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Abstract: Waiting and transferring in transit travel are often perceived negatively and can be significant obstacles to mode shifts between automobile to transit. High-amenity stations, transit centers served by multiple routes and multimodal hubs are becoming increasingly popular as strategies for mitigating transit users' aversion to waiting and transferring. However, beyond recent evidence that realtime departure information reduces perceived waiting time, there is limited empirical evidence as to which other specific station and stop amenities can effectively influence user perceptions of waiting time. To address this knowledge gap, the authors conducted a passenger survey and video-recorded waiting passengers at different types of transit stops and stations to investigate the impacts of various station characteristics on transit users' perceptions of waiting and transferring time, controlling for weather and time of day. The authors employ regression analysis to explain the variation in riders' waiting time estimates as a function of their objectively observed waiting times, as well as station and stop amenities, while controlling for weather, time of day, self-reported and observed socio-demographic characteristics and trip characteristics. Based on the results, waits at stops with no amenities are perceived as twice as long or longer than they actually are. Benches, shelters and realtime departure information signs significantly reduce perceived waiting times. A complete package of all three nearly erases the time perception penalty of waiting. Women waiting in surroundings perceived to be insecure report waits as dramatically longer than they really are, and longer than do men and/or respondents in surroundings perceived to be secure. However, the provision of stop amenities significantly reduces this disparity. The authors recommend a focus on providing basic stop amenities as broadly as possible, continued exploration of methods for communicating arrival information and a particular focus on stops in less safe areas for improvements.

PERCEPTION OF WAITING TIME AT TRANSIT STOPS AND STATIONS

ABSTRACT

Waiting and transferring in transit travel are often perceived negatively and can be significant obstacles to mode shifts between automobile to transit. High-amenity stations, transit centers served by multiple routes and multimodal hubs are becoming increasingly popular as strategies for mitigating transit users' aversion to waiting and transferring. However, beyond recent evidence that realtime departure information reduces perceived waiting time, there is limited empirical evidence as to which other specific station and stop amenities can effectively influence user perceptions of waiting time. To address this knowledge gap, the authors conducted a passenger survey and video-recorded waiting passengers at different types of transit stops and stations to investigate the impacts of various station characteristics on transit users' perceptions of waiting and transferring time, controlling for weather and time of day. The authors employ regression analysis to explain the variation in riders' waiting time estimates as a function of their objectively observed waiting times, as well as station and stop amenities, while controlling for weather, time of day, self-reported and observed socio-demographic characteristics and trip characteristics. Based on the results, waits at stops with no amenities are perceived as twice as long or longer than they actually are. Benches, shelters and realtime departure information signs significantly reduce perceived waiting times. A complete package of all three nearly erases the time perception penalty of waiting. Women waiting in surroundings perceived to be insecure report waits as dramatically longer than they really are, and longer than do men and/or respondents in surroundings perceived to be secure. However, the provision of stop amenities significantly reduces this disparity. The authors recommend a focus on providing basic stop amenities as broadly as possible, continued exploration of methods for communicating arrival information and a particular focus on stops in less safe areas for improvements.

KEYWORDS

Transit; waiting time; perception; realtime information; security, gender

HIGHLIGHTS

- Transit users perceive waiting times as longer than they really are.
- We measure actual and estimated wait times via observation and survey data.
- A shelter, bench and realtime information sign nearly erase perceived time penalty.
- Women in unsafe surroundings perceive waits dramatically longer.
- Stop amenities mitigate gender disparities in unsafe areas.

FUNDING DISCLOSURE

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1 INTRODUCTION

Travel time has consistently been found the strongest predictor of mode choice, stronger than monetary costs associated with modes, urban form, and personal socio-demographics (Cervero, 2002; Frank, Bradley, Kavage, Chapman, & Lawton, 2008).Time, however, can be measured both objectively and subjectively. Objectively, "time is what clocks measure." (Caroll, 2011). Subjectively, time can be perceived and experienced differently based on events (Andersen & Grush, 2009). This brings in a contrasting viewpoint: time can be defined as a fundamental intellectual structure within which humans sequence and compare events (Allison, 2004). Individual perceptions of time can vary significantly from any externally measurable "objective" time. (Block, 2014; Fraisse, 1984) Events experienced can either moderate or exacerbate these variations. Research has shown that events occurring at regular intervals lead to underestimates of objective time, while events occurring at irregular intervals produce overestimates. (Yarmey, 2000) Intense experiences—positive or negative—are found to produce overestimates of duration. (Ariely & Zakay, 2001). In a transportation context, increasing driving route (task) complexity may also increase perceived time (Carrion & Levinson, 2013; Parthasarathi, Levinson, & Hochmair, 2013).

When it comes to travel times of different modes, public transit faces an inherent disadvantage not shared by other modes: waiting time. Waiting time in transit travel tends to be perceived negatively. Walking time to and from transit, and time spent aboard transit vehicles (In-Vehcile Time, or IVT) are generally perceived as taking roughly as long as they really do (Wardman, 1998b; Wardman, 2004). Transit users, however, perceive waits for transit vehicles to arrive as significantly *longer* than they really are—anywhere from 1.2 to 4.4 times as long in existing research (Dziekan & Kottenhoff, 2007; Parsons Brinkerhoff Quade and Douglas, Inc., 1993; Watkins, Ferris, Borning, Rutherford, & Layton, 2011). Auto users similarly overweight stopped time at traffic lights and ramp meters (Levinson, Harder, Bloomfield, & Winiarczyk, 2004; Wu, Levinson, & Liu, 2009). These perceptions have negative implications for users' overall feelings about their mode (St-Louis, Manaugh, van Lierop, & El-Geneidy, 2014), and present a significant obstacle to increasing the competitiveness of public transit, which is much more environmental friendly than the private automobile mode (El-Geneidy, Hourdos, & Horning, 2009; Watkins et al., 2011).

Transit agencies increasingly propose high-amenity transit stops and stations for mitigating the perceived burden of waiting time and transfers (*Denver Union Station Master Plan.*2004; Metropolitan Council, 2012; Transit Planning Board, 2008)

However, beyond the amenity of realtime, at-stop information (Brakewood, Barbeau, & Watkins, 2014; Brakewood, Macfarlane, & Watkins, 2015; Brakewood, Rojas, Zegras, Watkins, & Robin, 2015; Dziekan & Kottenhoff, 2007; Gooze, Watkins, & Borning, 2013; Watkins et al., 2011), existing research does not sufficiently explore how specific station and stop amenities (e.g., benches, shelters) can effectively reduce transit users' perceptions of waiting time. In addition, while the literature investigates how station and stop amenities shape users' overall perception of transit service quality (Iseki & Taylor, 2010; Taylor, Iseki, Miller, & Smart, 2009), the studies in question do not offer direct, quantitative evidence that amenities can effectively make waiting time during transit trips seem "shorter" to users.

To address this gap in transit planning knowledge, the authors conducted a unique study in the Minneapolis-St Paul (MSP) metropolitan region that combines an onboard survey with video observation to compare transit users' self-estimates of waiting time with external measures of their actual waiting time. The study takes a uniquely systematic perspective, including a wide range of stop and station types, transit modes, times of day and seasons. We then explain waiting time perceptions as a function of stop/station design and environment. We offer generalizable recommendations that can be applied from a light rail station to a curbside bus stop for reducing perceived waiting times.

2 RELATED STUDIES

Transit users often perceive their waiting time as considerably longer than it actually is. Table 1 summarizes existing research assessing perceived waiting time in comparison with other travel time concepts. These studies found that a minute of perceived waiting time is equivalent to up to 4.4 minutes of in-vehicle time (IVT), and is equivalent to 1.2 minutes of actual wait time. For example, Wardman (2004) finds that a 2.5:1 ratio of waiting time to in-vehicle time (IVT) is more appropriate for schedule planning and ridership forecasting than the traditional British 2:1 assumption (Wardman, 2004). Horowitz finds that any wait at all is perceived as equivalent to an extra 8.4 minutes' IVT in a 30 minute trip and 13 minutes' IVT in a 45 minute trip, and that a ten-minute wait is equivalent to an extra 18.9 or 23.2 minutes of IVT, respectively. (Horowitz, 1981) A 1993 study of the Twin Cities transit system found that an average rider perceived one minute of waiting time as equal to 4.36 minutes of IVT—albeit without analyzing perceived waiting time under varying conditions. (Parsons Brinkerhoff Quade and Douglas, Inc., 1993)

Perceptions of waiting time may vary depending on circumstances including transit service factors, such as on-time performance and service information, as well as stop/station factors, such as surroundings, perceived security, and amenities such as enclosed waiting areas, seating or restrooms (Evans et al., 2004; Wardman, 1998a). However, beyond recent evidence that realtime departure information reduces perceived waiting time, there is limited empirical evidence as to which other specific station and stop amenities can effectively influence user perceptions of waiting time. For example, Cascetta and Carteni (2014) find that Neapolitan commuters will accept an additional seven minutes of waiting time and ten minutes of access time in order to use a new rail line with markedly more attractive stations than an older line serving similar trips (Cascetta & Cartenì, 2014)

, yet their study does not isolate the impact of specific station and stop amenities. Diab and El-Geneidy find average waiting time perception reductions as great as 4.4 minutes following a variety of largely schedule reliability-focused improvements (reserved lanes, signal priority, articulated buses, etc.) to a major bus corridor in Montreal, QC, but do not focus specifically on stops. (Diab & El-Geneidy, 2014). Fan and Guthrie (2012), as well as Iseki and Taylor (2010), find station and stop characteristics to be important in shaping users' overall perceptions of transit service quality based on stated preference surveys. Neither of their studies, however, considered how stop and station characteristics influence riders' perceptions of the travel and waiting times they did find important. (Fan & Guthrie, 2012; Iseki & Taylor, 2010)

Table 1: Waiting Time Ratios in Existing Research

Study	Ratio	Notes
(Dziekan & Kottenhoff, 2007)	1.2:1	Perceived vs. actual wait time before implementation of realtime info on high-frequency streetcar line; 1:1 after implementation.
(Watkins et al., 2011)	1.2:1	Perceived vs. actual time in at-stop survey after ~5min wait time, without realtime departure mobile app. Difference with app statistically insignificant.
(Wardman, 1998a)	1.2:1—1.7:1	Perceived waiting time vs. perceived IVT.
(Horowitz, 1981)	1.9:1—2.3:1	Plus a fixed 8.4 to 13 minute perceived penalty for any wait at all. Perceived waiting time vs. perceived IVT; found non-linear relationship by length of wait and trip.
Wardman, 2004	2.5:1	Perceived waiting time vs. perceived IVT.
(Henderson & Engineers, 1972)	3:1	Perceived waiting time vs. perceived IVT.
(Parsons Brinkerhoff Quade and Douglas, Inc., 1993)	4.4:1	Perceived waiting time vs. perceived IVT.

Recent evidence on the provision of realtime transit arrival information at stations and stops has been consistent. Dziekan and Kottenhoff (2007) find that adding realtime arrival information signs to streetcar stops reduced perceived waiting times by more than twenty percent based on a longitudinal, before/after survey of passengers. They contend this improved the experience of using transit as much as reducing headways from ten to eight minutes, at less than one-fifth the cost. (Dziekan & Kottenhoff, 2007) Watkins, et al (2011) reach nearly identical results for perceived versus measured waiting time for bus passengers in King County, Washington using an at-stop, in person survey. (Watkins et al., 2011) In a 2014 follow-up study, Gooze, Watkins and Borning find continued effects of shortened time perceptions, as well as self-reported more frequent transit use due to realtime information availability by nearly 30% of respondents. They also find that inaccurate realtime information increases waiting time estimates (Gooze et al., 2013). Recent studies on the effects of smartphone-based realtime departure information applications find similar results with the effects of electronic realtime information signs. Brakewood, et al.'s work on realtime information via mobile devices finds a decrease in reported wait times of (on average) 1-2 minutes for Boston commuter rail riders and Tampa bus riders who used realtime information apps (Brakewood et al., 2014; Brakewood, Rojas et al., 2015). In addition, the more heavily-used routes in a New York realtime information pilot program see a median 2.3% increase in ridership after implementation (Brakewood et al., 2015).

Methodologically, research on waiting time perceptions includes some form of survey focused on transit passengers. This component is difficult to avoid, as individual perceptions of time—by definition—cannot be externally observed. Most existing research compares perceived waiting time with perceived in-vehicle time (Henderson & Engineers, 1972; Horowitz, 1981; Parsons Brinkerhoff Quade and Douglas, Inc., 1993; Wardman, 1998b; Wardman, 2004). The more recent studies compare perceived waiting time with a direct measurement of actual waiting time. (Dziekan & Kottenhoff, 2007; Watkins et al., 2011) Studies comparing perceived waiting time to perceived IVT have the practical data collection advantage of not requiring an external measurement of subjects' actual waiting time, which can significantly simplify data collection. Studies comparing perceived waiting time to actual waiting time offer the ability to compare results based on a standard, external reference point. They also offer a direct focus on the waiting experience, regardless of the quality of in-vehicle experience provided. However, this type of research requires an objective, external measurement of how long subjects actually wait (Dziekan & Kottenhoff, 2007; Reed, 1995; Watkins et al., 2011).

This research adopts the recently prominent approach of comparing subjects' estimates of waiting times to external measures of their actual waiting times. We conduct a unique study in which an onboard survey is combined with at-station/stop video footage to measure participants' subjective and objective lengths of waiting time.

3 METHODS

The research revolved around comparing transit riders' actual and self-estimated waiting times at 36 light rail, commuter rail and bus rapid transit stations, bus transit centers and curbside bus stops in the MSP metropolitan region, U.S. The MSP region is nicknamed the Twin Cities for its two largest cities: Minneapolis, the largest city in the state of Minnesota, and St. Paul, the state capital. The two downtowns lie roughly 18 km (11 mi.) apart, surrounded by a variety of predominantly post-war suburbs. As of 2013 (the year most representative of data collection), the regional transit system carried 86.6 million rides on a variety local and express bus routes, one light rail line, one freeway bus rapid transit line, and one commuter rail line operated by six non-competing transit providers (Metro Transit, 2014; Minnesota Valley Transit Authority, 2015). Data were collected by an onboard survey of transit riders, a series of observations made from video footage of respondents' waiting time, and an audit of station and stop amenities, design characteristics and surrounding environments. Recognizing the importance of weather to the experience of using transit in Minnesota, both summer and winter data were collected. After data collection, regression analyses were preformed to examine respondents' waiting time estimates as a function of objectively observed waiting time and characteristics of station and stop amenities, while controlling for weather, time of day, self-reported and observed socio-demographic characteristics and trip characteristics.

3.1 Site Selection

The research team selected 36 data collection sites chosen from a complete list of MSP transit stations and stops,. Stratified sampling was used in the site selection process. The first step in the process began with removing all bus stops with fewer than 50 average weekday boardings. This left a total of 703 transit stops and stations. The second step developed a classification schema based upon station/stop types and neighborhood types. Thirty-six sites were selected to ensure representation from each classification. Figure 1 illustrates the distribution of study sites by each classification scheme. These sites offer a full range of amenity levels from full-featured light rail stations to simple curbside bus stops. The sites also provide a mix of urban and suburban locations as well as attractive and unattractive surrounding environments (as rated by the research team, discussed below).

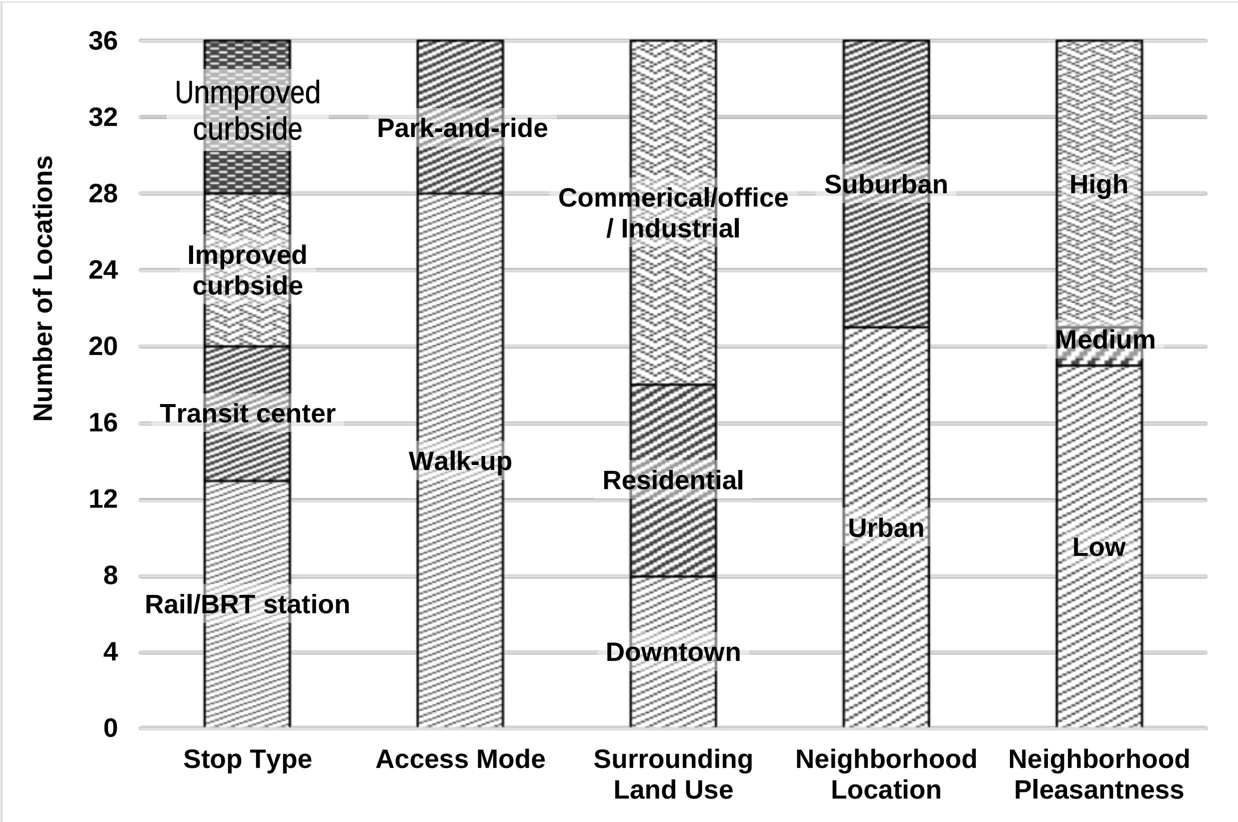

Figure 1: Distribution of Study Sites[1]

Figure 1 shows the distribution of study site characteristics and environments. Transitway stations are the most common individual site type with 13 locations, but are slightly surpassed if all curbside stops (15 locations) are combined. We deliberately include park-and-ride facilities to obtain a comprehensive picture of the transit system, but walk-and-ride stops and stations form a comfortable majority, with 28 of 36 locations. Just over half of all sites are located in commercial, office and/or industrial areas outside of either downtown, partially reflecting the study's focus on high-ridership stops, which tend to be on major thoroughfares. Twenty-one study sites are in one of the central cities, while 15 are in suburbs. Nineteen sites are in neighborhoods with a "low" initial pleasantness rating, while 17 were in neighborhoods with "Medium" or "High" ratings. (To maximize variation, we excluded areas of "medium" pleasantness, with the exception of two suburban transitway stations. We include these due to a lack of suburban transitway stations in areas with "high" pleasantness.) Figure 2 shows locations of study sites in the Twin Cities region, demonstrating the broad urban, suburban and modal distribution of data collection sites.

[1] Pleasantness ratings were done by a trained researcher via a rough, at-a-glance assessment to speed the selection process. Factors used in pleasantness ratings include sidewalk presence/width, amount and location of off-street parking, tree cover, enclosure of street scenes, architectural variety and ground floor window, etc.

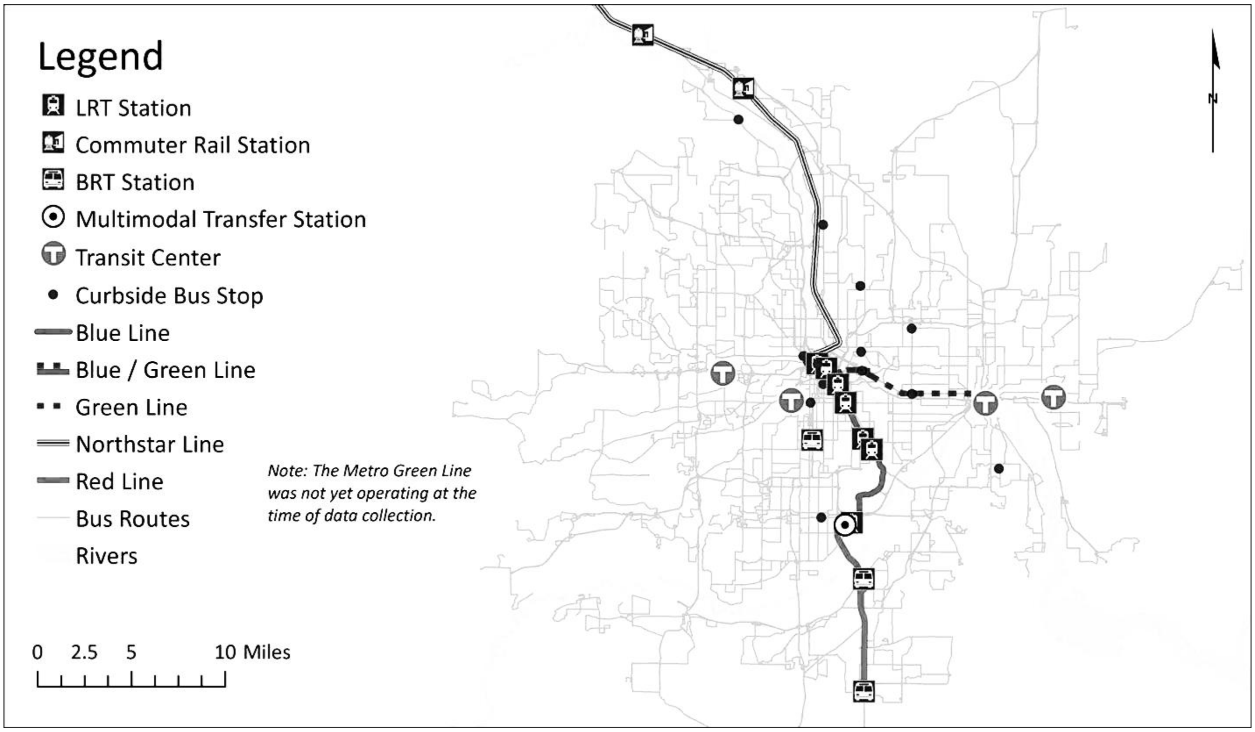

Figure 2: Study site locations

3.2 Onboard Survey

The first primary data collection task was a brief survey of Twin Cities transit riders who boarded trains or buses at the 36 study sites. The survey was conducted during July and August, 2013, and February, March and April, 2014. Each site was surveyed during each of four time periods as defined by Twin Cities Metro Transit: Morning Peak (6:00-9:00am), Mid-day Off-Peak (9:01am-2:59pm), Evening Peak (3:00-6:30pm) and Late Evening Off-Peak (after 6:30pm). Each site was visited in each time period until either at least four responses had been obtained for that site/time combination or three visits had been made.

To allow respondents to complete their entire waiting period as they normally would, recruiting and survey administration took place on board transit vehicles after all passengers had boarded. Survey team members waited unobtrusively at the station/stop, positioned themselves at the back of the boarding queue, and boarded with passengers. Once on board they recruited as many passengers who had just boarded as possible.

The survey questionnaire began with the key question "How many minutes do you think you waited at the station/stop before you boarded this train/bus?" This question captured the respondent's estimated waiting time—used as a measure of their perception. The questionnaire was self-administered in writing, and also collected basic information on perceptions of the "pleasantness" of the station/stop, forms of schedule information used (pocket schedules, realtime information app, etc.), approximate trip origin and destination, primary activities at origin and destination, access and planned egress modes, general travel behavior, and basic demographic information.

Upon collecting each completed questionnaire, surveyors (with respondents' permission) took a photograph of each respondent holding up their questionnaire, with a preprinted ID number visible. These photographs enabled the visual identification of respondents without the need to collect any information from which their names could be determined.

Self-reported estimates of waiting time are not necessarily identical to *perceptions* of waiting time. However, perceptions, by their very nature, cannot be directly measured. We employ self-reported estimates of waiting time as an externally measurable proxy for time perceptions. Our discussion of perceptions in this paper reflects the relationship between reported and observed waiting times, and the practical significance of perceptions: the light they shed on perceptions is the reason we care about self-reported estimates.

3.3 Respondent Observations

The second data collection task involved unobtrusively recording video footage of potential respondents during their wait for the train or bus, and making a series of observations about those who elected to participate from the video. The photographs taken of respondents with their questionnaires were used to connect survey responses with observations, and to assign each set of observations an ID number later used to merge the two data sets. Once a respondent was identified arriving at the station or stop, a researcher recorded the counter time in the video file. During video playback, the researcher made a series of observations about the respondent, including: demographics such as gender, race, and approximate age; manner of dress ; items carried; mobility devices, if any; activities engaged in while waiting; and travelling companions, if any.

Finally, the researchers recorded the counter time at which the respondent boarded the train or bus. The difference between this observation and the initial arrival time observation provided the observed waiting time for use in analysis.

3.4 Waiting Environment Audit

To obtain a standardized list of amenities and design features present at data collection sites, as well as information on surrounding environments, the researchers also conducted a waiting environment audit of each data collection site. Based on the common practice of pedestrian environment audits, the audit tool included both quantitative information (identifying the presence/absence/prevalence of features) and qualitative information (identifying the auditor's perception of a given quality using a four-part Likert scale ranging from "Not at all", "Somewhat", "Mostly", to "Very" for each quality). Specific topics covered by the audit included: the physical layout of the waiting area (separation from surrounding pedestrian flow, boarding from curb vs. transit platform, etc.), shelter provided, seating, other amenities such as water fountains or restrooms, overall physical comfort, route and schedule information provided, maintenance, visual appeal, traffic level, neighborhood security, noise and air quality, and overall perception of pleasantness.

The winter audit also included questions on snow removal. To lessen the influence of individual bias, each site was audited by two members of the research team, one male and one female; each site received the average of both auditors' responses in the final data.

4 RESULTS

The survey produced a total of 822 valid responses, for which the respondent was successfully identified in video footage, and for which the questionnaire was substantially complete, including an estimate of waiting time. Table 2 provides a sample distribution. The sample is, perhaps not surprisingly, composed heavily of population groups likely to use transit, particularly low-income riders, people belonging to minority racial or ethnic groups, and riders without cars.

Table 2: Sample Distribution

Household Income		**Race**	
< $25,000	38%	White	59%
$25,000 - $39,999	18%	Black	27%
$40,000 - $59,999	14%	Hispanic	5%
$60,000 - $99,999	15%	Asian	6%
$100,000 or more	15%	American Indian	1%
		Other	1%
Transit Use Frequency		**Transit Pass**	
5x/wk or more	60%	Have:	63%
2-4x/wk	19%		
1-4x/mo	9%	**Car**	
<1x/mo	8%	Have:	41%
First time	4%		

Figure 3a is a histogram showing percentages of Reported Wait Time in five-minute increments. Put together, estimates of 0-5 minutes and 5-10 minutes account for just over 70% of responses, with 5-10 minutes estimates the most common category. Of the nearly 30% of respondents who estimate their waiting time as longer than 10 minutes, estimates in the 10-15 minute range predominate, accounting for almost 20% of the overall sample.

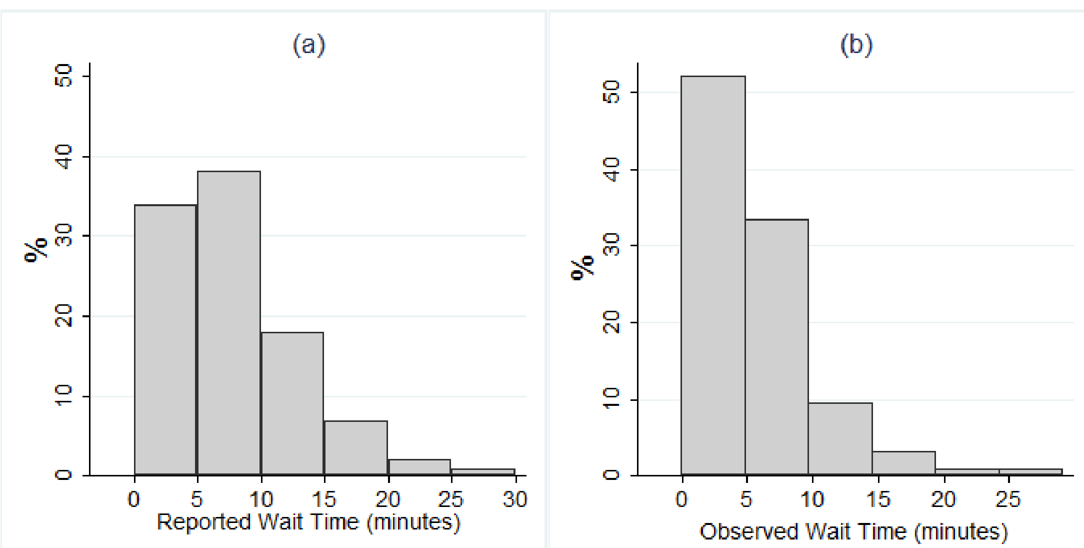

Figure 3: Distribution of Reported and Observed Waiting Times

Figure 3b is a histogram showing percentages of Observed Wait Time in five-minute increments. Significantly, just over half of all responses have observed waiting times between zero and five minutes. Roughly a third of responses have Observed Wait Time values in the five-to-ten minute range, with much smaller percentages for values greater than ten minutes.

The difference between Figure 3a and Figure 3b is striking: while the two most common ranges of observed waiting times are still 0-5 and 5-10, their relative sizes are reversed, with 0-5 minutes the most common by far, actually accounting for an outright majority of the sample. In addition, the percentage of respondents who actually wait more than 10 minutes is quite low—roughly 13%. The small number of observations with long observed waiting times is perhaps a limitation of this study, though likely an unavoidable consequence of the practical decision to constrain site selection to stops with relatively high ridership. Such stops tend to be located on heavily-used routes with relatively frequent service. It is also possible that users of lower frequency routes check schedules more carefully before setting out for the bus stop.

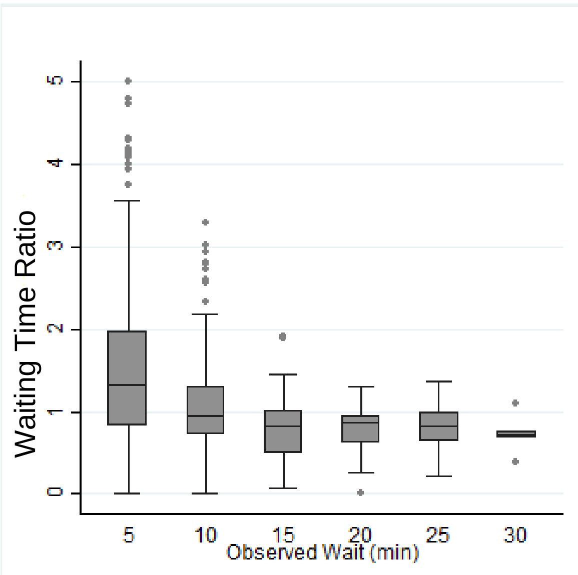

Figure 4: Distribution of Waiting Time Ratio by Observed Wait[2]

Figure 4 shows a box plot of the ratio of Reported Wait Time to Observed Wait Time in five-minute increments of Observed Wait Time. For each increment, the box shows the Inter-Quartile Range (IQR) and the "whiskers" above and below the box indicate values within 1.5 IQR of the near quartile; points show values outside this range. For zero to five minutes of Observed Wait Time (a majority of the sample), Reported Wait Time shows a significant trend of over-estimates, with a low near-quartile of 1, a median of roughly 1.3 and an upper near quartile of nearly 2. The upper whisker reaches nearly to 3.5, indicating a significant minority of large overestimates. Estimates tend to be more accurate for longer observed waits: 5-10 minutes of observed waiting time produces a median ratio close to 1, though the high near quartile extends considerably farther from the median than the low near quartile. Longer observed waits produce

[2] "Waiting Time Ratio" refers to estimated waiting time divided by observed waiting time.

even more accurate estimates, but, as shown in Figure 1a, account for only a small percentage of responses.

4.1 Regression Model

The three data sets were merged and used to estimate a log-log regression model with interaction terms using the equation:

$$y=c+\beta_O O+\beta_2 x_2+\beta_{O2} O*x_2+...+\beta_i x_i+\beta_{Oi}(O*x_i)\ ...\ \beta_i x_n+\beta_{On}(O*x_n)+e,$$

where:

y equals the natural logarithm of Reported Wait Time (with 0.01 added to the raw variable to avoid losing 0 values),

O equals the natural logarithm of Observed Wait Time (also with 0.01 added), and

x_2 through x_i equal the binary explanatory variables listed below.

Note that variables identified by † were also interacted with ln(Observed Wait) (i.e., x_1) to capture the change in its relationship with ln(Reported Wait) over objective time.

- Rail†—A response collected on a light rail or commuter train. Included to account for modal differences in passengers' perceptions.
- Hi-Frequency—A response collected on a route included in Metro Transit's Hi-Frequency network of arterial routes with all-day guaranteed short headways.
- Shelter†—A stop or stop/station with some form of shelter provided for waiting passengers. Included as an amenity.
- Bench†—A bench provided as part of the transit station or stop. Included as an amenity.
- Realtime Information Sign†—An electronic display giving passengers realtime departure/departure information. Included due to existing research on time perception impacts of realtime information.
- Senior†—A respondent estimated to be 65 years or older. Included (along with the preceding two) to account for generational differences in transit use patterns. "Young" (18-34) was omitted as the reference.
- Female—Female respondent. Included to account for potential gender differences in time perceptions.
- Not/Somewhat Safe—A station or stop rated as "Not safe at all" or "Somewhat safe". Included due to research showing users place high importance on security at transit stations and stops.
- Female & Not/Somewhat Safe†—The interaction of "Female" and "Not/Somewhat Safe". Included to account for gender differences in perceptions of personal security.

- Minority†—Non-white and/or Hispanic respondent. Included to account for cultural differences in transit use and perceptions of transit. (Note: Variables identifying individual minority groups were insignificant in early model runs.)
- Knew Schedule†—A respondent who reported having known the schedule in advance of boarding. Included to account for the potential effects of a known length of wait on time perceptions.
- Transfer—A respondent who arrived at the station or stop by train or bus and transferred to the route he/she was surveyed on. Included due to existing research indicating high perceived disutility of transfers.
- Utilitarian Personal Destination—A respondent who identified the primary activity at their destination as "Personal Business", "Shopping" or any other non-commute destination besides returning home.
- Recreational Destination—A respondent who identified the primary activity at their destination as "Social", "Recreation" or "Eat Out".
- Mid-Day—A trip made between 9:01am and 2:59pm, the mid-day, off-peak service period, as defined by Metro Transit.
- Evening Peak—A trip made between 3:00pm and 6:30pm, the evening peak service period, as defined by Metro Transit.
- Late Evening—A trip made after 6:30pm, the late-evening, off-peak service period, as defined by Metro Transit. Included (along with the two above) to account for potential differences in perceptions of time throughout the service day. "Morning Peak", 6:00am to 9:00am, was omitted as the reference.
- Traveled Alone—A respondent who had no traveling companions according to observations made from video footage. Included to account for time perception impacts of solitude versus companionship.
- Activity—A respondent who engaged in some type of activity while waiting other than sitting, standing, looking for the bus, etc. Included to account for the time perception impacts of diversion.
- Winter—A response collected during the winter months. Included to account for weather-linked differences in perceptions.

The raw Reported Wait variable (prior to the logarithmic transformation) has a mean of 6.79 minutes, with a median of 5 minutes. Raw values of Observed Wait are shorter as a group, with a mean of 5.66 minutes and a median of 4.5 minutes. That is, the reported wait time on average is about 1.18 times longer than the observed wait time. All dummy variables except Hi-Frequency, Shelter, Bench, Knew Schedule and Traveled Alone have a mode of zero.

The model (as shown in Table 3) includes 703 observations and achieves an adjusted R^2 of 0.32. Ln(Observed Wait) is significant, and, as expected, has a positive coefficient, indicating that longer observed waiting times are related to longer reported waiting times. None of the transit service variables is significant, indicating that, as intended, the model explains variations in reported wait time as a function of physical and environmental characteristics of stops.

Table 3 also presents a simpler version of the model, without interaction terms, to demonstrate the additional understanding they allow. We believe it is theoretically crucial to include both the raw variables and their interactions, for the simple reason that certain explanatory variables likely have different impacts on time perceptions in short and long waits. For example: a bench may have little impact at all on perceptions of a wait so short a rider faced with it would likely stand anyway, yet have a profound impact on perceptions of a very long wait. A woman waiting in unsafe surroundings might at first feel relieved at reaching her stop safely, then become increasingly apprehensive as her wait drags on. We do not assume such processes take place, but the use of interaction terms where appropriate allows us to see their effects if they do, an insight the raw variables alone do not offer. While it is true that interaction terms can introduce co-linearity into a regression model, none of the variables in our model correlate strongly enough with each other to raise this issue. In addition, our model is specified from the outset to avoid such problems through the exclusive use of binary variables for the base terms, with the sole exception of observed waiting time. Finally, as may be seen in Table 3, the simplified model performs significantly worse, with a lower R^2, and notably fewer significant explanatory variables, even considering variables only marginally significant. For these reasons, we base our analysis on the full model, with interaction terms included.

Among the station/stop amenities considered, Shelter is significant and negative, though with a positive, significant interaction term, dampening the effect for long waits. Bench is insignificant, but produces a significant, negative interaction, indicating that seating has little initial effect on waiting time perceptions but serves to moderate perceptions of longer waits. Realtime Sign has a significant, negative base term, but an insignificant interaction, indicating an initial shortening of perceived waits but no effect on the rate of increase for longer waits.

Among the respondent characteristics variables, it is particularly notable that Female and Not/Somewhat Safe are both insignificant on their own, but that their interaction is significant, along with its second-order interaction with ln(Observed Wait). Minority and its interaction term are significant, with positive base and negative interaction coefficients. Senior Respondent and its interaction is also significant. Among the trip characteristics variables, Mid-day and Evening Peak are significant, with positive coefficients. Interestingly, considering Minnesota weather, Winter Trip is insignificant.

Table 3: Log-Log Regression: Response Variable ln(Reported Wait)

		Full	Simplified
Explanatory Variables:		β	β
	ln(Observed Wait)	0.6797***	0.6303***
Transit Service	Rail	-0.3049	0.0320
	Rail*ln(Observed Wait)	0.0989	
	Hi-Frequency Network Route	0.1784	0.1579
Amenities	Shelter	-0.6227***	-0.3847*
	Shelter*ln(Observed Wait)	0.3392***	
	Bench	0.2584	0.1309
	Bench*ln(Observed Wait)	-0.2064**	
	Realtime Sign	-0.2942**	-0.2777*
	Realtime Sign*ln(Observed Wait)	0.0804	
Respondent Characteristics	Senior Respondent	1.1554***	0.1571
	Senior Respondent*ln(Observed Wait)	-0.5810**	
	Female Respondent	-0.0526	-0.0019
	Not/Somewhat Safe Environment	-0.1105	-0.0881
	Female & Not/Somewhat Safe Enviro.	-0.6740**	-0.1845
	Female & Not/Somewhat Safe Enviro.*ln(Observed Wait)	0.4334***	
	Minority Respondent	0.4637***	0.0786
	Minority Respondent*ln(Observed Wait)	-0.2988***	
Trip Characteristics	Knew Schedule in Advance	0.6395***	0.3383***
	Knew Schedule in Advance*ln(Observed Wait)	-0.2985***	
	Transferred from Another Route	0.2643**	0.2088
	Utilitarian Personal Destination	-0.1687	0.0327
	Recreational Destination	-0.2526	-0.2005
	Mid-Day Trip	0.3414**	0.3654**
	Evening Peak Trip	0.2415*	0.2275*
	Late Evening Trip	0.2505	0.2363
	Traveled Alone	0.3031***	0.2938**
	Engaged in an Activity while Waiting	-0.0941	-0.0024
	Winter Trip	-0.1758	-0.2144*
	Cons.	0.3089	0.3753
	N	703	703
	Adj. R^2:	0.32	0.27

Legend: * p<.1; ** p<.05; ***p<.01

4.2 Model Predictions

Due to the complexity of the equation produced by a Log-Log model specification with multiple interaction terms, key results are more conveniently interpreted graphically than via the raw regression coefficients. Figure 2 shows the model's predictions of Reported Wait Time under amenity and environment scenarios with significant policy implications over values of Observed Wait Time from zero to 10 minutes. (87% of participating responses have an Observed Wait Time of 10 minutes or less.) In each case, the named dummy variable is set equal to one, and ln(Observed Wait Time) and the dummy variable's interaction term (the product of 1 and ln(Observed Wait Time) are set equal to the natural logarithm of each *x*-axis value shown on the graph. Unless stated otherwise, all other dummy variables are held at their modal values. Graphed *y*-values are the exponential of the model's prediction of ln(Reported Wait Time), with 0.01 subtracted; they represent the model's prediction of Reported Wait Time on an arithmetic scale.

Figure 5a shows model estimate of subjective Wait Time for Bench, Bench with Shelter and Realtime Sign, as well as the combination of all three. (All studied stops with a shelter also have a bench; it would not be appropriate to predict the impacts of a shelter without a bench.) The baseline scenario is No Amenities—with all stop amenity variables set equal to zero. Specifically, this scenario predicts reported wait times for an 18-64 year old, white male traveling to work or school in the morning peak time period, from a station or stop with no amenities and a "Mostly Safe" or "Very Safe" surrounding environment, who knew the schedule ahead of time, is traveling alone, not transferring from another transit route and did not engage in another activity while waiting on a summer day. The baseline scenario produces a notable overestimate of waiting time. For example, a 10 minute wait is perceived as 21 minutes (a ratio generally in line with existing research), while even a brief 2.5 minute wait is perceived as 8 minutes. All of the amenity scenarios considered, however, significantly moderate the predicted overestimate. A bench alone has little impact on short waits, but has a progressively larger impact on longer waits, with a 10 minute wait perceived as 13 minutes. Both a bench with a shelter and a realtime information sign alone yield larger reductions in the perceptions of short waits but smaller reductions in perceptions of longer waits. It seems especially noteworthy that a realtime information sign alone yields almost the same reduction in perceived waiting time as both a bench and a shelter. The combination of all three amenities has by far the largest impact on reported waiting time, reducing it to consistently within a minute or so of observed waiting time. In other words, our model indicates that with only the provision of seating, shelter and realtime information, the time perception penalty incurred as passengers wait for a bus or train can be nearly erased.

Figure 5b shows the model estimate of reported waiting time based on respondents' gender and perceived security of stop surroundings with different amenity levels. The baseline scenario considers a male respondent and/or a "mostly safe" or "very safe" surrounding environment with no stop amenities. The prediction line for a female respondent *and* a "somewhat safe" or "not safe at all" surrounding environment tracks the baseline fairly closely for the first five minutes of observed waiting time, then diverges increasingly sharply upward. For a woman waiting at a simple "pole-in-the-ground" curbside stop with perceived insecure surroundings, a 10 minute wait seems to take nearly half an hour. Stop amenities dramatically moderate this effect, however. A female respondent waiting in perceived insecure surroundings at a stop with a bench, shelter and realtime information sign still has similar perceptions to a male respondent or perceived secure surroundings with the same amenities for the first five minutes, and diverges upward afterwards, but now only perceives a 10 minute wait as taking 15 minutes. This is a significantly smaller difference between actual and perceived waits than for a male respondent or secure perceived surroundings with no amenities.

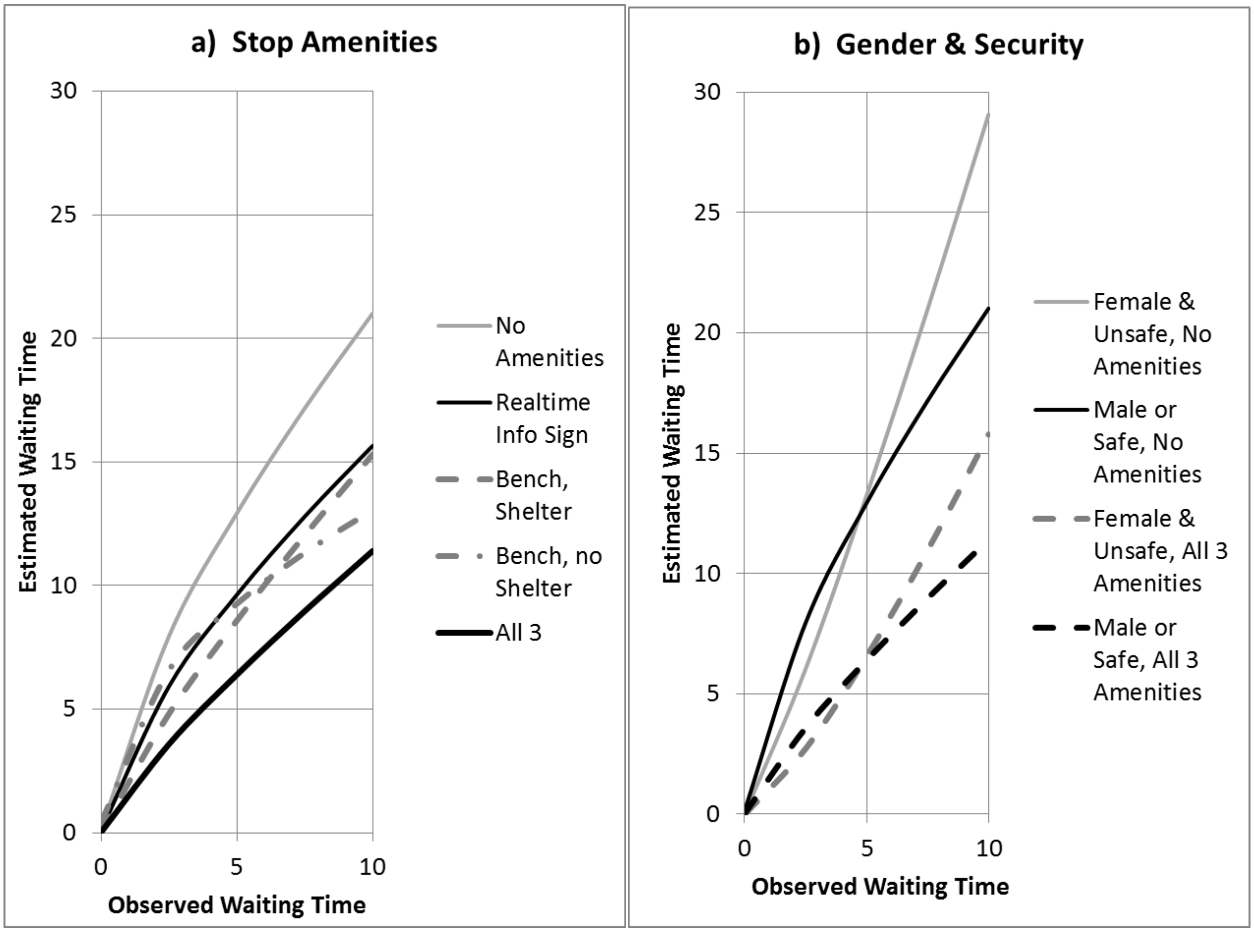

Figure 5: Model Prediction of Reported Wait Time (Estimated Waiting Time) vs. Observed Waiting Time for Stop Amenities and for Gender and Security

5 CONCLUSIONS AND DISCUSSION

The survey and model results support the basic research hypothesis that transit users, on the whole, tend to perceive the time spent waiting for a train or bus as longer than it actually is, and that characteristics of the station or stop and its environment can alter those perceptions. Nonetheless, the study findings show that the relationships between station/stop amenities and waiting time perceptions are more complicated than generally assumed. Our results indicate a non-linear relationship between reported and observed waiting time variables, and that some amenities (e.g., bench) are more important to longer waits than shorter waits.

Realtime information alone reduces a transit user's perception of waiting time almost as much as both a bench and a shelter. This finding has important implications for stops with space constraints and for high-ridership locations that cannot accommodate adequate seating and/or shelter capacity. That is, it is possible to significantly improve the experience of using transit by providing realtime information signs in locations where space and/or pedestrian traffic considerations do not allow for a bench or shelter. Moreover, when all three amenities (bench, shelter, realtime information) are combined, they produce nearly accurate estimates of waiting time: the time perception penalty of waiting nearly vanishes. The variables considered do not differentiate between different bench or shelter types or designs—indeed, early attempts to distinguish between "basic" and "premium" shelters found little difference. This conclusion appears to echo the findings of existing stated-preference research on the relative importance of service frequency and station amenity levels.(Iseki & Taylor, 2010; Liu, Pendyala, & Polzin, 1997) In practice, the broad provision of basic stop amenities and departure information can dramatically reduce the perceived burden of transit use.

Due to respondents' apparent conflation of online schedules and realtime information apps (based on common responses to a question about mobile device use), our survey failed to produce reliable data on the use of "next bus" apps, which may serve as a substitute for realtime signs. In addition, a strong correlation between the presence of a shelter and the presence of a posted schedule prevented the inclusion of posted schedules in the final model. Given the recent evidence that realtime information via mobile devices are effective in reducing waiting time perceptions (Brakewood et al., 2014; Brakewood et al., 2015; Brakewood, Rojas et al., 2015), more detailed comparative study of alternative methods for communicating departure information may present a valuable direction for further research. Such research on alternative communication methods will have important policy implications because broad deployment of at-stop realtime information signs often face cost limitations. Notably, new bus stop signage in the MSP region includes route frequency by time of day but not precise schedules.

The significance, and gentle slope of the minority variable may capture important community-level differences in familiarity with and attitudes towards transit. Compared to the white, non-Hispanic population, racial/ethnic minority groups have relatively high transit use rates and may be less likely to associate social stigma with transit use. These differences may be responsible for the shorter perception of waiting time among minority transit users than white, non-Hispanic transit users. If correct, this situation speaks to the importance of social perceptions in shaping the experience of transit use.

Finally, the stark difference between the No Amenities and Female Respondent in Unsafe Environment scenarios points to an important direction for improving the experience of using transit. In the region studied, women account for a majority of transit commutes, (United States Bureau of the Census, 2014). It appears that, in some locations, their experience of waiting for a train or a bus differs substantially from men's, and not in a good way. Further qualitative study may be warranted to determine specific issues such as fear of crime, street harassment, etc. Still, focusing on basic security improvements around less-safe transit stops appears to be an important gender equity measure, and one with the potential, at least, for significant returns in terms of perceived waiting times. Further, the finding that the provision of basic stop amenities is highly effective at reducing gender disparities in waiting time perceptions may justify such amenities at lower ridership levels than elsewhere in less safe areas. This study is not able to show direct ridership impacts of differences in perceived waiting times. Still, the long reported waits for women in not, or somewhat safe, environments appear to indicate a needlessly stressful passenger experience which at least seems unlikely to help ridership. Perceptions of personal security in some locations may impede female choice riders from relying on transit.

To summarize, the results of this analysis indicate the potential for transit stations and stops, and the waiting environments they create, to significantly influence passengers' perceptions of waiting time. In particular, they point to the importance of seating, shelter and information, as well as the importance of providing a basic complete package of amenities where possible and increasing perceptions of personal security around the least safe stops, particularly from the perspective of female passengers. Each of these present promising avenues for further analysis using these data and/or topics for more tightly focused research on each topic identified.

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