the lowest value (6.370). A *t*-test revealed that there was a significant difference between the average value of Q22 (M = 7.80, SD = 2.007) and the average value of Q19 (M = 6.37, SD = 2.310), t (91) = −6.694, $p < 0.001$.

Table 23. Comparison of Cohort-Based Average, Minimum, and Maximum Values of App-Related Questions

Question	Average (Sorted)	Min.	Max.
Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?	7.804	6.909	8.389
Q23. Do you think this transit app can be used for school bus operation?	7.511	6.818	8.625
Q26. Are you willing to use the app and flexible transit service, if it can meet your need?	7.489	6.909	8.769
Q27. Do you think this transit app can increase transit ridership?	7.261	6.824	8.000
Q20. Do you think this transit app makes for a safer transit experience at night?	7.250	6.767	8.750
Average	***7.190***	-	-
Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?	7.109	5.952	7.957
Q25. Can you recommend this type of mobile app for transit users?	6.978	6.095	8.538
Q21. Do you think this transit app can improve safety on the university campus?	6.978	6.413	8.125
Q19. Do you think this transit app makes for a safer transit experience during the daytime?	6.370	5.604	7.410

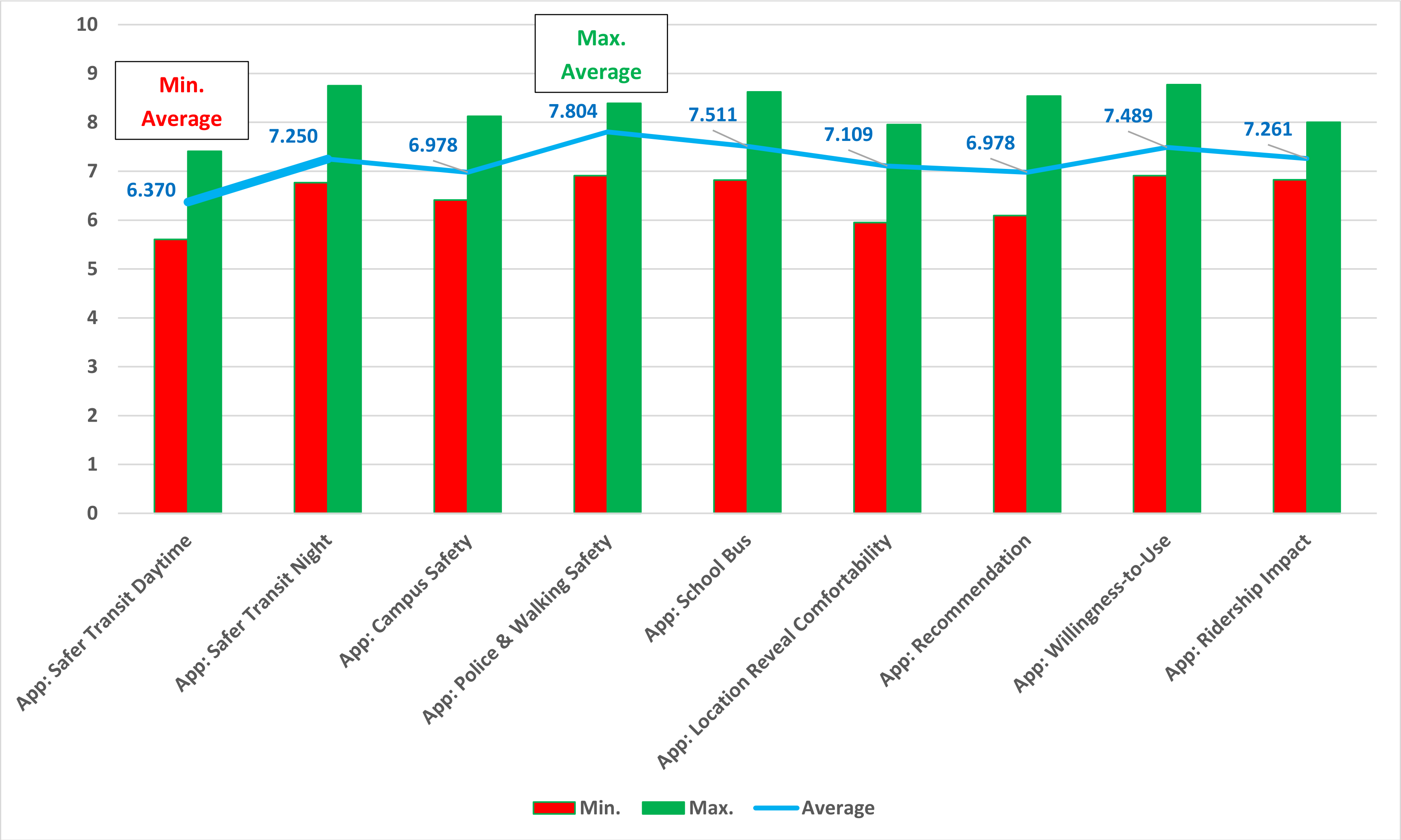


Figure 60. Comparison of cohort-based average, min., & max. of app-related questions.

Combined Ratings

The research team decided to combine some of the ratings of the nine app-related questions together and categorize them based on their similar attributes under either safety, efficiency, or privacy, as shown in Table 24. The unweighted total score was calculated as an average value of all app-related ratings.

Table 24. Combining Rating Scores

Question	Category			
	Safety	Efficiency	Privacy	Unweighted Total Score
Q19. Do you think this transit app makes for a safer transit experience during the daytime?	●			●
Q20. Do you think this transit app makes for a safer transit experience at night?	●			●
Q21. Do you think this transit app can improve safety on the university campus?	●			●
Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?	●			●
Q23. Do you think this transit app can be used for school bus operation?		●		●
Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?			●	●
Q25. Can you recommend this type of mobile app for transit users?	●	●	●	●
Q26. Are you willing to use the app and flexible transit service, if it can meet your need?	●	●	●	●
Q27. Do you think this transit app can increase transit ridership?	●	●	●	●

Combined Safety Attribute

The average rating for the combined safety attribute was 7.161. Figure 61 shows the distribution (in percent) of the average rating of this attribute. The average rating ranges from 6.728 (participants whose transit transfer was "Yes") to 7.982 (participants whose car ownership was "No"). Cohorts with significantly higher average ratings were as follows:

- Commute time: "More than 20 minutes" with an average rating of 7.652 ($p < 0.05$)
- Transit transfer: "No" with an average rating of 7.978 ($p < 0.1$)

Figure 62 and Figure 63 depict average ratings by participant characteristic cohorts for the combined safety attribute.

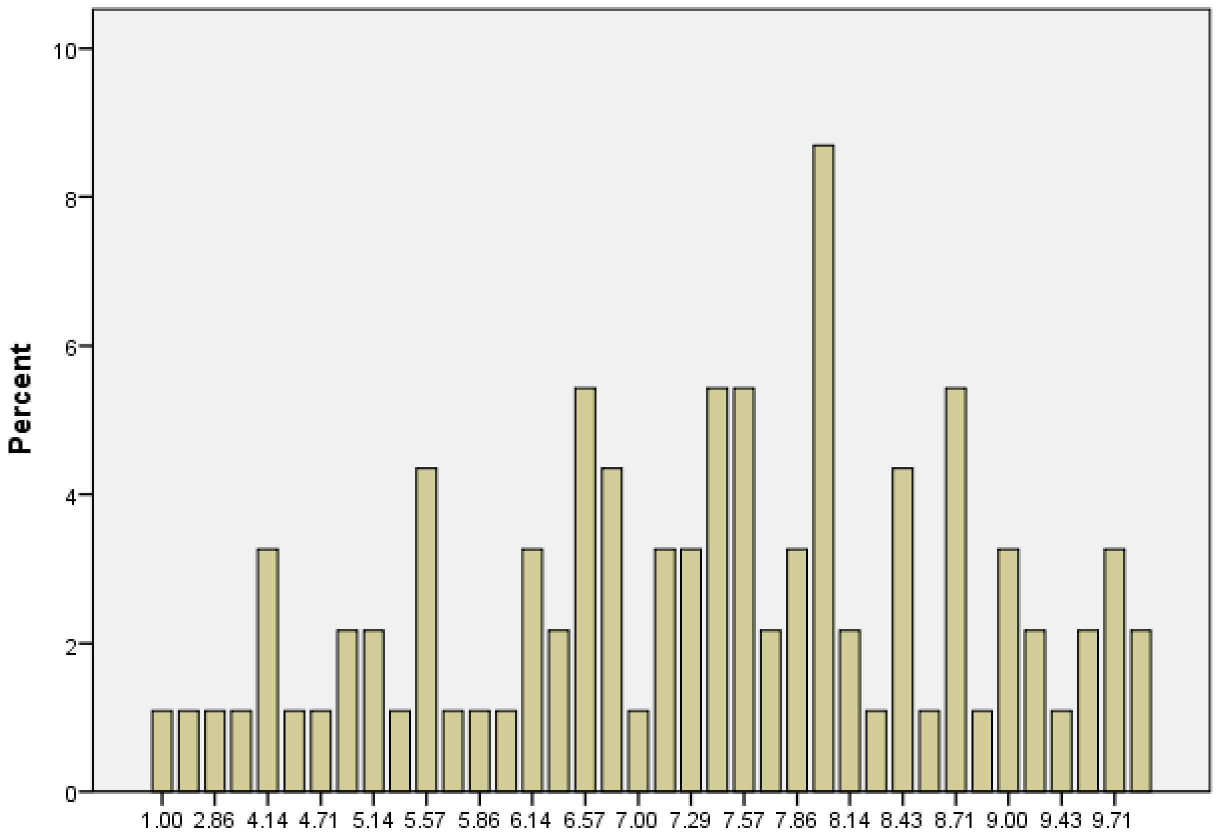


Figure 61. Distribution of average ratings for combined safety attribute.

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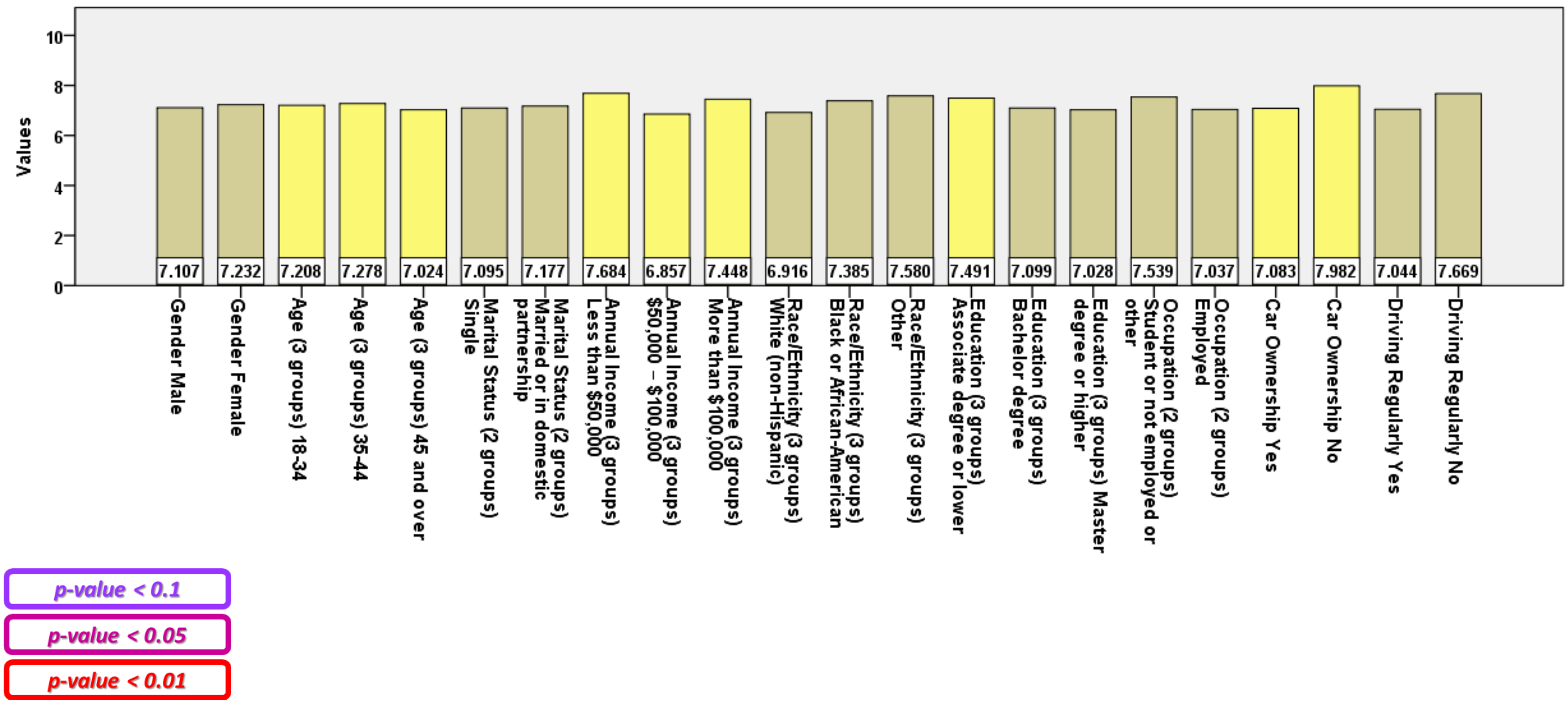

Figure 62. Average rating by participant characteristic for combined safety attribute (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

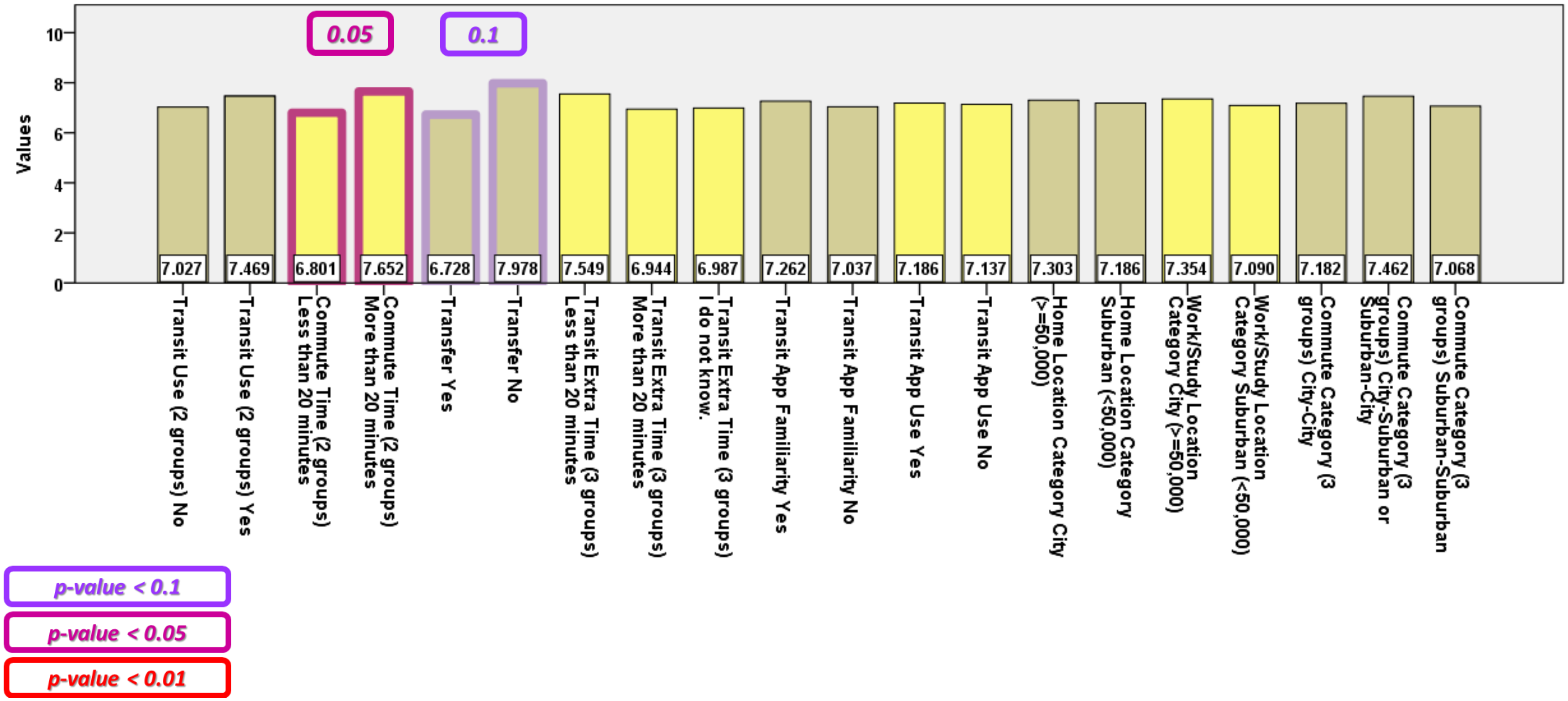

Figure 63. Average rating by participant characteristic for combined safety attribute (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Combined Efficiency Attribute

The average rating for the combined efficiency attribute was 7.310. Figure 64 shows the distribution (in percent) of the average ratings for this attribute. The average ratings range from 6.905 (participants whose transit transfer was "Yes") to 8.385 (participants whose transit transfer was "No"). Cohorts with significantly higher average ratings were as follows:

- Transit transfer: "No" with an average rating of 8.385 ($p < 0.05$)
- Transit extra time: "Less than 20 minutes" with an average rating of 7.942 ($p < 0.1$)

Figure 65 and Figure 66 depict average ratings by participant characteristic cohorts for this attribute.

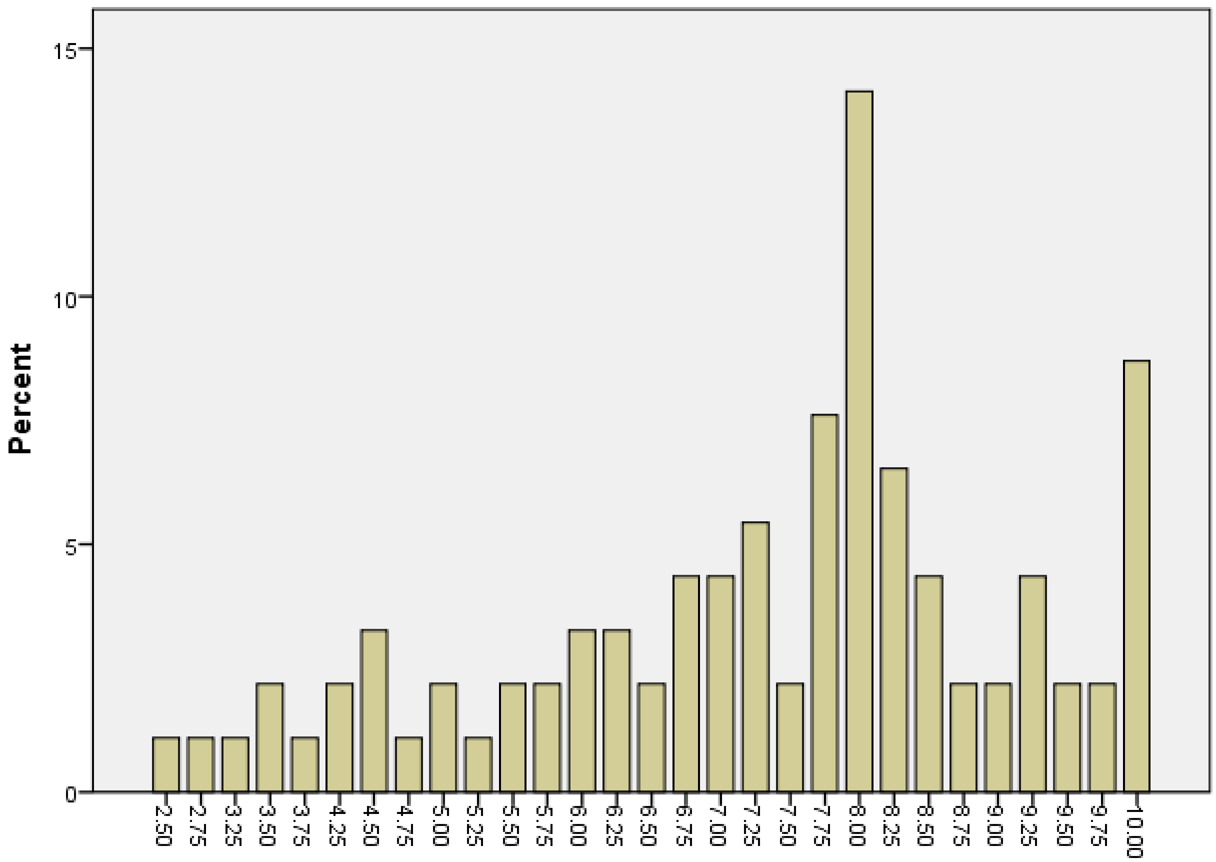

Figure 64. Distribution of average ratings for combined efficiency attribute.

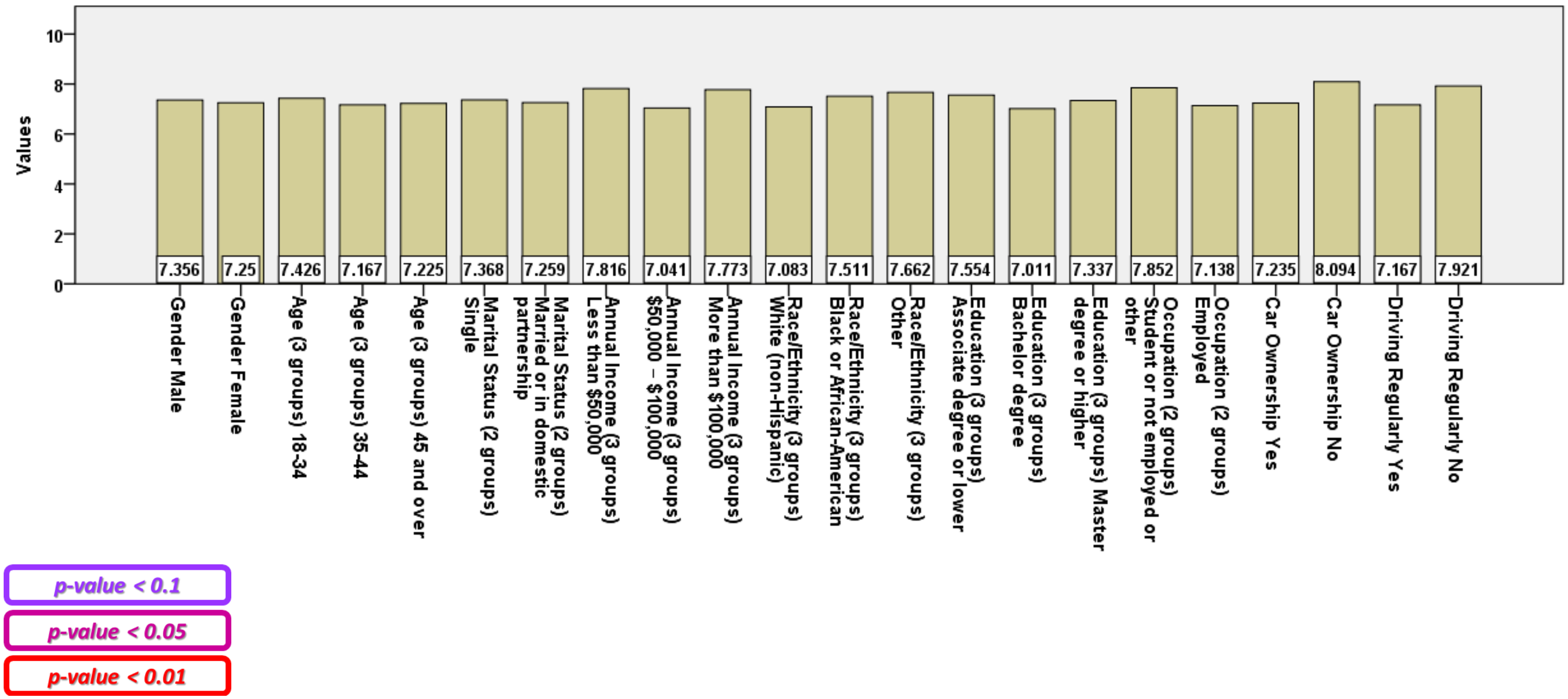

Figure 65. Average rating by participant characteristic for combined efficiency attribute (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

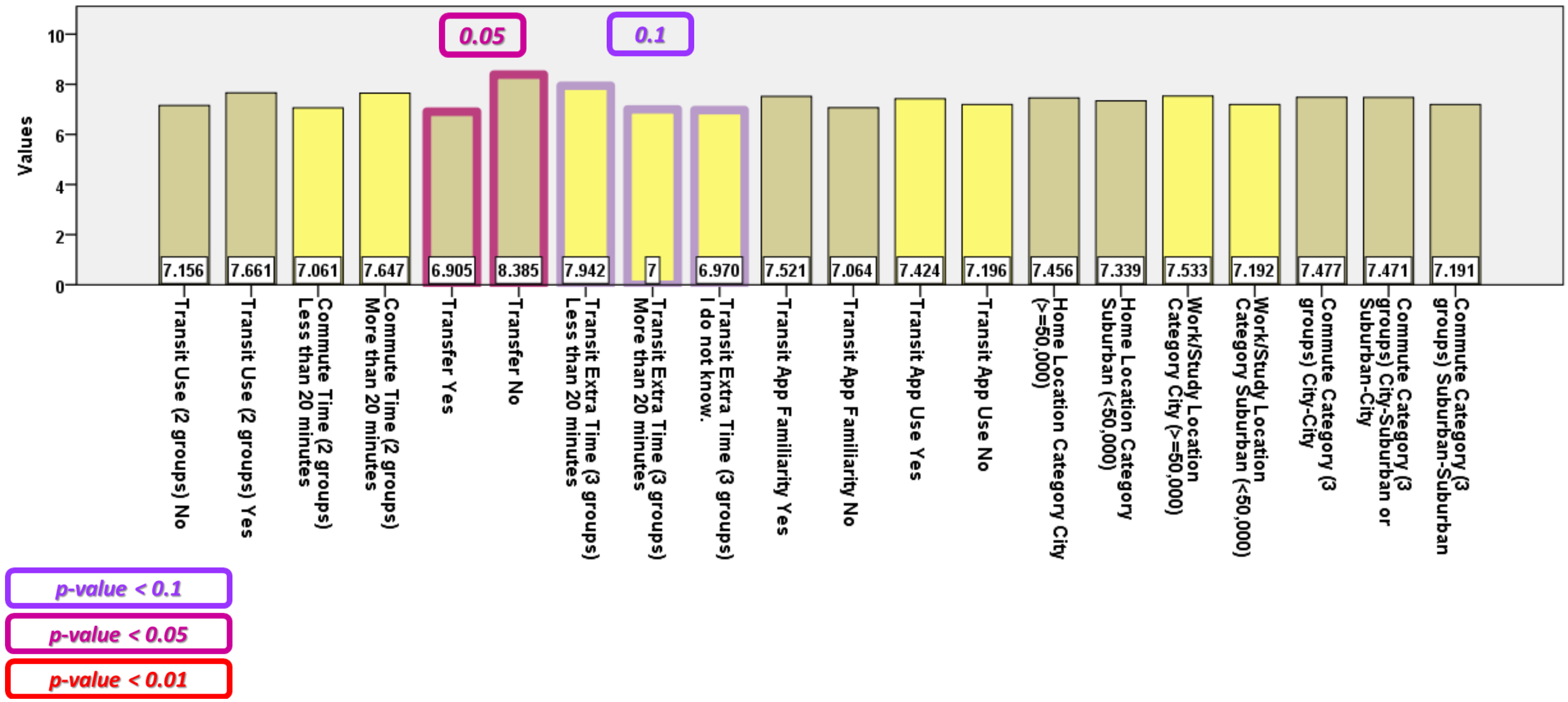

Figure 66. Average rating by participant characteristic for combined efficiency attribute (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Combined Privacy Attribute

The average rating for the combined privacy attribute was 7.290. Figure 67 shows the distribution (in percent) of the average ratings for this attribute. The average ratings range from 6.607 (participants whose transit transfer was "Yes") to 8.288 (participants whose transit transfer was "No"). The only cohort with a significantly higher average rating was as follows:

- Transit transfer: "No" with an average rating of 8.288 ($p < 0.05$)

Figure 68 and Figure 69 depict average ratings by participant characteristic cohorts for this attribute.

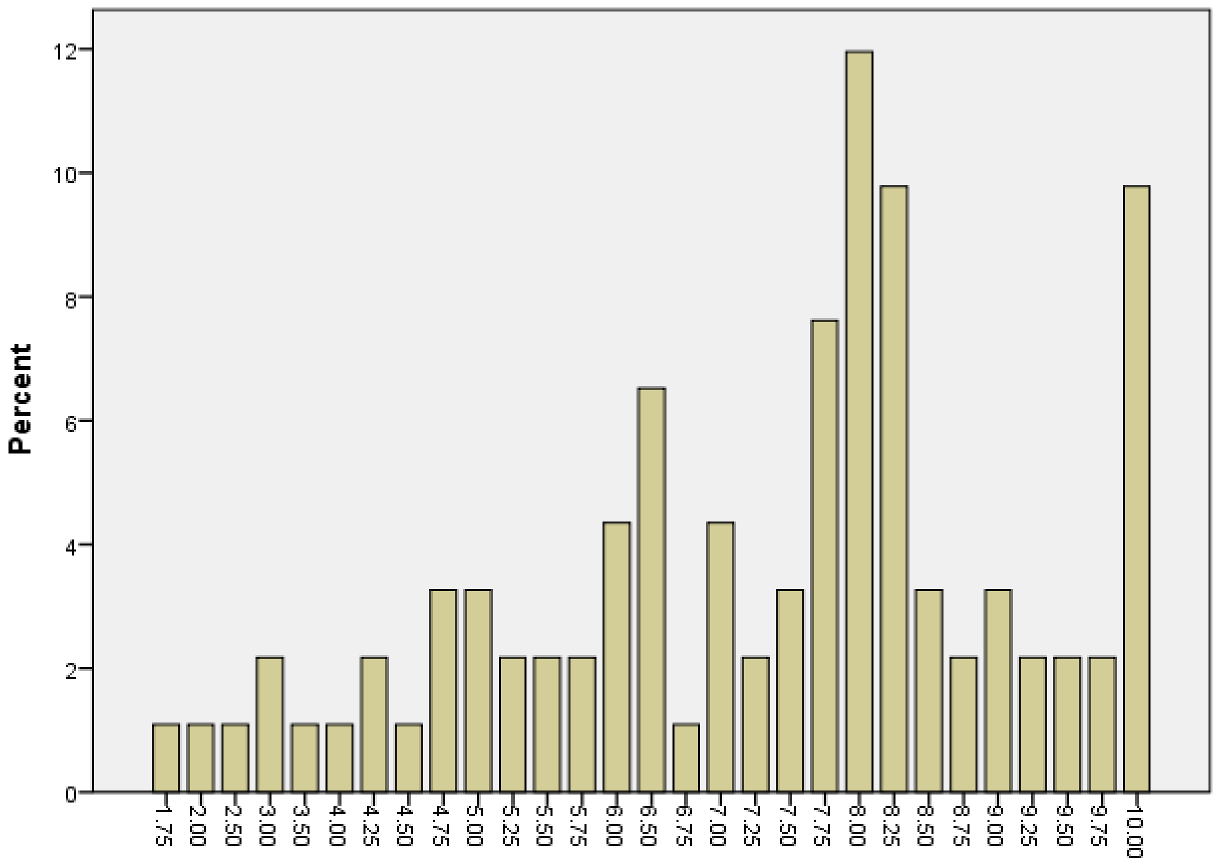

Figure 67. Distribution of average ratings for combined privacy attribute.

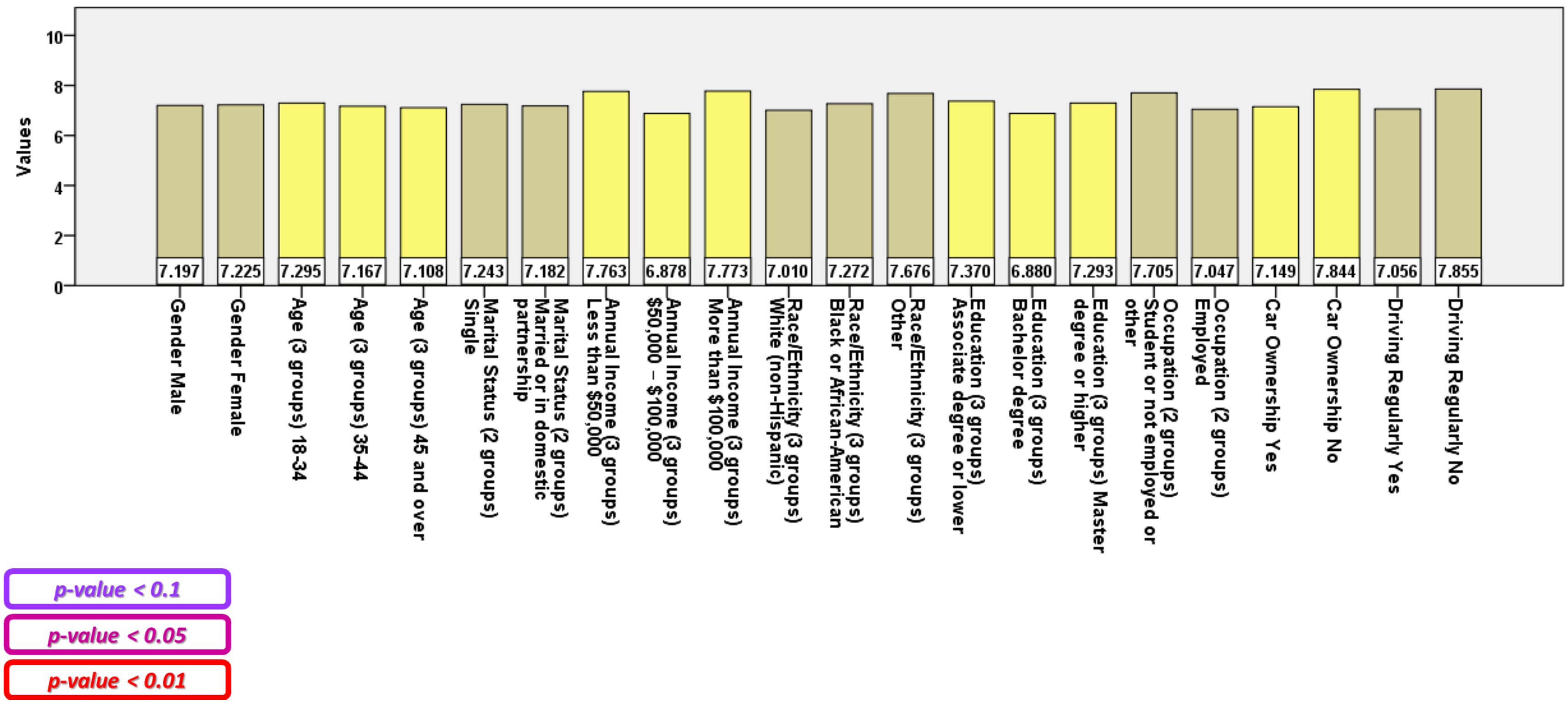

Figure 68. Average rating by participant characteristic for combined privacy attribute (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

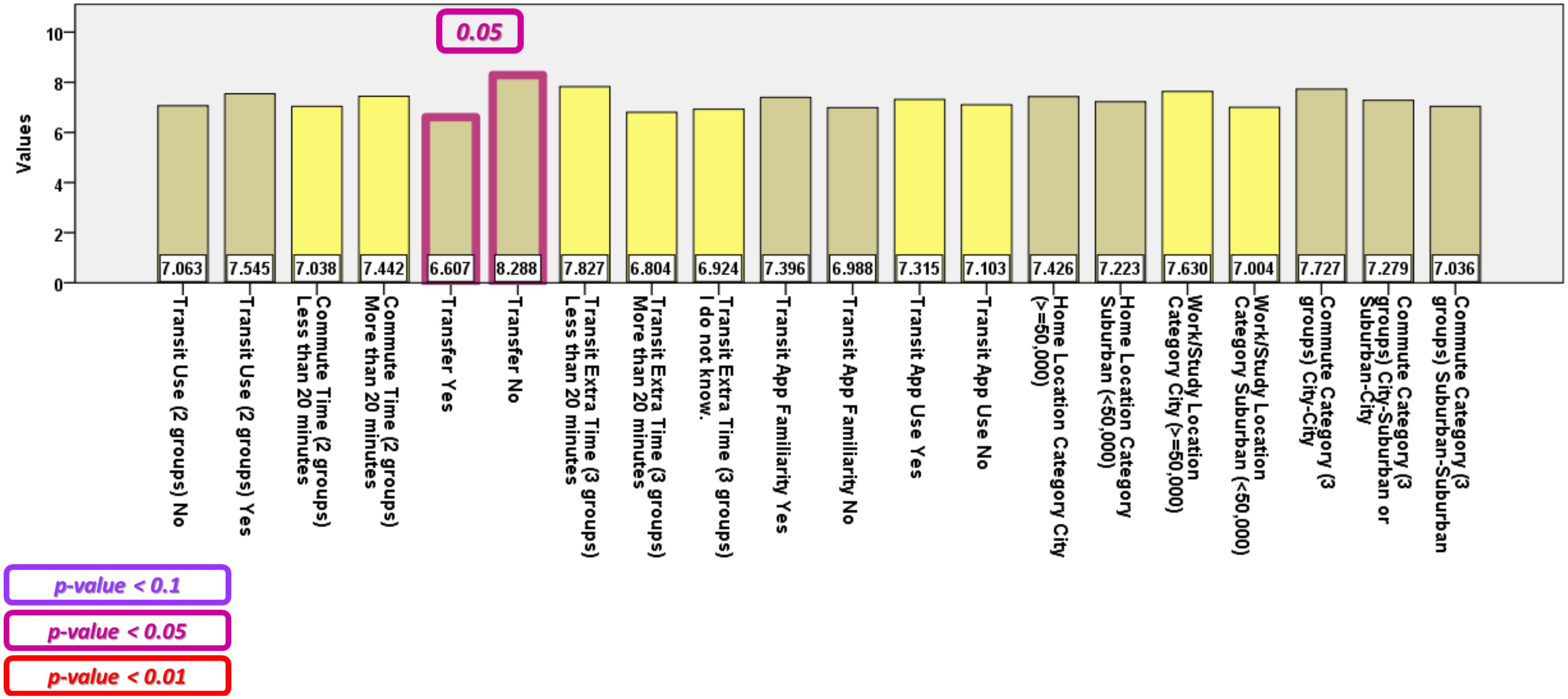

Figure 69. Average rating by participant characteristics for combined privacy attribute (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Unweighted Total Rating
The average rating for the unweighted total rating was 7.194. Figure 70 shows the distribution (in percent) of the average rating for this attribute. The average ratings range from 6.688 (participants whose transit transfer was "Yes") to 8.014 (participants whose car ownership was "No"). Cohorts with significantly higher average ratings were as follows:

- Commute time: "More than 20 minutes" with an average rating of 7.661 ($p < 0.05$)
- Transit transfer: "No" with an average rating of 8.009 ($p < 0.05$)

Figure 71 and Figure 72 depict average ratings by participant characteristic cohorts for this attribute.

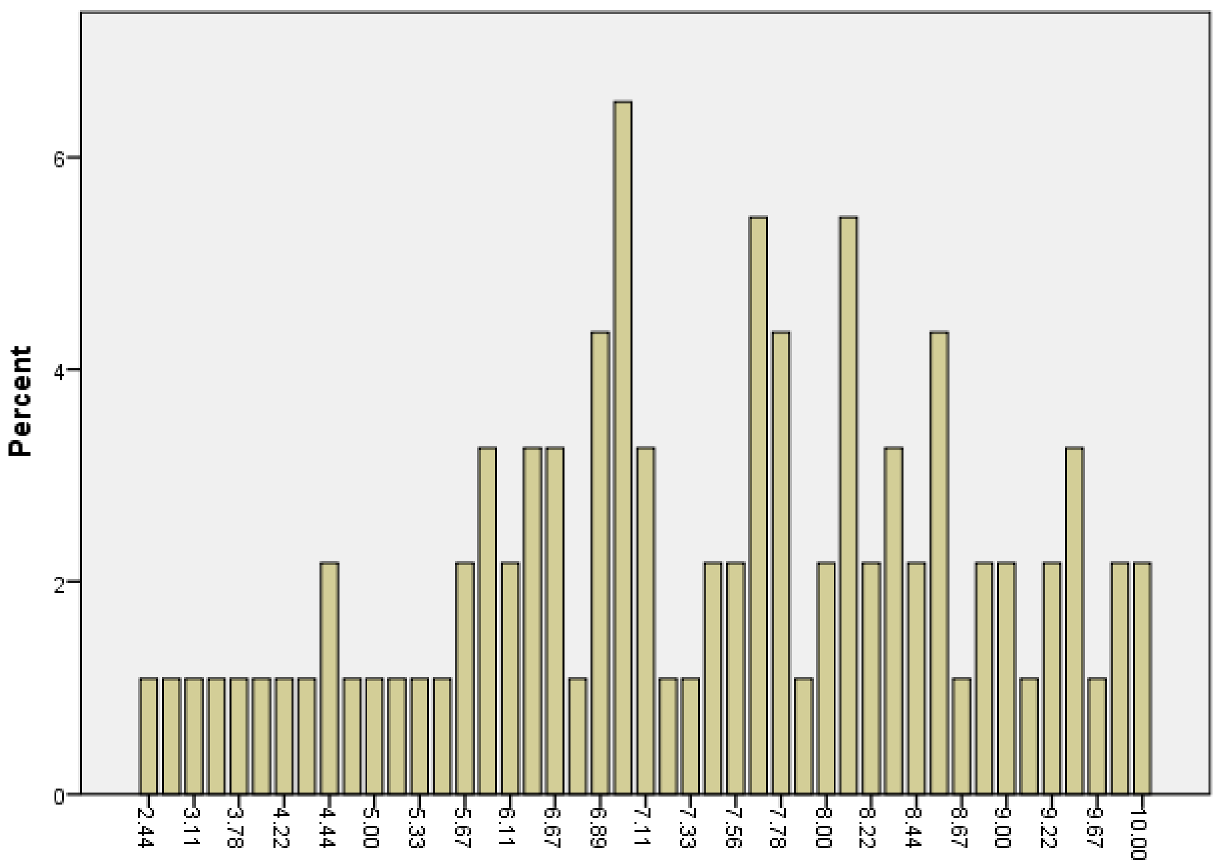

Figure 70**. Distribution of average ratings for unweighted total rating.**

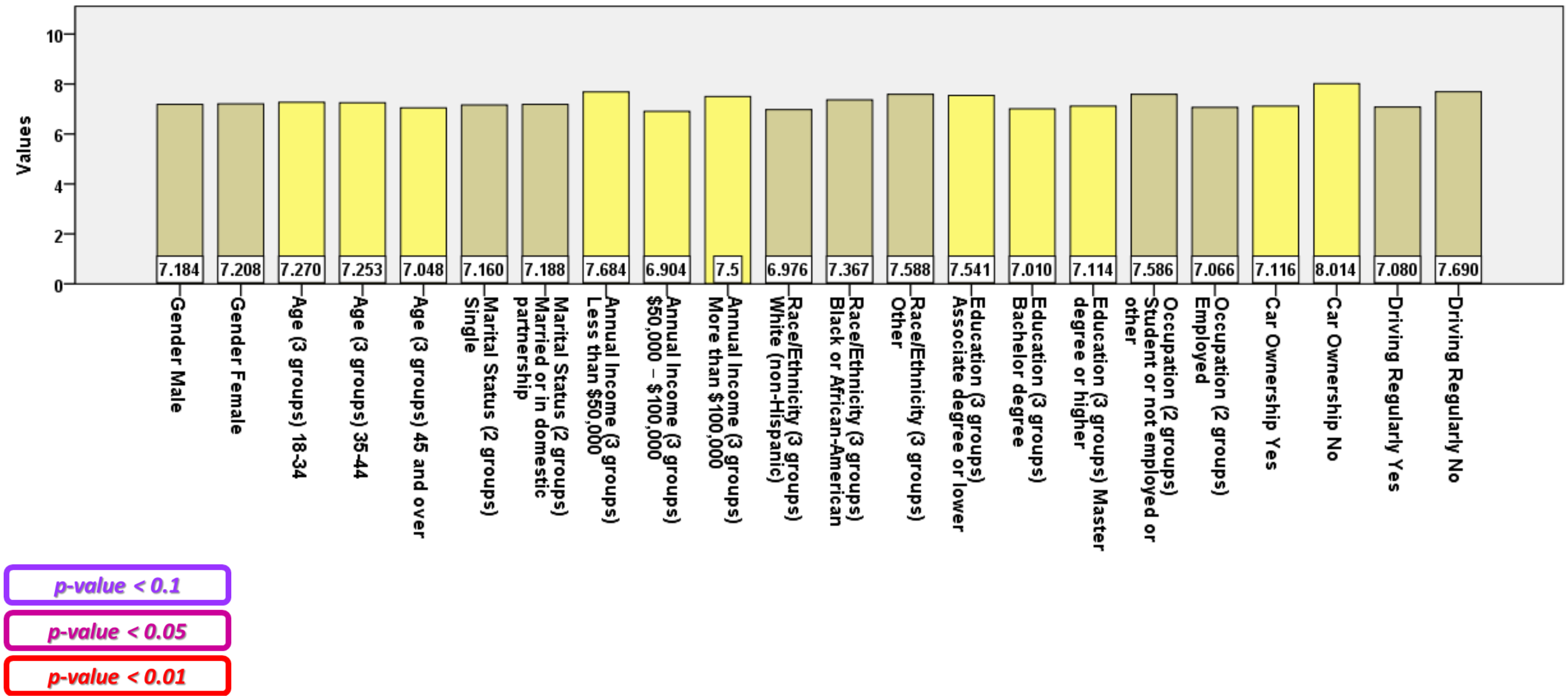

Figure 71. Average rating by participant characteristic for unweighted total rating (Part 1).

Notes:

- *From left to right*: Gender - Age - Marital Status - Annual Income - Race/Ethnicity - Education - Occupation - Car Ownership - Driving Pattern (Regularly)
- The two different bar colors are for easier distinction between variables only.

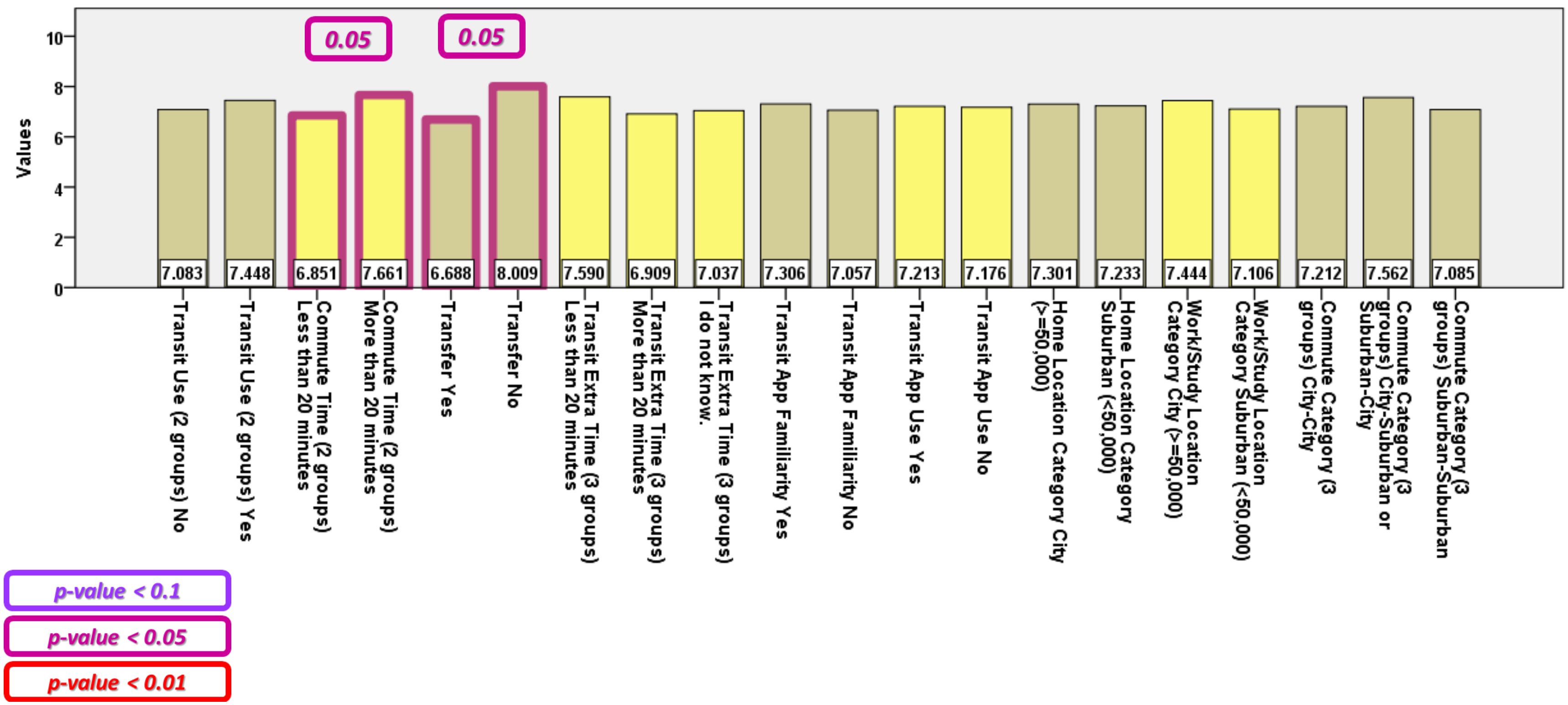

Figure 72. Average rating by participant characteristics for unweighted total rating (Part 2).

Notes:

- *From left to right*: Transit use - Commute time - Transfer - Transit extra time - Transit app familiarity - Transit app use - Home location category - Work/study location category - Commute category
- The two different bar colors are for easier distinction between variables only.

Analysis of Participant Characteristics

A series of individual analyses of participant characteristics was performed regarding the average ratings.

By Gender

Figure 73 and Figure 74 show app-related ratings and combined app-related ratings by gender, respectively. There was not a significant difference between males and females.

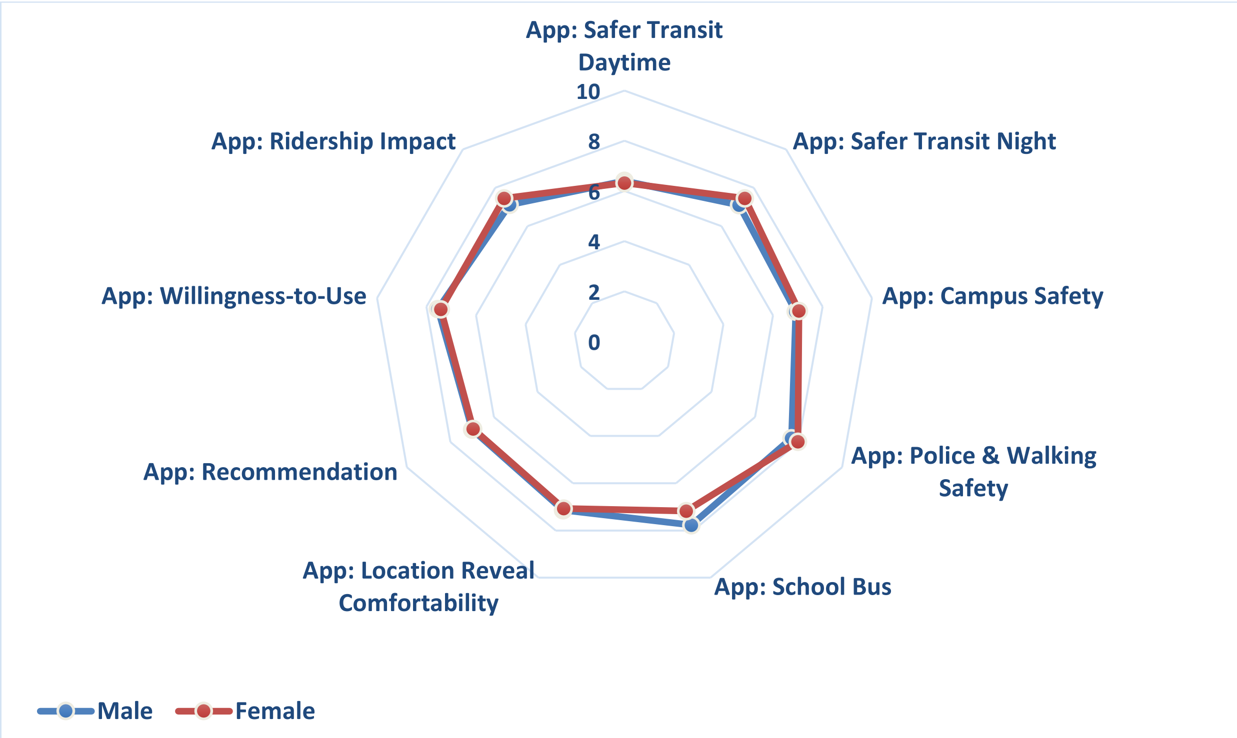

Figure 73. App-related ratings by gender.

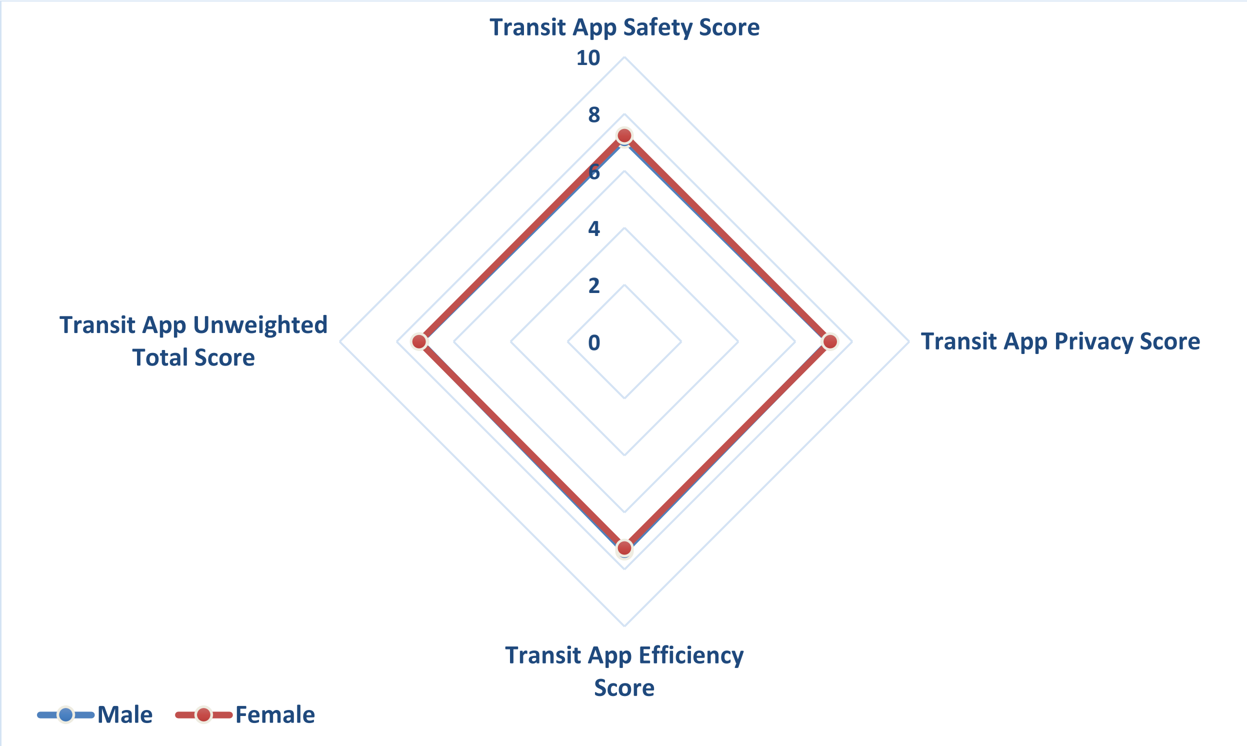

Figure 74. Combined app-related ratings by gender.

By Age

Figure 75 and Figure 76 show app-related ratings and combined app-related ratings by age, respectively. There was not a significant difference between different age cohorts; however, the age cohort of 45 and over had the lowest average rating of 6.767 for "*Q20. Do you think this transit app makes for a safer transit experience at night?*" The age cohort of 35–44 had the highest average rating of 8.389 for "*Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?*"

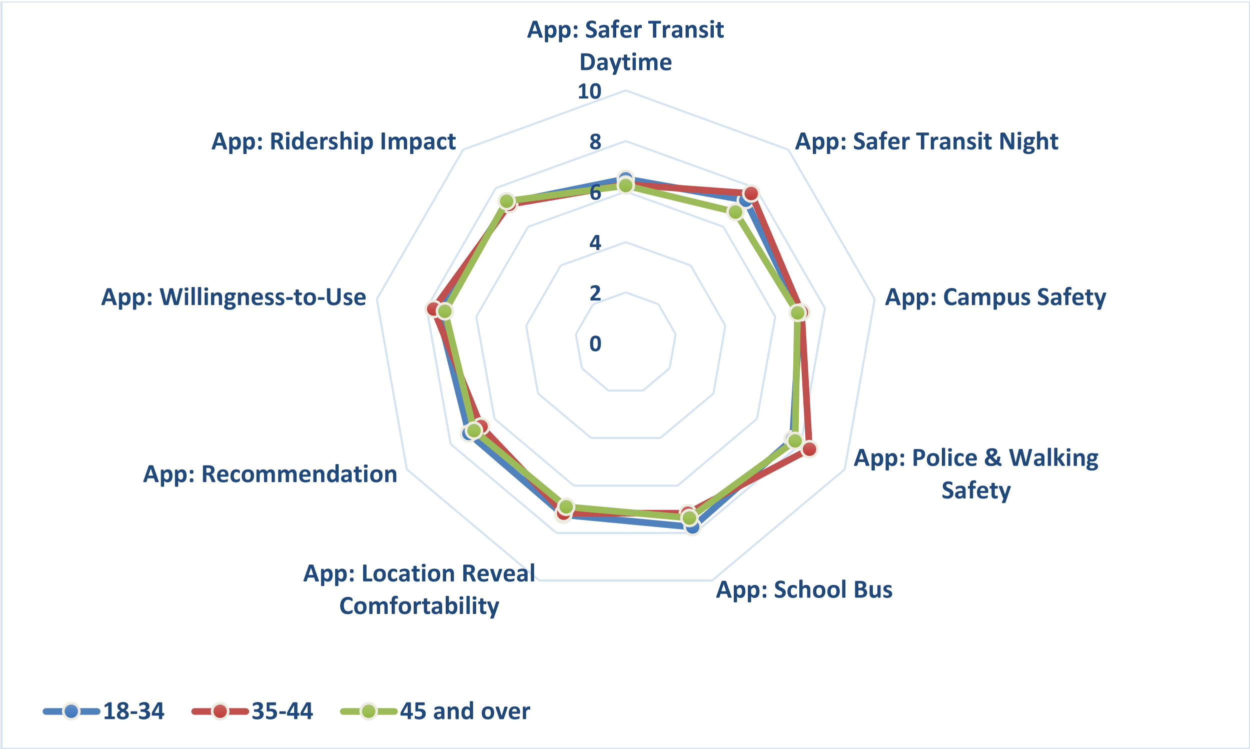

Figure 75. App-related ratings by age.

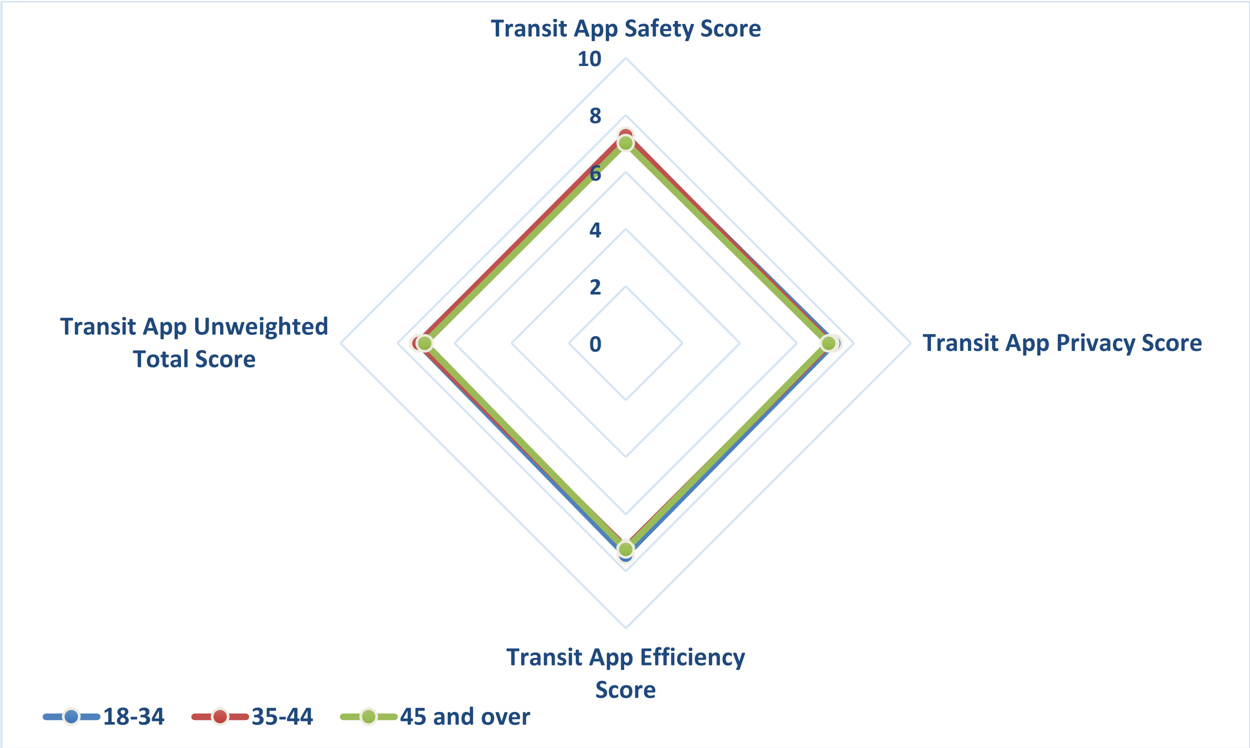

Figure 76. Combined app-related ratings by age.

By Marital Status

Figure 77 and Figure 78 show app-related ratings and combined app-related ratings by marital status, respectively. There was not a significant difference between single and married or in domestic partnership participants.

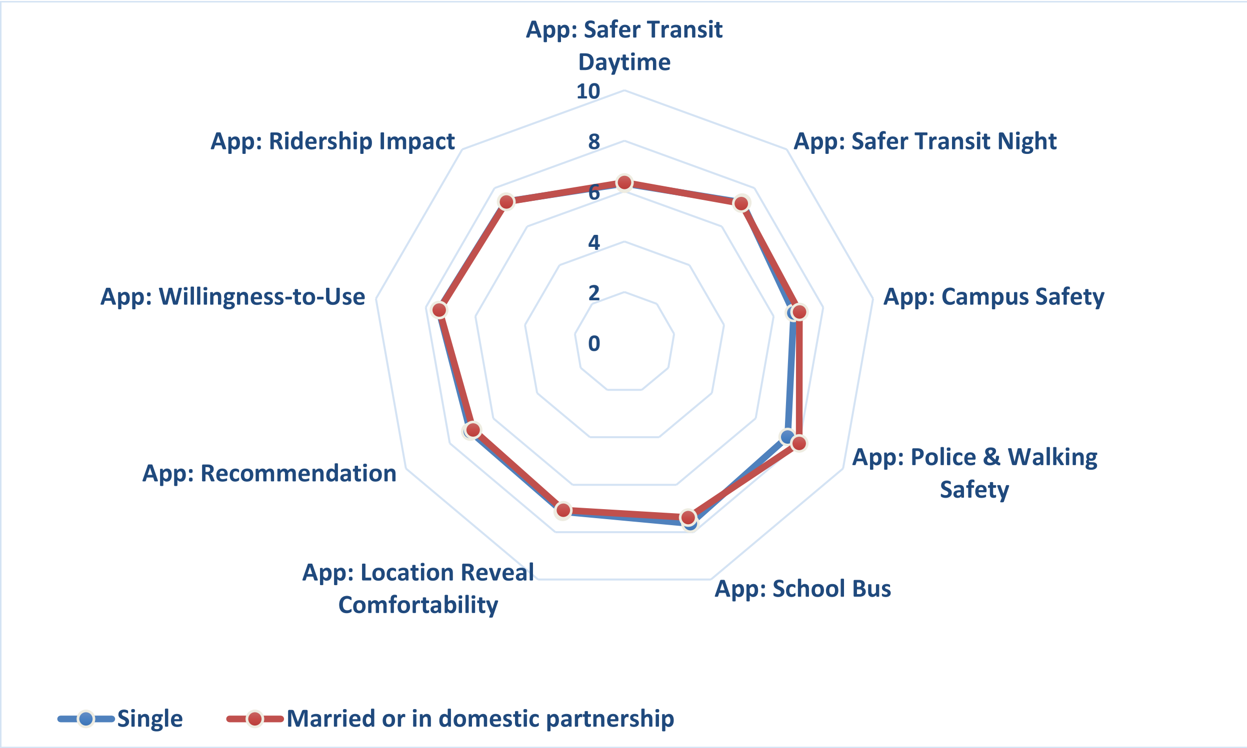

Figure 77. App-related ratings by marital status.

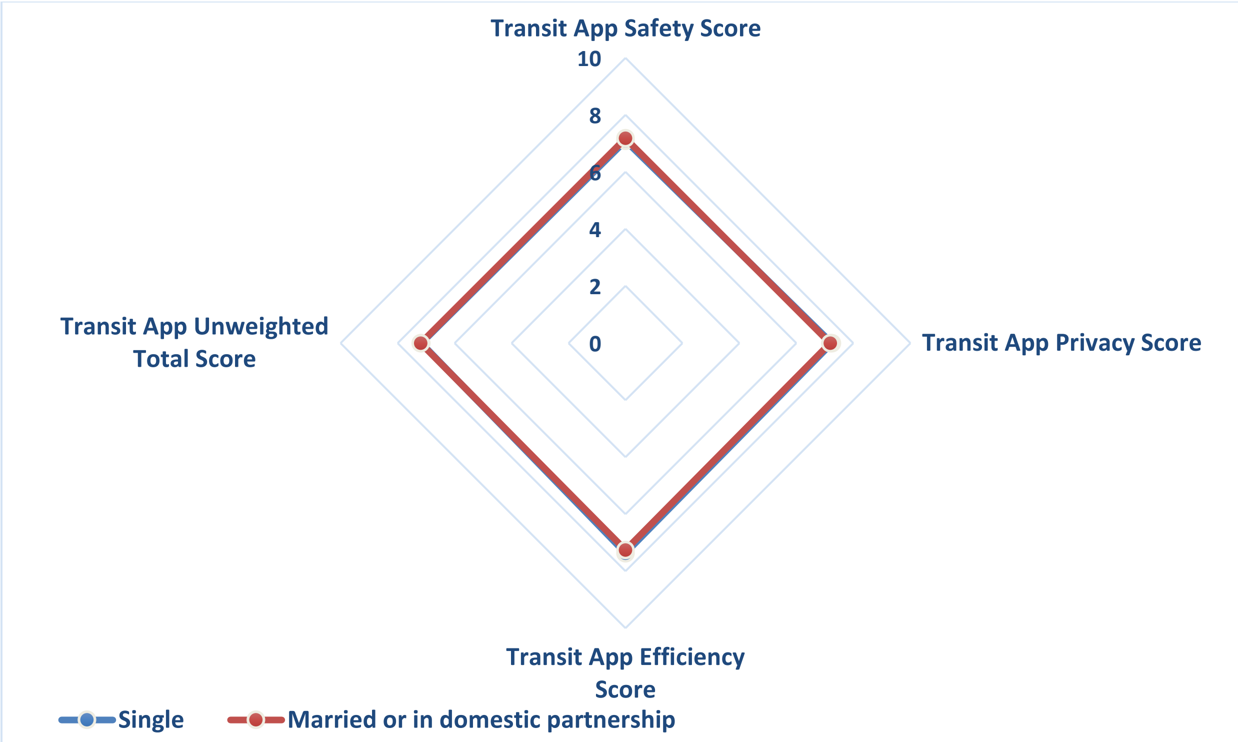

Figure 78. Combined app-related ratings by marital status.

By Annual Income

Figure 79 and Figure 80 show app-related ratings and combined app-related ratings by annual income, respectively. While visually some differences can be seen between different annual income cohorts, the only significant difference was for "*Q26. Are you willing to use the app and flexible transit service, if it can meet your need?*" where participants with $50,000–$100,000 annual income rated this question significantly lower ($p < 0.1$).

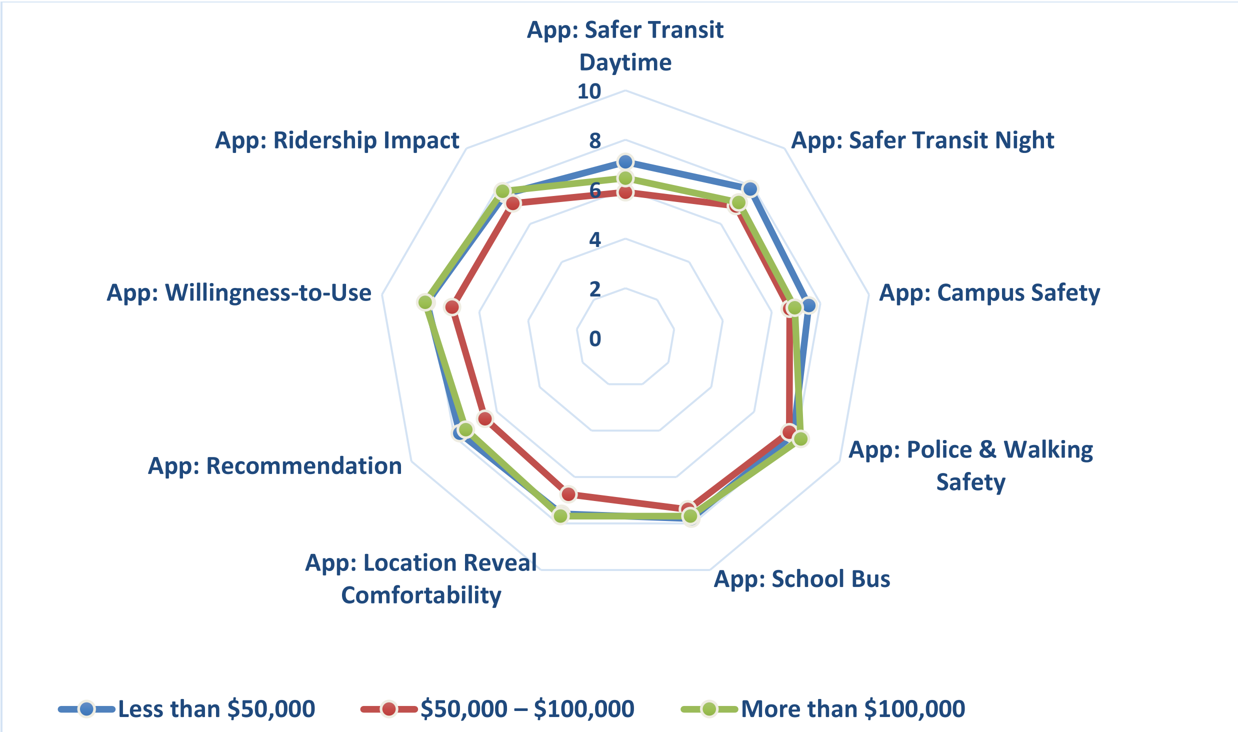

Figure 79. App-related ratings by annual income.

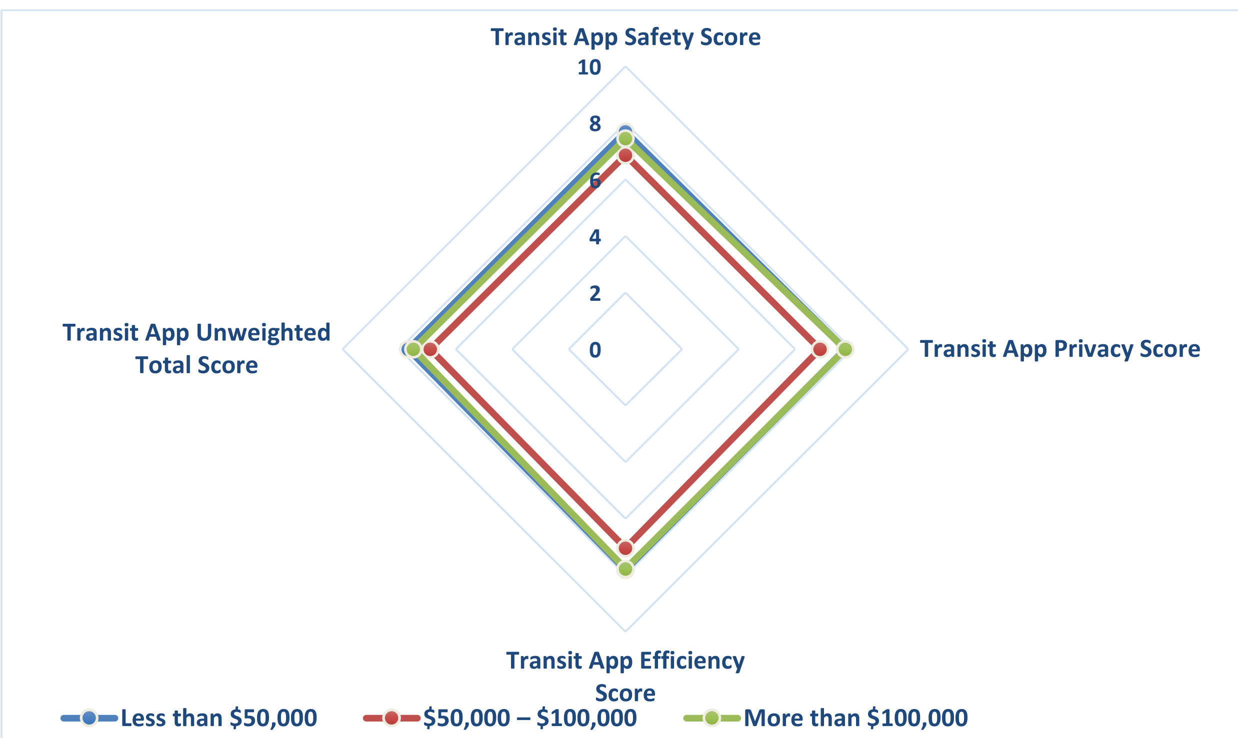

Figure 80. Combined app-related ratings by annual income.

By Race/Ethnicity

Figure 81 and Figure 82 show app-related ratings and combined app-related ratings by race/ethnicity, respectively. While visually some differences can be seen between different race/ethnicity cohorts, the only significant difference was for "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" where White (non-Hispanic) participants rated this question significantly lower ($p < 0.1$).

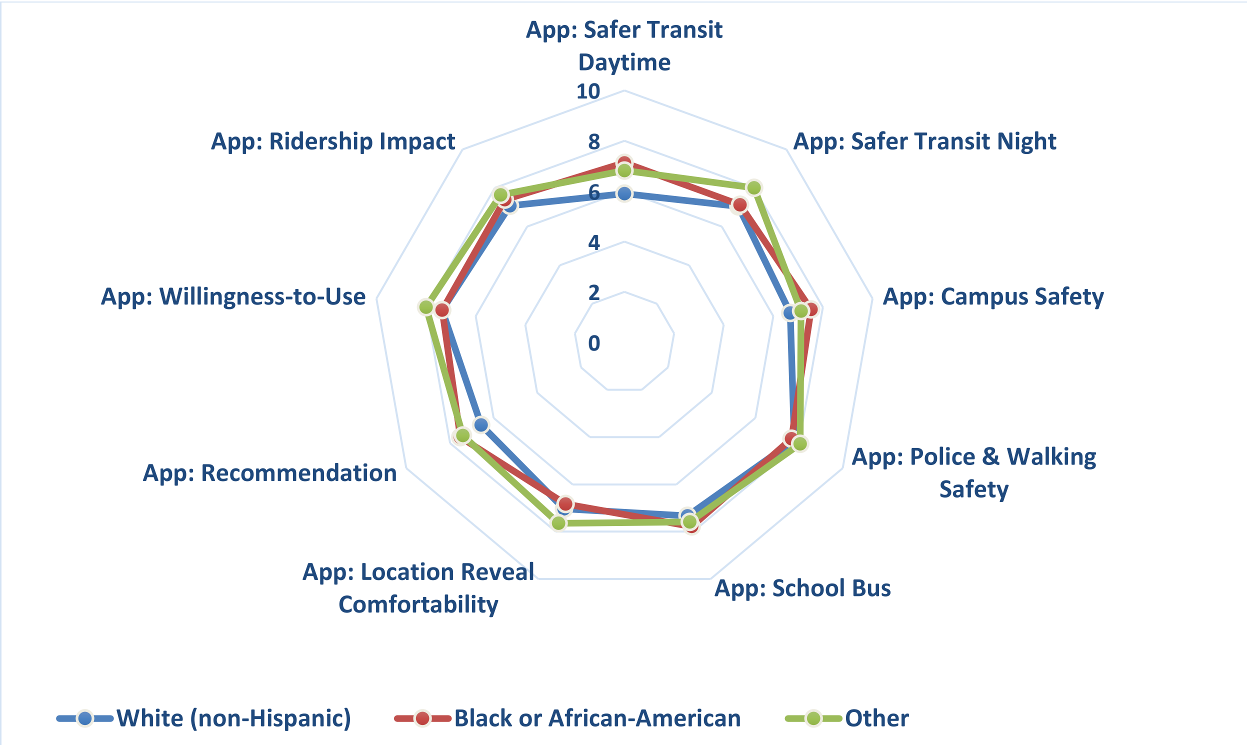

Figure 81. App-related ratings by race/ethnicity.

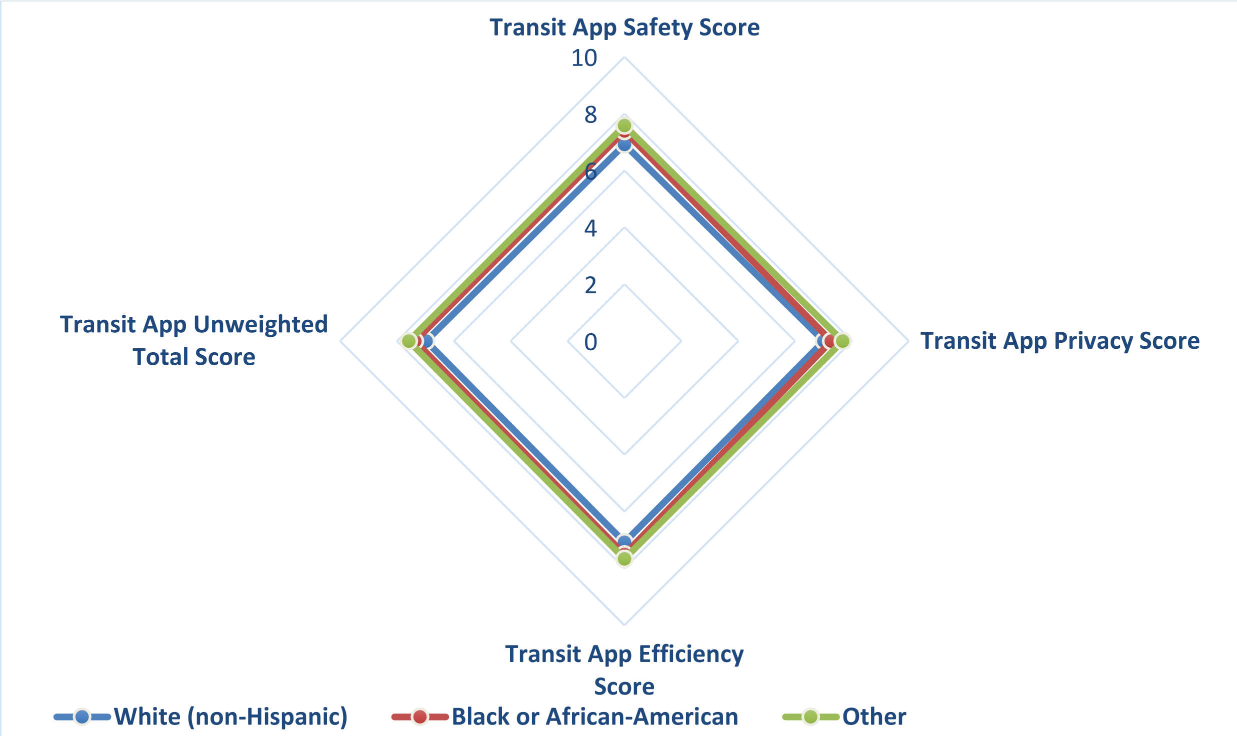

Figure 82. Combined app-related ratings by race/ethnicity.

By Education

Figure 83 and Figure 84 show app-related ratings and combined app-related ratings by education, respectively. While visually some differences can be seen between different education cohorts, the only significant difference was for "*Q21. Do you think this transit app can improve safety on the university campus?"* where ratings for participants with a master's degree or higher were significantly lower ($p < 0.05$). Moreover, participants with a master's degree or higher had the lowest average rating of 6.413 for this question in comparison with any other cohort in the study.

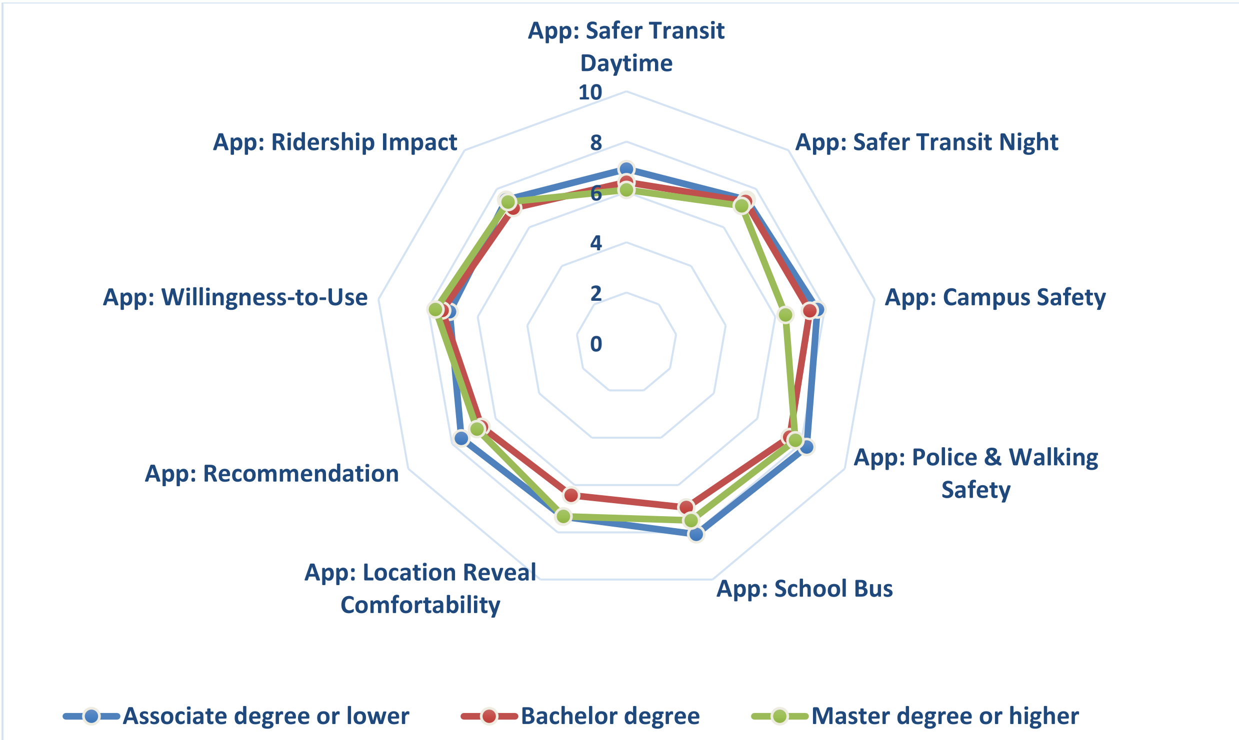

Figure 83. App-related ratings by education.

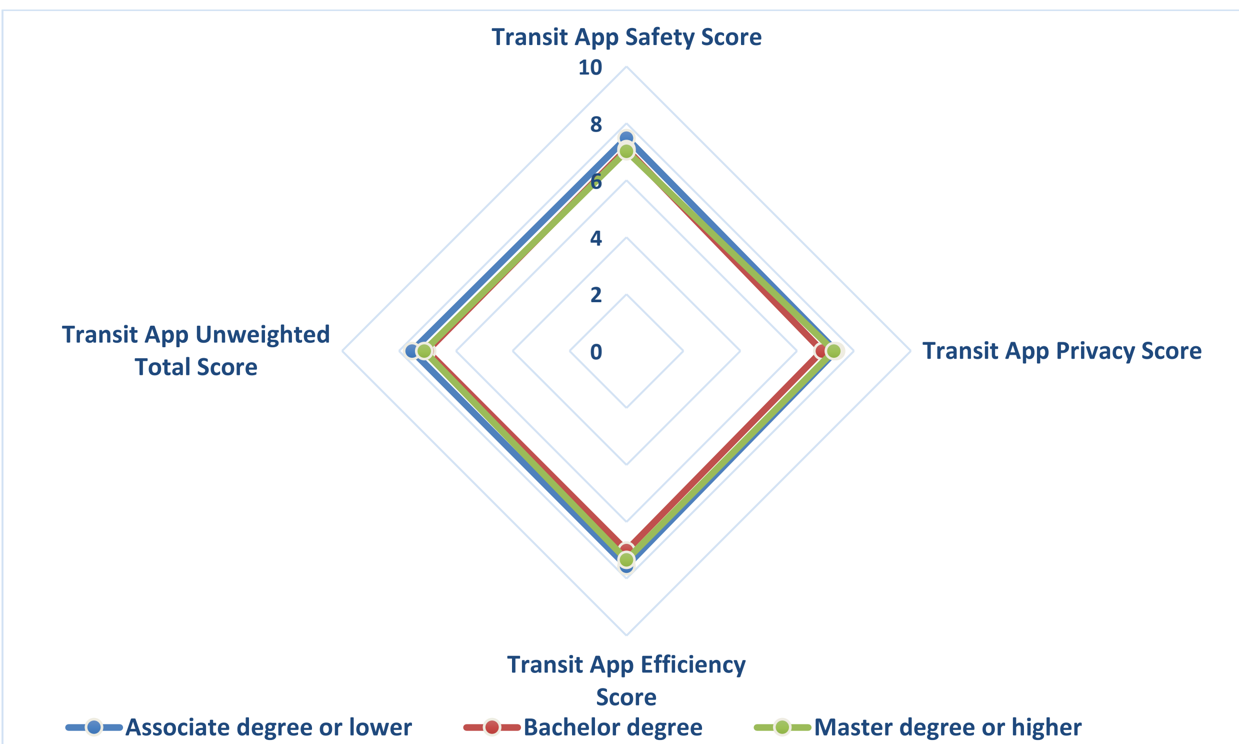

Figure 84. Combined app-related ratings by education.

By Occupation

Figure 85 and Figure 86 show app-related ratings and combined app-related ratings by occupation, respectively. While visually some differences can be seen between different occupation cohorts, the only significant difference was for "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" where ratings by employed participants were significantly lower ($p < 0.05$) in comparison with students, those not employed, and other participants.

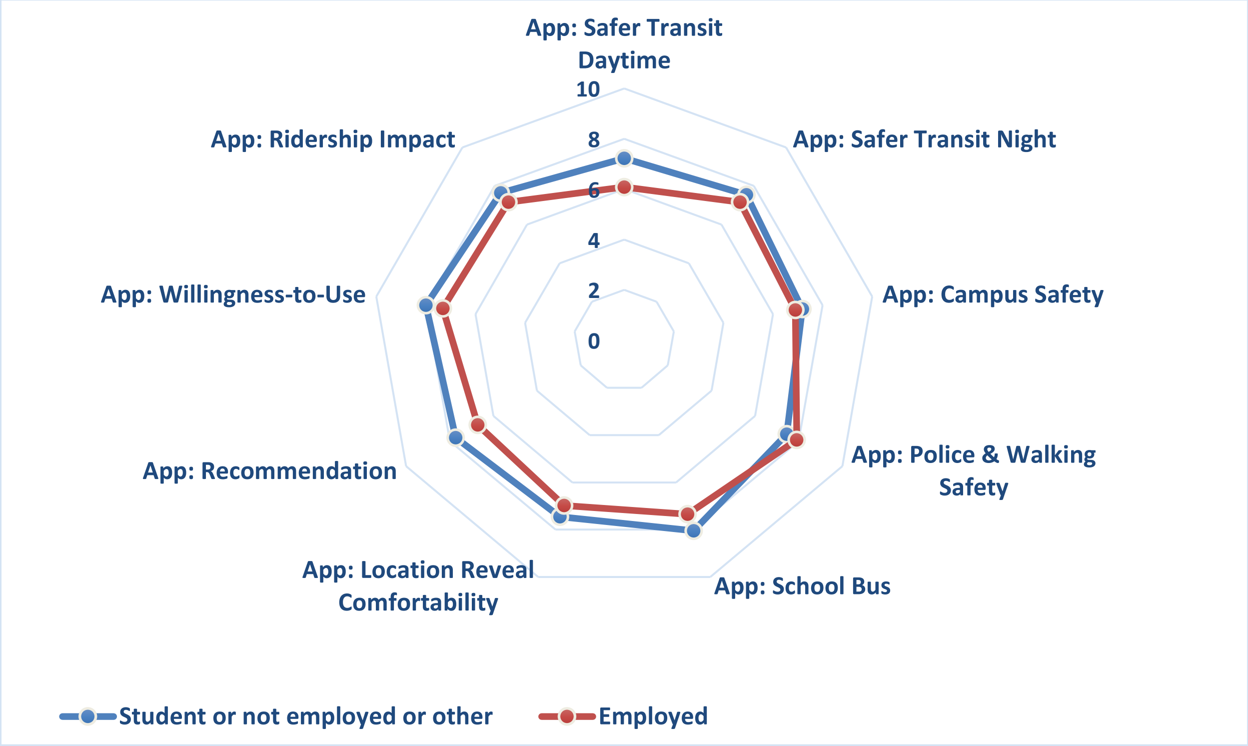

Figure 85. App-related ratings by occupation.

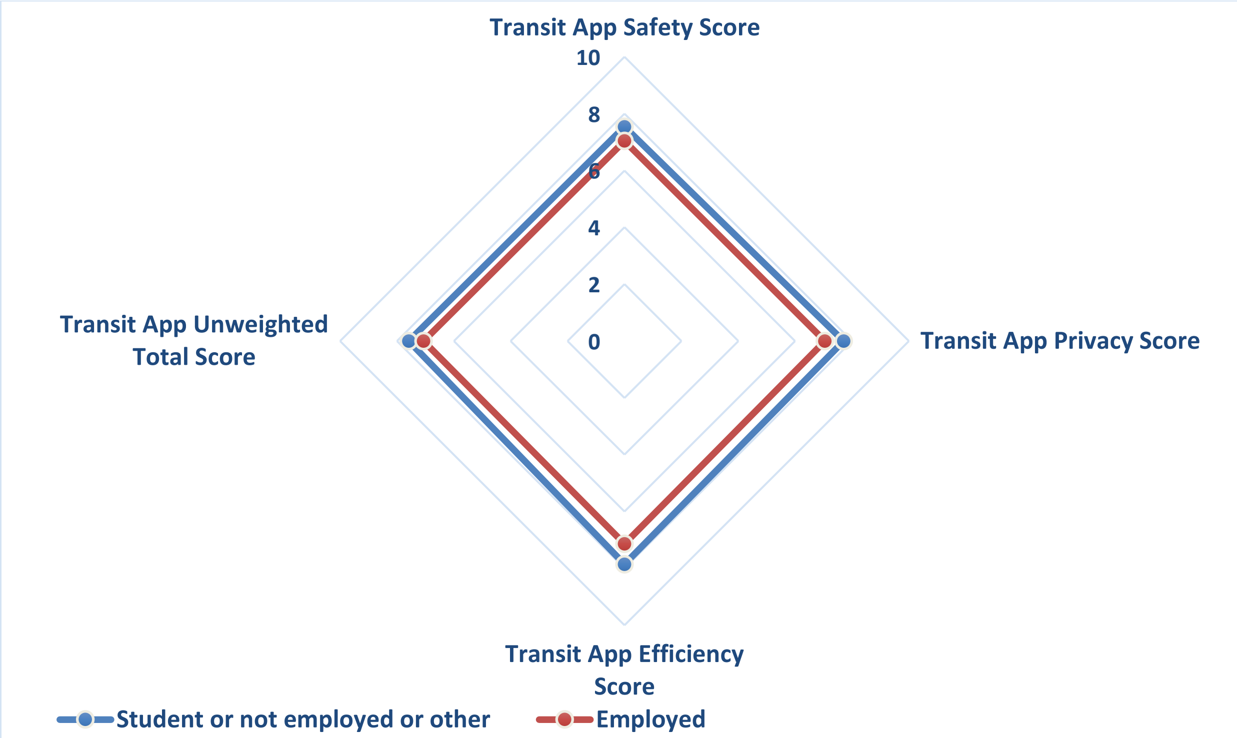

Figure 86. Combined app-related ratings by occupation.

By Car Ownership

Figure 87 and Figure 88 show app-related ratings and combined app-related ratings by car ownership, respectively. While visually some differences can be seen between different car ownership cohorts, the only significant difference was for "*Q20. Do you think this transit app makes for a safer transit experience at night?*" where ratings from participants without a car were significantly higher ($p < 0.05$) in comparison with participants who owned a car or had access to it for commuting.

However, car ownership was one of the key characteristics; average ratings from participants without a car were the highest average for the following app-related questions:

- "*Q20. Do you think this transit app makes for a safer transit experience at night?*" (8.750)
- "*Q21. Do you think this transit app can improve safety on the university campus?*" (8.125)
- "*Q23. Do you think this transit app can be used for school bus operation?*" (8.625)
- "*Q27. Do you think this transit app can increase transit ridership?*" (8)

Participants without a car also provided the highest average ratings for the combined safety (7.982) and unweighted total score (8.014) categories.

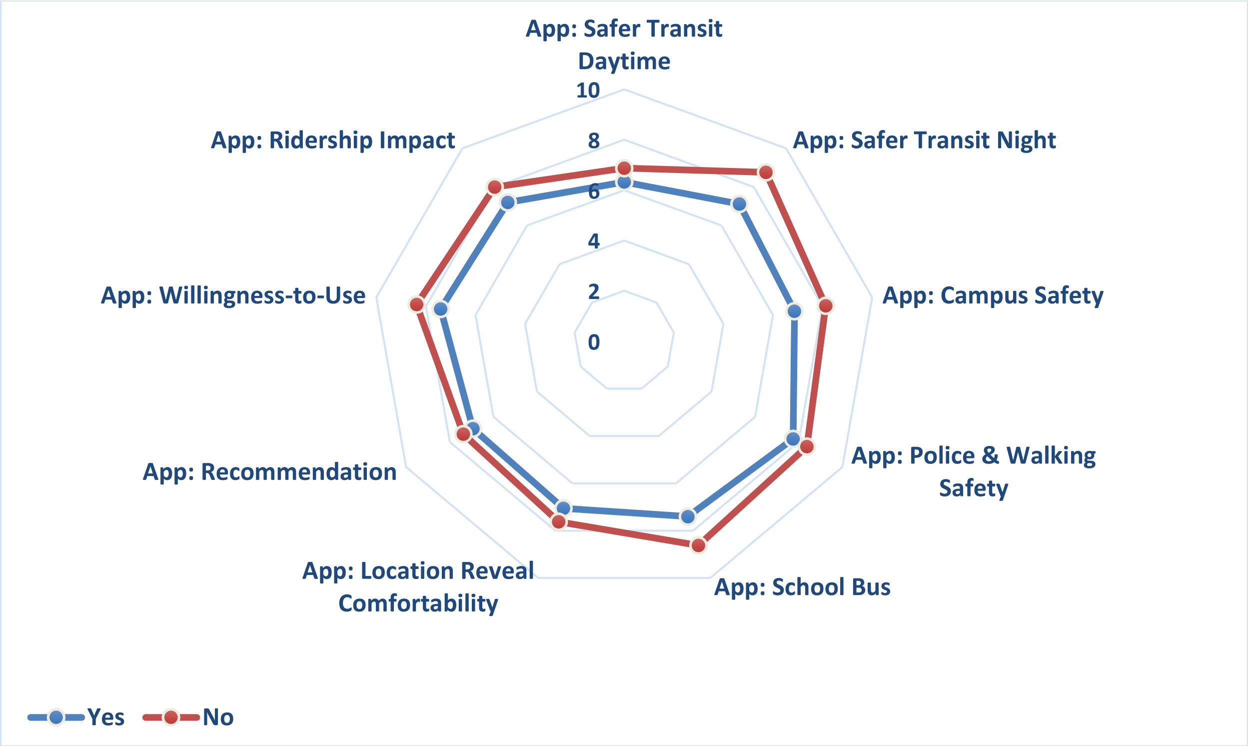

Figure 87. App-related ratings by car ownership.

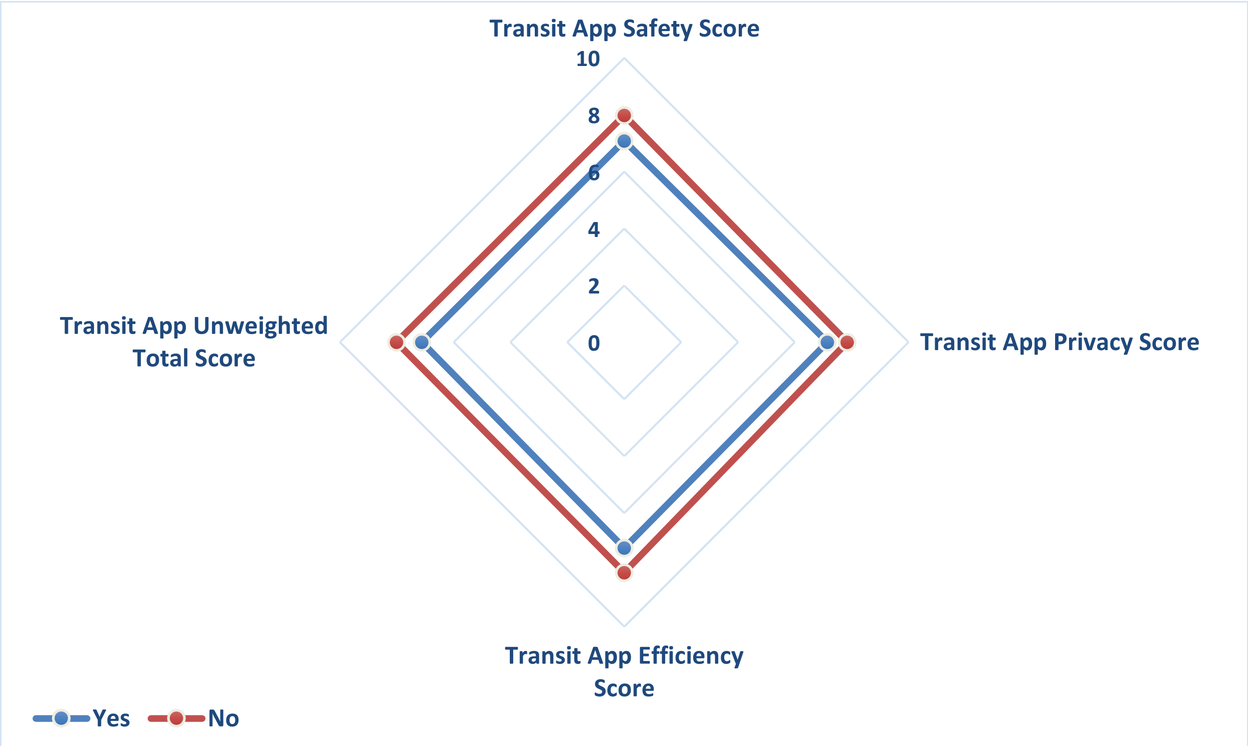

Figure 88. Combined app-related ratings by car ownership.

By Driving Pattern (Regularly)

Figure 89 and Figure 90 show app-related ratings and combined app-related ratings by driving pattern (regularly), respectively. While visually some differences can be seen between different driving pattern (regularly) cohorts, the two following questions were rated significantly higher by participants who did not drive regularly:

- *"Q21. Do you think this transit app can improve safety on the university campus?" (p* < 0.1)
- *"Q26. Are you willing to use the app and flexible transit service, if it can meet your need?"* ($p <$ 0.05)

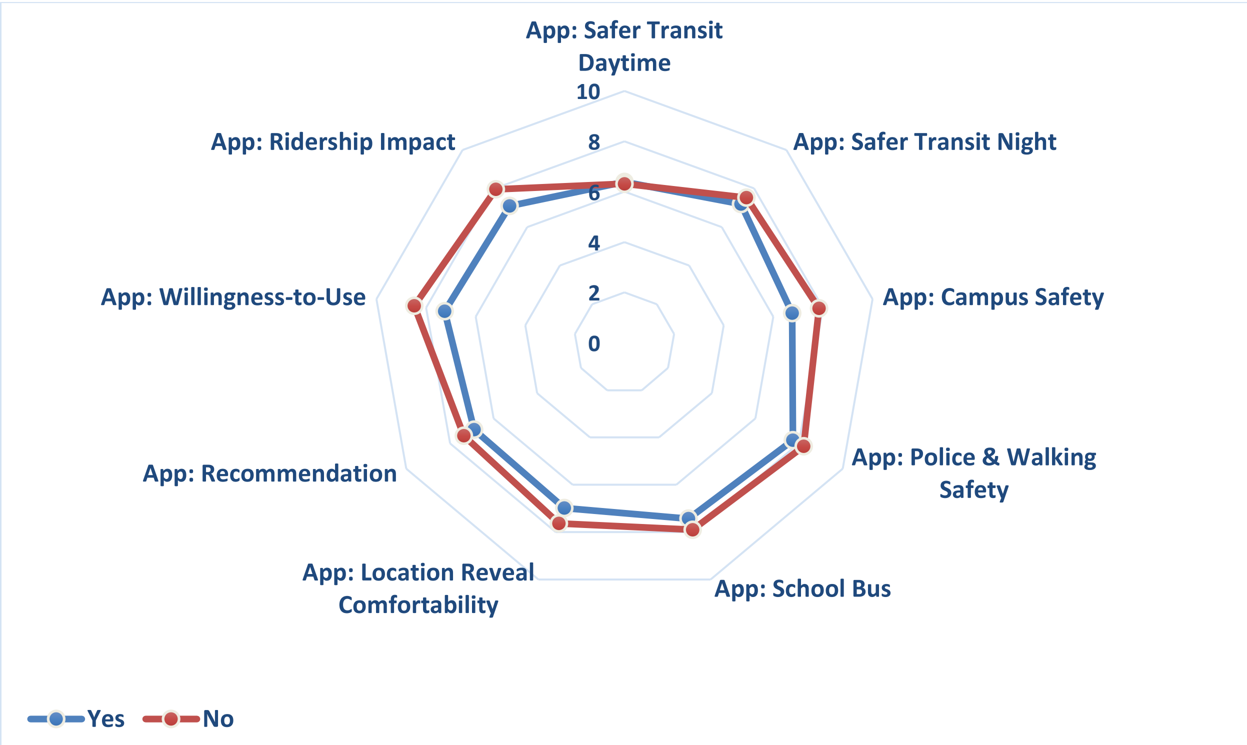

Figure 89. App-related ratings by "Driving Pattern (Regularly)."

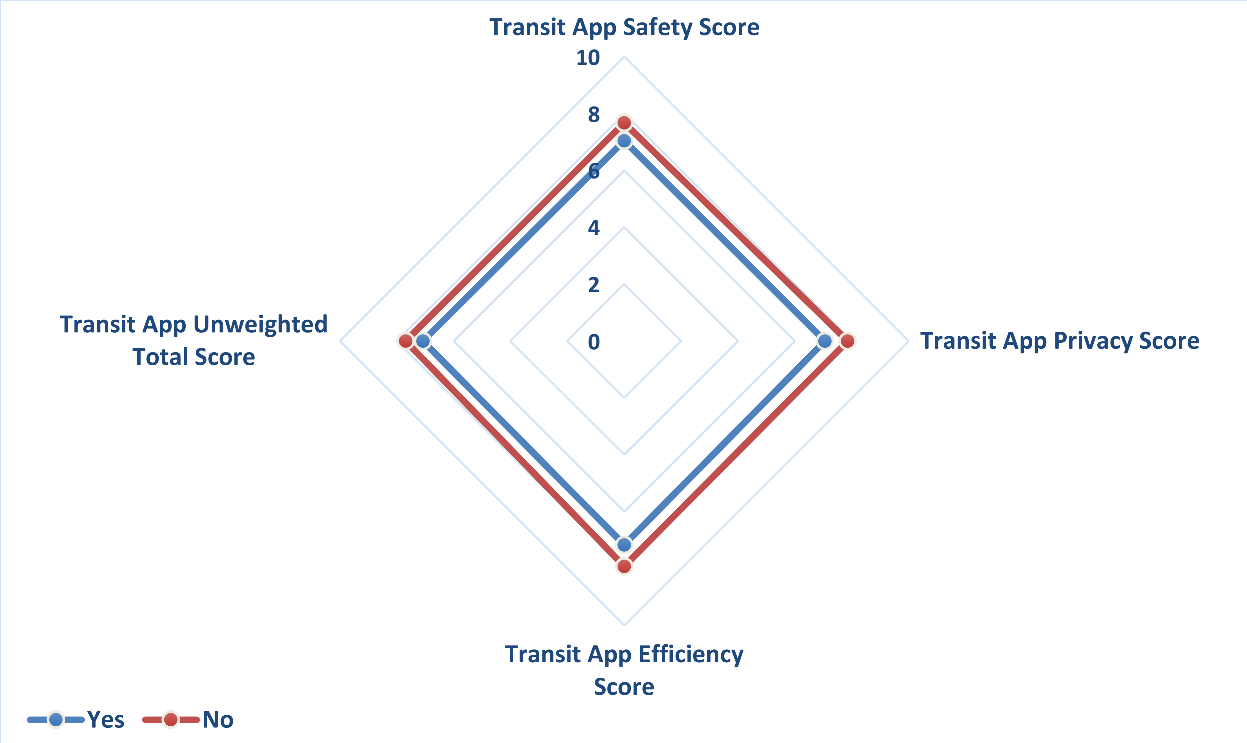

Figure 90. Combined app-related ratings by "Driving Pattern (Regularly)."

By Transit Use

Figure 91 and Figure 92 show app-related ratings and combined app-related ratings by transit use, respectively. While visually some differences can be seen between different transit use cohorts, participants who use transit rated the following two questions significantly higher:

- *"Q21. Do you think this transit app can improve safety on the university campus?"* ($p < 0.1$)
- *"Q26. Are you willing to use the app and flexible transit service, if it can meet your need?"* ($p < 0.05$)

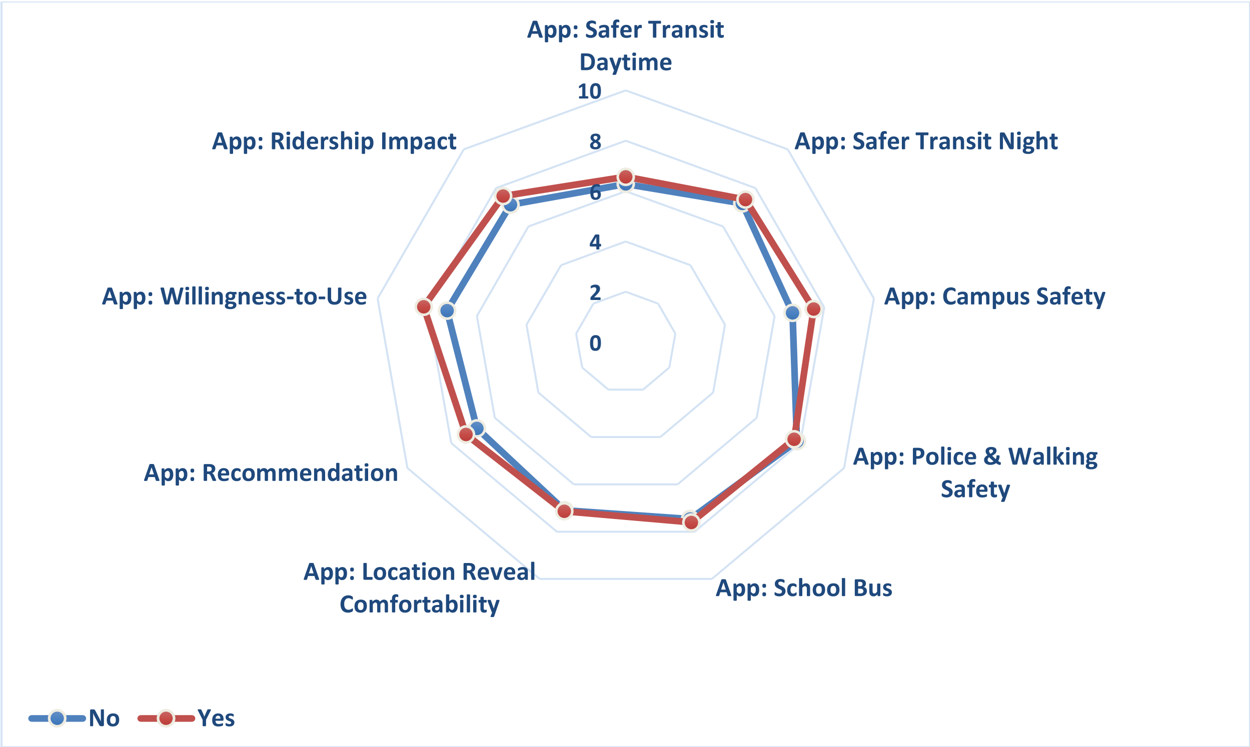

Figure 91. App-related ratings by transit use.

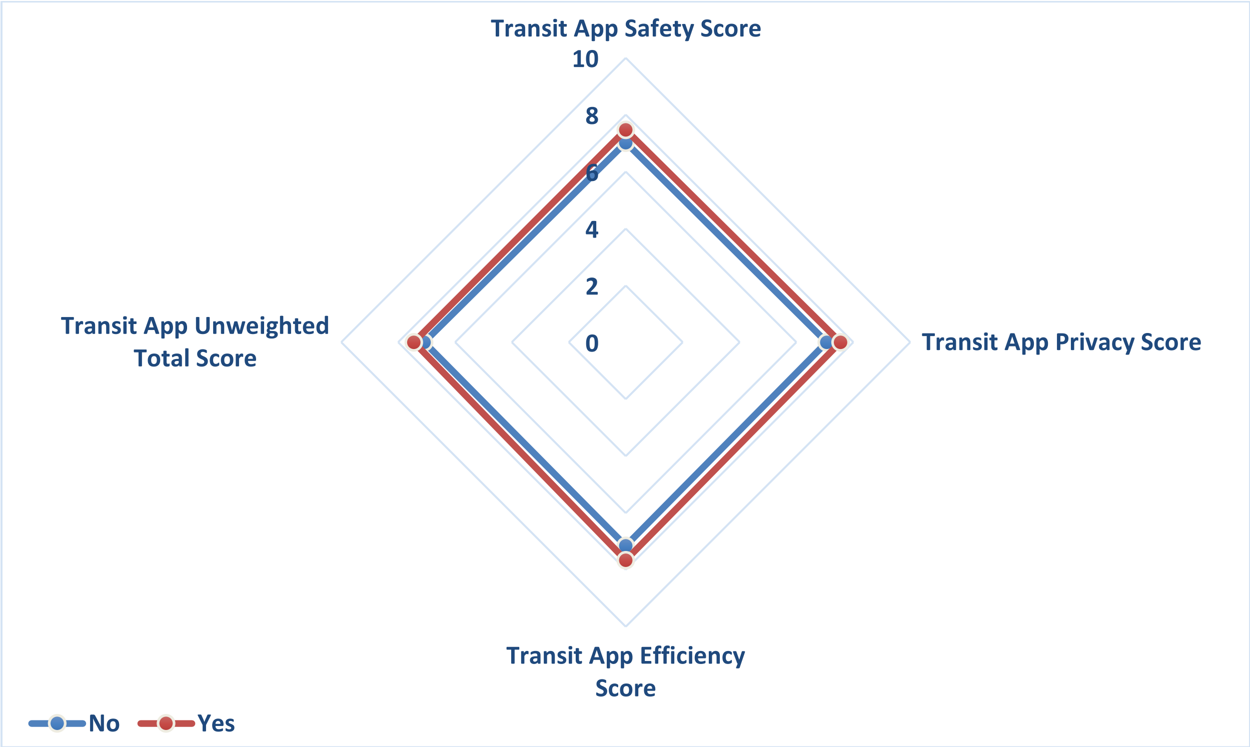

Figure 92. Combined app-related ratings by transit use.

By Commute Time

Figure 93 and Figure 94 show app-related ratings and combined app-related ratings by commute time, respectively. While visually some differences can be seen between different commute time cohorts, many of them were also statistically significant, which made commute time one of the key characteristics. Participants with a commuting time of more than 20 minutes rated the following app-related questions significantly higher:

- "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" ($p < 0.01$)
- "*Q20. Do you think this transit app makes for a safer transit experience at night?*" ($p < 0.05$)
- "*Q21. Do you think this transit app can improve safety on the university campus?*" ($p < 0.1$)
- "*Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?*" ($p < 0.05$)
- "*Q23. Do you think this transit app can be used for school bus operation?*" ($p < 0.05$)
- "*Q25. Can you recommend this type of mobile app for transit users?*" ($p < 0.05$)

Participants with a commuting time of more than 20 minutes also rated the following combined app-related scores significantly higher:

- Combined safety ($p < 0.05$)
- Unweighted total score ($p < 0.05$)

Also, participants with a commuting time of more than 20 minutes provided the highest average rating for "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" (7.410), while participants with a commuting time of less than 20 minutes provided the lowest average rating (5.604) for this question.

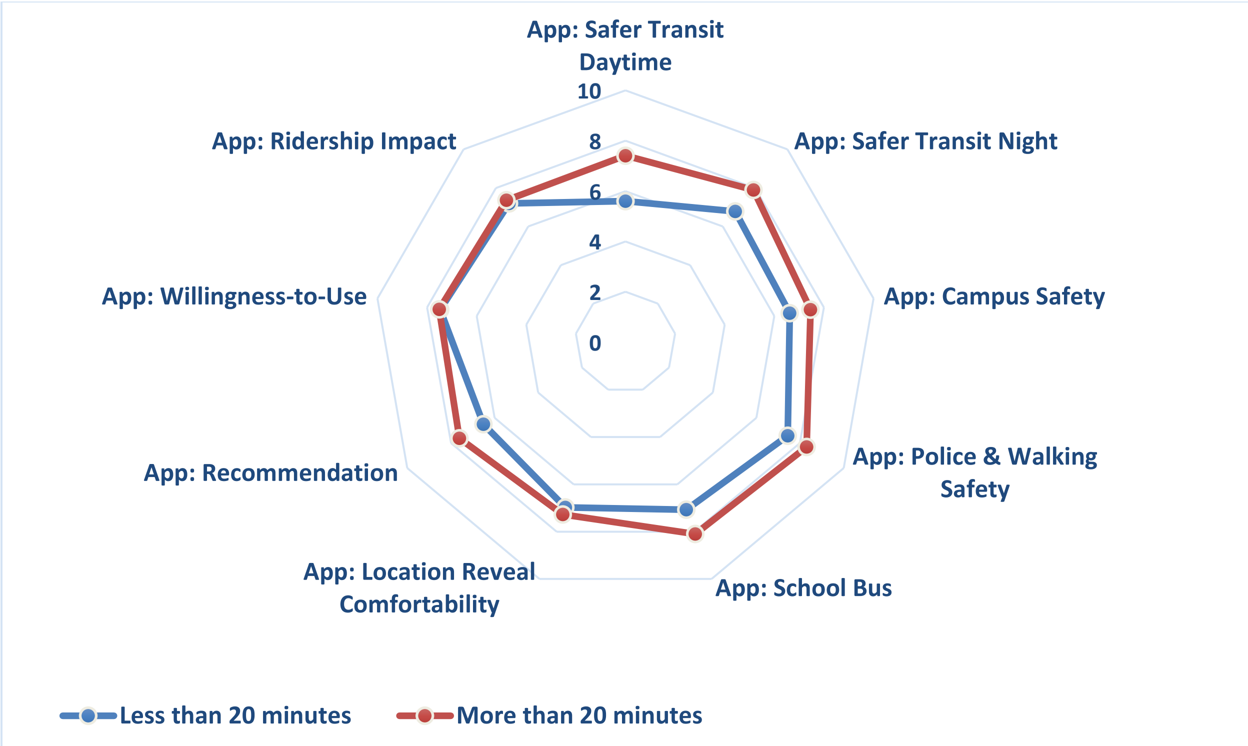

Figure 93. App-related ratings by commute time.

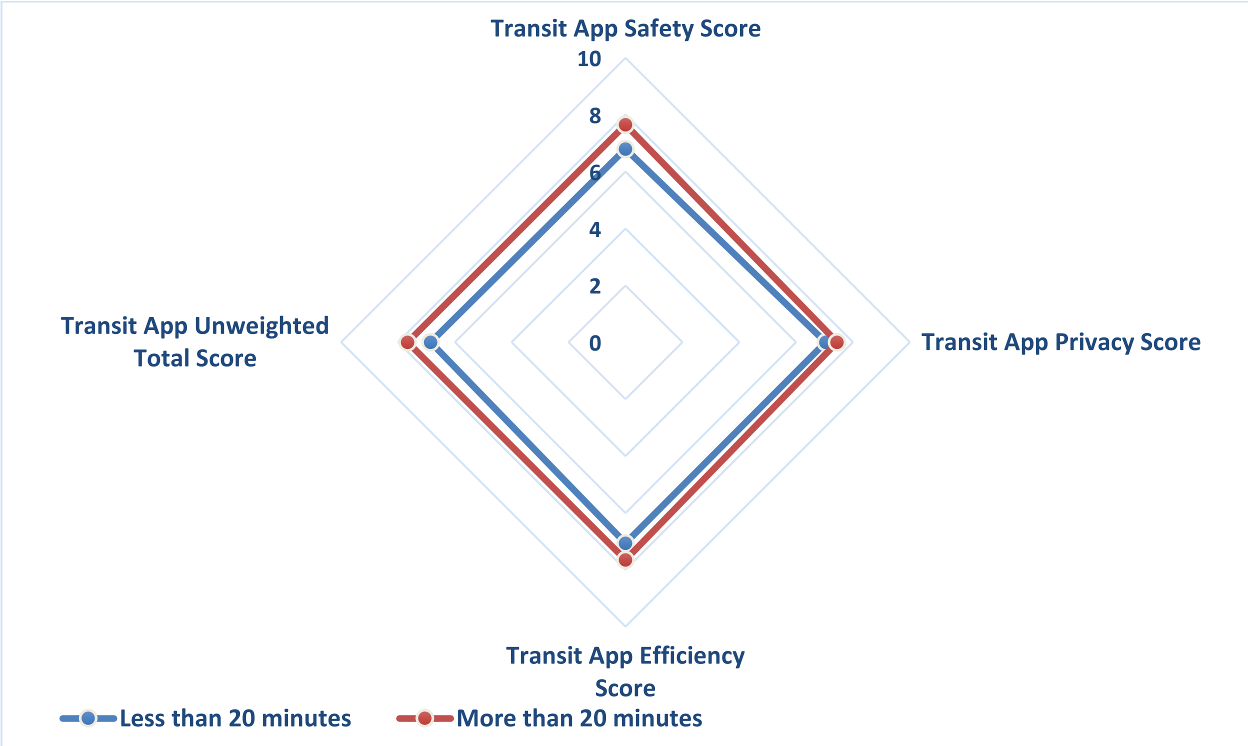

Figure 94. Combined app-related ratings by commute time.

By Transit Transfer

Figure 95 and Figure 96 show app-related ratings and combined app-related ratings by transit transfer, respectively. While visually some differences can be seen between different transit transfer cohorts, many of them were also statistically significant, which made transit transfer one of the key characteristics. The following app-related questions were rated significantly higher by participants without transit transfer:

- "*Q21. Do you think this transit app can improve safety on the university campus?*" ($p < 0.1$)
- "*Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?*" ($p < 0.05$)
- "*Q25. Can you recommend this type of mobile app for transit users?*" ($p < 0.01$)
- "*Q26. Are you willing to use the app and flexible transit service, if it can meet your need?*" ($p < 0.1$)

Participants without transit transfer also rated all the combined app-related attributes significantly higher:

- Combined safety ($p < 0.1$)
- Combined privacy ($p < 0.05$)
- Combined efficiency ($p < 0.05$)
- Unweighted total score ($p < 0.05$)

Moreover, different cohorts had the lowest and highest average ratings for the following app-related questions:

- "*Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?*" (lowest for participants with transit transfer, 5.952)
- "*Q25. Can you recommend this type of mobile app for transit users?*" (lowest for participants with transit transfer, 6.095; highest for participants without transit transfer, 8.538)
- "*Q26. Are you willing to use the app and flexible transit service, if it can meet your need?*" (highest for participants with transit transfer, 8.769)

Different cohorts had the lowest and highest average ratings for all combined app-related scores:

- Combined safety (lowest for participants with transit transfer, 6.728)
- Combined privacy (lowest for participants with transit transfer, 6.607; highest for participants without transit transfer, 8.288)
- Combined efficiency (lowest for participants with transit transfer, 6.905; highest for participants without transit transfer, 8.385)
- Unweighted total score (lowest for participants with transit transfer, 6.688)

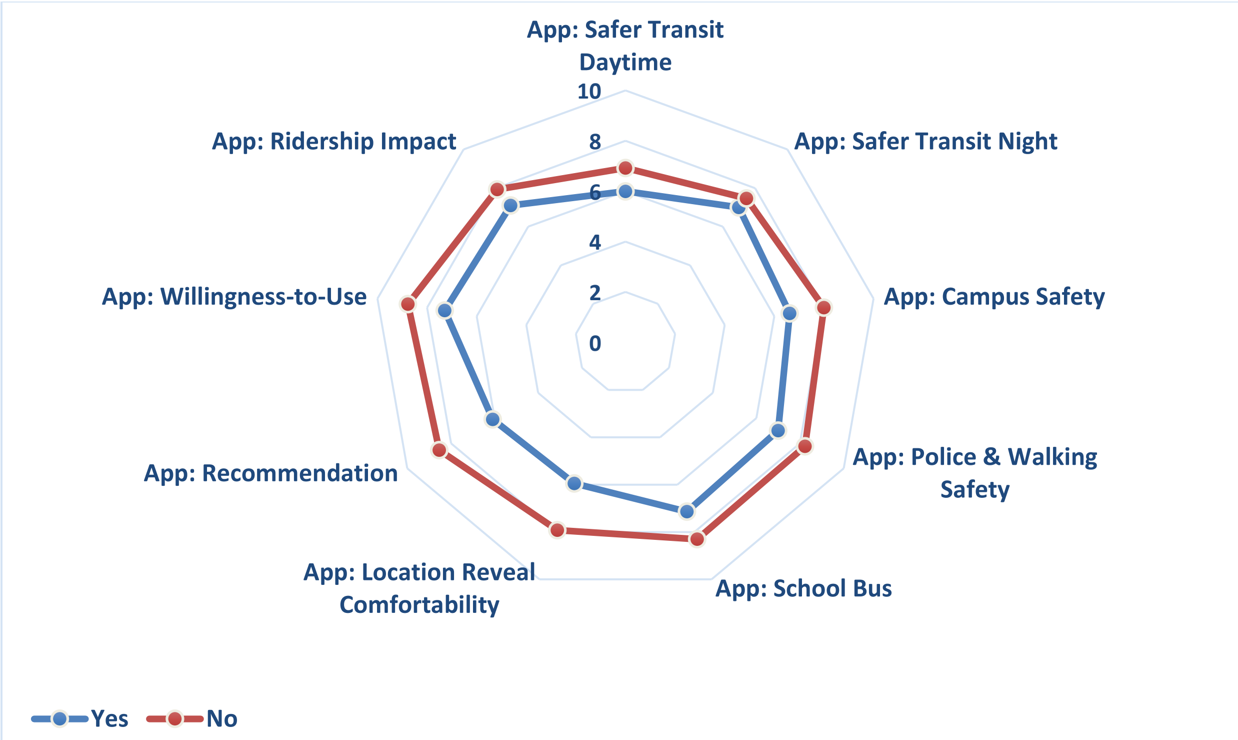

Figure 95. App-related ratings by "Transfer."

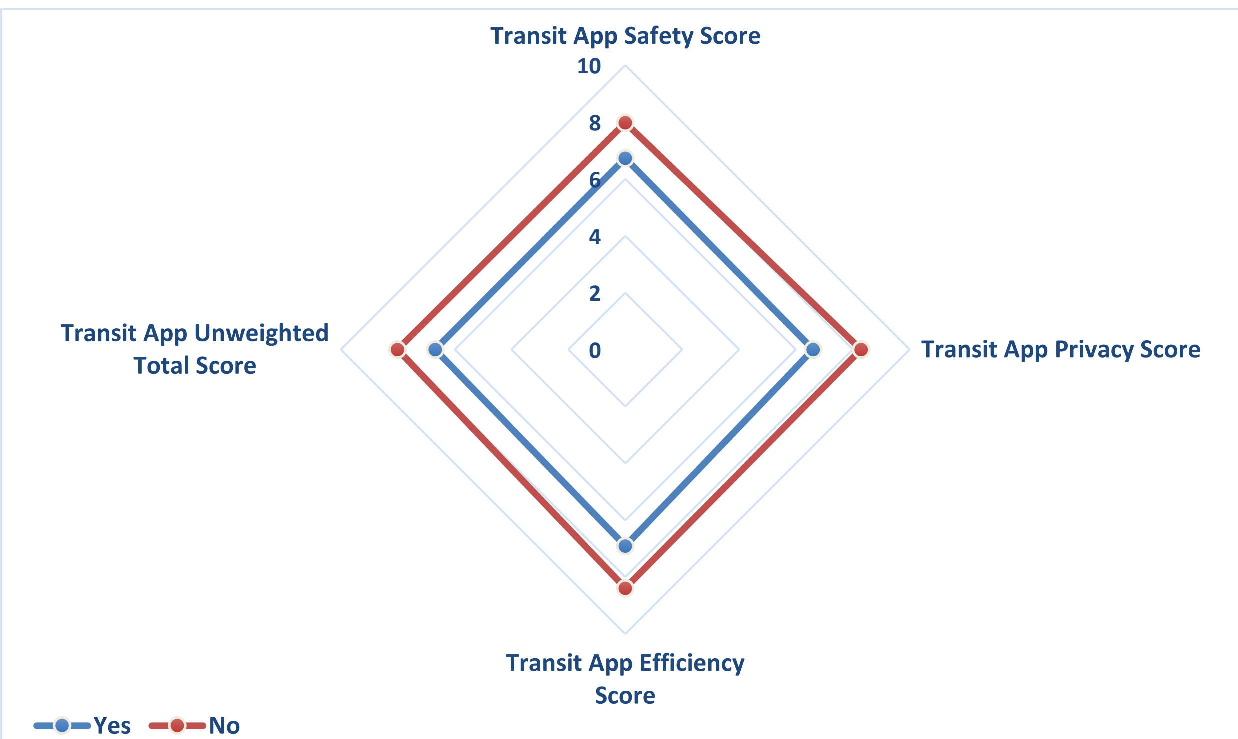

Figure 96. Combined app-related ratings by "Transfer."

By Transit Extra Time

Figure 97 and Figure 98 show app-related ratings and combined app-related ratings by transit extra time, respectively. While visually some differences can be seen between different transit extra time cohorts, there is only one statistically significant difference. Participants who had less than 20 minutes extra transit time to commute rated the following question higher in comparison with the other two cohorts:

- *"Q26. Are you willing to use the app and flexible transit service, if it can meet your need?"* ($p <$ 0.05)

The combined efficiency app-related score was also statistically significant ($p < 0.1$)

Participants who did not know their transit extra time (i.e., they selected "I do not know") had the lowest average rating of 6.909 for "*Q26. Are you willing to use the app and flexible transit service, if it can meet your need?*"

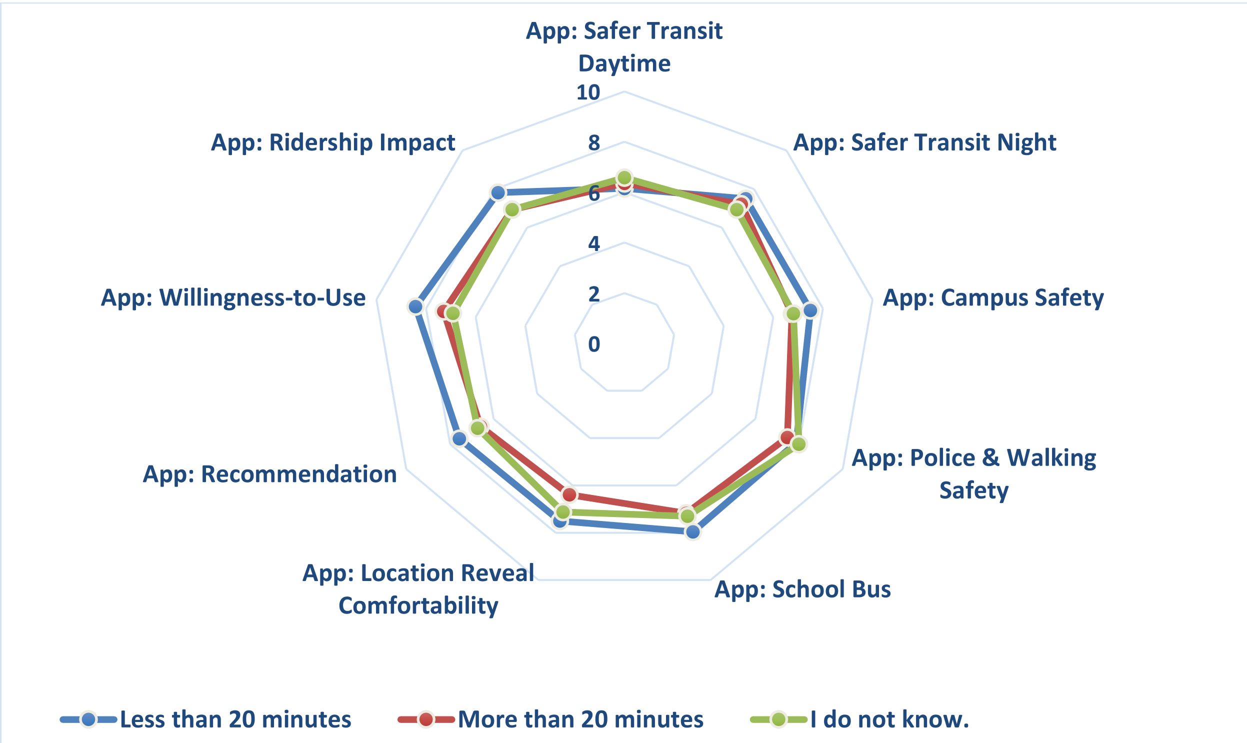

Figure 97. App-related ratings by "Transit Extra Time."

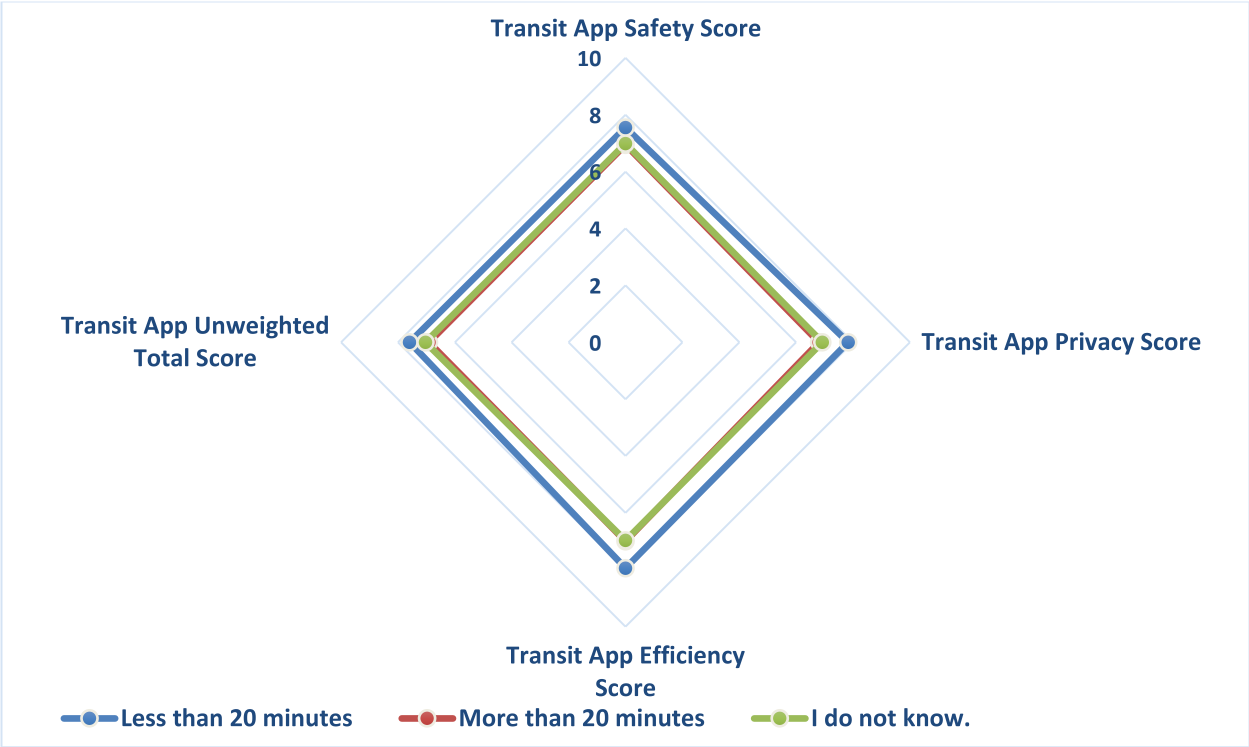

Figure 98. Combined app-related ratings by "Transit Extra Time."

By Transit App Familiarity

Figure 99 and Figure 100 show app-related ratings and combined app-related ratings by transit app (in general) familiarity, respectively. There were no significant differences between different cohorts.

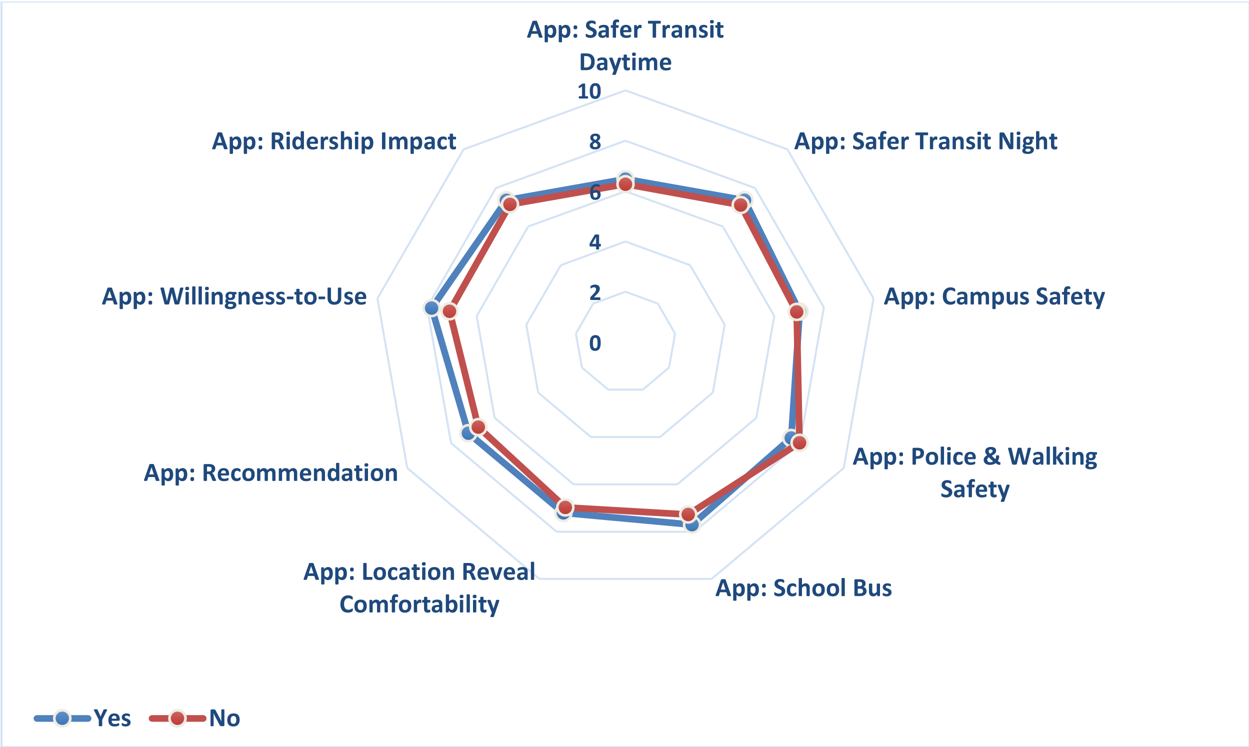

Figure 99. App-related ratings by "Transit App Familiarity."

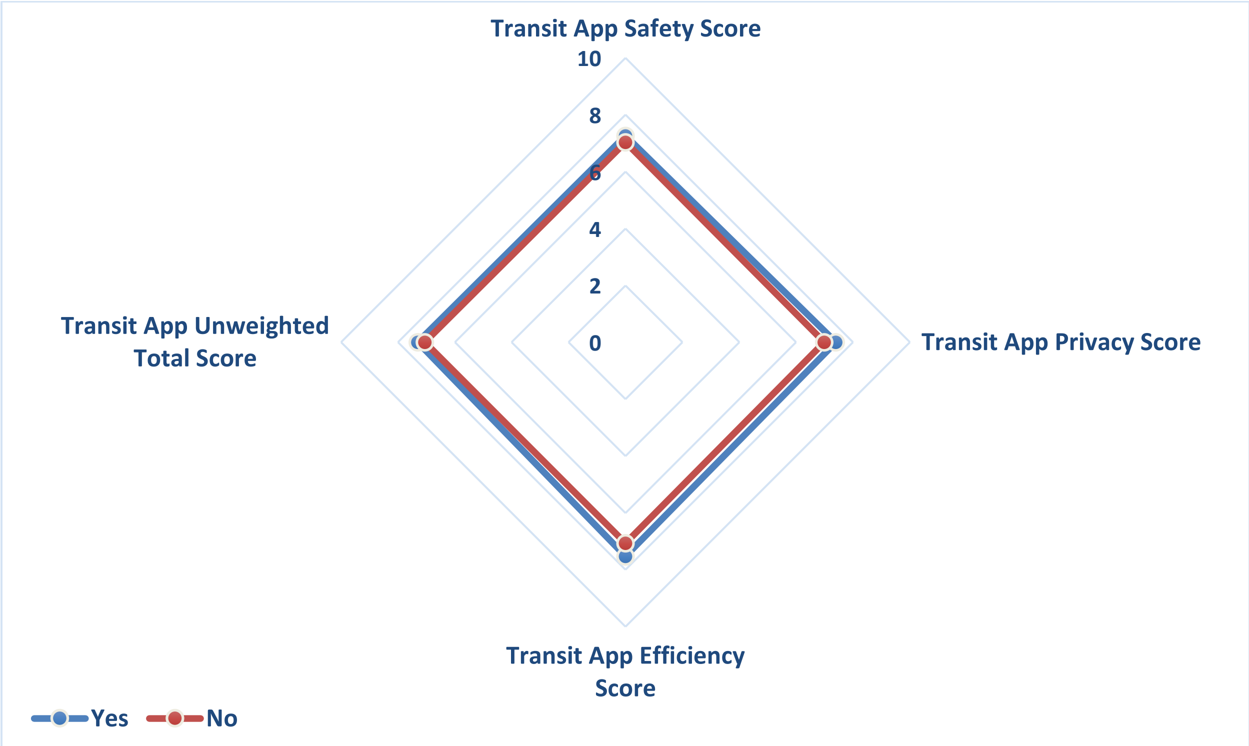

Figure 100. Combined app-related ratings by "Transit App Familiarity."

By Transit App Use

Figure 101 and Figure 102 show app-related ratings and combined app-related ratings by transit app (in general) use, respectively. There were no significant differences between different cohorts.

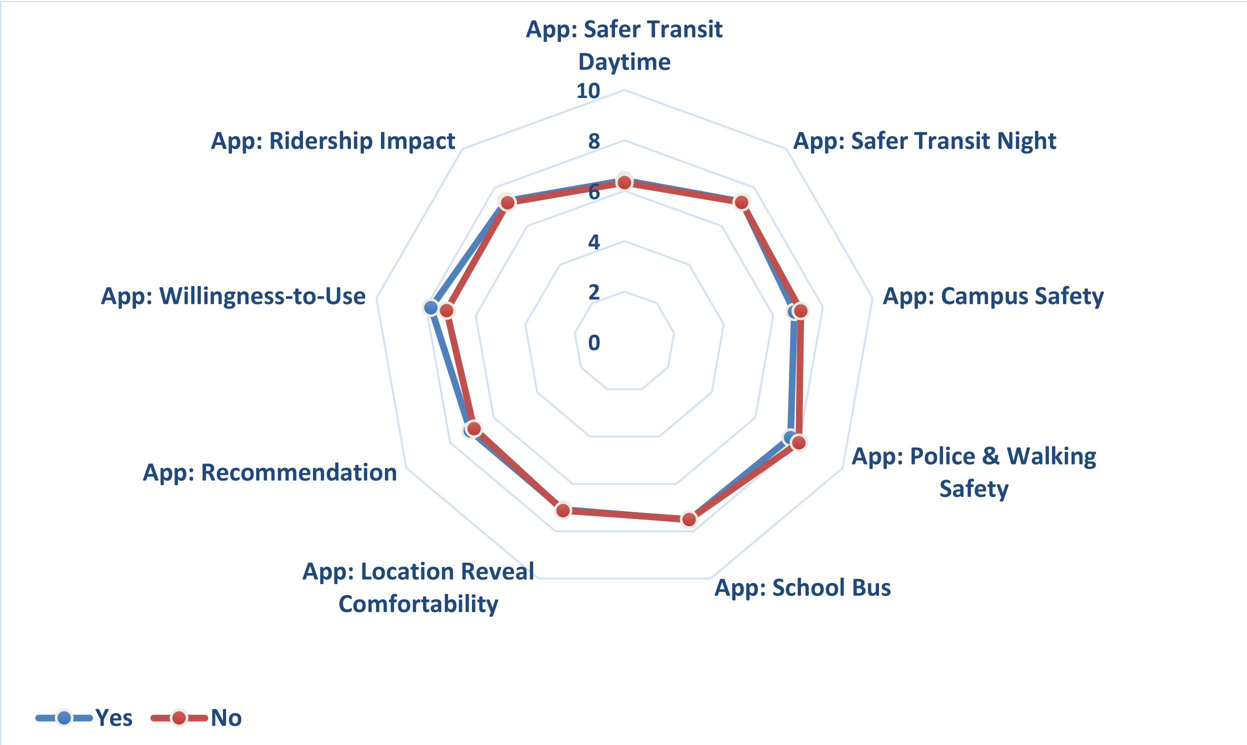

Figure 101. App-related ratings by "Transit App Use."

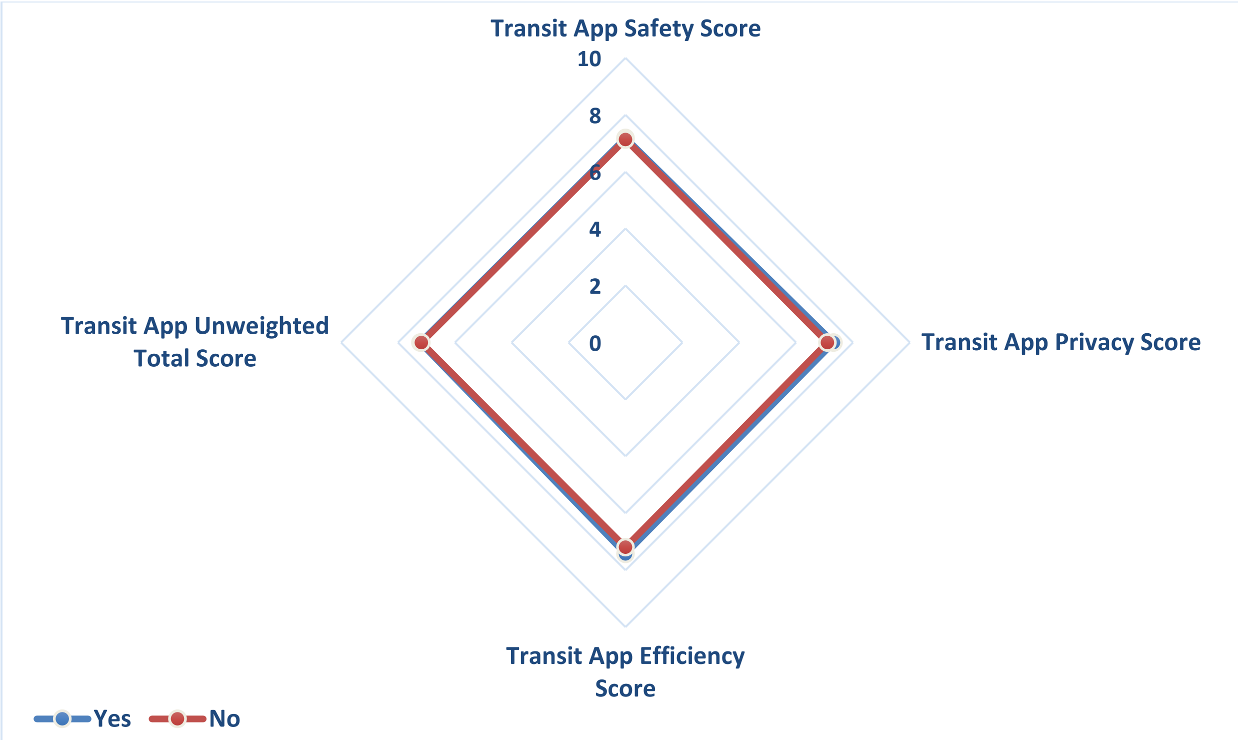

Figure 102. Combined app-related ratings by "Transit App Use."

By Home (Location)

Figure 103 and Figure 104 show app-related ratings and combined app-related ratings by home (location: city or suburban), respectively. While visually some minor differences can be seen between different cohorts, there were not any significant differences.

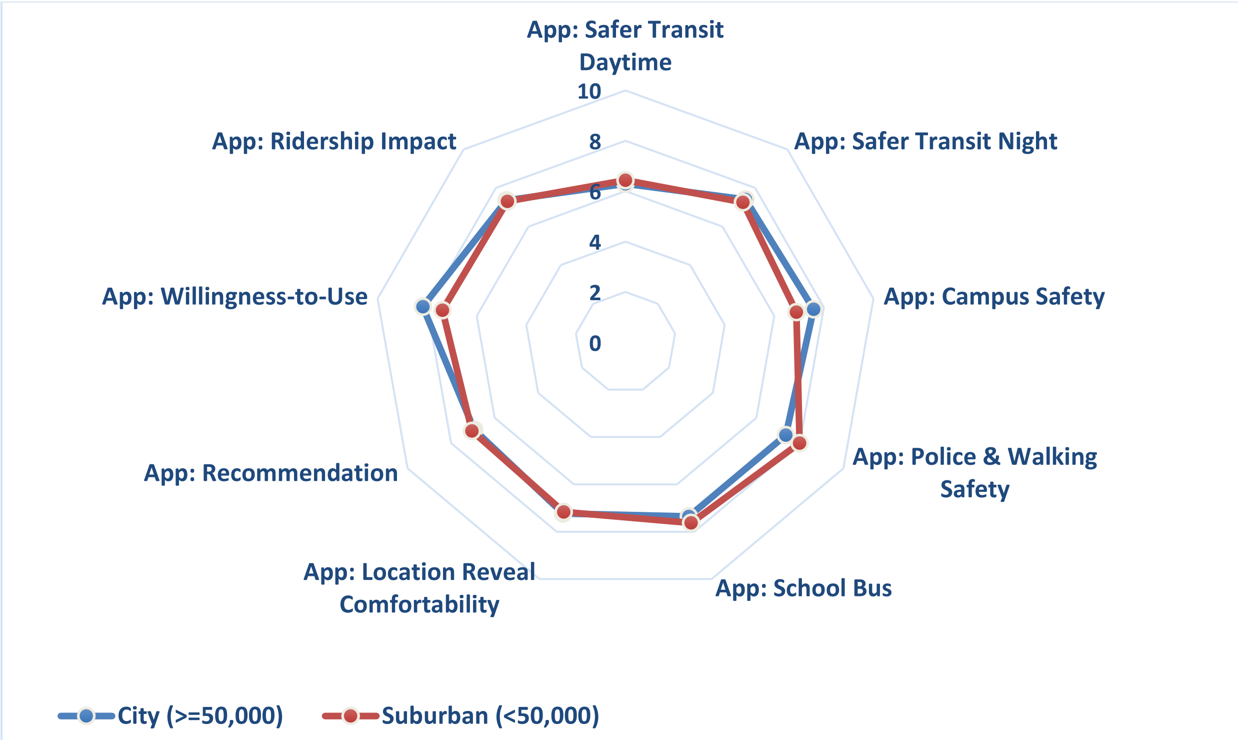

Figure 103. App-related ratings by "Home (Location)."

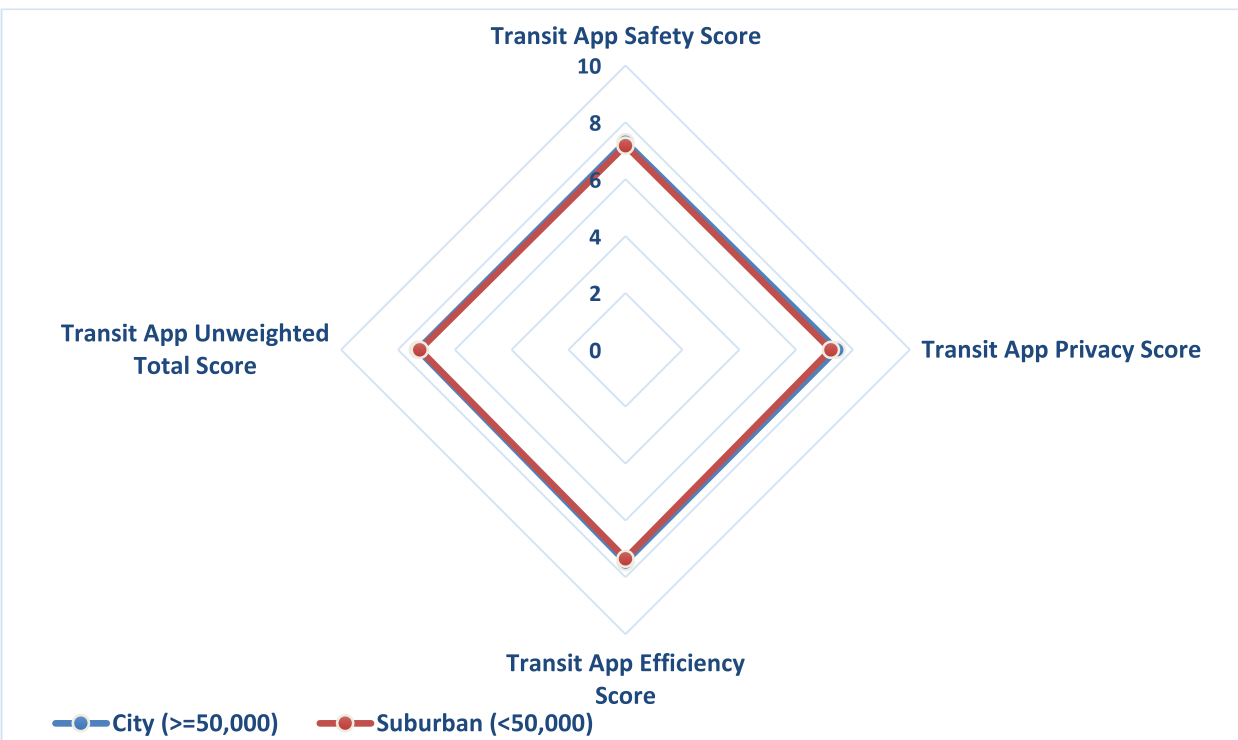

Figure 104. Combined app-related ratings by "Home (Location)."

By Work/Study Location

Figure 105 and Figure 106 show app-related ratings and combined app-related ratings by "Work/Study Location," respectively. While visually some differences can be seen between different cohorts, the only significant difference was for participants who work/study in a city with a population of 50,000 or more for the following app-related question, which was rated higher:

- "*Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation?*" ($p < 0.1$)

Participants who work or study in a city with a population of 50,000 or more had the highest average rating of 7.957 for the same app-related question.

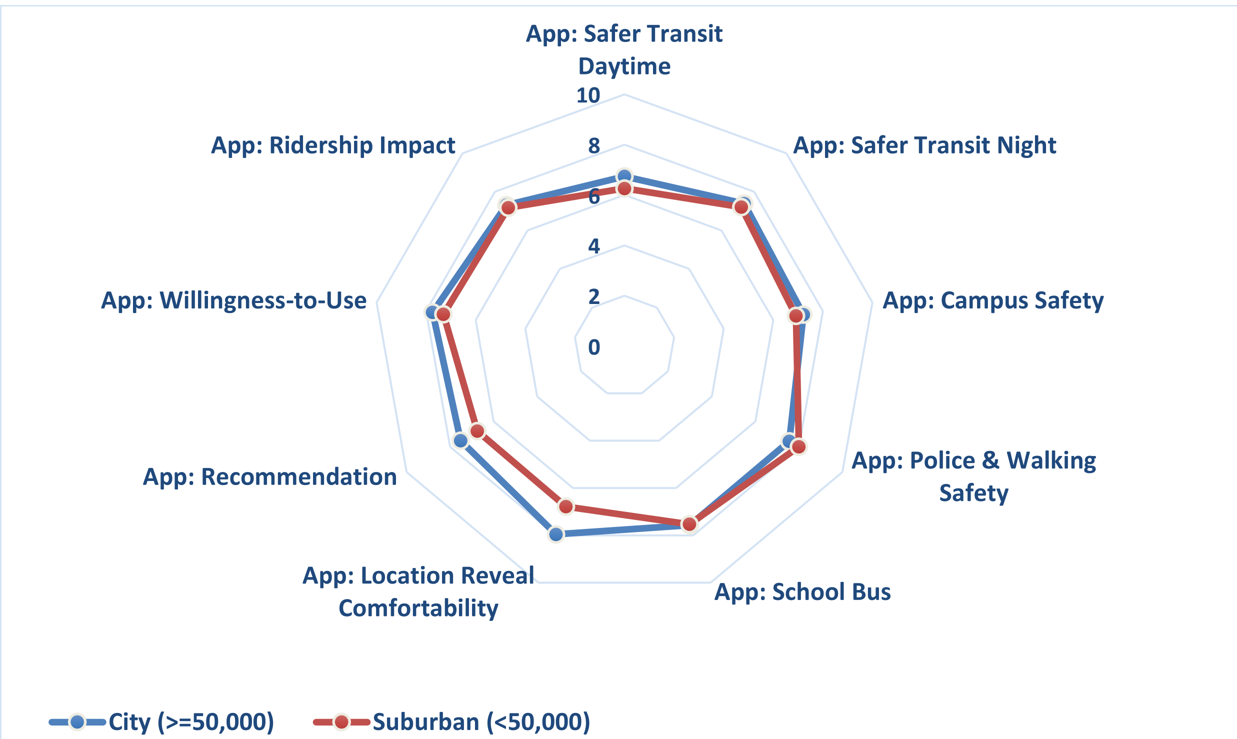

Figure 105. App-related ratings by "Work/Study Location."

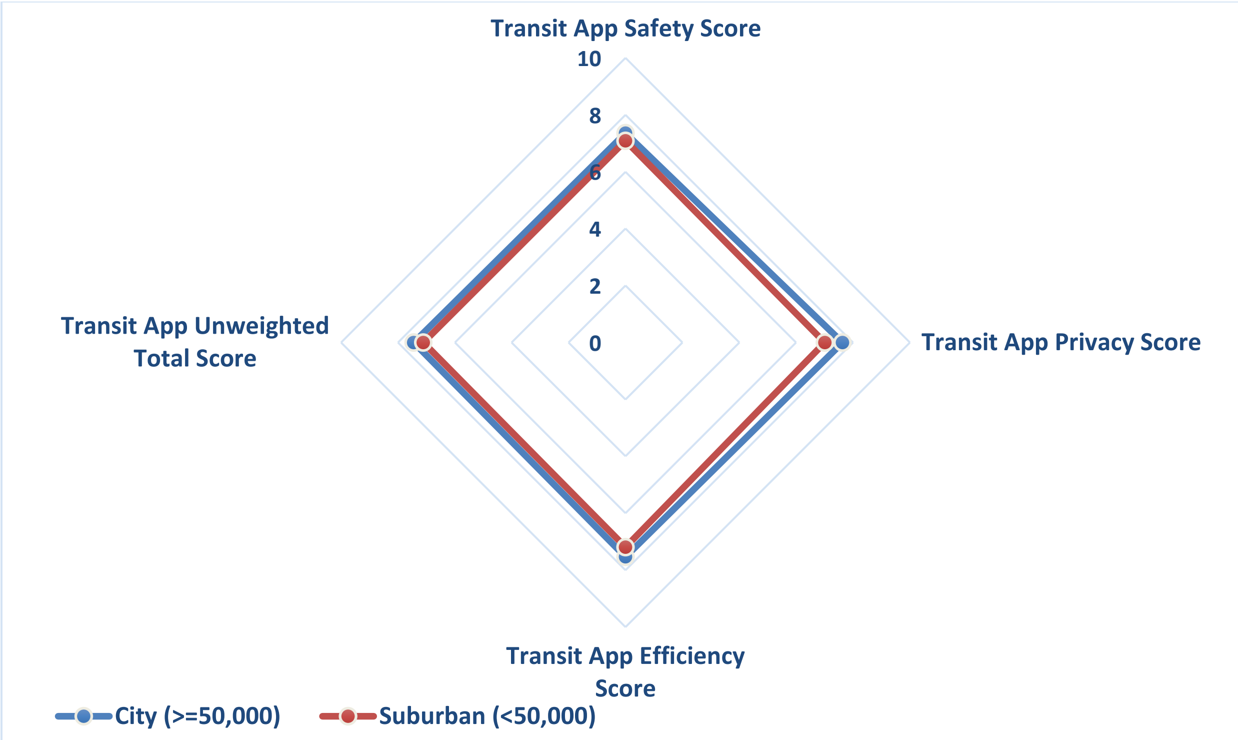

Figure 106. Combined app-related ratings by "Work/Study Location."

By Commute Type

Figure 107 and Figure 108 show app-related ratings and combined app-related ratings by commute type, respectively. While visually some differences can be seen between different cohorts, there were not any significant differences between different commute type cohorts. However, some of the lowest average ratings for different app-related questions belonged to some of the commute type cohorts as follows:

- "City-City" for "*Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety?*" (6.909)
- "City-City" for "*Q23. Do you think this transit app can be used for school bus operation?*" (6.818)
- "City-Suburban or Suburban-City" for "*Q27. Do you think this transit app can increase transit ridership?*" (6.824)

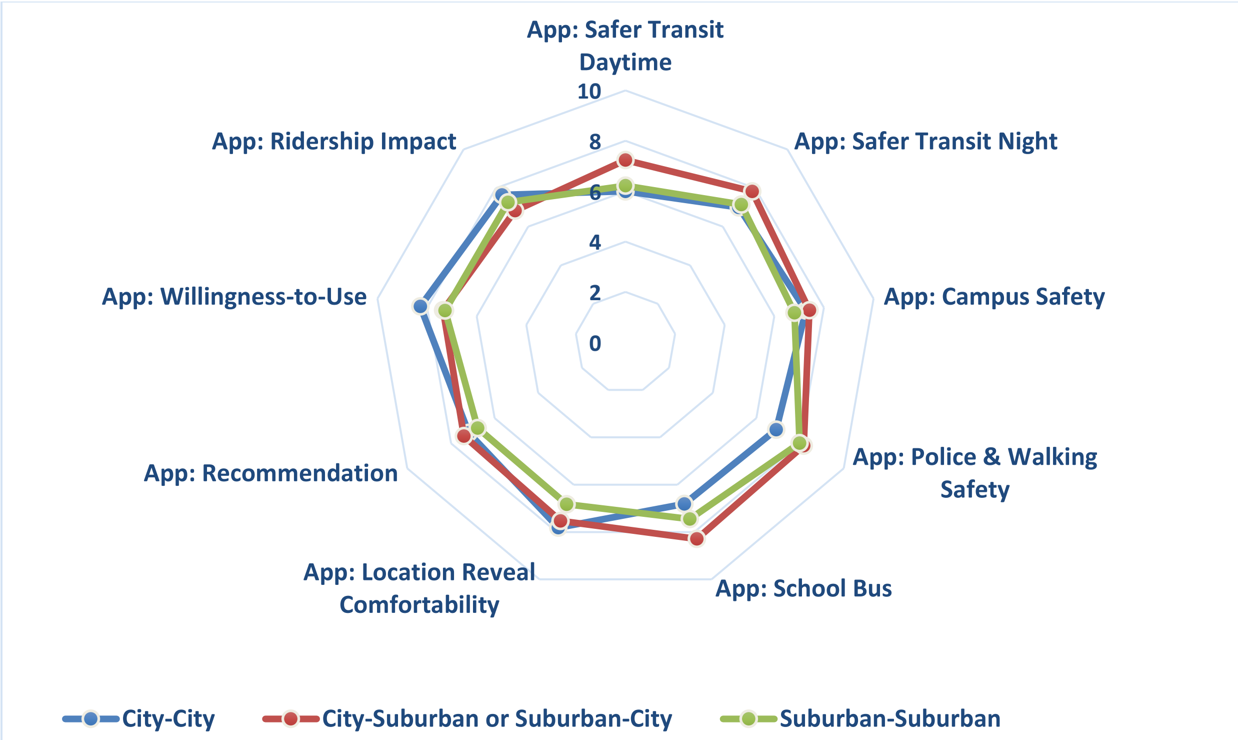

Figure 107. App-related ratings by "Commute Category (3 groups)."

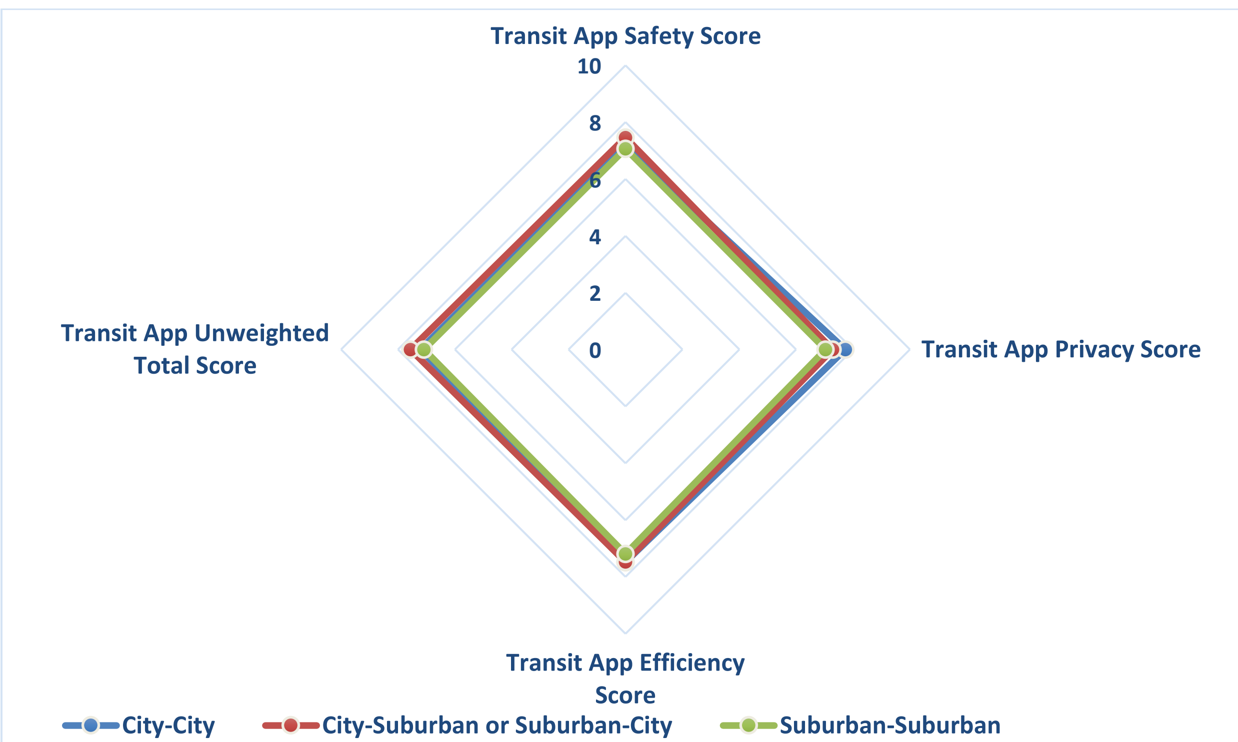

Figure 108. Combined app-related ratings by "Commute Category (3 groups)."

Analysis Summary

Table 25 summarizes the analysis of variance (ANOVA) results for the proposed transit app-related questions and participant characteristics. All of the individual ANOVA tables are available in Appendix E.

The following app-related questions faced significantly different cohorts from multiple participant characteristics:

- "*Q21. Do you think this transit app can improve safety on the university campus?*" for education, driving pattern (regularly), transit use, commute time, and transit transfer
- "*Q26. Are you willing to use the app and flexible transit service, if it can meet your need?*" for annual income, driving pattern (regularly), transit use, transit transfer, and transit extra time
- "*Q19. Do you think this transit app makes for a safer transit experience during the daytime?*" for race/ethnicity, occupation, and commute time

The following participant characteristics were identified as key characteristics for which different cohorts had significantly different attributes:

- Transit transfer: Participants without transit transfers rated four different app-related questions and also all four combined app-related questions higher. Two cohorts had several times (10) the highest/lowest average ratings.
- Commute time: Participants with more than 20-minute commute times rated six different app-related questions and two combined app-related scores higher.
- Car ownership: Participants without a car rated two different app-related questions higher. Participants without a car had the highest average ratings five times, including "Unweighted Total Score."

Table 25. ANOVA of App-Related Questions and Participant Characteristics

ANOVA	App: Safer Transit Daytime	App: Safer Transit Night	App: Campus Safety	App: Police & Walking Safety	App: School Bus	App: Location Reveal Comfortability	App: Recommendation	App: Willingness-to-Use	App: Ridership Impact	Transit App Safety Score	Transit App Privacy Score	Transit App Efficiency Score	Transit App Unweighted Total Score	#
Gender														0
Age (3 groups)														0
Marital Status (2 groups)														0
Annual Income (3 groups)								0.084						1
Race/Ethnicity (3 groups)	0.073													1
Education (3 groups)			0.037											1
Occupation (2 groups)	0.044													1
Car Ownership		0.046			0.100									2
Driving Pattern (Regularly)			0.054					0.042						2
Transit Use Frequency (2 groups)			0.083					0.075						2
Commute Time (2 groups)	0.000	0.016	0.066	0.038	0.014		0.034			0.022			0.023	8
Transfer			0.062			0.029	0.004	0.050		0.058	0.018	0.026	0.040	8
Transit Extra Time (3 groups)								0.041				0.093		2
Transit App Familiarity														0
Transit App Use														0
Home Location Category														0
Work/Study Location Category						0.055								1
Commute Category (3 groups)														0
#	3	2	5	1	2	2	2	5	0	2	1	2	2	29

p-value < 0.01

p-value < 0.05

p-value < 0.1

Conclusion

Although many transit agencies provide real-time operational information, including routing and scheduling through phone, Web, and smartphone applications, and also provide a trip-planning tool for a given origin and destination, they use a one-directional information flow from transit agencies to transit users. The authors believe that current smartphone technology and connected vehicle infrastructure (CVI) can allow two-directional information flow that includes information from users to transit agencies and transit vehicles.

The PIs proposed that users can send their origin and destination information to the agency, and the agency can use that information for DRT routing and scheduling, primarily for small urban area and rural transit operations. GPS data from smartphones can provide the locations of users, which can be used to support the flexible routing of transit vehicles to pick up passengers more efficiently (especially when they are not at the transit stop as expected) and save transit travel time. It is believed that identification of user location can also contribute to passengers' safety during nighttime operations.

Transit user input can also help fixed-route transit operations and passenger safety during nighttime operations. If the bus driver can identify the locations of passengers who are late to the bus stop, the bus driver can wait a short time, eliminating the chance that the passengers will miss the bus and have wait at the stop for the next bus that may come 20 or 30 minutes later.

While developing a two-way user location-based mobile app for transit service, the authors conducted a survey to determine the perception and acceptability of the app in terms of safety and efficiency enhancements and privacy issues related to location tracking. The survey results were analyzed mainly in three aspects: safety, efficiency, and privacy for different demographic, travel behavior, and geographic characteristics.

In general, users did not significantly consider the privacy issues of using a user location-based app (7.1/10.0) but believed that the user location-based app could improve nighttime safety (7.3/10.0). Also, it was believed that this app could improve nighttime pedestrian safety if it could be connected to the police department (7.8/10.0). This app was also expected to improve transit efficiency and increase ridership, and was seen as eventually being recommendable (7.3/10.0). The least expected improvement was daytime safety (6.4/10.0), which is reasonable and expected.

Appendices

Appendix A – Acronyms and Abbreviations

Acronyms, Abbreviations, and Symbols	Expansion and Explanation
3G	3rd Generation of wireless technology
4G	4th Generation of wireless technology
AASHTO	American Association of State Highway and Transportation Officials
ACW	All-Around Collision Warning
AERIS	Applications for the Environment: Real-Time Information Synthesis
AMI-C	Automotive Multimedia Interface Collaboration
AV	Automated/Autonomous Vehicle
CAN	Controller Area Network
CDMA	Code Division Multiple Access
CSP	Company Safety Profile
CV	Connected Vehicle
CVI-UTC	Connected Vehicle/Infrastructure University Transportation Center
CVP	Connected Vehicle Program
CVRIA	Connected Vehicle Reference Implementation Architecture
CVT	Connected Vehicle Technology
CVTA	Connected Vehicle Trade Association
DAC	Driver Acceptance Clinics
DCH	Dedicated Channel
DNPW	Do Not Pass Warning
DSRC	Dedicated Short Range Communication
DVB-H	Digital Video Broadcasting-Handheld
FCC	Federal Communications Commission
FCW	Front/Forward Collision Warning
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GAN	Global Area Network
GPS	Global Positioning System
GSM	Global System for Mobile communications
HSPA	High Speed Packet Access
IEEE	Institute of Electrical and Electronics Engineers

Acronyms, Abbreviations, and Symbols	Expansion and Explanation
ILTA	Intersection & Left Turn Assist
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS JPO	ITS Joint Program Office
IV	Intelligent Vehicle
LAN	Local Area Network
LDWS	Lane Departure Warning System
LiDAR	Light Detection and Ranging
LRS	Linear Referencing System
M2M	Machine-to-Machine
MAN	Metropolitan Area Network
MARAD	Maritime Administration
MBMS	Multimedia Broadcast/Multicast Service
MCMIS	Motor Carrier Management Information System
MNO	Mobile Network Operator
MSRP	Manufacturer's Suggested Retail Price
MSU	Morgan State University
NEISS	National Electronic Injury Surveillance System
NHTSA	National Highway Traffic Safety Administration
NTCIP	National Transportation Communications for ITS Protocol
NTIA	National Telecommunications and Information Administration
OBE	On-Board Equipment
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnect
PAN	Personal Area Network
PCA	Pedestrian & Cyclist Alert
PSL	Parking Spot Locator
RCN	Road Condition Notification
RFID	Radio Frequency Identification
RITA	Research and Innovative Technology Administration
RMEV	Rate per Million of Entering Vehicles
RMVM	Rate per 100 Million Vehicle-Miles
RSE	Roadside Equipment
RTRPRO	Real Time Route Planning and Route Optimization
SACH	Safety Analysis Chain
SAE	Society of Automotive Engineers
SAN	Storage Area Network
SCW	Side Collision Warning

Acronyms, Abbreviations, and Symbols	Expansion and Explanation
SEM	Structural Equation Modeling
SHSP	Strategic Highway Safety Plan
SSWWVA	Slow/Stop/Wrong-Way Vehicle Advisor
SV	Smart Vehicle
TAM	Total Addressable Market
TRB	Transportation Research Board
TRCC	Traffic Records Coordinating Committee
UA	User Acceptance
UMTRI	University of Michigan Transportation Research Institute
UMTS	Universal Mobile Telecommunications System
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Anything or Vehicle-to-Device
VCTIR	Virginia Center For Transportation Innovation and Research
VDOT	Virginia Department of Transportation
VII	Vehicle Infrastructure Integration
VIIC	Vehicle Infrastructure Integration Consortium
VMT	Vehicle Miles of Travel
VSC	Vehicle Safety Communications
VTTI	Virginia Tech Transportation Institute
WAN	Wide Area Network
WAVE	Wireless Access for Vehicular Environments
WLAN	Wireless Local Area Network
WTP	Willingness-to-Pay/Purchase

Appendix B – Definitions of Selected Connected Vehicles Applications

- **Advanced traveler information systems**: "*The Advanced Traveler Information Systems applications provide for the collection, aggregation, and dissemination of a wide range of transportation information. The collection of information includes traffic, transit, road weather, work zone, and connected vehicle related data. All the sources of data are aggregated into data environments that can be used to drive data portals allowing dissemination of the entire spectrum of transportation information to travelers via mobile devices, in vehicle displays, web portals, 511 systems, and roadside signage.*" (Iteris, Inc., 2016)
- **Dynamic ridesharing**: "*The Dynamic Ridesharing application allows travelers to arrange carpool trips through a stand-alone personal device with a wireless connection and/or an automated ride matching system (e.g., call center or web-based application loaded on a personal computer or kiosk at a transit facility). The application uses inputs from both passengers and drivers pre-trip, during the trip, and post-trip. These inputs are then translated into "optimal" pairings between passengers and drivers to provide both with a convenient route between their two origin and destination locations. After the trip, information is provided back to the application to improve the user's experience for future trips and monitor use of high-occupancy lanes.*" (Iteris, Inc., 2016)
- **Dynamic transit operations**: "*The Dynamic Transit Operations application allows travelers to request trips and obtain itineraries using a handheld mobile device (or personal computer). The trips and itineraries would cover multiple transportation services (public transportation modes, private transportation services, shared-ride, walking and biking). This application builds on existing technology systems such as computer-aided dispatch/ automated vehicle location (CAD/AVL) systems and automated scheduling software, providing a coordination function within and between transit providers that would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together*." (Iteris, Inc., 2016)
- **Eco-traffic signal timing**: "*The Eco-Traffic Signal Timing application is similar to current adaptive traffic signal control systems; however, the application's objective is explicitly to optimize traffic signals for the environment rather than the current adaptive systems' objective, which is to enhance the intersection level of service or throughput, which might improve the intersection's environmental performance. The Eco-Traffic Signal Timing application processes real-time and historical connected vehicle data at signalized intersections to reduce fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real time and adapts so that the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.*" (Iteris, Inc., 2016)
- **Eco-transit signal priority**: "*The Eco-Transit Signal Priority application allows a transit vehicle approaching a signalized intersection to request signal priority. The application considers a host of relevant parameters to determine whether signal priority should be granted. These parameters include the vehicle's location, speed, vehicle powertrain type, mass, grade, and associated modal GHG and criteria air pollutant emissions. Information collected from other vehicles approaching the intersection, a transit vehicle's adherence to its schedule, or the number of passengers on the transit vehicle may also be considered in granting priority. If*

priority is granted, the traffic signal holds the green on the approach until the transit vehicle clears the intersection" (Iteris, Inc., 2016)

- **Integrated multi-modal electronic payment**: "*The Integrated Multi-Modal Electronic Payment application uses connected vehicle roadside and vehicle systems to provide the electronic payment capability for toll systems, parking systems, and other areas requiring electronic payments.*" (Iteris, Inc., 2016)
- **Intelligent traffic signal system**: "*The Intelligent Traffic Signal System (ISIG) application uses both vehicle location and movement information from connected vehicles as well as infrastructure measurement of non-equipped vehicles to improve the operations of traffic signal control systems. The application utilizes the vehicle information to adjust signal timing for an intersection or group of intersections in order to improve traffic flow, including allowing platoon flow through the intersection. The application serves as an over-arching system optimization application, accommodating other mobility applications such as Transit Signal Priority, Freight Signal Priority, Emergency Vehicle Preemption, and Pedestrian Mobility to maximize overall arterial network performance. In addition, the application may consider additional inputs such as environmental situation information or the interface (i.e., traffic flow) between arterial signals and ramp meters.*" (Iteris, Inc., 2016)
- **Intermittent bus lanes**: "*The Intermittent Bus Lane (IBL) application provides dedicated bus lanes during peak demand times to enhance transit operations mobility. IBL consists of a lane that can change its status from regular lane (accessible for all vehicles) to bus lane, for the time strictly necessary for a bus or set of buses to pass. The status of the IBL is communicated to drivers using roadside message signs and through in-vehicle signage. The creation and removal of dedicated bus lanes is managed through coordination between traffic and transit centers*." (Iteris, Inc., 2016)
- **Motorcycle approaching indication**: "*The Motorcycle Approaching Indication application is intended to warn the driver of a vehicle that a motorcycle is approaching. The motorcycle could be approaching from behind or crossing at an intersection. Moreover, the application provides advisory information that is intended to inform the driver that a vehicle which affords limited visibility due to its size is approaching*." (Iteris, Inc., 2016)
- **Pedestrian in signalized crosswalk warning**: "*The Pedestrian in Signalized Crosswalk Warning application provides to the connected vehicle information from the infrastructure that indicates the possible presence of pedestrians in a crosswalk at a signalized intersection. The infrastructure based indication could include the outputs of pedestrian sensors or simply an indication that the pedestrian call button has been activated. This application has been defined for transit vehicles, but can be applicable to any class of vehicle. The application could also provide warning information to the pedestrian regarding crossing status or potential vehicle infringement into the crosswalk*." (Iteris, Inc., 2016)
- **Pedestrian mobility**: "*The Pedestrian Mobility application will integrate traffic and pedestrian information from roadside or intersection detectors and new forms of data from wirelessly connected, pedestrian (or bicyclist) carried mobile devices (nomadic devices) to request dynamic pedestrian signals or to inform pedestrians when to cross and how to remain aligned with the crosswalk based on real-time Signal Phase and Timing (SPaT) and MAP information. In some cases, priority will be given to pedestrians, such as persons with disabilities who need additional crossing time, or in special conditions (e.g., weather) where pedestrians may warrant priority or*

additional crossing time. This application will enable a "pedestrian call" to be routed to the traffic controller from a nomadic device of a registered person with disabilities after confirming the direction and orientation of the roadway that this pedestrian is intending to cross. The application also provides warnings to the personal information device user of possible infringement of the crossing by approaching vehicles." (Iteris, Inc., 2016)

- **Route ID for the visually impaired**: "*The Route ID for the Visually Impaired (RVI) application assist visibly impaired travelers to identify the appropriate bus and route to their intended destination. The application provides information from bus stop infrastructure to visually impaired travelers' portable devices that can be converted to audible information regarding the appropriate bus and route. The application could allow the visually impaired traveler to query the portable device to identify route options*." (Iteris, Inc., 2016)
- **Slow vehicle warning**: "*The Slow Vehicle Warning application is intended to warn the driver of a vehicle that they are approaching a slow moving vehicle. Moreover, the application provides advisory information that is intended to inform the driver that their vehicle is approaching a slow moving vehicle*." (Iteris, Inc., 2016)
- **Smart park and ride system**: "*The Smart Park and Ride application provides real-time information on Park and Ride capacity and supports traveler's decision-making on where best to park and make use of transit alternatives. The application uses connected vehicles to monitor in real time the occupancy of parking spaces and provide the information to travelers via smartphones and to connected vehicles*." (Iteris, Inc., 2016)
- **Transit connection protection**: "*The Transit Connection Protection application allows travelers to initiate a request for connection protection anytime during the trip using a personal mobile device, or potentially via transit vehicle or personal automobile onboard equipment / interface, and receive a confirmation indicating whether the request is accepted. Connection protection uses real time data to examine the arrival status of a transit vehicle and to transmit a hold message to a vehicle or other mode of transportation (e.g. rail) in order for the traveler to make a successful transfer from one vehicle to another. Connection protection can be performed within a single agency, across multiple agencies, and across multiple modes. In order to make this application viable a central transfer request brokerage system for processing transfer requests could be created. This tool would be particularly important in an intermodal, multimodal or interagency environment since the existing computer-aided dispatch/ automated vehicle location (CAD/AVL) systems at individual agencies may not have the ability to share or process real-time data available from various external sources (e.g., multi-agency and multimodal operational subsystems) to determine the feasibility of a connection protection request. The system will first determine the feasibility of a transfer based on fixed-schedule and then monitor the real-time status using input from the control center(s)*." (Iteris, Inc., 2016)
- **Transit pedestrian indication**: "*The Transit Pedestrian Indication application provides vehicle to device communications to inform pedestrians at a station or stop about the presence of a transit vehicle. In addition, this application would inform the transit vehicle operator about the presence of pedestrians nearby and those waiting for the bus. It would help prevent collisions between transit vehicles and pedestrians.*" (Iteris, Inc., 2016)
- **Transit signal priority**: "*The Transit Signal Priority application uses transit vehicle to infrastructure communications to allow a transit vehicle to request a priority at one or a series of intersection. The application includes feedback to the transit driver indicating whether the signal*

priority has been granted or not. This application can contribute to improved operating performance of the transit vehicles by reducing the time spent stopped at a red light." (Iteris, Inc., 2016)

- **Transit stop request**: "*The Transit Stop Request application allows a transit passenger to send a stop request to an approaching transit vehicle. This application allows a transit vehicle to know that a passenger has requested a transit stop from an infrastructure device*." (Iteris, Inc., 2016)
- **Transit vehicle at station/stop warnings**: "*The Transit Vehicle at Station/Stop Warnings application inform nearby vehicles of the presence of a transit vehicle at a station or stop. The application also indicates the intention of the transit vehicle in terms of pulling into or out of a station/stop.*" (Iteris, Inc., 2016)
- **Vehicle turning right in front of a transit vehicle**: "*The Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV) application determines the movement of vehicles near to a transit vehicle stopped at a transit stop and provides an indication to the transit vehicle operator that a nearby vehicle is pulling in front of the transit vehicle to make a right turn. This application will help the transit vehicle determine if the area in front of it will not be occupied as it begins to pull away from a transit stop.*" (Iteris, Inc., 2016)

Appendix C– Survey for the User Location-based Transit Mobile App

Thank you for your participation in this research survey conducted by the Morgan State University research team and sponsored by the Connected Vehicle Infrastructure University Transportation Center at Virginia Tech. This survey will take no more than 10 minutes.

The title of the research is "Applications of Connected Vehicle Infrastructure Technologies to Enhance Transit Service Efficiency and Safety," and as part of the research project, a User-based Two-way Mobile App has been developed.

Unlike most transit apps in the market, this new app enables transit passengers to communicate with the transit control center as well as a bus driver to request, modify and confirm a trip using two-way communication capability. Also, using user located capability, bus drivers can locate the passengers' locations and as long as they are near the bus stops, passengers are guaranteed to be picked up, which will enhance passenger safety at night.

The research team believes that this app can be used for

- Regular fixed-route transit service to provide the bus schedules, stop locations and bus locations to bus passengers to improve passengers' information and efficiency as well as potential safety, especially at night
- Flexible transit service to request, modify and confirm a transit trip. The user location-based app enables more efficient and safe trips for potential transit users
- Shuttle bus service including school bus service to arrange the trips and pick up passengers

Followings are the sample screen shots for the mobile app for transit passengers, bus drivers and transit agencies.

Please look at them to understand the app and go through the survey questions.

If you have any questions about the apps and this survey, please feel free to contact the principal investigator of this research project, Young-Jae Lee, Associate Professor at Morgan State University, (YoungJae.Lee@morgan.edu).

The survey can be accessed online using following link or QR Code as well:

http://tinyurl.com/cvi-survey-2016

Thank you.

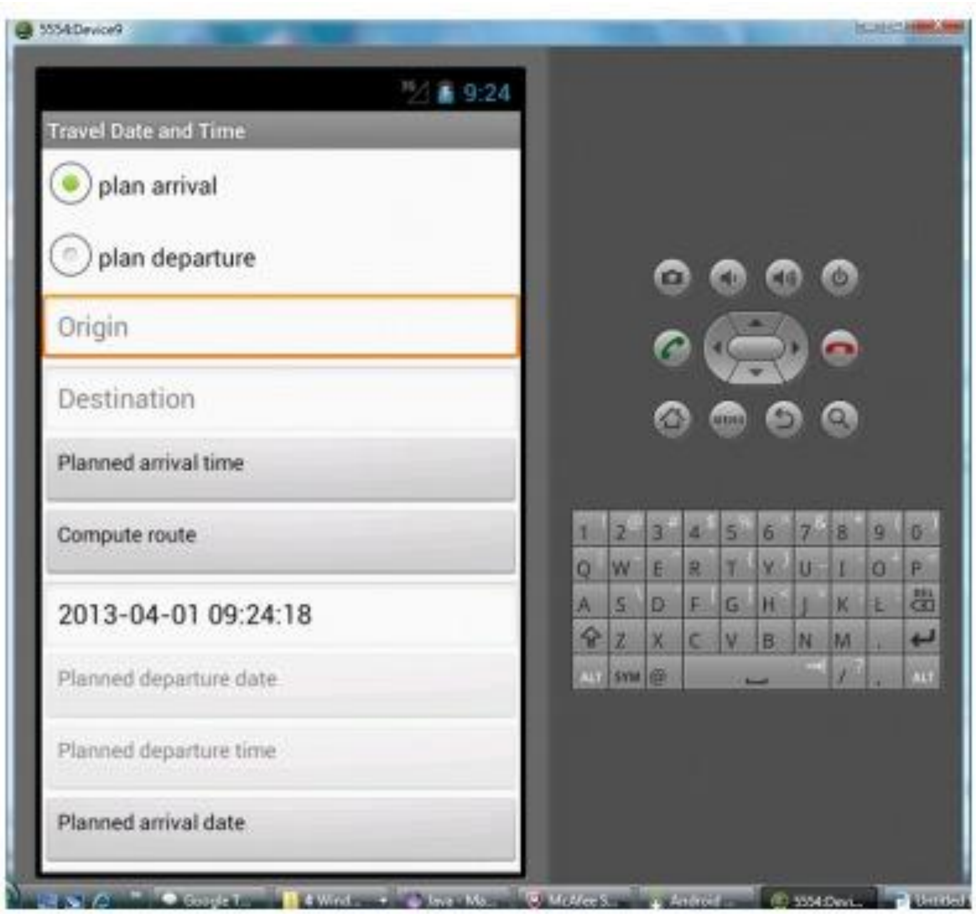

Figure 1. Sample User-Interface for the Mobile App

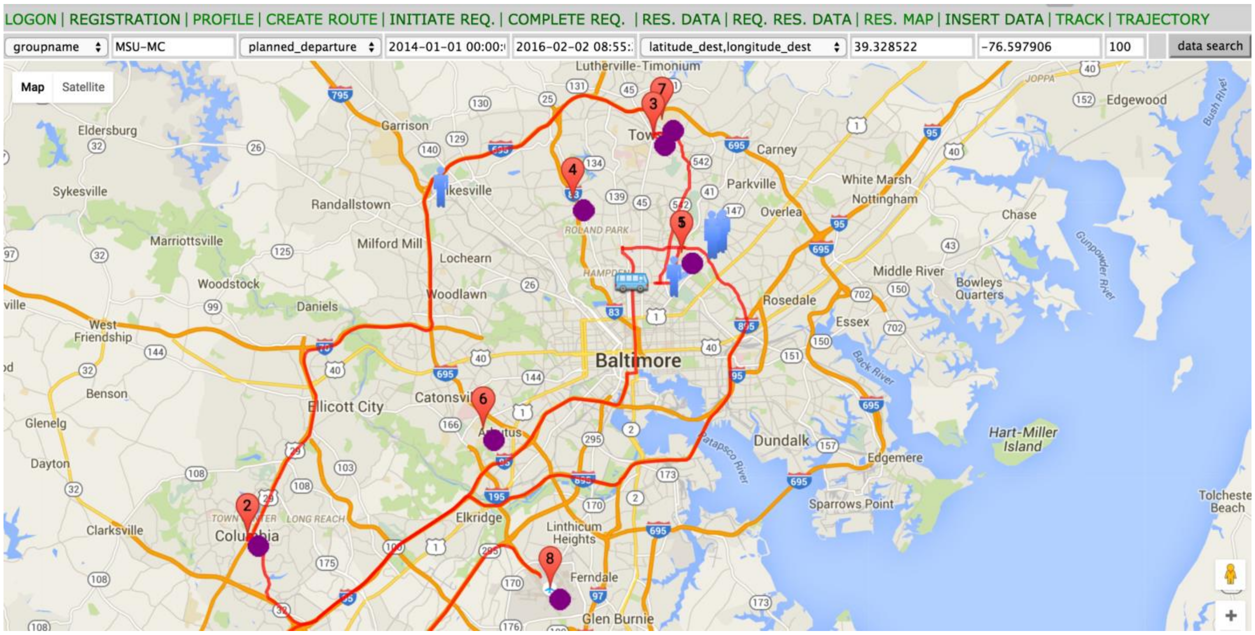

Figure 2. Sample Screen for a Transit Agency and a Bus Driver to show the Bus Stops, Bus and Passengers

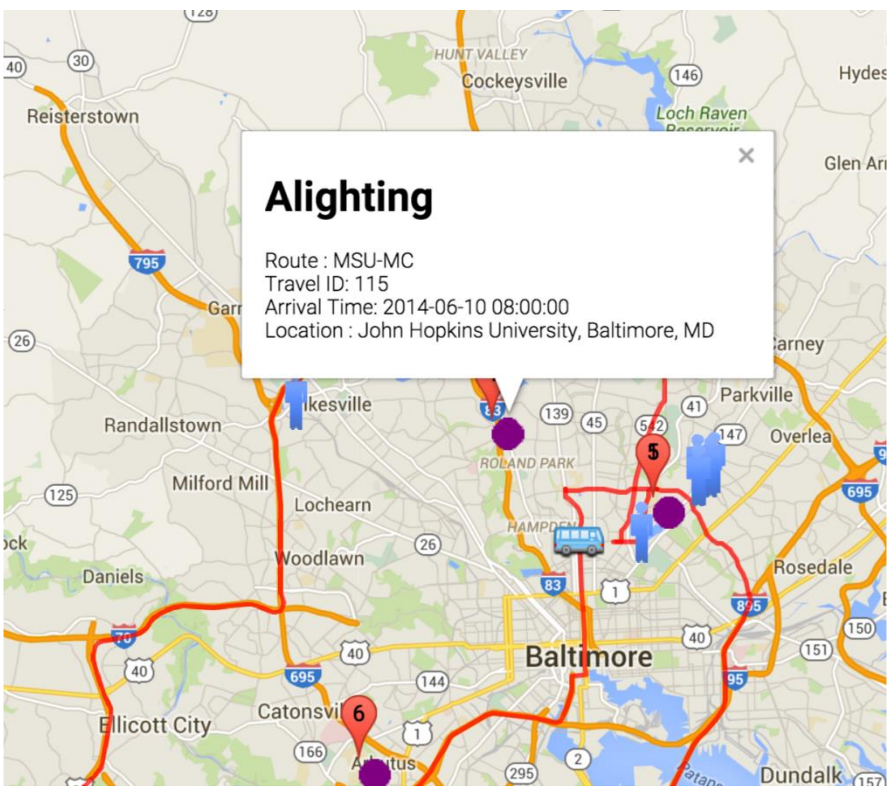

Figure 3. Sample Screen to Show the Passenger Information for the Particular Bus Stop

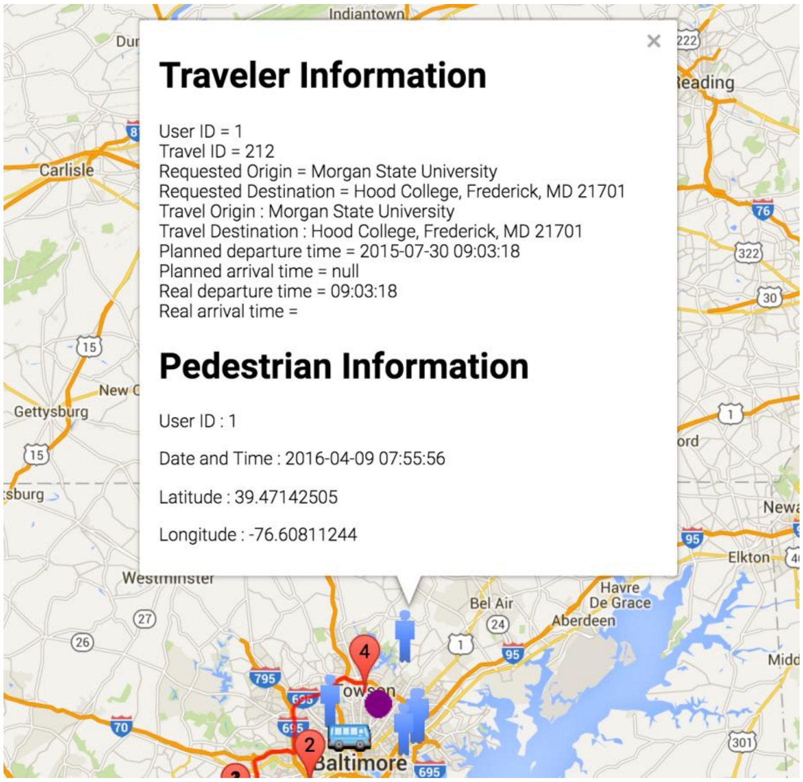

Figure 4. Specific Passenger Information for a Transit Agency and a Bus Driver

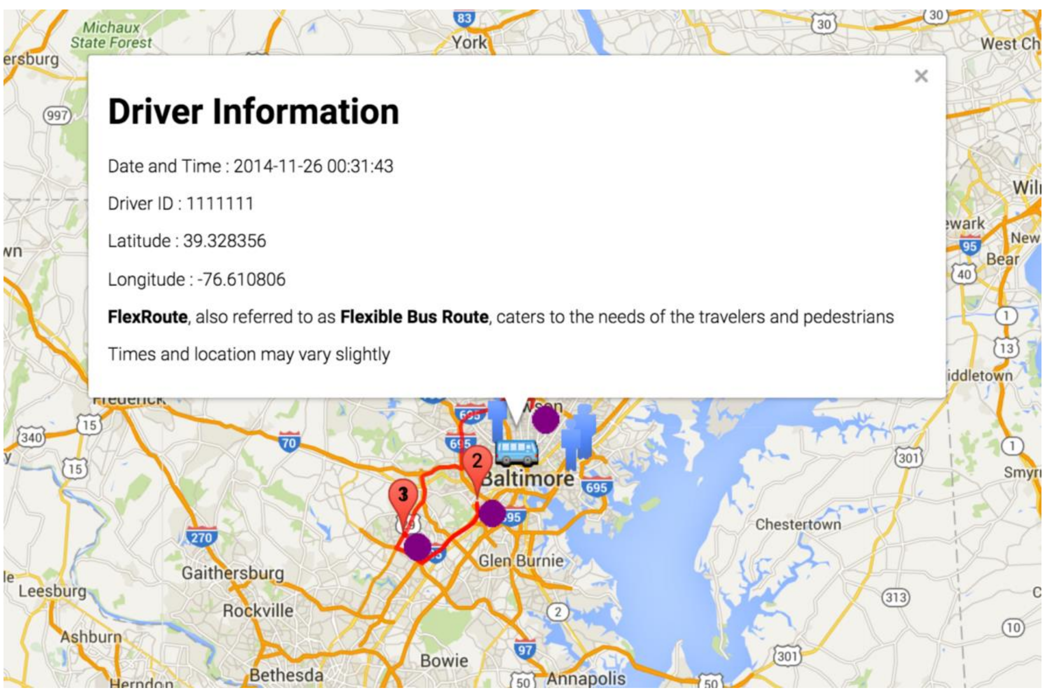

Figure 5. Bus and Bus Driver Information for Passengers

Survey

Q1. What is your gender?

☐ **Male** ☐ **Female**

Q2. What age group do you belong to?

☐ **18-24** ☐ **25-34** ☐ **35-44** ☐ **45-64** ☐ **65 and over**

Q3. What is your marital status?

☐ **Single** ☐ **In domestic partnership** ☐ **Married**

Q4. What is your annual household income?

☐ **Less than $25,000** ☐ **$25,000 - $50,000** ☐ **$50,000 - $75,000**

☐ **$75,000 - $100,000** ☐ **$100,000 - $200,000** ☐ **More than $200,000**

☐ **Prefer not to answer**

Q5. What is your race/ethnicity?

☐ **White (non-Hispanic)** ☐ **Hispanic** ☐ **Black or African-American**

☐ **Asian** ☐ **American Indian or Alaska Native** ☐ **Native Hawaiian or other Pacific Islander**

☐ **Other** ☐ **Prefer not to answer**

Q6. What is your highest level of education?

☐ **Some high school** ☐ **High school diploma or GED** ☐ **Associate's degree**

☐ **Bachelor's degree** ☐ **Master's degree** ☐ **Doctoral or higher**

Q7. What describes you the most?

☐ **Undergraduate student** ☐ **Graduate student** ☐ **Employed**

☐ **Not employed** ☐ **Other (Please specify)**

Q8. In which Zip Code area do you live?

Q9. In which Zip Code area do you work/study?

Please disregard if not applicable.

Q10. Do you own a car or can you access a car to commute?

☐ Yes **☐ No**

Q11. Do you drive regularly?

☐ Yes **☐ No**

Q12. Do you use transit? If so, how many times do you use it in a week?

☐ None **☐ 1-3** **☐ 4-6** **☐ 7 and more**

Q13. How far do you commute?

☐ Walking distance **☐ Less than 20 minutes** **☐ Less than 40 minutes**

☐ Less than an hour **☐ More than an hour**

Q14. Can you use a transit service to commute? If so, how many transfers?

☐ I do not use transit to commute **☐ 1 transfer** **☐ 2 transfer**

☐ 3 or more transfers **☐ I do not know**

Q15. How much time do you need to spend more if you use transit for your commuting?

☐ Almost the same **☐ Less than 20 minutes more** **☐ Less than 40 minutes more** **☐ Less than 1 hour more** **☐ More than 1 hour more** **☐ I do not know**

Q16. Do you have an electronic device (like smartphone, iPad, iPod, tablet and etc.) which you can install an app on it?

☐ Yes **☐ No**

Q17. Are you Familiar with any transit app?

☐ Yes **☐ No**

Q18. Have you used any transit apps before?

☐ **Yes** ☐ **No**

Please rate the following questions from 1 (least agree) to 10 (most agree)

Following questions are referring to the "User-based Two-way Mobile App" that has been developed as part of this research project. In the previous pages, there were few sample screen shots of the mobile app for transit passengers, bus drivers and transit agencies. Please look at them to understand the app and go through the following survey questions.

Q19. Do you think this transit app makes for a safer transit experience during the daytime? ( )

Q20. Do you think this transit app makes for a safer transit experience at night? ( )

Q21. Do you think this transit app can improve safety on the university campus? ( )

Q22. If this transit app is connected with the police department, can it be used to improve nighttime walking safety? ( )

Q23. Do you think this transit app can be used for school bus operation? ( )

Q24. Are you comfortable with letting a transit agency know your location, if this transit app is only used for the transit operation? ( )

Q25. Can you recommend this type of mobile app for transit users? ( )

Q26. Are you willing to use the app and flexible transit service, if it can meet your need? ( )

Q27. Do you think this transit app can increase transit ridership? ( )

Thank you for your participation!

Appendix D – Survey of Participants' Home or Work/Study City/Urban Area

City/Urban Area		Count	%
Location (Home)	Baltimore	8	8.9%
	Beltsville	1	1.1%
	Bethesda	0	0.0%
	Blacksburg	21	23.3%
	Blue Bell	1	1.1%
	Bridgeport	1	1.1%
	Burlington	1	1.1%
	Charlottesville	1	1.1%
	Christiansburg	12	13.3%
	Clarksville	1	1.1%
	Curtis Bay	0	0.0%
	Dundalk	1	1.1%
	Edgewood	1	1.1%
	Fairfax Station	1	1.1%
	Greenbelt	0	0.0%
	Gwynn Oak	1	1.1%
	Hyattsville	1	1.1%
	Laurel	1	1.1%
	Lutherville-Timonium	1	1.1%
	Manchester	3	3.3%
	Mansfield	0	0.0%
	Max Meadows	1	1.1%
	McLean	1	1.1%
	Narrows	1	1.1%
	New Britain	1	1.1%
	Newport News	2	2.2%
	Nottingham	1	1.1%
	Owings Mills	2	2.2%
	Parkville	5	5.6%
	Pearisburg	2	2.2%
	Philadelphia	1	1.1%
	Radford	4	4.4%
	Rosedale	2	2.2%
	Salem	1	1.1%
	Silver Spring	2	2.2%
	State College	1	1.1%

City/Urban Area		Count	%
	Swarthmore	2	2.2%
	Towson	0	0.0%
	University Park	0	0.0%
	Upper Marlboro	1	1.1%
	Vienna	1	1.1%
	Villanova	0	0.0%
	Washington	1	1.1%
	Westminster	1	1.1%
Location (Work/Study)	Baltimore	19	22.9%
	Beltsville	0	0.0%
	Bethesda	1	1.2%
	Blacksburg	42	50.6%
	Blue Bell	0	0.0%
	Bridgeport	0	0.0%
	Burlington	0	0.0%
	Charlottesville	1	1.2%
	Christiansburg	0	0.0%
	Clarksville	0	0.0%
	Curtis Bay	5	6.0%
	Dundalk	0	0.0%
	Edgewood	0	0.0%
	Fairfax Station	0	0.0%
	Greenbelt	1	1.2%
	Gwynn Oak	0	0.0%
	Hyattsville	0	0.0%
	Laurel	1	1.2%
	Lutherville-Timonium	0	0.0%
	Manchester	0	0.0%
	Mansfield	1	1.2%
	Max Meadows	0	0.0%
	McLean	1	1.2%
	Narrows	0	0.0%
	New Britain	0	0.0%
	Newport News	0	0.0%
	Nottingham	0	0.0%
	Owings Mills	0	0.0%
	Parkville	1	1.2%
	Pearisburg	0	0.0%
	Philadelphia	1	1.2%
	Radford	0	0.0%

City/Urban Area		Count	%
	Rosedale	1	1.2%
	Salem	0	0.0%
	Silver Spring	0	0.0%
	State College	0	0.0%
	Swarthmore	0	0.0%
	Towson	1	1.2%
	University Park	1	1.2%
	Upper Marlboro	0	0.0%
	Vienna	0	0.0%
	Villanova	5	6.0%
	Washington	1	1.2%
	Westminster	0	0.0%

Appendix E – ANOVA Tables for Participants' Characteristics

ANOVA						
Gender		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.141	1	0.141	0.026	0.872
	Within Groups	485.294	90	5.392		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	2.831	1	2.831	0.568	0.453
	Within Groups	448.419	90	4.982		
	Total	451.250	91			
App: Campus Safety	Between Groups	0.364	1	0.364	0.077	0.783
	Within Groups	427.592	90	4.751		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	2.061	1	2.061	0.509	0.477
	Within Groups	364.417	90	4.049		
	Total	366.478	91			
App: School Bus	Between Groups	7.983	1	7.983	2.013	0.159
	Within Groups	357.006	90	3.967		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	0.080	1	0.080	0.013	0.909
	Within Groups	554.833	90	6.165		
	Total	554.913	91			
App: Recommendation	Between Groups	0.057	1	0.057	0.009	0.924
	Within Groups	561.900	90	6.243		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	0.291	1	0.291	0.053	0.819
	Within Groups	494.698	90	5.497		
	Total	494.989	91			
App: Ridership Impact	Between Groups	2.531	1	2.531	0.500	0.481

ANOVA						
Gender		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	455.208	90	5.058		
	Total	457.739	91			
Transit App Safety Score	Between Groups	0.353	1	0.353	0.111	0.739
	Within Groups	285.778	90	3.175		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	0.018	1	0.018	0.004	0.948
	Within Groups	363.392	90	4.038		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	0.253	1	0.253	0.073	0.788
	Within Groups	311.543	90	3.462		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	0.014	1	0.014	0.005	0.946
	Within Groups	262.446	90	2.916		
	Total	262.460	91			

ANOVA						
Age_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	1.457	2	0.729	0.134	0.875
	Within Groups	483.978	89	5.438		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	11.840	2	5.920	1.199	0.306
	Within Groups	439.410	89	4.937		
	Total	451.250	91			
App: Campus Safety	Between Groups	0.312	2	0.156	0.032	0.968
	Within Groups	427.644	89	4.805		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	7.902	2	3.951	0.981	0.379

ANOVA						
Age_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	358.576	89	4.029		
	Total	366.478	91			
App: School Bus	Between Groups	5.272	2	2.636	0.652	0.523
	Within Groups	359.717	89	4.042		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	1.986	2	0.993	0.160	0.853
	Within Groups	552.927	89	6.213		
	Total	554.913	91			
App: Recommendation	Between Groups	3.926	2	1.963	0.313	0.732
	Within Groups	558.031	89	6.270		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	2.602	2	1.301	0.235	0.791
	Within Groups	492.387	89	5.532		
	Total	494.989	91			
App: Ridership Impact	Between Groups	0.322	2	0.161	0.031	0.969
	Within Groups	457.417	89	5.140		
	Total	457.739	91			
Transit App Safety Score	Between Groups	0.906	2	0.453	0.141	0.868
	Within Groups	285.225	89	3.205		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	0.665	2	0.333	0.082	0.922
	Within Groups	362.745	89	4.076		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	1.180	2	0.590	0.169	0.845
	Within Groups	310.616	89	3.490		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	0.957	2	0.478	0.163	0.850
	Within Groups	261.503	89	2.938		

ANOVA						
Age_R1		Sum of Squares	df	Mean Square	F	Sig.
	Total	262.460	91			

ANOVA						
Marital_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.035	1	0.035	0.007	0.936
	Within Groups	472.075	89	5.304		
	Total	472.110	90			
App: Safer Transit Night	Between Groups	0.054	1	0.054	0.011	0.917
	Within Groups	443.550	89	4.984		
	Total	443.604	90			
App: Campus Safety	Between Groups	1.159	1	1.159	0.247	0.620
	Within Groups	417.566	89	4.692		
	Total	418.725	90			
App: Police & Walking Safety	Between Groups	6.061	1	6.061	1.503	0.223
	Within Groups	358.972	89	4.033		
	Total	365.033	90			
App: School Bus	Between Groups	1.438	1	1.438	0.358	0.551
	Within Groups	357.287	89	4.014		
	Total	358.725	90			
App: Location Reveal Comfortability	Between Groups	0.095	1	0.095	0.015	0.902
	Within Groups	554.015	89	6.225		
	Total	554.110	90			
App: Recommendation	Between Groups	0.358	1	0.358	0.057	0.812
	Within Groups	561.598	89	6.310		
	Total	561.956	90			
App: Willingness-to-Use	Between Groups	0.007	1	0.007	0.001	0.972

ANOVA						
Marital_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	488.609	89	5.490		
	Total	488.615	90			
App: Ridership Impact	Between Groups	0.023	1	0.023	0.005	0.946
	Within Groups	452.548	89	5.085		
	Total	452.571	90			
Transit App Safety Score	Between Groups	0.144	1	0.144	0.045	0.832
	Within Groups	283.550	89	3.186		
	Total	283.694	90			
Transit App Privacy Score	Between Groups	0.082	1	0.082	0.020	0.888
	Within Groups	363.243	89	4.081		
	Total	363.324	90			
Transit App Efficiency Score	Between Groups	0.258	1	0.258	0.074	0.786
	Within Groups	311.056	89	3.495		
	Total	311.315	90			
Transit App Unweighted Total Score	Between Groups	0.016	1	0.016	0.006	0.941
	Within Groups	259.909	89	2.920		
	Total	259.925	90			

ANOVA						
Income_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	20.290	2	10.145	1.904	0.156
	Within Groups	431.663	81	5.329		
	Total	451.952	83			
App: Safer Transit Night	Between Groups	10.535	2	5.268	1.033	0.361
	Within Groups	413.024	81	5.099		
	Total	423.560	83			
App: Campus Safety	Between Groups	8.075	2	4.037	0.802	0.452

ANOVA						
Income_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	407.877	81	5.036		
	Total	415.952	83			
App: Police & Walking Safety	Between Groups	4.100	2	2.050	0.486	0.617
	Within Groups	341.566	81	4.217		
	Total	345.667	83			
App: School Bus	Between Groups	2.493	2	1.246	0.300	0.741
	Within Groups	336.210	81	4.151		
	Total	338.702	83			
App: Location Reveal Comfortability	Between Groups	16.731	2	8.366	1.413	0.249
	Within Groups	479.590	81	5.921		
	Total	496.321	83			
App: Recommendation	Between Groups	22.959	2	11.479	1.946	0.149
	Within Groups	477.743	81	5.898		
	Total	500.702	83			
App: Willingness-to-Use	Between Groups	24.477	2	12.239	2.550	0.084
	Within Groups	388.809	81	4.800		
	Total	413.286	83			
App: Ridership Impact	Between Groups	6.936	2	3.468	0.678	0.511
	Within Groups	414.623	81	5.119		
	Total	421.560	83			
Transit App Safety Score	Between Groups	10.863	2	5.431	1.717	0.186
	Within Groups	256.158	81	3.162		
	Total	267.021	83			
Transit App Privacy Score	Between Groups	16.640	2	8.320	2.228	0.114
	Within Groups	302.469	81	3.734		
	Total	319.109	83			
Transit App Efficiency Score	Between Groups	11.887	2	5.944	1.840	0.165
	Within Groups	261.585	81	3.229		

ANOVA						
Income_R1		Sum of Squares	df	Mean Square	F	Sig.
	Total	273.472	83			
Transit App Unweighted Total Score	Between Groups	10.079	2	5.039	1.770	0.177
	Within Groups	230.657	81	2.848		
	Total	240.735	83			

ANOVA						
RaceEthnicity_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	27.949	2	13.975	2.699	0.073
	Within Groups	455.589	88	5.177		
	Total	483.538	90			
App: Safer Transit Night	Between Groups	12.151	2	6.076	1.219	0.300
	Within Groups	438.530	88	4.983		
	Total	450.681	90			
App: Campus Safety	Between Groups	11.472	2	5.736	1.212	0.303
	Within Groups	416.484	88	4.733		
	Total	427.956	90			
App: Police & Walking Safety	Between Groups	1.654	2	0.827	0.199	0.820
	Within Groups	364.786	88	4.145		
	Total	366.440	90			
App: School Bus	Between Groups	3.383	2	1.692	0.414	0.662
	Within Groups	359.364	88	4.084		
	Total	362.747	90			
App: Location Reveal Comfortability	Between Groups	7.002	2	3.501	0.563	0.571
	Within Groups	547.108	88	6.217		
	Total	554.110	90			
App: Recommendation	Between Groups	18.535	2	9.267	1.504	0.228
	Within Groups	542.367	88	6.163		
	Total	560.901	90			

ANOVA						
RaceEthnicity_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Willingness-to-Use	Between Groups	5.817	2	2.908	0.526	0.593
	Within Groups	486.864	88	5.533		
	Total	492.681	90			
App: Ridership Impact	Between Groups	4.623	2	2.312	0.449	0.640
	Within Groups	453.047	88	5.148		
	Total	457.670	90			
Transit App Safety Score	Between Groups	7.199	2	3.599	1.136	0.326
	Within Groups	278.860	88	3.169		
	Total	286.059	90			
Transit App Privacy Score	Between Groups	5.823	2	2.911	0.718	0.491
	Within Groups	356.955	88	4.056		
	Total	362.777	90			
Transit App Efficiency Score	Between Groups	5.642	2	2.821	0.813	0.447
	Within Groups	305.261	88	3.469		
	Total	310.902	90			
Transit App Unweighted Total Score	Between Groups	5.753	2	2.876	0.987	0.377
	Within Groups	256.482	88	2.915		
	Total	262.234	90			

ANOVA						
Education_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	10.478	2	5.239	0.982	0.379
	Within Groups	474.957	89	5.337		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	1.924	2	0.962	0.191	0.827
	Within Groups	449.326	89	5.049		
	Total	451.250	91			

ANOVA						
Education_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Campus Safety	Between Groups	30.457	2	15.228	3.410	0.037
	Within Groups	397.500	89	4.466		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	7.435	2	3.717	0.921	0.402
	Within Groups	359.043	89	4.034		
	Total	366.478	91			
App: School Bus	Between Groups	14.707	2	7.353	1.868	0.160
	Within Groups	350.283	89	3.936		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	13.935	2	6.967	1.146	0.322
	Within Groups	540.978	89	6.078		
	Total	554.913	91			
App: Recommendation	Between Groups	11.152	2	5.576	0.901	0.410
	Within Groups	550.804	89	6.189		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	4.989	2	2.495	0.453	0.637
	Within Groups	490.000	89	5.506		
	Total	494.989	91			
App: Ridership Impact	Between Groups	2.348	2	1.174	0.229	0.795
	Within Groups	455.391	89	5.117		
	Total	457.739	91			
Transit App Safety Score	Between Groups	3.402	2	1.701	0.535	0.587
	Within Groups	282.730	89	3.177		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	3.404	2	1.702	0.421	0.658
	Within Groups	360.005	89	4.045		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	3.465	2	1.732	0.500	0.608

ANOVA						
Education_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	308.332	89	3.464		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	3.850	2	1.925	0.662	0.518
	Within Groups	258.610	89	2.906		
	Total	262.460	91			

ANOVA						
Occupation_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	21.691	1	21.691	4.166	0.044
	Within Groups	463.342	89	5.206		
	Total	485.033	90			
App: Safer Transit Night	Between Groups	2.486	1	2.486	0.493	0.484
	Within Groups	448.701	89	5.042		
	Total	451.187	90			
App: Campus Safety	Between Groups	1.339	1	1.339	0.280	0.598
	Within Groups	425.563	89	4.782		
	Total	426.901	90			
App: Police & Walking Safety	Between Groups	3.507	1	3.507	0.860	0.356
	Within Groups	362.933	89	4.078		
	Total	366.440	90			
App: School Bus	Between Groups	8.119	1	8.119	2.026	0.158
	Within Groups	356.607	89	4.007		
	Total	364.725	90			
App: Location Reveal Comfortability	Between Groups	3.670	1	3.670	0.593	0.443
	Within Groups	550.440	89	6.185		
	Total	554.110	90			
App: Recommendation	Between Groups	16.769	1	16.769	2.743	0.101

ANOVA						
Occupation_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	544.132	89	6.114		
	Total	560.901	90			
App: Willingness-to-Use	Between Groups	7.740	1	7.740	1.414	0.237
	Within Groups	486.986	89	5.472		
	Total	494.725	90			
App: Ridership Impact	Between Groups	3.795	1	3.795	0.747	0.390
	Within Groups	452.337	89	5.082		
	Total	456.132	90			
Transit App Safety Score	Between Groups	4.199	1	4.199	1.326	0.253
	Within Groups	281.861	89	3.167		
	Total	286.059	90			
Transit App Privacy Score	Between Groups	7.210	1	7.210	1.802	0.183
	Within Groups	356.114	89	4.001		
	Total	363.324	90			
Transit App Efficiency Score	Between Groups	8.518	1	8.518	2.500	0.117
	Within Groups	303.274	89	3.408		
	Total	311.793	90			
Transit App Unweighted Total Score	Between Groups	4.508	1	4.508	1.556	0.216
	Within Groups	257.889	89	2.898		
	Total	262.397	90			

ANOVA						
Car_Own		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	2.238	1	2.238	0.417	0.520
	Within Groups	483.196	90	5.369		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	19.714	1	19.714	4.112	0.046

ANOVA						
Car_Own		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	431.536	90	4.795		
	Total	451.250	91			
App: Campus Safety	Between Groups	11.522	1	11.522	2.490	0.118
	Within Groups	416.435	90	4.627		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	2.853	1	2.853	0.706	0.403
	Within Groups	363.625	90	4.040		
	Total	366.478	91			
App: School Bus	Between Groups	10.876	1	10.876	2.764	0.100
	Within Groups	354.113	90	3.935		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	2.336	1	2.336	0.380	0.539
	Within Groups	552.577	90	6.140		
	Total	554.913	91			
App: Recommendation	Between Groups	1.379	1	1.379	0.221	0.639
	Within Groups	560.577	90	6.229		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	6.876	1	6.876	1.268	0.263
	Within Groups	488.113	90	5.423		
	Total	494.989	91			
App: Ridership Impact	Between Groups	4.787	1	4.787	0.951	0.332
	Within Groups	452.952	90	5.033		
	Total	457.739	91			
Transit App Safety Score	Between Groups	5.901	1	5.901	1.895	0.172
	Within Groups	280.230	90	3.114		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	3.528	1	3.528	0.882	0.350
	Within Groups	359.882	90	3.999		

ANOVA						
Car_Own		Sum of Squares	df	Mean Square	F	Sig.
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	5.385	1	5.385	1.582	0.212
	Within Groups	306.411	90	3.405		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	5.884	1	5.884	2.064	0.154
	Within Groups	256.576	90	2.851		
	Total	262.460	91			

ANOVA						
Drive_Reg		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.080	1	0.080	0.015	0.904
	Within Groups	485.216	89	5.452		
	Total	485.297	90			
App: Safer Transit Night	Between Groups	1.656	1	1.656	0.329	0.568
	Within Groups	448.015	89	5.034		
	Total	449.670	90			
App: Campus Safety	Between Groups	17.477	1	17.477	3.798	0.054
	Within Groups	409.512	89	4.601		
	Total	426.989	90			
App: Police & Walking Safety	Between Groups	3.584	1	3.584	0.887	0.349
	Within Groups	359.602	89	4.040		
	Total	363.187	90			
App: School Bus	Between Groups	3.239	1	3.239	0.802	0.373
	Within Groups	359.442	89	4.039		
	Total	362.681	90			
App: Location Reveal Comfortability	Between Groups	6.263	1	6.263	1.018	0.316
	Within Groups	547.407	89	6.151		
	Total	553.670	90			

ANOVA						
Drive_Reg		Sum of Squares	df	Mean Square	F	Sig.
App: Recommendation	Between Groups	3.457	1	3.457	0.552	0.460
	Within Groups	557.532	89	6.264		
	Total	560.989	90			
App: Willingness-to-Use	Between Groups	22.510	1	22.510	4.260	0.042
	Within Groups	470.237	89	5.284		
	Total	492.747	90			
App: Ridership Impact	Between Groups	10.865	1	10.865	2.172	0.144
	Within Groups	445.267	89	5.003		
	Total	456.132	90			
Transit App Safety Score	Between Groups	5.882	1	5.882	1.877	0.174
	Within Groups	278.885	89	3.134		
	Total	284.767	90			
Transit App Privacy Score	Between Groups	9.614	1	9.614	2.429	0.123
	Within Groups	352.317	89	3.959		
	Total	361.931	90			
Transit App Efficiency Score	Between Groups	8.555	1	8.555	2.525	0.116
	Within Groups	301.507	89	3.388		
	Total	310.062	90			
Transit App Unweighted Total Score	Between Groups	5.590	1	5.590	1.948	0.166
	Within Groups	255.427	89	2.870		
	Total	261.018	90			

ANOVA						
Transit_Freq_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	3.810	2	1.905	0.352	0.704
	Within Groups	481.625	89	5.412		
	Total	485.435	91			

ANOVA						
Transit_Freq_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Night	Between Groups	7.396	2	3.698	0.741	0.479
	Within Groups	443.854	89	4.987		
	Total	451.250	91			
App: Campus Safety	Between Groups	19.165	2	9.582	2.086	0.130
	Within Groups	408.792	89	4.593		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	3.374	2	1.687	0.414	0.663
	Within Groups	363.104	89	4.080		
	Total	366.478	91			
App: School Bus	Between Groups	18.947	2	9.474	2.437	0.093
	Within Groups	346.042	89	3.888		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	0.476	2	0.238	0.038	0.963
	Within Groups	554.438	89	6.230		
	Total	554.913	91			
App: Recommendation	Between Groups	8.180	2	4.090	0.657	0.521
	Within Groups	553.776	89	6.222		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	19.213	2	9.607	1.797	0.172
	Within Groups	475.776	89	5.346		
	Total	494.989	91			
App: Ridership Impact	Between Groups	8.885	2	4.442	0.881	0.418
	Within Groups	448.854	89	5.043		
	Total	457.739	91			
Transit App Safety Score	Between Groups	7.551	2	3.776	1.206	0.304
	Within Groups	278.580	89	3.130		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	6.903	2	3.452	0.862	0.426

ANOVA						
Transit_Freq_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	356.507	89	4.006		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	10.984	2	5.492	1.625	0.203
	Within Groups	300.813	89	3.380		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	6.819	2	3.409	1.187	0.310
	Within Groups	255.641	89	2.872		
	Total	262.460	91			

ANOVA						
Transit_Freq_R2		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	1.640	1	1.640	0.305	0.582
	Within Groups	483.795	90	5.375		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	0.821	1	0.821	0.164	0.686
	Within Groups	450.429	90	5.005		
	Total	451.250	91			
App: Campus Safety	Between Groups	14.162	1	14.162	3.080	0.083
	Within Groups	413.795	90	4.598		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	0.326	1	0.326	0.080	0.778
	Within Groups	366.152	90	4.068		
	Total	366.478	91			
App: School Bus	Between Groups	0.373	1	0.373	0.092	0.762
	Within Groups	364.616	90	4.051		
	Total	364.989	91			
	Between Groups	0.047	1	0.047	0.008	0.931

ANOVA						
Transit_Freq_R2		Sum of Squares	df	Mean Square	F	Sig.
App: Location Reveal Comfortability	Within Groups	554.866	90	6.165		
	Total	554.913	91			
App: Recommendation	Between Groups	4.740	1	4.740	0.766	0.384
	Within Groups	557.217	90	6.191		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	17.201	1	17.201	3.240	0.075
	Within Groups	477.788	90	5.309		
	Total	494.989	91			
App: Ridership Impact	Between Groups	3.882	1	3.882	0.770	0.383
	Within Groups	453.857	90	5.043		
	Total	457.739	91			
Transit App Safety Score	Between Groups	3.816	1	3.816	1.216	0.273
	Within Groups	282.316	90	3.137		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	4.528	1	4.528	1.136	0.289
	Within Groups	358.882	90	3.988		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	4.957	1	4.957	1.454	0.231
	Within Groups	306.839	90	3.409		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	2.596	1	2.596	0.899	0.346
	Within Groups	259.864	90	2.887		
	Total	262.460	91			

ANOVA						
Commute_Time_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	73.320	1	73.320	16.012	0.000

ANOVA						
Commute_Time_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	412.115	90	4.579		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	28.377	1	28.377	6.040	0.016
	Within Groups	422.873	90	4.699		
	Total	451.250	91			
App: Campus Safety	Between Groups	15.811	1	15.811	3.453	0.066
	Within Groups	412.145	90	4.579		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	17.152	1	17.152	4.419	0.038
	Within Groups	349.327	90	3.881		
	Total	366.478	91			
App: School Bus	Between Groups	23.701	1	23.701	6.250	0.014
	Within Groups	341.288	90	3.792		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	2.034	1	2.034	0.331	0.566
	Within Groups	552.879	90	6.143		
	Total	554.913	91			
App: Recommendation	Between Groups	27.480	1	27.480	4.627	0.034
	Within Groups	534.476	90	5.939		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	0.038	1	0.038	0.007	0.934
	Within Groups	494.951	90	5.499		
	Total	494.989	91			
App: Ridership Impact	Between Groups	0.652	1	0.652	0.128	0.721
	Within Groups	457.088	90	5.079		
	Total	457.739	91			
Transit App Safety Score	Between Groups	16.289	1	16.289	5.433	0.022
	Within Groups	269.842	90	2.998		

ANOVA						
Commute_Time_R1		Sum of Squares	df	Mean Square	F	Sig.
	Total	286.131	91			
Transit App Privacy Score	Between Groups	3.677	1	3.677	0.920	0.340
	Within Groups	359.732	90	3.997		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	7.718	1	7.718	2.284	0.134
	Within Groups	304.078	90	3.379		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	14.734	1	14.734	5.353	0.023
	Within Groups	247.726	90	2.753		
	Total	262.460	91			

ANOVA						
Transfer_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	6.842	1	6.842	1.159	0.290
	Within Groups	188.923	32	5.904		
	Total	195.765	33			
App: Safer Transit Night	Between Groups	1.710	1	1.710	0.278	0.602
	Within Groups	197.231	32	6.163		
	Total	198.941	33			
App: Campus Safety	Between Groups	15.312	1	15.312	3.742	0.062
	Within Groups	130.952	32	4.092		
	Total	146.265	33			
App: Police & Walking Safety	Between Groups	12.163	1	12.163	2.398	0.131
	Within Groups	162.308	32	5.072		
	Total	174.471	33			
App: School Bus	Between Groups	10.895	1	10.895	2.695	0.110
	Within Groups	129.341	32	4.042		
	Total	140.235	33			

ANOVA						
Transfer_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Location Reveal Comfortability	Between Groups	31.183	1	31.183	5.255	0.029
	Within Groups	189.875	32	5.934		
	Total	221.059	33			
App: Recommendation	Between Groups	47.930	1	47.930	9.524	0.004
	Within Groups	161.040	32	5.033		
	Total	208.971	33			
App: Willingness-to-Use	Between Groups	17.671	1	17.671	4.140	0.050
	Within Groups	136.593	32	4.269		
	Total	154.265	33			
App: Ridership Impact	Between Groups	5.503	1	5.503	1.307	0.261
	Within Groups	134.733	32	4.210		
	Total	140.235	33			
Transit App Safety Score	Between Groups	12.549	1	12.549	3.868	0.058
	Within Groups	103.827	32	3.245		
	Total	116.375	33			
Transit App Privacy Score	Between Groups	22.698	1	22.698	6.205	0.018
	Within Groups	117.052	32	3.658		
	Total	139.750	33			
Transit App Efficiency Score	Between Groups	17.584	1	17.584	5.416	0.026
	Within Groups	103.886	32	3.246		
	Total	121.471	33			
Transit App Unweighted Total Score	Between Groups	14.006	1	14.006	4.596	0.040
	Within Groups	97.508	32	3.047		
	Total	111.514	33			

ANOVA						
Transit_ExtraTime_R1		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	2.609	2	1.304	0.228	0.796
	Within Groups	479.874	84	5.713		
	Total	482.483	86			
App: Safer Transit Night	Between Groups	4.585	2	2.293	0.449	0.640
	Within Groups	429.093	84	5.108		
	Total	433.678	86			
App: Campus Safety	Between Groups	9.341	2	4.670	0.999	0.373
	Within Groups	392.659	84	4.675		
	Total	402.000	86			
App: Police & Walking Safety	Between Groups	4.658	2	2.329	0.560	0.574
	Within Groups	349.618	84	4.162		
	Total	354.276	86			
App: School Bus	Between Groups	9.571	2	4.785	1.162	0.318
	Within Groups	346.038	84	4.120		
	Total	355.609	86			
App: Location Reveal Comfortability	Between Groups	17.306	2	8.653	1.418	0.248
	Within Groups	512.694	84	6.103		
	Total	530.000	86			
App: Recommendation	Between Groups	15.142	2	7.571	1.192	0.309
	Within Groups	533.570	84	6.352		
	Total	548.713	86			
App: Willingness-to-Use	Between Groups	34.936	2	17.468	3.329	0.041
	Within Groups	440.788	84	5.247		
	Total	475.724	86			
App: Ridership Impact	Between Groups	13.904	2	6.952	1.372	0.259
	Within Groups	425.774	84	5.069		
	Total	439.678	86			
Transit App Safety Score	Between Groups	6.208	2	3.104	0.945	0.393

ANOVA						
Transit_ExtraTime_R1		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	276.057	84	3.286		
	Total	282.265	86			
Transit App Privacy Score	Between Groups	16.954	2	8.477	2.124	0.126
	Within Groups	335.201	84	3.990		
	Total	352.155	86			
Transit App Efficiency Score	Between Groups	16.769	2	8.385	2.449	0.093
	Within Groups	287.633	84	3.424		
	Total	304.402	86			
Transit App Unweighted Total Score	Between Groups	7.068	2	3.534	1.179	0.313
	Within Groups	251.765	84	2.997		
	Total	258.834	86			

ANOVA						
TrApp_Familiarity		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.908	1	0.908	0.167	0.683
	Within Groups	482.630	89	5.423		
	Total	483.538	90			
App: Safer Transit Night	Between Groups	1.284	1	1.284	0.254	0.615
	Within Groups	449.398	89	5.049		
	Total	450.681	90			
App: Campus Safety	Between Groups	0.294	1	0.294	0.061	0.805
	Within Groups	426.607	89	4.793		
	Total	426.901	90			
App: Police & Walking Safety	Between Groups	3.148	1	3.148	0.782	0.379
	Within Groups	358.456	89	4.028		
	Total	361.604	90			
App: School Bus	Between Groups	4.179	1	4.179	1.032	0.313

ANOVA						
TrApp_Familiarity		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	360.568	89	4.051		
	Total	364.747	90			
App: Location Reveal Comfortability	Between Groups	1.216	1	1.216	0.196	0.659
	Within Groups	552.893	89	6.212		
	Total	554.110	90			
App: Recommendation	Between Groups	4.886	1	4.886	0.782	0.379
	Within Groups	556.103	89	6.248		
	Total	560.989	90			
App: Willingness-to-Use	Between Groups	11.741	1	11.741	2.173	0.144
	Within Groups	480.940	89	5.404		
	Total	492.681	90			
App: Ridership Impact	Between Groups	1.045	1	1.045	0.204	0.653
	Within Groups	456.142	89	5.125		
	Total	457.187	90			
Transit App Safety Score	Between Groups	1.152	1	1.152	0.360	0.550
	Within Groups	284.670	89	3.199		
	Total	285.822	90			
Transit App Privacy Score	Between Groups	3.766	1	3.766	0.933	0.337
	Within Groups	359.348	89	4.038		
	Total	363.114	90			
Transit App Efficiency Score	Between Groups	4.734	1	4.734	1.373	0.244
	Within Groups	306.866	89	3.448		
	Total	311.600	90			
Transit App Unweighted Total Score	Between Groups	1.403	1	1.403	0.479	0.491
	Within Groups	260.713	89	2.929		
	Total	262.116	90			

ANOVA						
TrApp_Use		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.174	1	0.174	0.032	0.858
	Within Groups	485.261	90	5.392		
	Total	485.435	91			
App: Safer Transit Night	Between Groups	0.011	1	0.011	0.002	0.963
	Within Groups	451.239	90	5.014		
	Total	451.250	91			
App: Campus Safety	Between Groups	1.565	1	1.565	0.330	0.567
	Within Groups	426.391	90	4.738		
	Total	427.957	91			
App: Police & Walking Safety	Between Groups	3.522	1	3.522	0.873	0.353
	Within Groups	362.957	90	4.033		
	Total	366.478	91			
App: School Bus	Between Groups	0.011	1	0.011	0.003	0.959
	Within Groups	364.978	90	4.055		
	Total	364.989	91			
App: Location Reveal Comfortability	Between Groups	0.043	1	0.043	0.007	0.933
	Within Groups	554.870	90	6.165		
	Total	554.913	91			
App: Recommendation	Between Groups	0.696	1	0.696	0.112	0.739
	Within Groups	561.261	90	6.236		
	Total	561.957	91			
App: Willingness-to-Use	Between Groups	9.141	1	9.141	1.693	0.196
	Within Groups	485.848	90	5.398		
	Total	494.989	91			
App: Ridership Impact	Between Groups	0.174	1	0.174	0.034	0.854
	Within Groups	457.565	90	5.084		
	Total	457.739	91			
Transit App Safety Score	Between Groups	0.057	1	0.057	0.018	0.894

ANOVA						
TrApp_Use		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	286.075	90	3.179		
	Total	286.131	91			
Transit App Privacy Score	Between Groups	1.033	1	1.033	0.257	0.614
	Within Groups	362.376	90	4.026		
	Total	363.410	91			
Transit App Efficiency Score	Between Groups	1.198	1	1.198	0.347	0.557
	Within Groups	310.598	90	3.451		
	Total	311.796	91			
Transit App Unweighted Total Score	Between Groups	0.030	1	0.030	0.010	0.919
	Within Groups	262.430	90	2.916		
	Total	262.460	91			

ANOVA						
Home_Cat		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	0.287	1	0.287	0.053	0.819
	Within Groups	477.502	88	5.426		
	Total	477.789	89			
App: Safer Transit Night	Between Groups	0.316	1	0.316	0.063	0.803
	Within Groups	444.172	88	5.047		
	Total	444.489	89			
App: Campus Safety	Between Groups	6.715	1	6.715	1.430	0.235
	Within Groups	413.241	88	4.696		
	Total	419.956	89			
App: Police & Walking Safety	Between Groups	5.531	1	5.531	1.411	0.238
	Within Groups	344.869	88	3.919		
	Total	350.400	89			
App: School Bus	Between Groups	1.060	1	1.060	0.270	0.604

ANOVA						
Home_Cat		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	344.896	88	3.919		
	Total	345.956	89			
App: Location Reveal Comfortability	Between Groups	0.069	1	0.069	0.011	0.915
	Within Groups	533.086	88	6.058		
	Total	533.156	89			
App: Recommendation	Between Groups	0.138	1	0.138	0.022	0.883
	Within Groups	553.818	88	6.293		
	Total	553.956	89			
App: Willingness-to-Use	Between Groups	8.669	1	8.669	1.597	0.210
	Within Groups	477.731	88	5.429		
	Total	486.400	89			
App: Ridership Impact	Between Groups	0.037	1	0.037	0.007	0.932
	Within Groups	447.252	88	5.082		
	Total	447.289	89			
Transit App Safety Score	Between Groups	0.188	1	0.188	0.060	0.808
	Within Groups	277.003	88	3.148		
	Total	277.190	89			
Transit App Privacy Score	Between Groups	0.573	1	0.573	0.143	0.706
	Within Groups	351.666	88	3.996		
	Total	352.239	89			
Transit App Efficiency Score	Between Groups	0.188	1	0.188	0.055	0.815
	Within Groups	300.701	88	3.417		
	Total	300.889	89			
Transit App Unweighted Total Score	Between Groups	0.063	1	0.063	0.022	0.882
	Within Groups	251.504	88	2.858		
	Total	251.568	89			

ANOVA						
WorkStudy_Cat		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	3.711	1	3.711	0.642	0.425
	Within Groups	468.168	81	5.780		
	Total	471.880	82			
App: Safer Transit Night	Between Groups	0.507	1	0.507	0.095	0.759
	Within Groups	431.662	81	5.329		
	Total	432.169	82			
App: Campus Safety	Between Groups	1.504	1	1.504	0.303	0.584
	Within Groups	402.496	81	4.969		
	Total	404.000	82			
App: Police & Walking Safety	Between Groups	3.143	1	3.143	0.754	0.388
	Within Groups	337.652	81	4.169		
	Total	340.795	82			
App: School Bus	Between Groups	0.017	1	0.017	0.004	0.950
	Within Groups	342.586	81	4.229		
	Total	342.602	82			
App: Location Reveal Comfortability	Between Groups	22.884	1	22.884	3.805	0.055
	Within Groups	487.140	81	6.014		
	Total	510.024	82			
App: Recommendation	Between Groups	9.902	1	9.902	1.522	0.221
	Within Groups	526.989	81	6.506		
	Total	536.892	82			
App: Willingness-to-Use	Between Groups	3.206	1	3.206	0.561	0.456
	Within Groups	463.035	81	5.716		
	Total	466.241	82			
App: Ridership Impact	Between Groups	0.243	1	0.243	0.045	0.832
	Within Groups	435.853	81	5.381		
	Total	436.096	82			
Transit App Safety Score	Between Groups	1.155	1	1.155	0.346	0.558

ANOVA						
WorkStudy_Cat		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	270.606	81	3.341		
	Total	271.761	82			
Transit App Privacy Score	Between Groups	6.521	1	6.521	1.575	0.213
	Within Groups	335.295	81	4.139		
	Total	341.816	82			
Transit App Efficiency Score	Between Groups	1.933	1	1.933	0.537	0.466
	Within Groups	291.584	81	3.600		
	Total	293.517	82			
Transit App Unweighted Total Score	Between Groups	1.909	1	1.909	0.628	0.430
	Within Groups	246.159	81	3.039		
	Total	248.068	82			

ANOVA						
CommuteCat_3		Sum of Squares	df	Mean Square	F	Sig.
App: Safer Transit Daytime	Between Groups	15.439	2	7.719	1.353	0.264
	Within Groups	456.441	80	5.706		
	Total	471.880	82			
App: Safer Transit Night	Between Groups	6.862	2	3.431	0.645	0.527
	Within Groups	425.307	80	5.316		
	Total	432.169	82			
App: Campus Safety	Between Groups	5.519	2	2.759	0.554	0.577
	Within Groups	398.481	80	4.981		
	Total	404.000	82			
App: Police & Walking Safety	Between Groups	12.434	2	6.217	1.515	0.226
	Within Groups	328.361	80	4.105		
	Total	340.795	82			
App: School Bus	Between Groups	15.800	2	7.900	1.934	0.151

ANOVA						
CommuteCat_3		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	326.802	80	4.085		
	Total	342.602	82			
App: Location Reveal Comfortability	Between Groups	12.625	2	6.313	1.015	0.367
	Within Groups	497.399	80	6.217		
	Total	510.024	82			
App: Recommendation	Between Groups	5.756	2	2.878	0.433	0.650
	Within Groups	531.136	80	6.639		
	Total	536.892	82			
App: Willingness-to-Use	Between Groups	9.268	2	4.634	0.811	0.448
	Within Groups	456.973	80	5.712		
	Total	466.241	82			
App: Ridership Impact	Between Groups	4.644	2	2.322	0.431	0.652
	Within Groups	431.452	80	5.393		
	Total	436.096	82			
Transit App Safety Score	Between Groups	2.027	2	1.013	0.301	0.741
	Within Groups	269.734	80	3.372		
	Total	271.761	82			
Transit App Privacy Score	Between Groups	4.597	2	2.298	0.545	0.582
	Within Groups	337.219	80	4.215		
	Total	341.816	82			
Transit App Efficiency Score	Between Groups	1.479	2	0.739	0.203	0.817
	Within Groups	292.038	80	3.650		
	Total	293.517	82			
Transit App Unweighted Total Score	Between Groups	2.960	2	1.480	0.483	0.619
	Within Groups	245.108	80	3.064		
	Total	248.068	82			

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