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4 **TRANSIT RIDERS' PERCEPTION OF WAITING TIME AND STOPS'**
5 **SURROUNDING ENVIRONMENTS**
6

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1 ABSTRACT

2 Reducing the burden of waiting in transit travel is critical to increase the attractiveness of public
3 transportation and encourage people's shift from automobile mode. Research shows that wait
4 time perception is highly subjective and varies according to various factors such as mode,
5 availability of schedule information or stops amenities. In addition, high-quality environments
6 are known to reduce stress and to encourage walking and biking. Nevertheless, little research
7 exists on the influence of the stops and stations surrounding environment on transit users' wait
8 time perception. This study aims to respond to this knowledge gap in order to optimize stop
9 localization and micro urban design around stops. The study compares transit users' actual and
10 estimated wait time at 36 stops and stations offering a mix of environmental situations in the
11 Twin Cities region. A regression analysis is used to explain the variation in riders' waiting time
12 estimates as a function of their objectively observed waiting times, as well as stop and station
13 surrounding environment characteristics. The results show that, for waits longer than five
14 minutes, the more the environment is polluted and exposed to traffic, the more transit users tend
15 to overestimate their wait time and that, on the contrary, the more mature trees are present the
16 shorter the wait time is perceived. The combination of the three variables indicates that after 5
17 minutes wait, the presence of trees achieves to compensate the effects of both air pollution and
18 traffic awareness. Policy implications and further research needs are discussed.

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23 *Keywords:* Public transportation, transit, rail, bus, stop, station, waiting time, time perception,
24 environment, air pollution, traffic, tree, planning, urban design.

25

1 INTRODUCTION

2 Improving the attractiveness of public transportation is imperative for sustainable development,
3 given the benefits from environmental, economic, and social points of view. High-quality,
4 attractive transit reduces air pollution, carbon emissions, congestion, oil dependency, and travel
5 expenses due to personal vehicles.

6 Research on travel mode choice shows that time and service quality are key factors,
7 before the monetary cost (1). Reducing the burden of waiting appears to be critical: transit users
8 perceive waiting time as significantly “longer” either than an equal amount of in-vehicle time, as
9 well as significantly longer than it actually is. Long-seeming wait times may negatively affect
10 users’ satisfaction. Improving wait times perceptions is an important issue with potentially lower
11 costs than actions focusing on reducing actual wait times (2).

12 Previous research shows that time perception is largely subjective (3) and can be
13 distorted by the context. In transportation, wait time perception varies according to several
14 factors such as the trip length, the journey purpose, the availability of information (4, 5, 6), the
15 activity while waiting (7), the stop amenities (6), or the aesthetic of the station (8).

16 Stop and station design, as well as the perceived security of surroundings have been
17 shown to profoundly affect waiting time perceptions (6). Little, however, is known regarding the
18 impacts of the surrounding environment more generally on users’ wait time perceptions. The
19 hypothesis of this research is that the more pleasant the environment of the stops and stations, the
20 shorter the wait time is perceived. The importance of the quality of urban public space has
21 mostly been investigated from pedestrians’ and cyclists’ perspectives; little research exists on the
22 role of the surrounding environment for transit riders’ time perception. This study responds to
23 this knowledge gap to provide policy recommendations to optimize stop locations and urban
24 design around stops with the aim of reducing riders’ perceptions of waiting time.

25

26 RELATED STUDIES

27 Despite the lack of specific research on transit stop environments, research in psychology and
28 marketing generally consider how environment influences perception of time. In psychology,
29 Droit-Volet and Gil (3) explain how the emotional state and the surrounding rhythm influences
30 time perception. Marketing research also establishes the influence of the service environment on
31 customer waiting time perception, through affect, as well as the negative relationship between
32 waiting time and service satisfaction (9, 10). Hornik (11) shows that positive mood tends to
33 underestimate the durations of activities while negative or neutral mood tends to overestimated
34 them. Baker and Cameron (12) review the different environmental factors affecting customers’
35 time perception such as lighting, temperature, music, color, furnishing, organization of the
36 service, distractions available while waiting, and social interactions. Pruyn and Smidts (13)
37 confirm that the waiting environment influences customers’ wait perception and suggest that
38 attractive waiting environment induce a positive mood which improves slightly the wait
39 perception and strongly the service evaluation. Nie (14) approaches waiting from customers’
40 stress management perspective and shows that uncertainty and ambiguity tend to overestimations
41 of wait durations.

42 Much research exists on transit users’ valuation of time, due to strong implications for
43 mode choice. Waiting and transferring are perceived more burdensome than travelling. Indeed,
44 out-of-vehicle times (OVT) appear longer than In-Vehicle Time (IVT). Fan, Guthrie and
45 Levinson (6) summarize the research findings regarding the factors affecting waiting time
46 perception, including the existing ratios of OVT/IVT. According to Wardman’s (2), planners

1 should consider an average ratio of 2.5, meaning that waiting time worth 2.5 IVT. Although, a
2 study in the Twin cities (15) finds that riders perceived the waiting time 4.4 longer than the IVT.

3 Iseki & Taylor (16) propose a classification of factors affecting the perception and
4 valuation of waiting and walking for transit: “operational factors” (frequency, reliability, and
5 availability of information), “physical environmental factors” (safety, security, comfort and
6 convenience), and “passenger factors” (such as activity while waiting, physical condition,
7 familiarity with the transit system, destination).

8 Regarding the operational factors, Horowitz (17) and Wardman, (2) explain that mode
9 length trip and trip purpose affect wait time values. Wait time value increases slightly with
10 journey duration for transit walk and wait and appears higher for car and train users than for
11 transit riders (2). Parsons Brinckerhoff (18) shows that complete and clear information reduces
12 the actual and perceived waiting time. Frequency appears to significantly improve the perception
13 of waiting time (19) but the lack of reliability of service with unpredictable delays tends to
14 increase the perception of waiting time (20).

15 Regarding the passengers’ factors, Dziekan (21) finds that regular riders have relatively
16 lower burdens for waiting than occasional transit users. Passengers’ negative emotions such as
17 anxiety, boredom or stress tend to increase time perception of time while distractions appear to
18 reduce their wait time estimates. Millonig’s and Sleszynski’s (7) study on the effects of
19 entertainment activities at different kinds of public transport stations show that playing while
20 waiting can either have the effect to shorten or make longer time perception according to users’
21 or stations characteristics. Among other activities, talking with others appears to reduce the
22 perception of waiting time. Fan, Guthrie and Levinson (6) find women perceive longer waiting
23 time at stops or stations located in an unsafe environment: at a simple curbside bus stop, a 10
24 minute wait seems to take nearly half an hour.

25 Regarding the influence of stops and stations characteristics on wait time perception, few
26 studies are available. Research suggests that real-time information diminishes the perceived
27 waiting time of customers by reducing their stress due to the uncertainty of bus time arrival (3, 4,
28 22). Tang (23) finds a modest increase in ridership associated with the implementation of the
29 Chicago Transit Authority’s real-time bus tracker system between 2002 and 2010. Fan & Guthrie
30 study (5) suggests that shelters and posted schedules on lower frequency bus routes reduce
31 perceived waiting time. Cascetta and Carteni (7) observe that the architectural design of railways
32 terminals has a significant impact on users’ behavior: Commuters are willing to wait longer in
33 high aesthetic stations and are willing to spend more time to go to these stations, extending
34 significantly their catchment area. It introduces the concept of “hedonic value” of stations and
35 shows that high quality environment can reduce the cost of waiting and even procure rewarding
36 effects such as pleasure. This study also underlines that female travelers are significantly more
37 sensitive to high quality stations.

38 Few academic studies are available specifically regarding the role of stops’ and stations’
39 surrounding environments on riders’ perceptions. Those that are mainly deal with safety and
40 security issues. Loukaitou-Sideris (24) identifies that environmental characteristics surrounding
41 bus stops has a significant influence on perception of safety. She indicates that the ten high crime
42 bus stops in Los Angeles are situated at the intersections of multilane streets and have a
43 combination of features among the following: lack of amenities in crowding areas, lack of
44 visibility from surrounding shops, proximity to liquor stores or bars, situation in desolated places
45 without adequate lighting, surrounded by surfaces parking lot or vacant buildings, and suffering
46 from neglect and incivilities. In these places, grassy areas and bushes can have negative effects

1 providing setting for drinking or hiding attacks. She suggests that relocating the stops or
 2 improving the design of the sidewalk and shelter can increase riders' security. Iseki and Taylor
 3 (25) also observe that a safe environment and frequent and reliable service matter most to riders
 4 than attractive or elaborated stops.

5 Even though the literature does not address the specific issue of environmental impact on transit
 6 riders' time perception, it underlines the effects of the environment on people's mood and level
 7 of stress, which influence wait time perception. Noise, traffic and pollution appear factor of
 8 important stress (26) whereas neighborhood vegetation is found to have direct stress mitigation
 9 effects (27). Research addresses the cost effectiveness of planting trees in urban settings (28, 29).
 10 The cost benefit analysis of planting one million trees canopy cover in Los Angeles shows that
 11 the average annual benefits for the 35-year period were \$38 and \$56 per tree planted, according
 12 to the mortality scenario. 81% of total benefits were related to aesthetic, including property
 13 values and well-being, 8% were storm water runoff reduction, 6% air-conditioning savings, 4%
 14 air quality improvement, and less than 1% atmospheric carbon reduction (29).

15 An extensive literature is also dedicated to the influence of urban environment on travel
 16 behaviour, and especially on walking and biking (30). This research does not directly address
 17 travel behavior, but proceeds from the hypothesis that shorter perceived waiting times indicate a
 18 more pleasant user experience. As more pleasant user experiences are likely to relate to higher
 19 transit use, travel behavior offers clues to conditions that may lead to shorter perceived waits..
 20 Estupiñan and Rodriguez (31) find a relation between the surrounding environment of the stops
 21 and BRT boarding in Bogota. Environmental supports for walking and barriers to cars were
 22 related to higher boardings. Cervero and Kockelman (32) find that pedestrian oriented urban
 23 design, such as the presence of street trees, exert a modest effects on walking non-work trips.
 24 Cervero and Duncan (33) also observe only a moderate influence of land-use design on walking
 25 and a far stronger effect on bicycling. Cao, Mokhtarian, and Handy (34) note a relationship
 26 between the built environment and changes in travel behavior. His findings suggest that the
 27 presence of bike routes, sidewalks, parks and the overall attractiveness of the neighborhood
 28 (appearance, level of upkeep, variety in housing styles, and big street trees) increase walking.

29 The existing literature supports the research hypothesis that the surrounding environment
 30 of transit stops may affect riders' wait time perception but little research exists on this topic. This
 31 study has the objective to address this knowledge gap in order to understand how to optimize
 32 location and stops environment.

34 **METHODOLOGY**

35 The researchers Y. Fan, A. Guthrie and D. Levinson designed the methodology and collected the
 36 data. Additional details on the methodology and data collection are available (5).

37 The research is based on a comparison between transit riders' actual and self-reported waiting
 38 times at 36 transit stations and stops in the Twin Cities region. Regression analysis is used to
 39 explain the variation in riders' waiting time estimates as a function of their objectively observed
 40 waiting times, as well as station surrounding environment, while controlling for variables known
 41 to influences wait time perception.

43 **Data Collection Sites**

44 The 36 stops and stations were selected among 12,382 bus stops, 19 light rail stations, 7
 45 commuter rail stations and 5 Bus Rapid Transit (BRT) stations in the Twin Cities region to offer

1 a full range of station and stop types, as well as a mix of neighborhood types, urban and
2 suburban locations and attractive and unattractive surrounding environments.

3 *Station/Stop Type:* the 36 sites include light rail, commuter rail and bus rapid transit
4 stations, bus transit centers and curbside bus stops. Each site was recorded as a transitway station
5 (including LRT, commuter rail and online BRT stations), a transit center (with multiple bus
6 routes), an unimproved curbside stop (“pole-in-the-ground” stop) or an improved curbside stop
7 (a bus stop with at least some amenity). The presence of park-and-ride facilities was also
8 identified.

9 *Neighborhood type:* The researchers selected stops to obtain of a mix of residential and
10 commercial surrounding areas, so as to account for any differences in perceptions based on
11 neighborhood activity character or level. This step involved aggregating the specific residential,
12 commercial and industrial land use categories in the Metropolitan Council’s current land use
13 shapefile into overall “Residential” and “Commercial” categories, then producing a 100m buffer
14 around each stop and station (chosen as a rough measure of immediate surroundings within
15 sight), and calculating the largest land use within each buffer.

16 *Urban vs. suburban:* All sites were also classified as either urban or suburban based on
17 the bus stops/transitway stations layer and the municipality they are located in. Urban stops are
18 located in Minneapolis or Saint Paul. Suburban stops are located in any other municipality in the
19 7 county metro area.

20 *Pleasantness:* a pleasantness score based on the general character of the neighborhood or
21 suburb was assigned to each stop: “Low”, “Medium” or “High”. This is a rough, at-a-glance
22 assessment to speed the selection process. Factors including sidewalk presence/width, amount
23 and location of off-street parking, tree cover, enclosure of street scenes, architectural variety and
24 ground floor windows were considered generally, and in more detail in cases of difficult
25 decisions. To obtain the maximum pleasantness variation possible, we excluded neighborhoods
26 and suburbs with a medium pleasantness score and focused on those with either high or low
27 pleasantness.

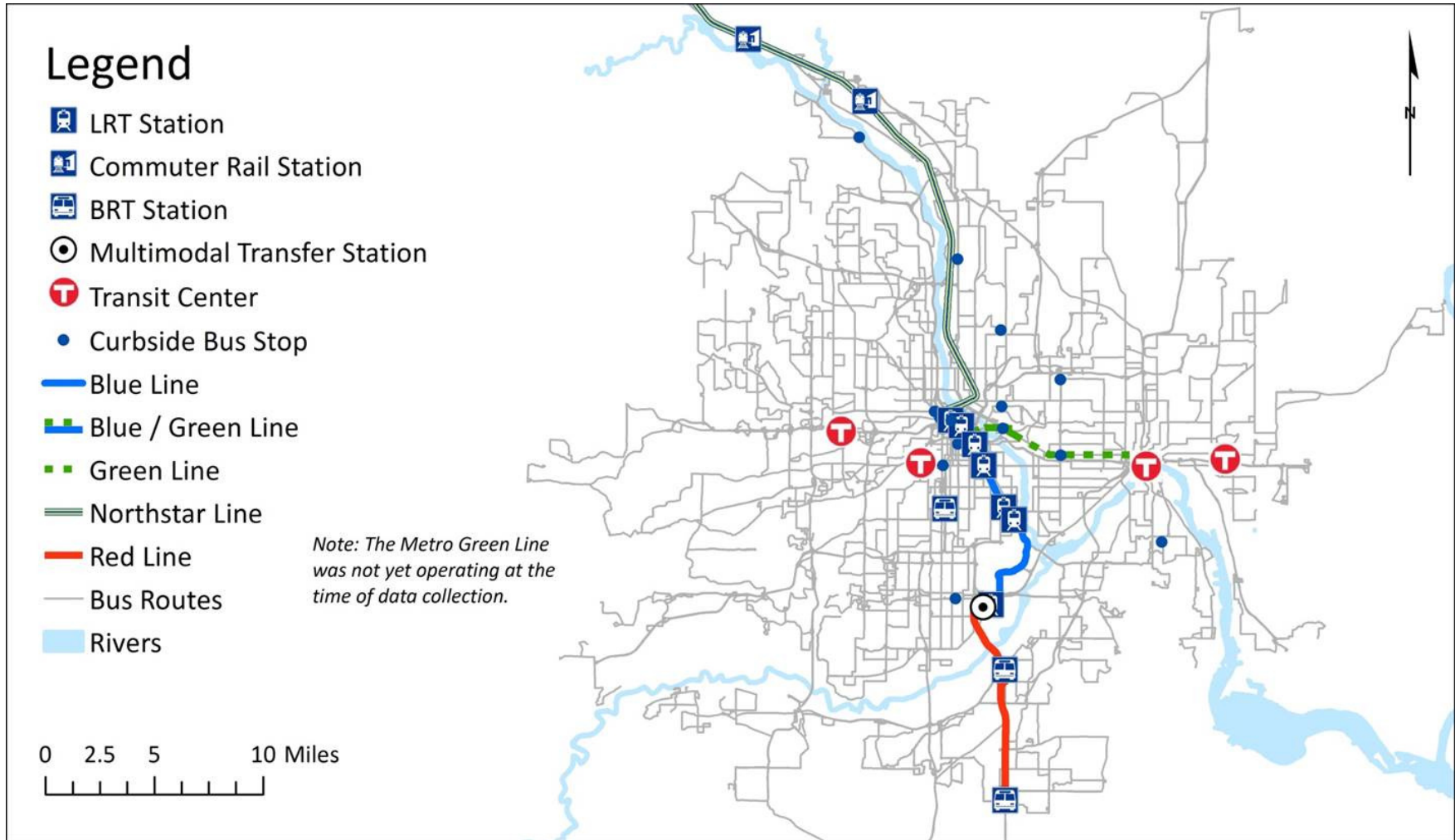
28 All sites were then organized into a single spreadsheet, with one worksheet for each stop
29 type/neighborhood type combination. Each sheet was sorted first by boardings, then by
30 pleasantness, producing three pleasantness categories, each in order of ridership. TABLE 1
31 shows the final classification of sites; FIGURE 1 shows the distribution of study sites across the
32 region.

33

1 **TABLE 1: Site selection matrix**

	<i>Pleasant mess</i>	Station/Stop Types - Sub-categories roughly based on degree of integration with/insulation from surrounding street scene.						
		Transitway Station		Bus transit center		Curbside Stop		
		Walk-up	Park-and-ride	Walk-up	Park-and-ride	Unimproved	Improved	
Downtown	High	<i>Urban</i>	Nicollet Mall LRT	n/a	Union Depot	n/a	7th St & Nicollet (NB, Mpls)	8th St S & Lasalle St/Nicollet Mall (EB, Mpls)
	Mid	<i>Urban</i>	Target Field	n/a	Minnesota & 6th St (StP)	n/a	Smith Ave & Ramp Exit/ Kellog (WB, StP)	LaFayette Rd & University Ave (SB, StP)
	Low	<i>Urban</i>	Downtown East-Metrodome LRT	n/a	n/a	n/a	10th St N & Twins Way (Mpls)	4th St S & Chicago Ave/ Kirby Puckett Dr (EB, Mpls)
Residential Neighborhood	High	<i>Urban</i>	50th St LRT (NB)	n/a	n/a	n/a	Como Ave SE & 22nd Ave SE (WB, Mpls)	University Ave SE & 25th/26th Ave (WB, Mpls)
		<i>Suburban</i>	n/a	n/a	n/a	117th Ave P & R (Champlin)	Harding St & 39th Ave N (SB, St Anthony)	n/a
	Mid	<i>Urban</i>	n/a	n/a	n/a	n/a	7th St N & Girard Ave (SB, Mpls)	7th St W & W Maynard Dr (NB, StP)
		<i>Suburban</i>	140th St BRT	Cedar Grove BRT	n/a	n/a	n/a	Minnetonka Bvd & Louisiana Ave (EB, St Louis Pk)
	Low	<i>Urban</i>	46th St & 35W BRT	n/a	n/a	n/a	n/a	n/a
		<i>Suburban</i>	n/a	Coon Rapids CR (SB)	n/a	n/a	Oakdale Ave & Wentworth Ave (NB, W StP)	University Ave & Mississippi St (SB, Fridley)
Commercial/ Industrial	High	<i>Urban</i>	46th St LRT	Lake St LRT	Uptown TC (NB, Mpls)	n/a	Franklin Ave E & Chicago Ave (WB, Mpls)	University Ave & Snelling Ave (EB, StP)
		<i>Suburban</i>	n/a	28th Ave LRT	n/a	n/a	n/a	n/a
	Mid	<i>Urban</i>	Cedar-Riverside LRT	n/a	n/a	South Bloomington TC (Bloomington)	Lyndale Ave N & W Broadway (NB, Mpls)	Emerson Ave N & W Broadway (NB, Mpls)
		<i>Suburban</i>	Bloomington Central LRT	AVTS BRT (NB)	Robbinsdale TC (190)	n/a	n/a	Nicollet Ave S & 66th St (NB, Richfield)
	Low	<i>Urban</i>	Franklin Ave LRT	n/a	Sunray TC (StP)	n/a	Olson Mem Hwy & 7th St N (WB, Mpls)	1st Ave S & Lake St (NB, Mpls)
		<i>Suburban</i>	MOA LRT	Ramsey CR	MOA (Bus Transit Center)	Louisiana Ave TC (St Louis Pk)	American Blvd @ Walmart (WB)	Snelling Ave & CR B (SB, Roseville)

1



2

3 **FIGURE 1: Data collection sites**

1 **Data Collection Method**

2 Data were collected with three different instruments and the three resulting datasets were then
3 connected together: an audit of the 36 selected stations and stops, a video footage of riders' while
4 waiting, and an onboard survey of riders. In order to take into account the weather, the data
5 collection took place in summer (July and August, 2013) and also in winter and early spring
6 (February, March and April, 2014).

7 8 *Waiting Environment Audit*

9 The researchers (5) conducted a Waiting Environment Audit for each selected stop and station in
10 order to collect data on their amenities and their surrounding environment.

11 Regarding the stops /stations characteristics, the audit covered the following topics: physical
12 layout of the waiting area, presence of shelter, seating, or other amenities such as water fountains
13 or restrooms, overall physical comfort, presence of route and schedule information, station/ stop
14 security, maintenance, and cleanliness.

15 Regarding stops and stations surrounding environment, the audit recorded the following
16 elements:

- 17 • Safety and traffic level: number of lanes of the street, speed limits, street design
18 features, sidewalk characteristics, traffic volume and traffic awareness.
- 19 • Neighborhood security: vacant lot or abandoned buildings, graffiti visible, litter or
20 trash visible, streetlights, buildings with street level windows.
- 21 • Noise and air quality: level of noise and air pollution in term of smell and in terms
22 of look.
- 23 • Appeal: presence of landmarks, identifiers for building use, mature trees, ground
24 covered by vegetation, and overall appeal.
- 25 • Overall perception of pleasantness.

26 Two members of the research team, one male and one female, conducted the audit in
27 order to minimize personal bias and the average of both auditors' responses was taken into
28 account. Environmental variables were mainly assessed using a Likert scale with a score ranging
29 from 1 to 4 ("Not at all", "Somewhat", "Mostly", "Very"). The audit was repeated during the
30 winter when the users' survey took place with snow on the ground.

31 32 *Video Observations*

33 A video of transit users at the stops allowed to record the counter times at which they arrived at
34 the station or stop and at which they boarded the train or bus. The difference between boarding
35 time and the arrival time provided the observed waiting time used for the analysis.

36 The video served also to make a series of observations about the respondent, including
37 demographics, mobility devices, activities while waiting, and travelling companions, if any.

38 39 *Onboard Survey*

40 A brief survey of transit riders who boarded trains or buses at study sites allowed to obtain the
41 respondent's reported waiting time. The survey also gathered information on:

- 42 • Perceptions of the "pleasantness" of the station/stop,
- 43 • Forms of schedule information used (pocket schedules, realtime information app,
44 etc.),
- 45 • Approximate trip origin and destination,
- 46 • Primary activities at origin and destination,

- 1 • Access and planned egress modes,
- 2 • General travel behavior, and
- 3 • Basic demographic information.

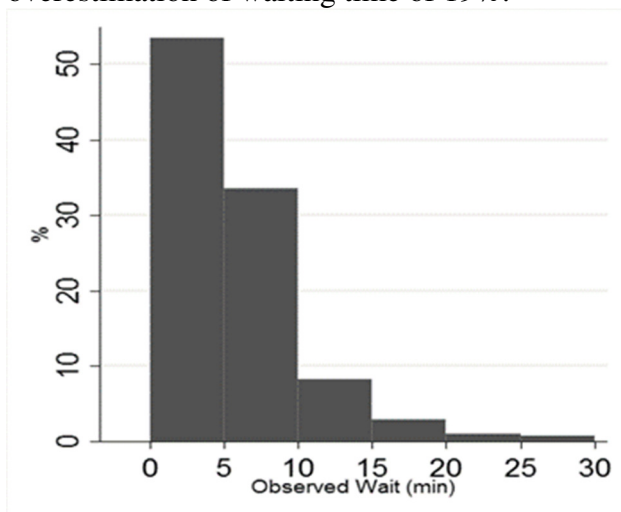
4 A photograph of each respondent holding up their questionnaire enabled the visual
5 identification of respondents and the connection with the dataset from the video observation.

7 RESULTS

9 Observed Wait Time and Reported Wait Time

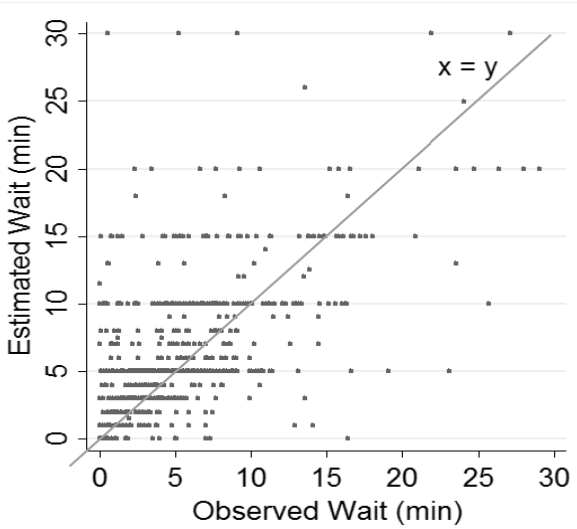
10 A total of 822 responses were considered valid connecting the datasets from the video and the
11 survey. The sample represents a population who use more likely transit, including more low
12 income people (38% under \$25,000 per year), people belonging to minorities (41%), and people
13 without cars (59%).

14 Approximately half of respondents actually waited less than 5 minutes, a third waited
15 between 5 and 10 minutes, and 8% waited between 10 and 15 minutes. Longer waits are much
16 less common. The FIGURE 2 shows the distribution of wait times and the FIGURE 3 shows a
17 significant correlation between reported and observed waiting times with an average
18 overestimation of waiting time of 19%.



19
20 **FIGURE 2: Distribution of observed wait times**

21



1
2 **FIGURE 3: Reported waits versus observed waits**

3 The Reported Wait variable has a mean of 6.78 minutes and a median of 5 minutes;
4 whereas the Observed Wait variable has lower values with a mean of 5.57 and a median of 4.6
5 minutes.

6 The analysis shows that, for shorter Observed wait, riders tend to overestimate their
7 Reported Wait, with a median ratio of Reported/Observed Wait Times of 1.52 for 0 to 5 minutes.
8 This ratio approaches 1 for longer observed waits (more than 5 minutes) implying more accurate
9 estimates of longer wait times.

10
11 **Regression Model**

12 To assess the relationship between estimation of wait time and stops environment variables for
13 our sample of riders, we use the following equation:

$$14 Y = c + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \dots + \beta_i x_i + \beta_{i+1} (x_1 * x_i) + e,$$

15 where Y is the natural logarithm of Reported Wait Time (with 0.01 added to the raw variable to
16 avoid losing 0 values), x_1 is the natural logarithm of Observed Wait Time (also with 0.01 added),
17 and x_2 through x_i represent the binary explanatory variables. These explanatory variables include
18 variables related to the stops and stations surrounding environment and additional variables
19 related to the station type and to the respondents' characteristics.

20 The explanatory variables are defined as following:

- 21 • **Polluted Air:** The surrounding environment of the stop is “mostly” or “very
22 polluted” in terms of either smell (vehicles emissions, industrial activity or other sources) or
23 appearance (diesel exhaust soot or construction dust) according to the Waiting Environment
24 Audit. The audit itself produced two pollution variables, Smell Pollution and Look Pollution.
25 These two variables were combined into a single one for this model due to collinearity.
- 26 • **Aware of traffic:** The situation of the stop leads the transit user to be “mostly” or
27 “very aware of traffic” in the nearest street, according to the Waiting Environment Audit.
- 28 • **Lot of Trees:** “A lot” of mature trees are visible from the waiting area according
29 to the Waiting Environment Audit.
- 30 • **Shelter:** Presence of some form of shelter at the stop according to the Waiting
31 Environment Audit. Included as control variable because research shows that it is a strong
32 predictor of wait time perception.

- 1 • Rail Station: Light rail or commuter rail station. Included as a control variable due
2 to potential effect of mode on wait time perception.
- 3 • High Frequency Bus Stop: A response collected on a route in Metro Transit's Hi-
4 Frequency network of arterial routes with all-day guaranteed short headways. Included as a
5 control variable.
- 6 • Knew Schedule: Respondent who reported having known the schedule before
7 arriving at the stop. Included as control variable because research shows that the impacts of
8 known length of wait on time perceptions.
- 9 • Traveled Alone: Respondent who traveled alone according to observations made
10 from video footage. Included as control variable.
- 11 • Snow Fall : A response was collected on a day during which snow fell. Included
12 as control variable to capture the impact the weather conditions.
- 13 • Female: Female respondent. Included to control for gender differences.
- 14 • Female and Not/Somewhat Safe: Included as control variable because previous
15 research shows it significantly influences wait time perception.

16
17 Stop Environment variables were interacted with $\ln(\text{Observed Wait})$ in order to account
18 for potential differences in environmental factors' impacts over time. The initial model included
19 a larger set of stop environment variables such as "Traffic Volume", "Vacant lot or abandoned
20 buildings", "Graffiti visible", "Litter or Trash visible", "Buildings with Street level Windows",
21 "Ground covered by Vegetation", and "Overall Appeal" and "Overall Pleasantness". Inclusion of
22 a large number of environmental explanatory variables is complicated by natural correlations
23 between various aspects of stop environments. For example the "Noise" and "Appeal" variables
24 are also related to Traffic and Pollution variables. In addition, "Traffic Aware" and "Traffic
25 Volume" variables are distinct but strongly related ($r=0.52$). Due to such considerations, the
26 model focuses on a limited number of explanatory variables which reveal clearer significant
27 correlations with stop environment variables.

28 29 **Regression Results**

30 The model takes into account 712 observations and the adjusted R^2 equals 0.265. It means that
31 26.5% of the variation is explained by the model, which is acceptable for a model based on
32 people's perceptions.

33 The TABLE 2 presents the regression results. $\ln(\text{Observed Wait})$ is significant with a
34 positive coefficient indicating that a longer observed wait time is still correlated with longer
35 reported waiting times.

36 Among the "stop surrounding environment" variables, Polluted Air and Aware of Traffic
37 are significant along with their interaction terms. Both have a negative base coefficient and a
38 positive interaction coefficient. Lot of Trees variable is also relatively significant ($P < 0.1$) with a
39 negative coefficient but its interaction is not significant. It means that Lot of Trees has more
40 initial effects on shortening wait time and less effects on longer waits.

41 Shelter, Knew Schedules and Female Not/Somewhat Safe are not significant indicating
42 that these variables do not affect the effect of stop environment variables in the model. It is
43 notable because previous research (5) shows that these variables have a strong impact on wait
44 time perception. It demonstrates that, as intended, the model explains variations in estimated wait
45 time as a function of environmental characteristics of stops.

1 Rail Station and High Frequency Bus Stop are significant, both with a positive
 2 coefficient, indicating that these kinds of stations, and especially the High frequency Bus Stops,
 3 is related to an increase of the wait time perception. Traveled Alone is also significant but with a
 4 positive coefficient. Unexpectedly, Snow Fall is also significant but with a negative coefficient
 5 reducing the wait time perceived.

7 **TABLE 2: Regression Model Results**

Observations		N=	712
		R ²	
		Adj R ²	0.265
Response Variable: ln(Estimated Wait)		β	
	ln(Observed Wait)		0.3730***
Stops and Stations Surrounding Environment	Mostly/ Very Polluted Air	-	0.3858**
	Mostly/ Very Polluted Air *ln(Observed Wait)		0.2207**
	Mostly/ Very aware of Traffic	-	0.3882**
	Mostly/ Very aware of Traffic*ln(Observed Wait)		0.2278***
	Lot of mature Trees	-	0.28611*
	Lot of mature Trees*ln(Observed Wait)		0.1477
	Snow Fall	-	0.3871***
Respondent Characteristic s	Light rail station		0.02459**
	High Frequency Bus Stop		0.1715***
	Shelter	-	0.391
Respondent Characteristic s	Female & Not/Somewhat Safe	-	0.2345
	Traveled alone		0.2430
	Knew schedules		0.2794
Constant			1.13511***

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

9 Model Predictions

10 The results are more easily understandable and interpretable with the support of model
 11 predictions graphics. The FIGURE 3 predictions of Reported Wait Times under environment
 12 variables over values of observed Wait time from zero to fifteen minutes. 95% of participating
 13 responses have an Observed Wait Time of 15 minutes or less. In each case, the named dummy
 14 variable is set equal to one, and ln(Observed Wait Time) and the dummy variable's interaction
 15 term are set equal to the natural logarithm of each x-axis value shown on the graph. Unless stated
 16 otherwise, all other dummy variables are held at their modal values.

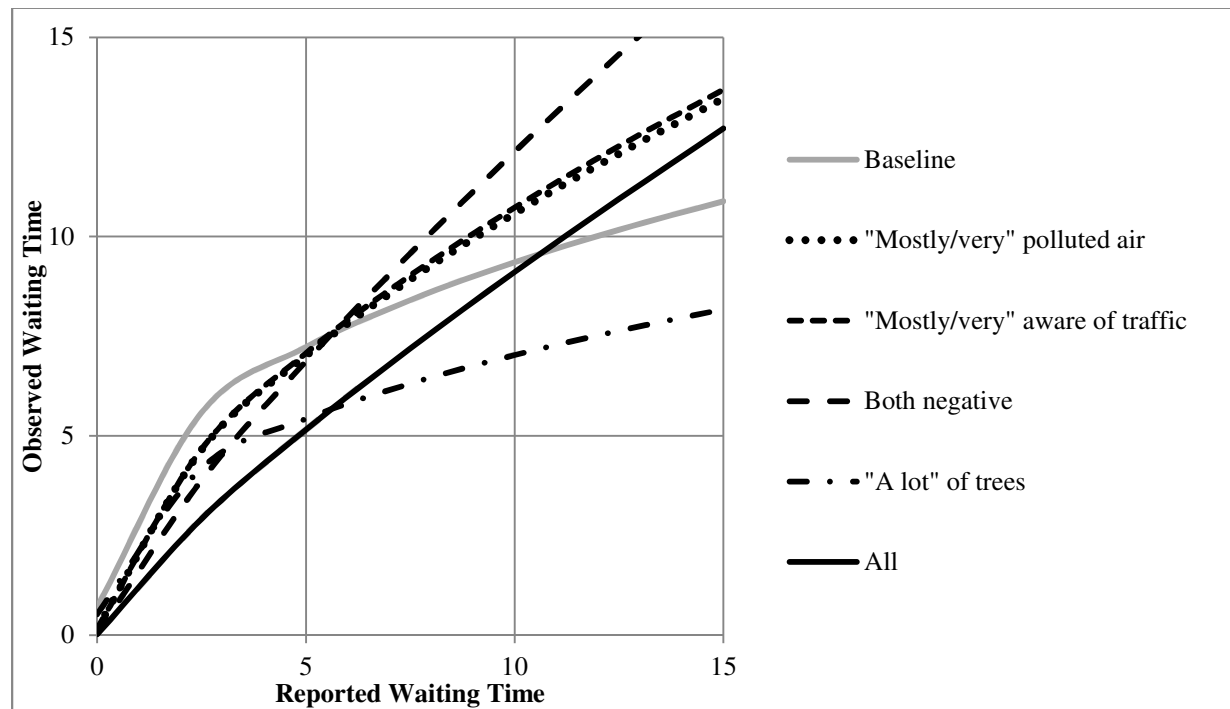
17 This FIGURE 3 shows the impact on Reported Wait Time of Air Polluted, Traffic Aware
 18 and, Lot of Trees variables, the combination of the two first variables, the combination of the
 19 three variables and a baseline scenario.

1 The baseline scenario is based on median values of explanatory variables. The baseline
 2 line indicates an overestimate of waiting time for shorter waits and more accurate estimations for
 3 longer waits. For example, a 2.5 minutes wait is perceived 5.58 minutes whereas a 10 minutes
 4 wait is perceived as 9.3 minutes.

5 Polluted Air and Traffic Awareness lead to moderate overestimation for wait time shorter
 6 than 5 minutes and to larger overestimations for wait longer than 5 minutes. For example a 2.5
 7 minutes wait is perceived as 3.88 minutes and 10 minutes wait is perceived as 12.13 minutes.

8 Lot of Tree significantly decreases the overestimation of waiting time for short wait and
 9 lead to significantly underestimate longer wait: a 2.5 minutes wait is perceived as 4.19 minutes
 10 and a 10 minutes wait as 7 minutes.

11 The combination of all three factors shows that Lot of Trees compensate the negative
 12 effects of Polluted Air and Traffic Aware on Waiting Time perception especially for wait longer
 13 than 5 minutes and conduct to almost accurate estimations of time. The High Frequency Bus
 14 stops increase the wait time perception.



16
 17 **FIGURE 4: Prediction of observed waiting times**

18 CONCLUSION

19 The results strongly support the research hypothesis that the surrounding environment of transit
 20 stops and stations affects transit user's wait time perception. They show in particular that air
 21 pollution, traffic awareness, and presence of mature trees are significantly correlated with wait
 22 time perception. The model predicts significant overestimates of the relatively short waits most
 23 riders who participated experienced. For waits longer than 5 minutes, both air pollution and
 24 traffic awareness increase the overestimation of wait time. The presence of a lot of mature trees,
 25 however, reduces the wait time perception and even leads transit users to underestimate the wait
 26 times for waits longer than 5 minutes. The combination of the three variables indicates that after
 27 5 minutes wait, the presence of trees achieves to compensate the effects of both air pollution and
 28

1 traffic awareness. During the first 5 minutes the quality of the environment appears to have less
2 impact on the respondent perception and its impact becomes progressively more important as the
3 wait time increases. The results also show that, at the high frequency bus stops, the wait time
4 appears more likely overestimated than at other kinds of stops but with shorter wait in absolute
5 terms. This appears coherent with the results above because high frequency bus stops are mostly
6 located on streets with high levels of pollution and exposure to traffic. The effect of the snow
7 cover is unexpectedly positive and shows that the weather does not affect negatively transit
8 users' time perception. Transit users may be happy about the fact they aren't driving, and
9 alternatively, transit users on such days may have a high tolerance for cold weather, due to self-
10 selection.

11 Generally, the results suggest that the more trees are present, the shorter the wait time is
12 perceived by riders while the more polluted and exposed to the traffic the more transit users tend
13 to overestimate wait time. These findings advocate for high quality urban environment
14 surrounding stops and stations.

15 The findings regarding traffic awareness and air pollution lead to the conclusion that
16 transit users will perceive shorter waits at stops located on quiet streets. In practice, of course,
17 transit routes need to be located on streets with high travel demand, which often equates to high
18 traffic volumes. This contradictory situation suggests two practical interventions to reduce
19 waiting time perceptions: first, the implementation of traffic calming measures along primary
20 transit routes, particularly at stops. Creating exclusive transit lanes or streets reserved for transit,
21 bicycles and pedestrians (where feasible) are likely to reduce waiting time perceptions the most,
22 due to low traffic volumes in terms of vehicle frequency compared with automotive traffic.
23 Second, the alignment of transit routes and the location of stops avoiding highly polluted areas
24 where possible without affecting travel demand can also contribute to shorter wait time
25 especially when headways are greater than five minutes.

26 The findings also point to the importance of cooperation between transit providers and
27 local governments to improve the transit user experience through urban greening. Planting trees
28 around stops offers local authorities an opportunity to significantly improve users' wait time
29 perception, but falls outside the purview of transit providers themselves. The ability of the
30 presence of trees to compensate for the negative effects of pollution and traffic suggests that
31 planting trees or moving a problematic stop to take advantage of existing tree cover can
32 significantly improve the user experience at reasonable costs. These costs should be compared to
33 other costs of measures able to enhance customer satisfaction such as higher frequency, transit
34 information and stops amenities. In addition, studies on the cost effectiveness of planting trees
35 should take into account their effect on travel behavior.

36 The findings call for further research to refine understanding of issues such as the specific
37 roles of traffic volumes, streetscapes and stop locations in shaping transit users' perception of
38 traffic and air pollution. In addition research on the minimum numbers and sizes of trees needed
39 to reduce perceived waiting times would also be useful. Even so, these findings suggests that
40 avoiding spots with traffic and pollution and developing stops and stations surrounded with trees
41 can significantly contribute to enhance riders' waiting experience and attractiveness of transit.

42
43

1 **REFERENCES**

- 2 1. Cervero, R. Transit Pricing Research: A Review and Synthesis. *Transportation*, Vol.17,
3 1990, pp 117-139.
- 4 2. Dziekan K. and Kottenhoff K. Dynamic at Stop Real-Time Information Displays for
5 Public Transport: Effects on Customers. *Transportation Research Part A*, 41: 2007, pp
6 489-501.
- 7 3. Droit-Volet, S. and Gil, S. The Time Emotion Paradox. *Philosophical Transactions of*
8 *the Royal Society*. Trans. R. Soc. B 364, 2009, pp 1943–1953.
9 Doi:10.1098/rstb.2009.0013.
- 10 4. Wardman, M. Public Transport Values of Time. *Transport Policy*, Vol.11, No. 4, 2004,
11 pp 363-377. doi:10.1016/j.tranpol.2004.05.001.
- 12 5. Watkins K. E., Ferris B., Borning A., Rutherford G., and Layton D. Where is my Bus?
13 Impact of Mobile Real-Time Information on the Perceived and Actual Wait Time of
14 Transit Riders. *Transportation Research Part A*, Vol.45 No 8, 2011, pp 839-848.
- 15 6. Fan, Y. and Guthrie, A. Perception of Waiting Time at Transit Stops and Stations.
16 Submitted at 94th Transportation Research Board 94th annual meeting, 2014.
- 17 7. Millonig, A. and Sleszynski, M. Sitting, Waiting, Wishing: Waiting Time Perception in
18 Public Transport, *15th International IEEE Conference on Intelligent Transportation*
19 *Systems*, 2012, pp.1852-1857.
- 20 8. Cascetta E. and Carteni A. The Hedonic Value of Railways Terminals. A Quantitative
21 Analysis of the Impact of Stations Quality on Travelers' Behavior. *Transportation*
22 *Research Part A*, Vol 61, No. 0, 2014, pp 41-52.
- 23 9. Maister, D.H. The Psychology of Waiting Lines. In Czepiel, JA Solomon, MR
24 Surprenant, CF (Eds) *The Service Encounter*. Lexington Books, Lexington MA, 1985,
25 pp 113-123.
- 26 10. Taylor, S. Waiting for the Service: The Relationship between Delays and Evaluation of
27 the Service. *Journal of marketing* 58. 1994, pp 56-59.
- 28 11. Hornik, J. Time Estimation and Orientation Mediated by Transient Mood. *Journal of*
29 *socio-economics* Vol. 21 (3), 1992, pp 209-227.
- 30 12. Baker, J. and Cameron, M. The Effects of the Service Environment on Affect and
31 Consumer Perception of Waiting Time: an Integrative Review of Research Propositions.
32 *Journal of the Academy of Marketing Science* Vol. 24, N4, 1996, pp 338-349.
- 33 13. Pruyn, A. and Smidts, A. Effects of Waiting on the Satisfaction with the Service:
34 Beyond Objective Time Measures. *The International Journal of Research in Marketing*
35 15. 1998, pp 321–334.
- 36 14. Nie, W. Waiting: Integrating Social and Psychological Perspectives in Operations
37 Management. *Omega, the International Journal of Marketing Science*. Vol.28, 2000, pp
38 611-629.
- 39 15. Parsons Brinkerhoff Quade and Douglas, Inc. *Calibration of the Mode Choice Models*
40 *for the Minneapolis, St. Paul Region*. Saint Paul: Prepared for the Metropolitan Council.
41 1993.
- 42 16. Iseki, H and Taylor, T. Not All Transfers Are Created Equal: Towards a Framework
43 Relating Transfer Connectivity to Travel Behaviour. *Transport Reviews*, Vol. 29, No. 6,
44 2009, pp 777–800, November 2009.
- 45 17. Horowitz, A. A Subjective Value of Time in Bus transit Travel. *Transportation*, Vol.10,
46 1981, pp149-174.

- 1 18. Parsons Brinckerhoff. Intermodal Facilities, *PB Network*, May 2002, p. 60.
- 2 19. Wardman, M. A Review of British Evidence on Time and Service Quality Valuations,
3 *Transportation Research Part E: Logistics and Transportation Review*, 37E(2–3), 2001,
4 pp.107–128.
- 5 20. Evans, J. E. Transit Scheduling and Frequency, *TCRP Report 95: Traveler Response to*
6 *Transportation System Changes*, 2004, p 41.
- 7 21. Dziekan, K. The transit experience of newcomers to a city—learning phases, system
8 difficulties and information search strategies. Paper presented at the 87th *Transportation*
9 *Research Board Annual Meeting*, Washington, DC, January 2008.
- 10 22. Rahman M, Wirasinghe S.C, Kattan Lina. Users' view on current and future real-time
11 bus information systems. *Journal of advanced transportation*. 47, 2013, pp 336-354.
- 12 23. Tang, L. and Thakuriah, P. Ridership Effects of Real-Time Bus Information System: A
13 Case Study in the City of Chicago; *Transportation Research Part C: Emerging*
14 *Technologies* Volume 22, June 2012, Pages 146–161
- 15 24. Loukaitou-Sideris, A. Hot Spots of Bus Stop Crime: the Importance of Environmental
16 Attributes. *Journal of the American Planning Association*, Vol. 65(4), 1999, pp. 395–
17 411.
- 18 25. Iseki, H & Taylor, T. Style versus Service? An Analysis of User Perceptions of Transit
19 Stops and Stations *Journal of Public Transportation*, Vol. 13, No. 3, 2010, pp23-48.
- 20 26. Bell, P.A., Greene, T., Fisher, J., and Baum, A. Environmental Psychology. *Psychology*
21 *Press*. 2005.
- 22 27. Fan Y, Das K, Chen Q. Neighborhood Green, Social Support, Physical Activity, and
23 Stress: Assessing the Cumulative Impact. *Health and Place* 17, 2011, pp 1202–1211.
- 24 28. McPherson, E. G Simpson J. R, Xiaob, Q., and Wub, C. Million Trees Los Angeles
25 Canopy Cover and Benefit Assessment. *Landscape and Urban Planning Volume 99,*
26 *Issue 1*, 2011, pp 40–50.
- 27 29. McPherson, E. G. Scott, K.I. and Simpson J. R. Estimating Cost Effectiveness of
28 Residential Yard Trees for Improving Air Quality in Sacramento, California Using
29 Existing Models. *Atmospheric Environment*. Vol. 32, No. I, pp. 75 84, 1998.
- 30 30. Ewing, R. and Cervero, R. Travel and the Built Environment: a Synthesis.
31 *Transportation Research Record* 1780, 2001, pp 87–113.
- 32 31. Estupiñán, N. and Rodriguez, D.A. The Relationship between Urban Form and
33 Boardings for BRT Stations in Bogotá. *Transportation Research Part A* Vol 42. 2008. pp
34 296–306.
- 35 32. Cervero, R., & Knockelman, K. (1997). Travel Demand and the 3Ds: Density, Diversity,
36 and Design. *Transportation Research Part D: Transport and Environment*, 2, 199-219.
- 37 33. Cervero, R. and Duncan, M. Walking, Bicycling, and Urban Landscapes: Evidences
38 from San Francisco Bay Area. *American Journal of Public Health* 93 (9), 2003, pp1478–
39 1483.
- 40 34. Cao, X., Mokhtarian, P.L., and Handy, S.L. Do Changes in Neighborhood
41 Characteristics Lead to Changes in Travel Behavior? A Structural Equations Modelling
42 Approach. *Transportation* Vol. 34 (5), 2007, pp 535–556.