Travel Mode Choice Since the 2007 Beijing Public Transit Fare Reform:
A Study of the Effect of Crowding and Thermal Comfort[1]

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Diwen Shen
Department of Economics
University of California, Berkeley
stevendshen@berkeley.edu; stevendshen@gmail.com

Advisor:
Professor Daniel G. Chatman
Associate Professor, Department of City and Regional Planning
University of California, Berkeley
dgc@berkeley.edu

ABSTRACT

The 2007 Beijing Public Transit Fare Reform likely resulted in high crowding and poor air-conditioning provision on transit in Beijing. This paper explores how crowding and thermal comfort affect commuters' travel mode choice using both revealed preference and stated preference approaches. Through an intercept survey, I collected travel data and both perceived and preferred crowding and temperature levels for transit. Overall, high levels of dissatisfaction regarding crowding and thermal comfort were found for transit riders. The revealed preference found statistically significant effects of crowding on mode choice for car-owners, while other coefficient estimates were either non-significant or counterintuitive. On the other hand, the stated preference approach found statistically significant effects on mode choice for different crowding and temperature scenarios, many of which even exceed the effect of doubling fare prices. Overall, crowding and thermal comfort are highly subjective and their effects are context specific. The challenge is how limited transit agency budgets are allocated most effeciently to satisfy needs for both "hard" and "soft" service quality attributes of current and potential riders.

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PART 1: Introduction

1.1 Background

Beijing, China is a rapidly developing mega-city home to 21.1 million residents, whose income level is equivalent to a middle-income country according to World Bank Standards. Prior to 2007, Beijing's public transit sector consisted of two major bus operators. The larger operator Beijing Public Transport Holdings, Ltd (BPT) was owned and subsidized by the government. It operated non-air-conditioned buses eligible for the "Month Pass", a bus pass that granted unlimited rides for ¥ 40 per month. The smaller operator Beijing Bashi Co., Ltd ("Bashi"), on the other hand, operated under market forces and did not receive direct government financial support. Bashi specialized in air-conditioned bus routes that charged a base price of ¥1.6 per trip, much higher than traveling with a "Month Pass" for daily commuters. Bashi was part of an experimental policy in Beijing to bring competition into the traditionally government-monopolized transit sector, with a mission to exploit "efficiency benefits of the market economy, maximize the interests and profits of its shareholders, and become a modern transit operator" (Beijing Bashi Co., Ltd 2001-2007). As of 2006, Bashi operated 199 of the 800 bus routes (25%) in Beijing. In terms of market share, however, Bashi transported less than 20% of all bus passengers with much lower loads than BPT's routes.

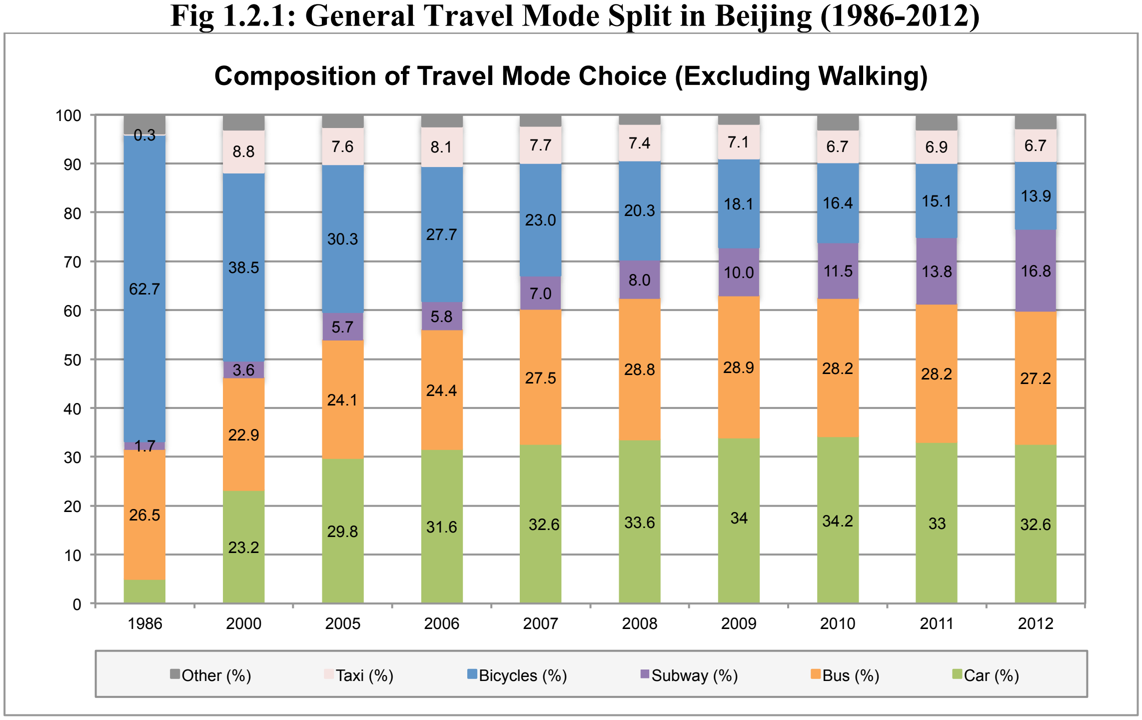
Bashi was initially profitable but ran into losses in 2003 amid SARS and high fuel costs. In 2007, facing worsening traffic congestion, Beijing enacted the "Beijing Public Transit Fare Reform" and merged BPT with Bashi, eliminating competition among bus operators but also extending subsidies to Bashi. The "Monthly Pass" was replaced by flat fares of ¥0.4 per ride (US 6.5¢) for almost all city-area bus routes operated by BPT and Bashi. Especially, fares for Bashi's air-conditioned buses were cut by up to 80%. Subway fares were also cut from ¥2-3, with additional charges each transfer, to a flat fare of ¥2. These fares were mandated by the government who then covered deficits. Detailed pricing schemes are presented in Figure 1.2.1.

Fig 1.1.1: History of Bus, Subway & Taxi Fares in Beijing (2006-2015)

Time Period	Prior to 2006		Since 1/1/2007		Since 1/1/2015
Policy Measure	-		"Public Transit Fare Reform"		"Public Transit Fare Adjustment"
Air-Conditioning	No AC	AC	No AC	AC	AC
Bus	¥0.4-1.0 /ride (¥40/mo.)	¥1.6 /first 12km +¥0.4/km	¥0.4 /first 12 km +¥0.25/km		¥1.0 /first 10km +¥0.5/5km
Subway	¥2.0-3.0 /ride +¥1.0-2.0/transfer		¥2.0 /ride		¥3.0 /first 6km +¥1.0/next 6km then +¥1.0/next 10-20km
Taxi	¥10 /first 3km +¥1.2/km	¥10 /first 3km +¥1.6/km	-	¥10 /first 3km +¥2/km	¥13 /first 3km +¥2.3/km
Average Cost Per 8km Trip	Bus: ¥1 Subway: ¥3-5 Taxi: ¥16	Bus: ¥1.6 Subway: ¥3-5 Taxi: ¥18	Bus: ¥0.4 Subway: ¥2 Taxi: ¥20		Bus: ¥1 Subway: ¥4 Taxi: ¥24.5

Note: By 2015, all subways, taxis, as well as most buses in Beijing are equipped with air-conditioning. There was a transitional period in 2006-2007 where some other variations of price schemes were implemented but not included in this table.

Fig 1.2.1: General Travel Mode Split in Beijing (1986-2012)



Source: BTRC 2006-2013.

Fig 1.2.2: Maximum Hourly Passenger Load by Subway Line (2012)

Subway Line	1	2	4	5	8	9	10	13	15	CP	FS	YZ	BT
Max Hourly Passenger Load /Design Capacity	136%	86%	132%	138%	135%	8%	123%	135%	82%	150%	16%	86%	142%

Source: BTRC 2006-2013.

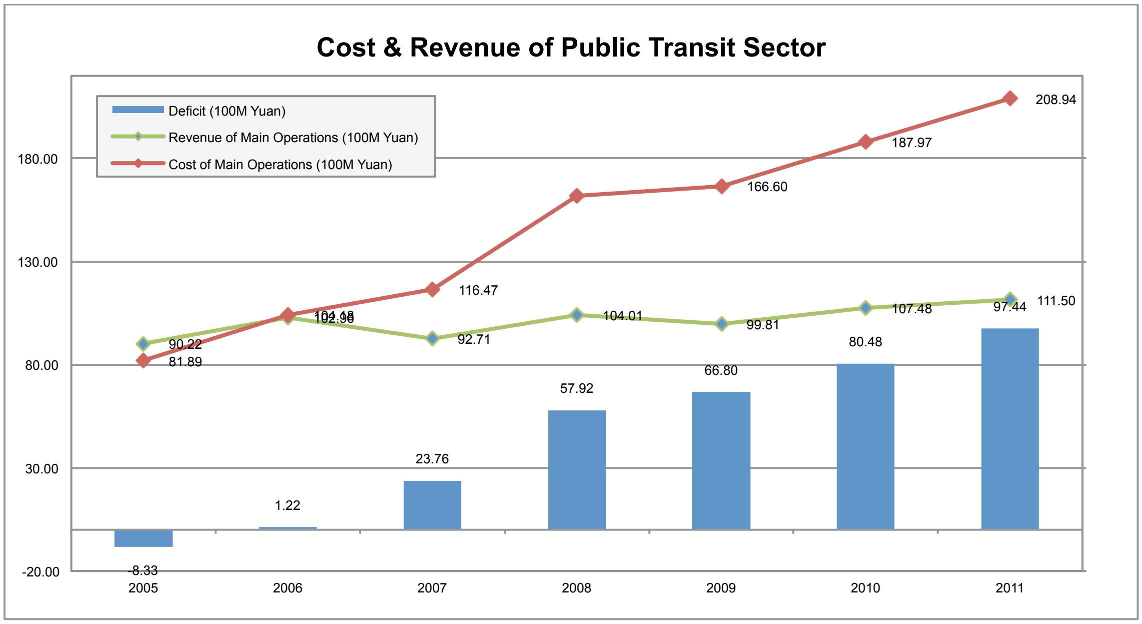
1.2 The 2007 Beijing Public Transit Fare Reform

The 2007 reform led to higher transit ridership especially for Bashi's air-conditioned bus routes and the subway. Shown in Figure 1.2.1, from 2006 to 2012, the mode share for general travel purposes rose from 24.4% to 27.2% for bus, and from 5.8% to 16.8% for subway as new lines opened; private car use increased only slightly from 31.6% to 32.6% (BTRC 2006-2013). On the other hand, bicycle use dropped significantly during this period from 27.7% to 13.9%, contributing to most transit ridership gains and contradicting the initial goal of reducing auto use. Whether the 2007 reform was successful in alleviating traffic congestion remains debatable.

Problems of high crowding levels and insufficient air-conditioning onboard transit were prominent following the reform. In 2012, peak hour subway passenger loads for 8 out of Beijing's 13 subway lines surpassed design capacity, with the Changping Line having a load factor of up to 150%, as shown in Figure 1.2.2 (BTRC 2006-2013). Crowding and high onboard temperatures during the summer have been a consistent problems for BPT's bus routes in Beijing even before the reform. For Bashi's routes, however, crowding and poor "thermal comfort" were new problems.

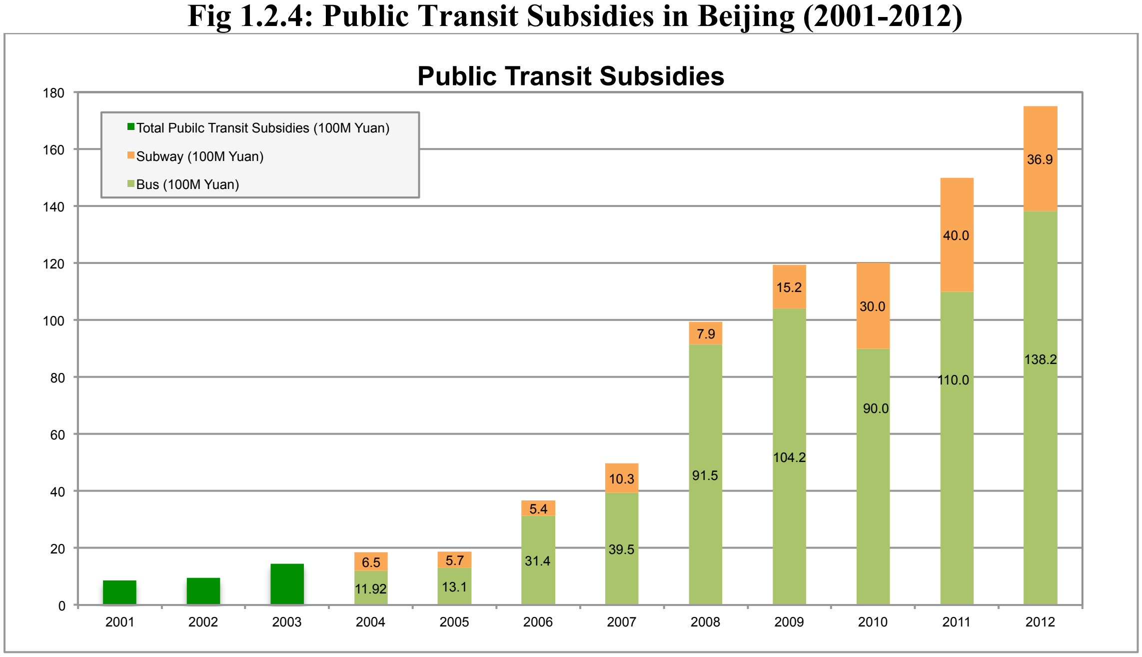
The 2007 fare cut greatly increased deficits for Beijing's transit sector, with an annual deficit of ¥9,744 Million where revenues only covered about 53.4% of operating costs in 2011, as shown in Figure 1.2.3 (BMSB 2000-2013). Most government subsidies were allocated to cover the deficit of bus operations, as shown in Figure 1.2.4. These high bus operating costs were mainly associated with significantly higher fuel prices, which rose 49.9% from 2006 to 2012 (BMSB 2000-2013), and would not be surprising if they led to aggressive budget cutting measures such as reducing the provision of air-conditioning. The larger context at that time, though, was that China aggressively implemented nationwide "energy conservation and emissions reduction" measures. In June, 2007, China announced the "Notice Regarding Strict Enforcement of Air-conditioning Temperature Setting Standard in Public Buildings" (General Office of the State Council 2007), which mandated that all public building spaces must not "set" indoor air-conditioning temperatures below 26 °C (78.8 °F) in the summer, regardless of "actual" indoor temperatures and the activity, clothing level, and density of people within those spaces. Buses and subways mainly followed this mandate and stirred complaints, with China's official Xinhua News Agency citing an article titled "Air-conditioned Buses Do Not Operate Air-conditioning, Beijing Low Bus Fares Mean Bearing High Temperatures?" just eight days after the mandate was issued (Zhang et al. 2007).

Fig 1.2.3: Costs & Revenues of the Public Transit Sector in Beijing (2001-2011)



Source: BTRC 2006-2013.

Fig 1.2.4: Public Transit Subsidies in Beijing (2001-2012)



Source: BTRC 2006-2013.

1.3 Main Research Questions

Beijing's 2007 reform created an interesting context where differentiated transit service was eliminated – fares were cut across the board but some "soft" service quality attributes such as crowding and thermal comfort also worsened. The variation in prices, crowding and onboard temperatures during this period provide an opportunity to study how they affect mode choice.

The main questions I would like to ask are: First, what are the observed and preferred levels of crowding and temperatures onboard transit in Beijing and how do they vary between different demographic and socioeconomic groups? Second, how do crowding and thermal comfort affect commuters' travel mode choice and how large is this effect in price-equivalent terms? Third, what are the implications of these results on public transit operations, differentiated service provision, financing, and monopolization versus privatization?

PART 2: Literature Review

The review of literature will focus mainly on (1) results from the 4th Beijing Comprehensive Transportation Survey (2010), (2) how "soft" service quality factors affect mode choice, (3) quantifying the effect of crowding, (4) quantifying the effect of thermal comfort, while also reviewing different methodologies. Most studies deploy stated preference approaches and analyze choices using multinomial logit (MNL) and/or mixed logit (ML) models.

2.1 The 4th Beijing Comprehensive Transportation Survey (2010)

In 2010, The Beijing Municipal Commission of Transport conducted the city's 4th Comprehensive Transportation Survey, covering travel behavior, locations, public transit, traffic flows, travel willingness, and other base data. According to the report of the survey (2012), a stated preference approach was conducted to estimate the elasticity of demand with respect to travel time and cost for 5 travel modes: bike, bus, car, subway and taxi. The report uses mixed logit models controlling for socioeconomic factors. The sample size is 4500 (0.02%) Beijing residents, and each respondent completed up to 8 games.

As shown in Figure 2.1.1, the elasticities of demand with respect to travel cost is very low for bus and subway, ranging from around -0.17 to -0.06. These results suggest that given already low bus and subway fares, changes in fare prices are not likely to induce large shifts in ridership. Car and taxi have relatively higher elasticities of -0.36 and -0.93 respectively. While taxi ridership is the most sensitive to price, its mode share was only 6.7% as of 2012.

Fig. 2.1.1: Cross-Elasticities of Demand for Each Travel Mode w.r.t Travel Cost

	Bike	Bus	Car	Subway	Taxi
Bus	0.038	-0.17	0.03	0.04	0.05
Car	0.016	0.09	-0.36	0.11	0.14
Subway	0.075	0.04	0.04	-0.06	0.07
Taxi	0.020	0.05	0.04	0.06	-0.93

Note: Coefficients associated with bike are for general travel purposes. Other coefficients are for the commute between home and work. Values for commute are generally larger in magnitude than for general-purpose travel.

Figure 2.1.2 presents elasticities of demand with respect to travel time. Bus and taxi have the highest elasticity in magnitude, ranging between -1.83 and -1.81, suggesting large impacts on ridership as travel time increases. Given an increase in travel time, bus ridership tends to shift towards bike (0.63) and taxi riders ten to shift to car (0.86). Subway demand is also quite elastic with a value of -0.86, and given an increase in travel time, subway riders tend to shift to bike (1.02) and taxi (1.06). The least elastic to travel time is car demand with a value of -0.65.

Fig. 2.1.2: Cross-Elasticities of Demand for Each Travel Mode w.r.t Travel Time

	Bike	Bus	Car	Subway	Taxi
Bike	-1.76	0.26	0.24	0.66	0.68
Bus	0.63	-1.83	0.37	0.44	0.57
Car	0.11	0.17	-0.65	0.20	0.28
Subway	1.02	0.64	0.61	-0.86	1.06
Taxi	0.02	0.09	0.86	0.11	-1.81

Note: coefficients associated with bike are for general travel purposes. Other confidents are for the commute between home and work. Values for commute are generally larger in magnitude than for general-purpose travel.

Overall, the elasticities with respect to travel time are all larger than elasticities with respect to travel cost. Since transit fare prices are already low, new policies on transit fare pricing are not likely to affect demand significantly. On the other hand, transit demand remains highly elastic to travel time. Pertaining to the topic of this paper, important questions to ask are whether crowding and thermal comfort affect perceived travel times, which in turn may affect mode choice.

2.2 "Soft" Service Quality Factors

Transit ridership is determined by "hard" service quality factors such as travel cost, time, and reliability. On the other hand, pleasant riding conditions are needed to make public transit less stressful and reduce perceived costs and travel times, although its effect varies between "sticky" and "discretionary" travelers (Litman 2007, 2008). Some of these "soft" service quality factors are information, safety, customer service, and cleanliness and can be as important in attracting more riders as the "hard" factors (Cervero 1990; Syed et al. 2000; Taylor et al. 2003). Kittelson & Assoc, Inc. et al. (2013) suggest that personal comfort factors also include seat and ride comfort (seat size, padding, leg room, acceleration, braking, vehicle sway, odors, and noise) and appropriate climate control for local conditions (heating, air conditioning).

On the other hand, studies such as Redman et al. (2013) show that transit comfort improvements can be praised highly by passengers but not necessarily lead to higher ridership. More important for transit is to provide basic levels of access, reliability and competitive costs that are already offered by the auto, and only after these are achieved should other “context-specific, perceived” service quality attributes be emphasized. Many studies on travel mode choice do not account for crowding and thermal comfort likely because they are not “context specific”, which, as I have previously shown, might not be the case in Beijing. The following sections will specifically look at various studies that document the effects of crowding and thermal comfort, with a final summary pertaining to the context of Beijing.

2.3 Crowding

The effect of crowding has been well documented. Tirachini et al. (2013) provided a comprehensive review of existing evidence around crowding on transit, and shows crowding leads to longer boarding times, longer waiting times, bunching, and increased unreliability (randomness of bus arrivals). Basu et al. (2012) used a stated preference approach to study the influence of headway time and train ride time associated with a particular crowding level (expressed in density of standing passengers/m^2) in Mumbai, and found that the equivalent perceived length of train ride increases as crowding increases.

The disutility from crowding also includes stress and anxiety, although subjective opinions vary largely between individuals (Litman 2007; 2008). Cantwell et al. (2009) studied factors leading to high levels of commuting stress in Dublin using a stated preference approach. It found commuting stress correlated significantly with features of the respondent’s commute, and reductions in crowding for bus and rail were more beneficial than improvements in reliability. However, there was not much agreement with verbal statements pertaining to commuting stress. The benefits from crowding reduction also very between bus and rail, with rail users deriving greater benefits. Tirachini et al. (2013) showed crowding also can result in increased anxiety, stress, exhaustion, symptoms such as headaches and sleeplessness, privacy invasion, loss of productivity when riding, and that crowding increases passengers' willingness to pay for reduced travel times. Crowding also affects air quality. Li et al. (2006), among other scholars, showed that subway trains in Beijing saw significantly higher concentrations of carbon dioxide, TVOC, TSP and PM10 during rush hours compared to during regular hours.

There is also a plentitude of discussion on methods to quantify crowding, mostly using stated preference surveys. Tirachini et al. (2013) tested two approaches: "the proportion of users sitting" (which affects the probability of getting a seat), and "the number of users standing". It suggested seat availability plays a significant role and that the density of standees cannot properly account for the disutility of crowding. Li et al. (2013) suggested that for short journeys, standing allowance should be treated as an additional component of capacity when defining crowding measures, while for long journeys, only the number of seat should be used to measure capacity.

Evans et al. (2007) used a revealed preference method to study train passenger stress using self-reported data, salivary cortisol samples, and performance aftereffect exams. They also found that passenger density was mostly inconsequential but the immediate seating density proximate to the passenger significantly affected stress. These studies suggest that the effect of crowding when seated differs from when standing, although seating status is less consequential given consistently high crowding levels on transit in Beijing. Overall, the objective measurement of crowding cannot fully represent passenger experiences given that the perception of crowding is subjective and context dependent.

2.4 Thermal Comfort

The International Organization for Standardization (ISO)'s ISO 7730 is a standard for ergonomics of the thermal environment. It provides optimal indoor temperatures using calculations of PMV (predicted mean vote), PPD (predicted percentage of dissatisfied) and local thermal comfort. Optimal temperatures are affected by outdoor temperatures, thermal radiation, humidity, air speed, and personal factors such as activity and clothing. Working with the East Japan Railway Company, Nakano, J., et al. (2006) conducted a field survey to investigate the thermal satisfaction of passengers at select train stations through surveys using a stated preference approach as well as collecting clothing and time-stamped thermal measurements at the station. They suggested a "comfort range" of 11-27 °C for transit users in the station concourse and platform in an operative environment, though passenger density and occupancy times at stations were smaller compared to onboard levels.

de Dear, R.J. et al. (1998) also showed that acceptable indoor temperatures also very between air-conditioned spaces and naturally ventilated spaces due to the adaptability of individuals' body, expectations and behavior (activity and clothing levels). For summer indoors with light activity levels, the mean suggested temperature is around 23.5 °C for air-conditioned spaces and 25.5 °C for non-air-conditioned spaces. Exact values depend on outdoor temperatures. This might imply that passengers might be more demanding on onboard temperatures if transit vehicles were designed to be air-conditioned, and that vehicles operating with air-conditioning but not at sufficient levels might be more unpleasant to riders than naturally ventilated vehicles with no air-conditioning to begin with.

In many cases, the effect of thermal comfort improvements seem to be less pronounced than crowding and other service improvements. Litman (2007; 2008) cited Douglas Economics (2006)'s research for RailCorp, an Australian rail company, which found that passengers' willingness to pay for a 10% improvement (from 50% to 60% acceptability ratings) in "heating and air-conditioning" to be 2.2¢/min in 2003 Australian Dollars, lower than other improvements in layout and design, cleanliness, ease of boarding, quietness, train outside appearance, and announcements. Crowding has a more significant effect. Compared to an uncrowned seat, the extra cost of having a "crowded seat" is 2¢/min, "standing 10 min or less" is 5¢/min, "standing 20 min or longer" is 11¢/min, "crush standing 20 min or longer" is 17¢/min, compared to the baseline value of travel 15.8¢/min during peak hours. Currie et al. (2008) also found that the most important "soft" bus improvements are air conditioning, security and a smoother ride but each unlikely to have a patronage effect above 2%. Paulley et al. (2006) found improvements in train ride quality, ventilation, ambience, and seating comfort through refurbishments from old stock to new air-conditioned stock is worth merely around 1.5% of the fare. Hensher et al. (2002; 2003) found, through a stated preference survey in Sydney and Melbourne, approximately 29%

of passengers reported onboard temperatures to be too hot but overall passengers would prefer no air conditioning if a higher fare is required. Their sample, however, had a very high proportion of riders who “had a seat all the way” and differs from the context of Beijing, which likely has much higher baseline levels of crowding and temperatures than in western cities.

Finally, thermal comfort, like other service quality attributes, are very subjective and vary largely. Eboli et al. (2011) compared passengers’ self-reported crowding and temperatures onboard with actual measurements of passenger densities and air-conditioning functionality status. They found high variability of the judgments on ‘air conditioning’, motivated by “personal tastes” rather than the functioning of the air-conditioning system.

2.5 Summary & Discussion

In summary, crowding appears to increase the perceived cost of a transit ride by a significant amount. These estimated effects depend on how “crowding” is defined and measured. On the other hand, the effect of thermal comfort is usually less pronounced but is difficult to quantify and highly subjective. Most of these results assume initial conditions of “normal levels” of crowding and temperatures to begin with, which is likely not the case in post-2007 Beijing due to high demand and budgetary constraints due to low fares, as well as radical and inflexible energy conservation measures. Almost none of these studies measure the effect of crowding and thermal comfort in such contexts, and none of them study the interaction between crowding and thermal comfort as well as how they affect ridership for alternative travel modes. The purpose of this paper is to fill this gap using survey data collected in Beijing.

PART 3: Methodology, Data Collection & Data Summary

3.1 Methodology

An intercept survey was conducted in Beijing in the summer of 2014 that targeted adult regular Beijing residents. The questionnaire is included in the appendix. The following data categories were collected in the order of appearance in the questionnaire: (1) Travel characteristics for their commute in both 2014 and 2006, (2) self-reported preferred and perceived thermal comfort and crowding information on their transit options, (3) demographics and socioeconomic data, and (4) a set of stated preference games that included 4 travel mode options, with varying levels of air-conditioning and crowding levels for bus and subway.

Using this data, I will produce a comprehensive data summary regarding travel behavior and self-reported information on thermal comfort and crowding in section 3.3. In section 4 and section 5, I will model travel mode choice using revealed preference (RP) and stated preference (SP) respectively using multinomial logit (MNL) models. The implications and limitations of these results will be discussed in each section as well as in the final summary.

3.2 Data Collection

In July, 2014, I hired 10 college students from local Renmin University and other institutions to conduct the intercept survey[2]. Survey locations were major commercial districts in Beijing, including Zhongguancun, Xidan, Shijingshan, Wangjing, and Guomao (CBD), as shown in Figure 3.2.1. The intercept survey took place between 7/15 and 8/3 after a brief pre-test and format revision. Survey workers were instructed to randomly approach adults without bias against gender or age and obtain consent. About 1 in every 2 to 3 potential respondents were approached, and among them, around 1 in every 2 to 3 individuals agreed to complete the questionnaire. Survey workers then orally asked questions and recorded responses on paper.

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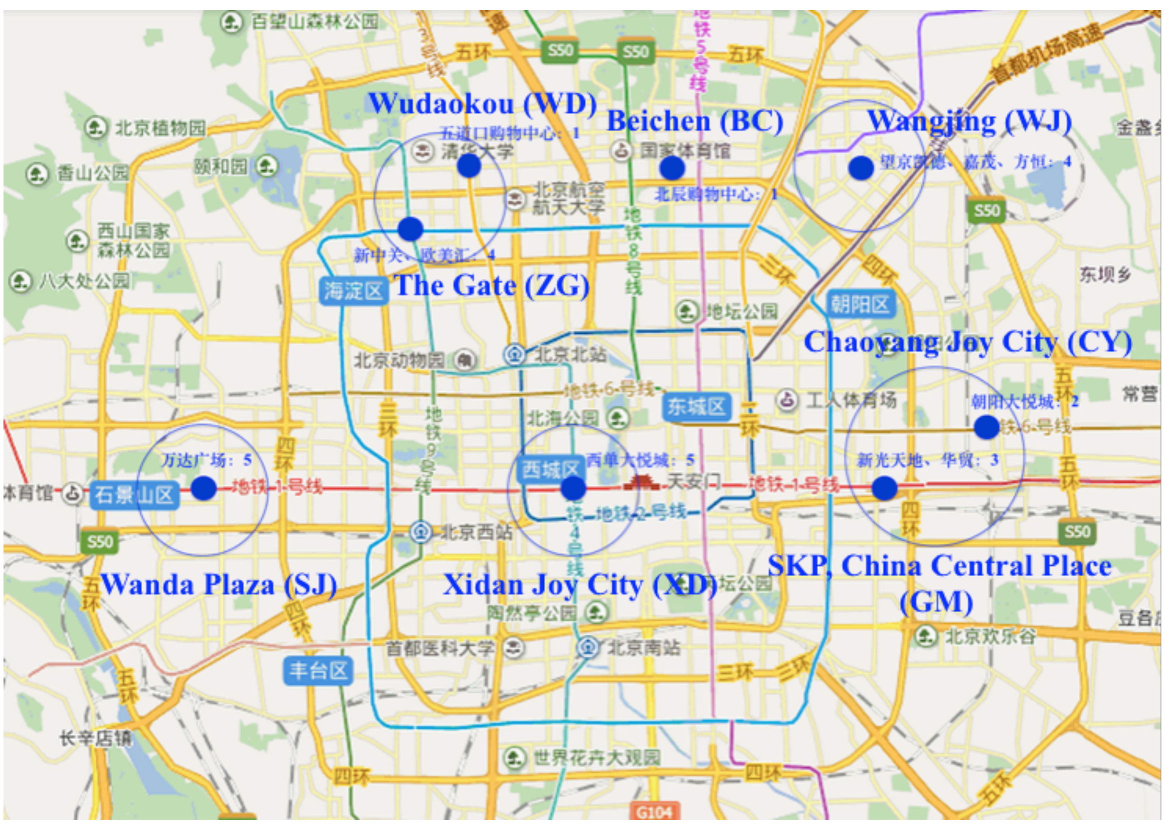
[2] This research was deemed exempt from full committee and subcommittee review by the UC Berkeley Committee for Protection of Human Subjects (CPHS) (Protocol Number: 2014-03-6182).

Some respondents preferred to complete the questionnaire themselves and were allowed to do so; under tight deadlines for survey workers, the respondent recruitment process was not perfectly random and might have contained biases towards women, college students, etc.

Each survey worker completed around 5-20 questionnaire daily over a time period of around 3-5 hours. Each survey worker completed about 30-150 questionnaires total, obtaining a total sample size of 813. This figure includes a very small number of online surveys, which were emailed to potential respondents in .doc/.docx form. Survey workers were compensated ¥ 5 for each of the first 100 questionnaire completed. After 100 questionnaire, the compensation increased to ¥ 6 each. Survey workers were also given "red bags" containing perks of ¥ 5 in cash to offer respondents after obtaining consent. However, most respondents refused to be compensated and survey workers were then allowed to keep the limited amount of "reg bags" prepared. See Figure A4 in the Appendix for survey logistics.

Fig. 3.2.1: Survey Sites, Map of the Beijing City Area



Source: Baidu Maps

3.3 Data Summary

Figure 3.3.1 and Figure 3.3.2 summarize sample data and provide comparisons with citywide averages according to government census and transportation survey data.

Demographic and socioeconomic wise, 72.5% of the sample consists of full-time employed Beijing residents, higher than the citywide level of 53.3%. In addition, the sample consists of 22.7% full-time students, which is also higher than the citywide level of 17.2%. As a partial result of the way the intercept survey was conducted, the sample in my survey consists of more females, is younger, more educated, and has a higher average household income than the citywide average. Among respondents, 44.1% and 26.7% use subway and bus respectively as their primary travel mode for commuting, which are higher than the citywide average of 14.8% and 22.8%. The respondents' commute distances were higher than the citywide average while travel times were very close to average levels. This indicates that the respondents have much better access to public transit (especially subways) compared to the entire Beijing population. The difference between the sample and the actual population of Beijing are not exceedingly different, and it is worth noting that official census data covers rural areas that are not of interest to this paper. In the further discussions, though, I will take note of the possible systematic difference between the sample and the population.

My sample saw a significant increase in car ownership between 2006 and 2014, shown in Figure 3.3.2. Most notably, around 40% of all respondents purchased their household's first car between 2006 and 2014, reducing the non-car owning rate from 83.3% to 41.7%. Many households have also added a second or third car. Interestingly, the proportion of respondents who use the auto as their primary travel mode only increased slightly from 11.5 to 12.6%. In comparison, over this period, subway ridership saw significant growth from 31.6% to 44.1%, and bus ridership saw a slight decrease. I also measured respondents' attitudes towards transit by asking "rate your satisfaction on your current public transit options" on a 5 point scale. Approximately 34.8% reported general satisfaction while 23.6% reported general dissatisfaction. In terms of attitude changes between 2006 and 2014, 37.4% reported satisfaction improvements, while 31.4% reported satisfaction degradation between 2006 and 2014. This is shown in Figure 3.3.3.

Fig. 3.3.1 Data Summary Table

	2014			2006			2014 Less 2006		City-Wide Averages[1]		
	Mean	St. Dev.	N	Mean	St. Dev.	N	Diff	p	Mean	Diff	p
Occupation											
Full-Time Employed	0.725	0.446	797	0.458	0.499	788	0.267***	0.000	0.533[2]	0.192***	0.000
Full-Time Student	0.227	0.419	797	0.236	0.425	788	-0.009	0.673	0.172	0.055***	0.000
Other	0.048	0.213	797	0.306	0.461	788	-0.258***	0.000	-	-	-
Characteristics for PM Commute											
Workdays Per Month	21.521	5.574	784	21.396	5.574	785	0.126	0.656	-	-	-
Workplace Ringroad	3.374	1.123	690	3.355	1.182	734	0.019	0.758	-	-	-
Start Time (Hr of Day)	17.568	1.901	734	17.517	1.821	747	0.051	0.595	17.000[3] (mode)	0.568***	0.000
Travel Distance (Km)	14.515	11.940	750	13.298	12.533	749	1.216*	0.055	10.600	3.915***	0.000
Primary Travel Mode											
Car	0.126	0.332	803	0.116	0.320	807	0.010	0.516	0.229	-0.103***	0.000
Taxi	0.021	0.144	803	0.025	0.156	807	-0.004	0.629	0.033	-0.012**	0.020
Bike	0.065	0.246	803	0.072	0.258	807	-0.007	0.572	0.139	-0.074***	0.000
Subway	0.441	0.497	803	0.317	0.465	807	0.124***	0.000	0.148	0.293***	0.000
Bus	0.267	0.442	803	0.342	0.474	807	-0.075***	0.001	0.228	0.039**	0.014
Walk	0.067	0.251	803	0.122	0.327	807	-0.054***	0.000	0.194	-0.127***	0.000
Other	0.014	0.116	803	0.010	0.099	807	0.004	0.482	0.029	-0.015***	0.000
Travel Time (Min)	45.482	29.784	788	43.694	33.241	795	1.788	0.260	47.000	-1.518	0.153
Monthly Cost (¥)	221.394	508.842	747	184.283	488.269	770	30.219	0.231	227.167[4]	-5.773	0.484
Self-Reported Data Onboard Transit											
Transit Satisfaction (1-5)	3.060	0.982	807	-	-	-	-	-	-	-	-
Δ From 2006	3.184	1.099	695	-	-	-	-	-	-	-	-
Crowding (ppl/m^2)	8.008	4.238	742	-	-	-	-	-	-	-	-
Temperature (°C) (1-5)	3.427	1.005	762	-	-	-	-	-	-	-	-
Preferred Temp. (°C)	25.092	2.014	802	-	-	-	-	-	-	-	-
Demographics											
Gender (1=Female)	0.545	0.498	809	-	-	-	-	-	0.484	0.061***	0.001
Age	29.517	10.171	802	-	-	-	-	-	37.700	-67.217***	0.000
Education (Yrs)	14.358	2.584	783	-	-	-	-	-	11.500	-25.858***	0.000
Household Income (¥10K)	15.142	9.162	721	-	-	-	-	-	11.098[5]	-26.240***	0.000
Δ From 2006	2.491	1.145	766	-	-	-	-	-			
Household Pop.	3.172	1.097	797	-	-	-	-	-	2.700	-5.872***	0.000
Households w/ Cars	0.583	0.493	811	0.167	0.373	761	0.416***	0.000	0.420	-1.003***	0.000
# Cars in Household	0.760	0.812	811	0.192	0.459	761	0.568***	0.000	0.197	-0.957***	0.000

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

[1]Unless otherwise noted, city-wide averages are drawn from the 2013 Beijing Statistical Yearbook (for 2012 data) for occupation and demographic data, and from the 2010 Beijing 5th Transport Comprehensive Survey for commuter (full-time employees and students) travel mode data. More recent data is not available at this time.

[2]Number of persons that are employed.

[3]This is the peak time for commuters to leave work, not the average.

[4]Monthly Cost is given by the 2013 Beijing Statistical Yearbook, and includes all transport costs.

[5]Average household gross income.

Fig 3.3.2

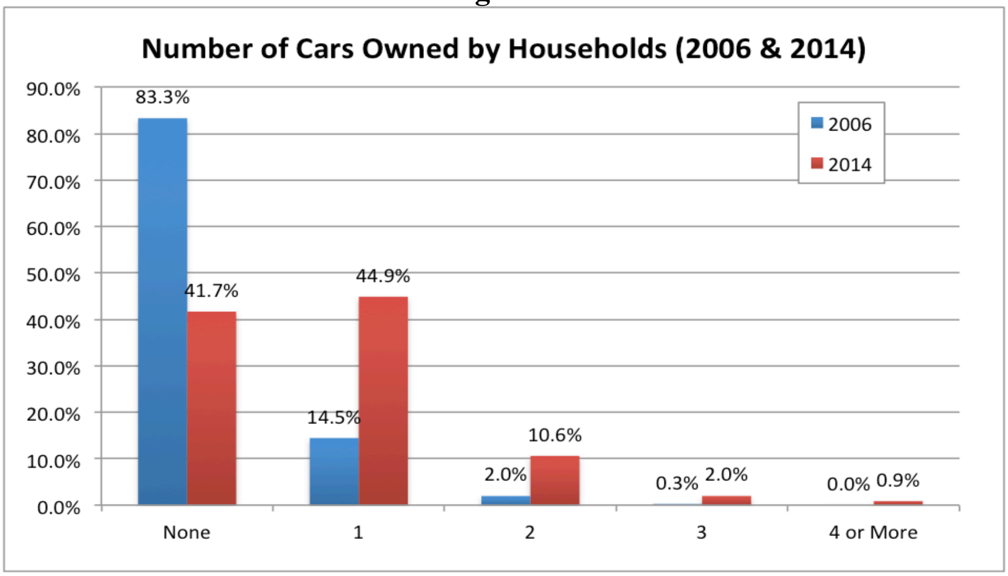
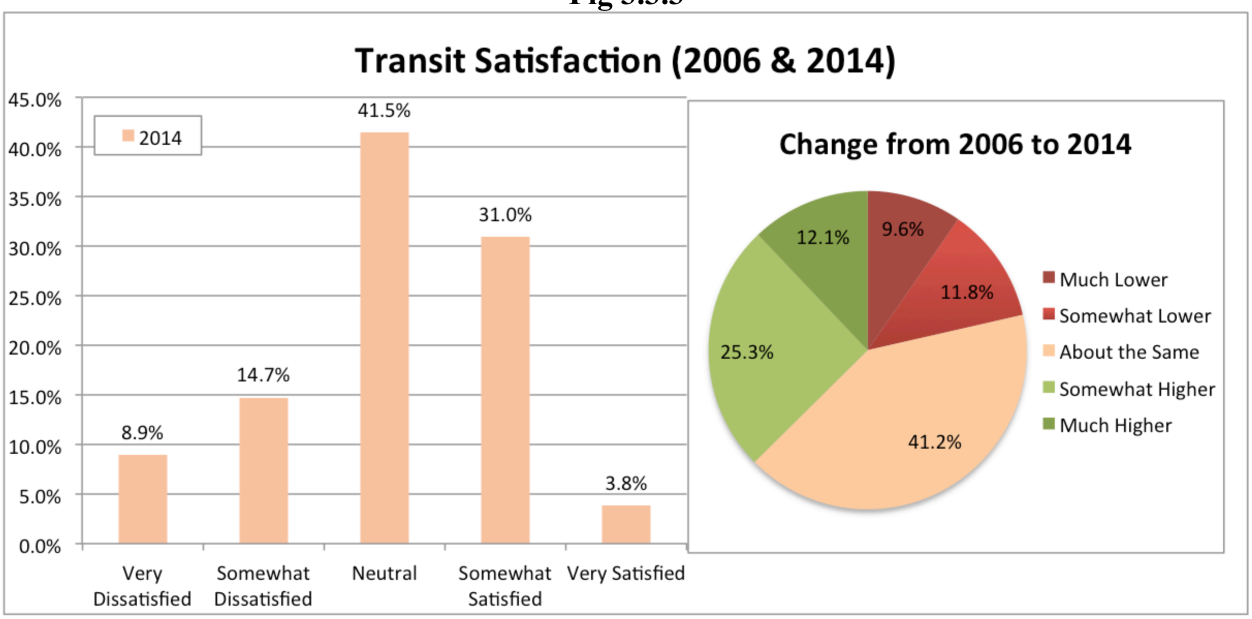


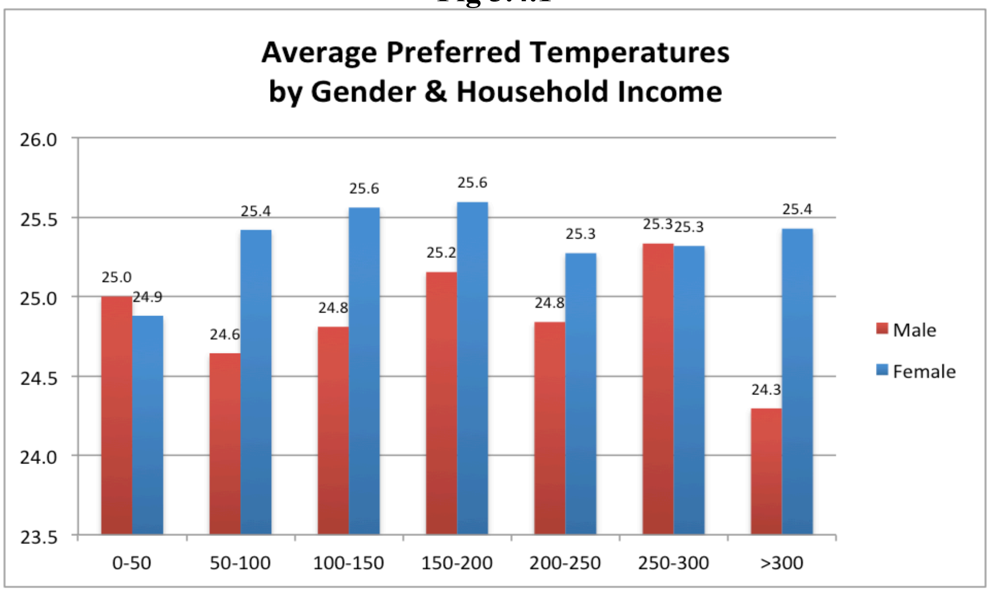
Fig 3.3.3



3.4 Self-Reported Thermal Comfort & Crowding Data

In this section I will present respondents' self-reported preferences and observed thermal comfort and crowding data. As shown in 3.4.1, respondents were asked what their preferred temperatures were at home or at work. The average preferred temperature was 25.1 °C (77.2 °F), agreeing with the results by de Dear, R.J. et al. (1998) and is slightly lower than the 26 °C (78.8 °F) standard set by the Chinese government. Preferred temperatures also very between people and environment. Male respondents, with an average preferred temperature of 24.76 °C, are statistically significantly more sensitive to temperatures than females, who have an average preferred temperature of 25.37 °C. The variation in preferences is more pronounced for males than females. In addition, on average, higher income groups and lower income groups are more sensitive to temperatures compared the middle group. This might be the result of different work environments and different clothing levels.

Fig 3.4.1



In terms of observed onboard temperatures, 38.2% of car/taxi riders reported their average onboard temperatures are "somewhat hot" or "very hot" compared to their preferred temperatures, 47.3% for subway, and 50.5% for bus, as shown in Figure 3.4.2. Bus riders have the highest dissatisfaction, but there is a high proportion of dissatisfied riders even for car/taxi. This shows satisfaction ratings should only be compared relative to each other and not evaluated by its absolute value. In terms of crowding, 82.7% subway riders reported "somewhat crowded" or "very crowded" compared to their preferred levels, 90.1% for bus riders, as shown in Figure 3.4.3. The severity of crowding on buses is higher than for subway.

Overall, approximately 40-50% of respondents reported dissatisfaction with onboard temperatures regardless of their travel mode (bus, subway or car/taxi), showing high temperatures are common during the summer regardless of taking transit or not. However, a significantly higher proportion of respondents reported high temperatures on buses and subways compared to car/taxi; the result is similar for crowding, a problem that does not exist for car or taxi riders.

Fig 3.4.2

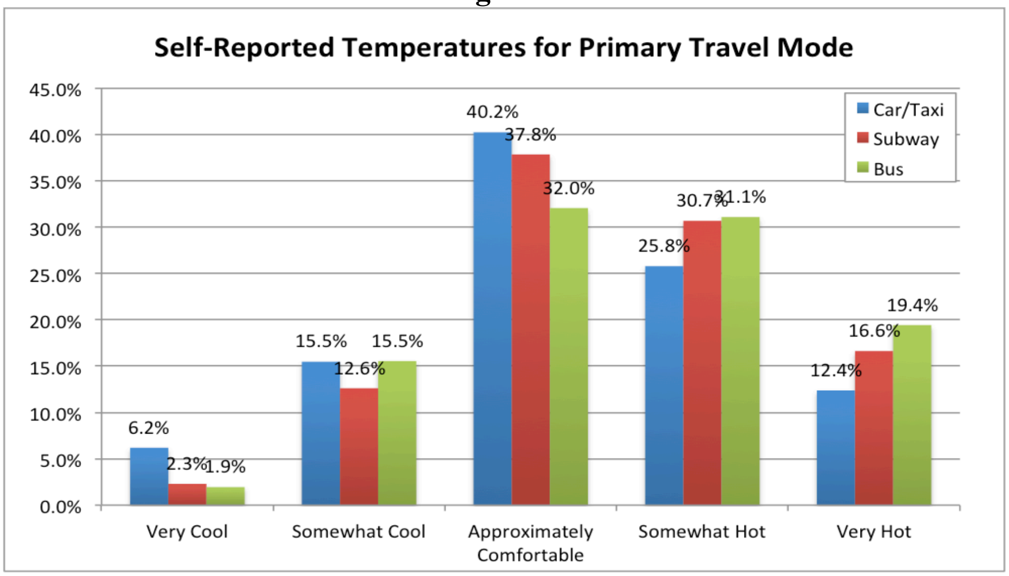
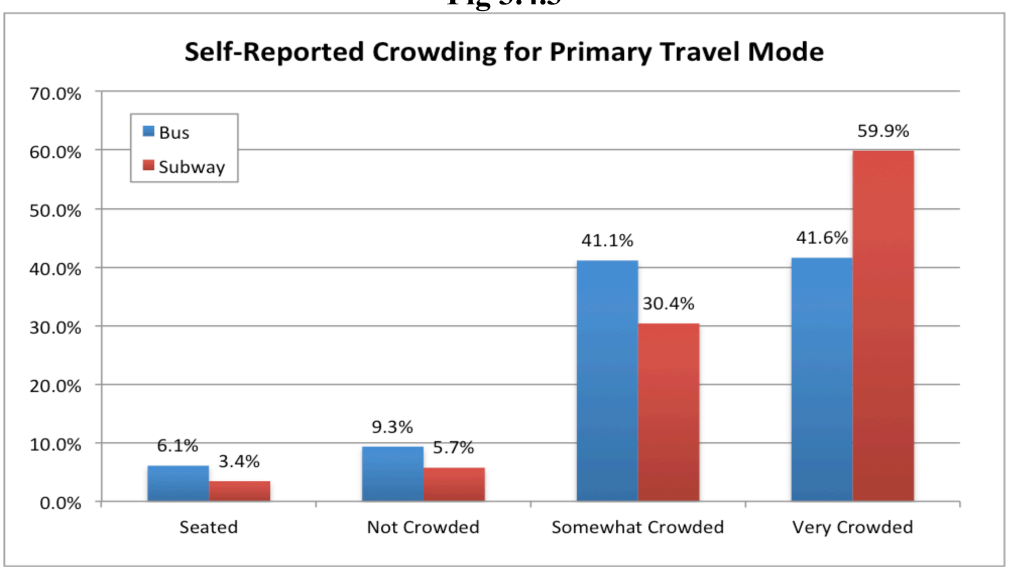


Fig 3.4.3



3.5 Self-Reported Factors Affecting Mode Choice

In order to understand what factors travelers take into consideration when deciding how to travel, the questionnaire also included an open-ended question that asked "What (other) factors affect how you travel”. Its initial purpose was to capture omitted factors other than air-conditioning and crowding, but survey respondents tended to feed back on what they think about air-conditioning and crowding as well.

616 survey respondents provided valid responses to this question. The responses were divided into 8 different categories, as shown in Figure 3.4.1: “In Vehicle Travel Time (IVT)”, “Out of Vehicle Travel Time (OVT)”, “Specific Characters of Other Alternative Travel Modes (ALT)”, “Psychological Factors (PSYCH)”, “Price (PRICE)”, and “Travel Purpose/Distance (DIST)”. IVT and OVT were further divided into “hard” and “soft” categories. “Hard” refers to factors that contribute to actual travel time, such as travel speed, transfer distance; “soft” refers to factors that contribute to perceived travel time, such as comfort and safety.

The frequency of responses are shown below in Figure 3.4.2. The most reported and complained about factors are Hard IVT (45%), Soft IVT (38%), Hard OVT (28%), Soft OVT (10%). Within Soft IVT, complaints regarding air-conditioning and crowding were most prominent. In addition, Soft IVT also included many other factors such as “cleanliness”, “noise”, “odor”, “quality of driving”, “public manners of other passengers”, and “private space”.

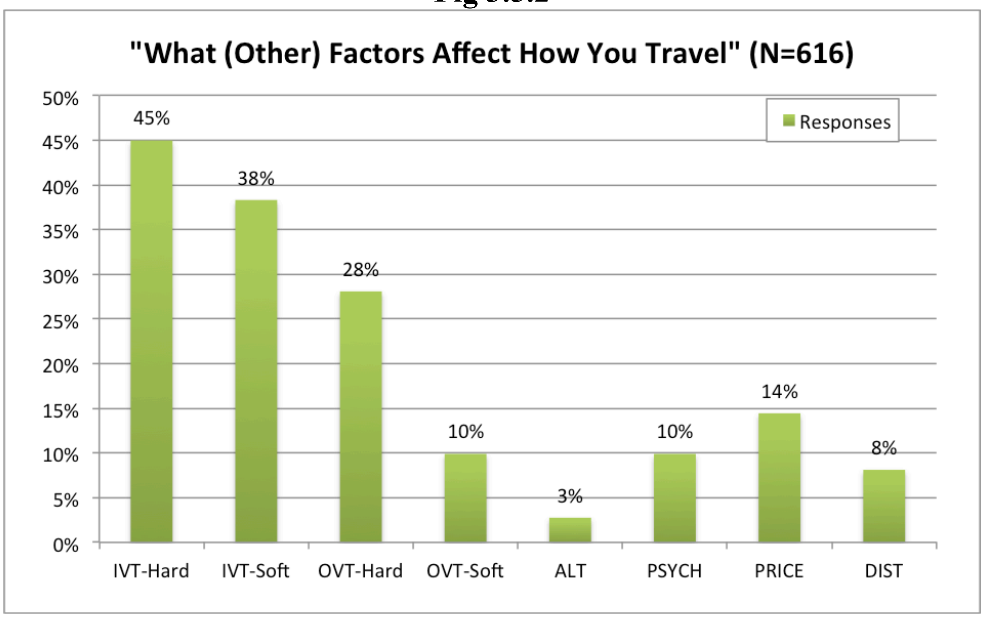
This approach has many limitations, however. First, factors that respondents complain about are not necessarily the factors that actually affect travel behavior. Second, the question was asked at the end of the survey, and respondents were reminded of air-conditioning and crowding problems from the main body of the survey before putting in a response. This leads to bloated numbers of responses regarding air-conditioning and crowding. Third, many respondents have not taken every alternative travel mode possible, so they cannot unbiasedly compare the quality of their current mode with other potential modes. Overall, though, as I have shown in the previous section, people do not deny that thermal comfort, crowding, and other “soft” factors are problems – the next step would be to quantify the effect of such factors.[3]

[3] This section of the questionnaire was added after pre-test, and I did not have the chance to prepare the factor categorizations presented in Figure 3.6.1 in advance. This led to problems of non-response, and also could not let me distinguish between (1) which factors will affect how respondents travel, (2) which factors respondents have complaints about but will not likely change how they travel. Of course, the benefit of the current design is that the question is very open-ended.

Fig 3.5.1 "What (Other) Factors Affect How You Travel": Response Categories

Category	Definition
IVT-Hard	Relative Speed, Delay
IVT-Soft	Comfort, Overall Onboard Environment
OVT-Hard	Walkability, Service Proximity, Transfer, Reliability, Access Convenience
OVT-Soft	Safety, Waiting Conditions, Weather
ALT	Parking Conditions, Car Use Restrictions
PSYCH	Social Status, Personal Biases
PRICE	Fare/Fuel/Parking Prices
DIST	Trip Purpose, Distance

Fig 3.5.2



PART 4: Revealed Preference Approach

4.1 Model

My questionnaire collected travel data for each respondent's p.m. commute by requesting them to "describe your daily commute from work back to your residence". The p.m. commute was chosen instead of the a.m. commute because people's travel times are more flexible and possibly more likely to make mode choice decisions based on factors other than travel time. I use this travel data to develop a multinomial logit model to predict mode choice based on a variety of factors. Other socioeconomic and demographic factors are controlled. Given that various literature show low significance levels for the effects of crowding and thermal comfort, I conduct this analysis bearing in mind that my results will likely be non-significant as well.

The survey data contained several important limitations. First, many respondents failed to provide meaningful details about their alternative travel modes other than the primary mode chosen, as well as detailed origin and destination addresses for privacy protection. Second, respondents who provided observed temperatures and crowding levels on transit did not specify for which mode (bus or subway) they referred to. Given these limitations, I imputed missing data based on calculations from Chinese online map provider *Baidu Maps* based on OD pairs from the survey. I also grouped "bus" and "subway" into one category, "transit". Imputed data were calibrated based on similar trips that have satisfactory quality data. Finally, the survey did not collect data on parking availability, prices, population density, and employment density which potentially affect mode choice as well. These factors are approximated using the distance between the respondents' workplace location to Beijing's city center (the 2nd Ring Road). This is done through the variable "Workplace Ringroad", defined as the closest Ringroad Expressway next to the respondents' work location. See Figure 4.1.1.

Two separate models are estimated – one for non-car-owners, one for car-owners. Car ownership is defined as owning at least one car in the household, which makes the "auto" a more feasible alternative compared to for non-car-owners. Respondents whose primary and alternative travel modes in 2014 are bus, subway, car, taxi and/or bike are selected as the sample for this model. The sample size is 738.

Fig. 4.1.1: Variables and Descriptions

Variable	Description
Travel Distance	Calculated using *Baidu Maps* based on OD pair.
Travel Time on Transit	Calculated using *Baidu Maps* based on OD pair during peak hours in Beijing. Transit modes include bus and subway, and the subway was not chosen if it did not provide significant time savings relative to bus. Predicted travel times were calibrated with available data.
Travel Time on Transit Less Travel Time in Auto	Travel time on auto calculated using *Baidu Maps* based on OD pair during peak hours in Beijing.
Travel Cost on Transit	Calculated based on mode(s) and number of transfers required.
Crowding on Transit	Directly from survey. Dummy variables for each of the 3 levels of crowding:
Onboard Temperature on Transit Less Preferred Temperature	Self-reported temperatures in likert scale (1-5) were converted to actual temperatures according to ISO7730-1993 guidelines for temperatures and satisfaction. See Appendix 4.
Transit Satisfaction	Directly from survey. Likert scale (1-5).
Workplace Ringroad[1]	Refers to the closest Ringroad near the respondents' workplace, and serves as a proxy of the distance of the respondents' work location and the city center.

Notes: [1]Beijing has 5 Ringroad expressways numbered from 2 to 6, with number 2 located in the city center. Each Ringroad is approximately 2-4 km apart.

4.2 Results

Results are shown in Figure 4.2.1. In terms of crowding, for respondents in car-owning households, slight crowding on transit (5 persons/m^2) reduces the odds of taking transit by 85.3% relative to no crowding. In terms of thermal comfort, for respondents in car-owning households, onboard temperatures relative to preferred temperatures increases the odds of taking transit by 8%, a counterintuitive result. Other coefficients regarding crowding and thermal comfort did not yield statistically significant results. For both car-owners and non-car-owners, transit ridership is negatively correlated with transit travel time, but also negatively correlated with the travel time-savings on the auto versus transit, another counterintuitive result.

Fig 4.2.1: Multinomial Logit Choice Model Based on 2014 Travel Data (Relative to Auto)

		(1) Non-Car-Owners		(2) Car-Owners	
Variable	Alternative	Odds	p	Odds	p
Intercept	Bike	144.164	p = 1.000	37.073	p = 0.345
	Transit (Bus or Subway)	128E+07	p = 0.995	133.880	p = 0.018**
Workplace Ringroad	Bike	0.277	p = 0.187	1.139	p = 0.707
	Transit (Bus or Subway)	0.438	p = 0.196	0.793	p = 0.209
Travel Distance	Bike	1.271	p = 0.412	1.082	p = 0.342
	Transit (Bus or Subway)	1.038	p = 0.644	1.058	p = 0.076*
Travel Time on Transit	Bike	0.615	p = 0.046**	0.894	p = 0.011**
	Transit (Bus or Subway)	0.928	p = 0.048**	0.965	p = 0.008***
Travel Time on Transit Less	Bike	1.503	p = 0.055*	1.065	p = 0.084*
Travel Time in Auto	Transit (Bus or Subway)	1.066	p = 0.045**	1.042	p = 0.000***
Travel Cost on Transit	Bike	0.994	p = 0.807	1.003	p = 0.561
	Transit (Bus or Subway)	1.013	p = 0.379	1.006	p = 0.092*
Crowding on Transit:					
5per/m^2 (Dummy)	Bike	25.662	p = 1.000	0.451	p = 0.633
	Transit (Bus or Subway)	0.000	p = 0.997	0.147	p = 0.095*
12 per/m^2 (Dummy)	Bike	42.622	p = 1.000	0.459	p = 0.647
	Transit (Bus or Subway)	0.000	p = 0.997	0.257	p = 0.240
Onboard Temperature on Transit Less	Bike	1.299	p = 0.126	1.051	p = 0.536
Preferred Temperature	Transit (Bus or Subway)	1.117	p = 0.335	1.080	p = 0.067*
Transit Satisfaction	Bike	0.468	p = 0.490	0.718	p = 0.408
	Transit (Bus or Subway)	0.753	p = 0.683	0.868	p = 0.451
Gender	Bike	15.531	p = 0.208	0.666	p = 0.581
	Transit (Bus or Subway)	18.525	p = 0.051*	1.973	p = 0.079*
Age	Bike	1.178	p = 0.123	1.019	p = 0.455
	Transit (Bus or Subway)	0.995	p = 0.948	0.939	p = 0.000***
Education	Bike	1.154	p = 0.719	1.059	p = 0.705
	Transit (Bus or Subway)	1.429	p = 0.152	1.102	p = 0.228
Household Income	Bike	0.905	p = 0.415	0.868	p = 0.028**
	Transit (Bus or Subway)	0.809	p = 0.015**	0.957	p = 0.046**
N		300		436	
Log Likelihood		-27.146		-128.476	
Likelihood Ratio Test (LR)		53.620*** (df = 28)		92.689*** (df = 28)	

Note: *p<0.1; **p<0.05; ***p<0.01.

4.3 Discussion

These results suggest potential endogeneity in the model, in that crowding and auto time-savings are positively correlated with other non-observed factors that cause higher transit ridership. For example, high crowding is observed on transit where transit is attractive in terms of route design, stop location and other factors, which leads to higher ridership rather than lower ridership. On the other hand, transit might be attractive in areas with poor parking availability even though driving might save time relative to transit. I have tried to control for unobserved factors such as parking availability, population and employment density. This is done using the "Nearby Ringroad" variable as a proxy of the distance between the respondents' workplace and the city center. However, data quality issues do exist, in that self-reported locations, travel data and imputed values are inaccurate or too vague to reflect the characteristics of the different mode choices for each respondent. Data quality may also be limited by the ability for respondents to accurately recall information during the brief duration of the intercept survey. Finally, the sample sizes of 300 and 436 are also relatively small, leading to high variances. The revealed preferences approach does not produce all intuitive results. It also remains possible that crowding and thermal comfort do not play significant role in travel mode choice.[4]

[4] Appendix 5 models travel mode switching between 2006 and 2014. However, data was not collected regarding crowding and thermal comfort levels in 2006. Results from these models show similar patterns as from those discussed in this section.

PART 5: Stated Preference Approach

5.1 Model

In this section I used a stated-preference (SP) approach to directly measure the effect of thermal comfort and crowding on travel mode choice. The purpose of the SP approach is to compensate for the data availability and data quality issues in the revealed preferences approach for each alternative.

The SP approach consisted of a set of six game cards. Survey respondents were asked to complete all six. For each game card, the respondents were given the prompt: "Suppose travel distance is 8km. Given the information provided below, choose your most preferred travel mode for commuting from work/school back to your residence", and were given 4 options: (1) Bus, (2) Subway, (3) Car/Taxi, (4) Bike. Factors included onboard temperatures and crowding for buses; onboard temperatures and crowding for subways; and finally, a scenario which doubled fare prices simultaneously for both buses and subways. All of these factors are dummy variables for high temperatures, high crowding and high prices respectively. Other factors such as travel distance, travel time, and travel cost were fixed based on city-wide averages (BTRC 2012).

Based on these factors, as shown in Figure 5.1.1, the 6 game cards were categorized into 3 scenarios based on onboard temperatures and crowding levels. Scenario 3 is the baseline scenario in which onboard temperatures, crowding levels are all low ("cool", "not crowded"). In Scenario 1, bus and subway temperatures are "hot", while crowding levels remain the same as baseline. In Scenario 2, compared to Scenario 1, subway temperature is "cool" but crowding status is "crowded" in exchange. In Jan 2015, Beijing revoked the 2007 Public Transit Fare Reform by eliminating low, flat fares for both bus and subway and switching to a distance-based fare structure. The effect was approximately doubling all bus and transit fares. This scenario is described in games 2, 4 and 6.

Fig 5.1.1: Game Cards Used in Questionnaire

Scenario	Game	Bus		Subway		Bus & Subway Fares
1	1	Hot	Not Crowded	Hot	Not Crowded	Baseline (2014 Levels)
	2					×2 (2015 Levels)
2	3	Hot	Not Crowded	Cool	Crowded	Baseline (2014 Levels)
	4					×2 (2015 Levels)
3	5	Cool	Not Crowded	Cool	Not Crowded	Baseline (2014 Levels)
	6					×2 (2015 Levels)

The alternative variant effects of onboard air-conditioning, crowding, and price levels on ridership are estimated using a multinomial logit model, as shown in Figure 5.3.1. The model also controls for socioeconomic and demographic factors as I have done in the revealed preference approach.

5.2 Results

The estimated model in Figure 5.2.1 shows statistically significant reductions in bus and subway ridership in Scenario 1 ("Bus Hot, Subway Hot") relative to car/taxi. In Scenario 2 ("Bus Hot, Subway Crowded"), there is also a statistically significant reduction in subway ridership relative to car/taxi. In the additional scenario where both bus and subway fares are doubled, there is a statistically significant reduction in subway ridership, as well as a statistically significant increase in bike ridership relative to car/taxi. These results are intuitive: reductions in transit onboard crowding and thermal comfort likely hurt transit ridership compared to other modes.

The model also provides interesting information regarding demographics. Compared to men, women are more likely to ride buses and subways, and less likely to ride on bikes; older citizens are less likely to ride on subways and bikes, but not buses; higher educated citizens are less likely to ride on buses and bikes, but not subways; and finally, higher income citizens are less likely to ride on any mode other than car/taxi compared to other income groups.

Fig 5.2.1: Predicted Change in Ridership, Relative to Car/Taxi

Variable	Alternative	Coefficient	SE	Odds
Intercept	Bus	4.483***	(0.351)	88.498***
	Subway	3.751***	(0.313)	42.543***
	Bike	3.393***	(0.488)	29.756***
Scenario 1 (Dummy): Bus Hot, Subway Hot	Bus	-0.732***	(0.126)	0.481***
	Subway	-0.722***	(0.110)	0.486***
	Bike	0.091	(0.179)	1.095
Scenario 2 (Dummy): Bus Hot, Subway Crowded	Bus	-0.090	(0.124)	0.914
	Subway	-0.673***	(0.114)	0.510***
	Bike	0.109	(0.186)	1.116
Additional Scenario (Dummy): Transit Fares Doubled	Bus	0.106	(0.099)	1.112
	Subway	-0.205**	(0.088)	0.814**
	Bike	0.322**	(0.140)	1.381**
Gender (1=Female)	Bus	0.218**	(0.099)	1.244**
	Subway	0.256***	(0.089)	1.291***
	Bike	-0.547***	(0.143)	0.579***
Age (Years)	Bus	-0.005	(0.005)	0.995
	Subway	-0.023***	(0.004)	0.978***
	Bike	-0.024***	(0.007)	0.976***
Education (Years)	Bus	-0.144***	(0.020)	0.866***
	Subway	-0.024	(0.017)	0.977
	Bike	-0.175***	(0.028)	0.840***
Household Income (10,000 Yuan)	Bus	-0.087***	(0.006)	0.917***
	Subway	-0.063***	(0.005)	0.939***
	Bike	-0.053***	(0.008)	0.949***
N	4,122			
Log Likelihood	-4,687.397			
LR Test	604.144*** (df = 24)			

Note: *p<0.1; **p<0.05; ***p<0.01.

Scenario 3 is the baseline scenario, where all onboard temperature, crowding dummies are zero.

5.3 Significance Tests

In this section I conduct Wald tests to compare the magnitude of the coefficients for air-conditioning, crowding, and price levels discussed above. See Figure 5.3.1. The baseline scenario is that crowding and temperature levels on both bus and subway are low. Each "scenario" is a dummy variable and the coefficients are differences in log-odds relative to the baseline.

Fig 5.3.1: Comparison of Coefficients Using Wald Tests

Coefficients in Comparison		Difference	p-value
Scenario 1, Bus:	Scenario 2, Bus:		
-0.732^{***}	-0.090	-0.642^{***}	0.00
Scenario 1, Subway:	Scenario 2, Subway:		
-0.722^{***}	-0.673^{***}	-0.049	0.64
Scenario 1, Bus:	Scenario 1, Subway:		
-0.732^{***}	-0.722^{***}	-0.01	0.92
Scenario 2, Bus:	Scenario 2, Subway:		
-0.090	-0.673^{***}	0.583^{***}	0.00
Transit Fares Doubled, Bus:	Transit Fares Doubled, Subway:		
0.106	-0.205^{**}	0.311^{***}	0.00

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.
The overall effect of Scenario 1, 2, and "Doubled Transit Fares" is also significant.

I first compare coefficients in Scenario 1 and Scenario 2. Both Scenarios have "bus hot, but not crowded". The difference is that Scenario 1 has "subway hot, but not crowded", whereas Scenario 2 has "subway crowded, but not hot". The log-odds for bus is significantly higher in Scenario 2, suggesting that bus ridership is higher when the subway is "crowded" compared to when the subway is "hot". This is in line with literature that suggests crowding has more impact on ridership than thermal comfort. There is no statistically significant difference in the log-odds for subway between the two scenarios, which might suggest that crowding and high temperatures on subway create similar levels of disutility. This shows that although the effect of thermal comfort is smaller than crowding, it still has a sizable influence.

For each scenario, I then compare the coefficients for bus and subway. In Scenario 1, "bus hot, subway hot" yields a similar negative effect for buses and subways with no statistically significant difference. In Scenario 2, "bus hot, subway crowded", though, the impact on subway is significantly higher than for bus. This again shows that travelers are more sensitive to crowding than to air-conditioning, especially for subway.

Finally, in the final scenario, “doubled bus and subway fares”, subway ridership is more sensitive to the price increase compared to bus, given the same percentage price change. Of course, Beijing’s 2014 bus fares were much lower than subway fares, and it is reasonable that a doubling of bus fares will not impact bus ridership as much as for subway. This scenario closely resembles the new transit reform enacted in January 2015, where average fares were approximately doubled for both bus and subway.

5.4 Predicted Probabilities

Using the logit model above, I can now predict ridership for each of the 4 modes for given scenarios given average socioeconomic levels. Figures 5.4.1-5.4.4 below present predicted mode choices according to household incomes. In general, as household income increases, mode choice for buses, subways decrease, ridership for cars/taxis increase, and ridership for bikes remains flat. Ridership is sensitive to income for car/taxi and bus but not as so for subway and bike. Intuitively, subway maintains large advantages in speed and reliability compared to bus, and it is thus reasonable for subway ridership to be less sensible to income levels.

Most interestingly, in most cases, the impacts of doubling bus and subway fares are not as large as those of certain “crowding and thermal comfort” scenarios. A reduction of fares from the “fare prices doubled” scenario to the baseline scenario would only result in a ridership drop of 5-10 percentage points, while improving air-conditioning and crowding combined may result in ridership gains of up to 20 percentage points. The limitations of these results are discussed in the next section.

Fig 5.4.1

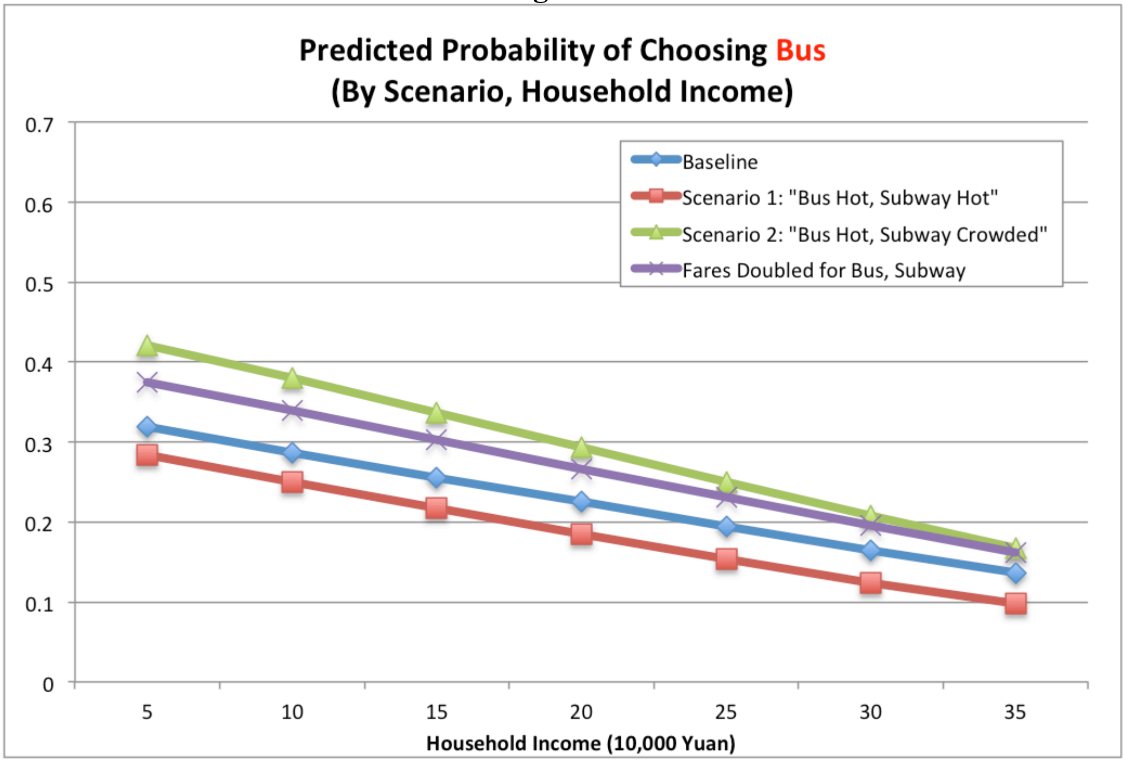


Fig 5.4.2

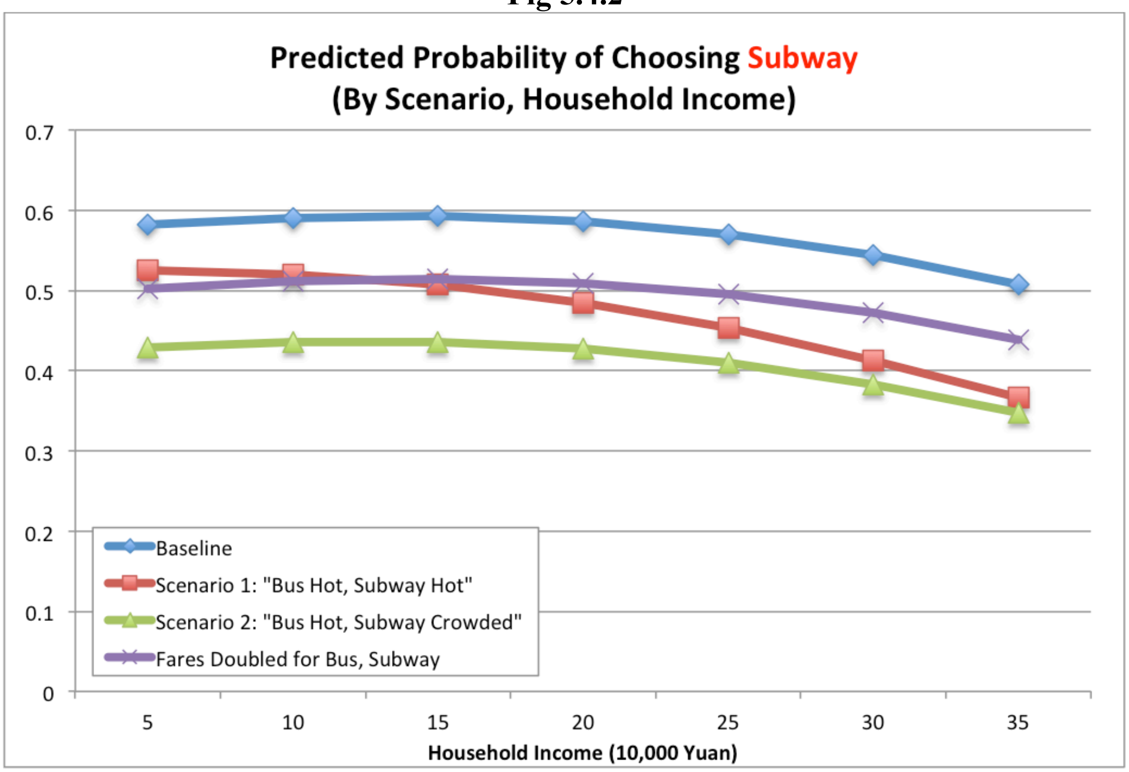


Fig 5.4.3

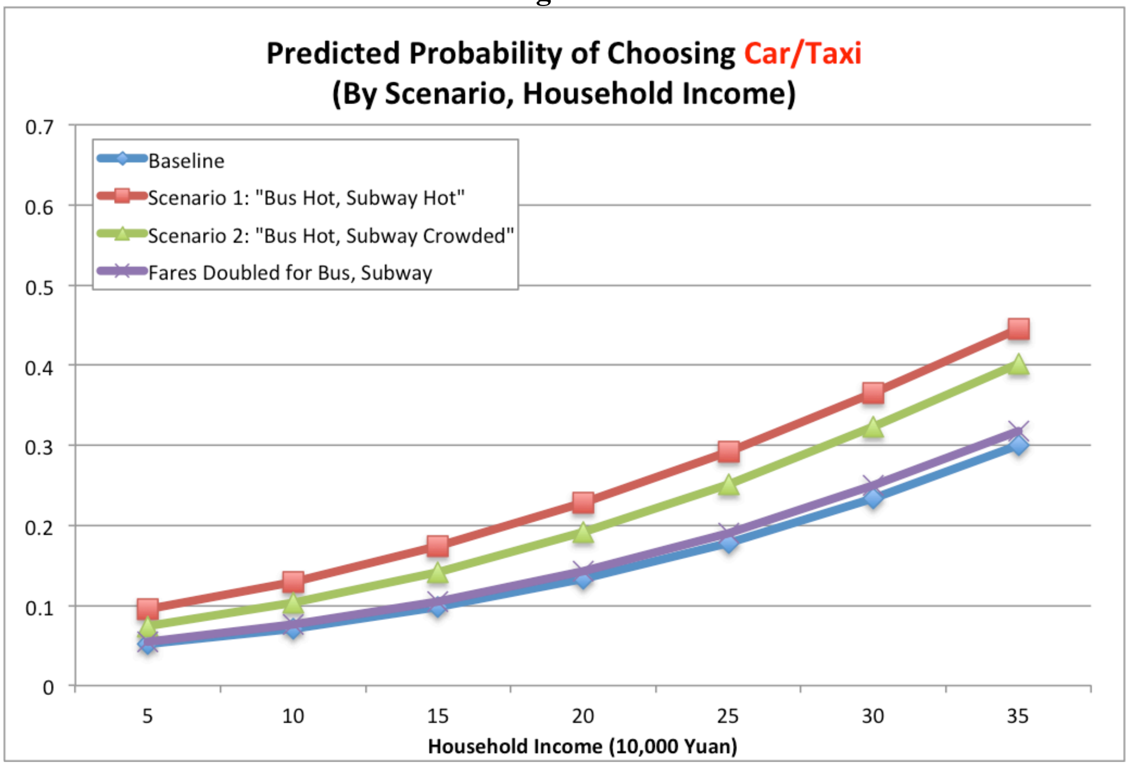
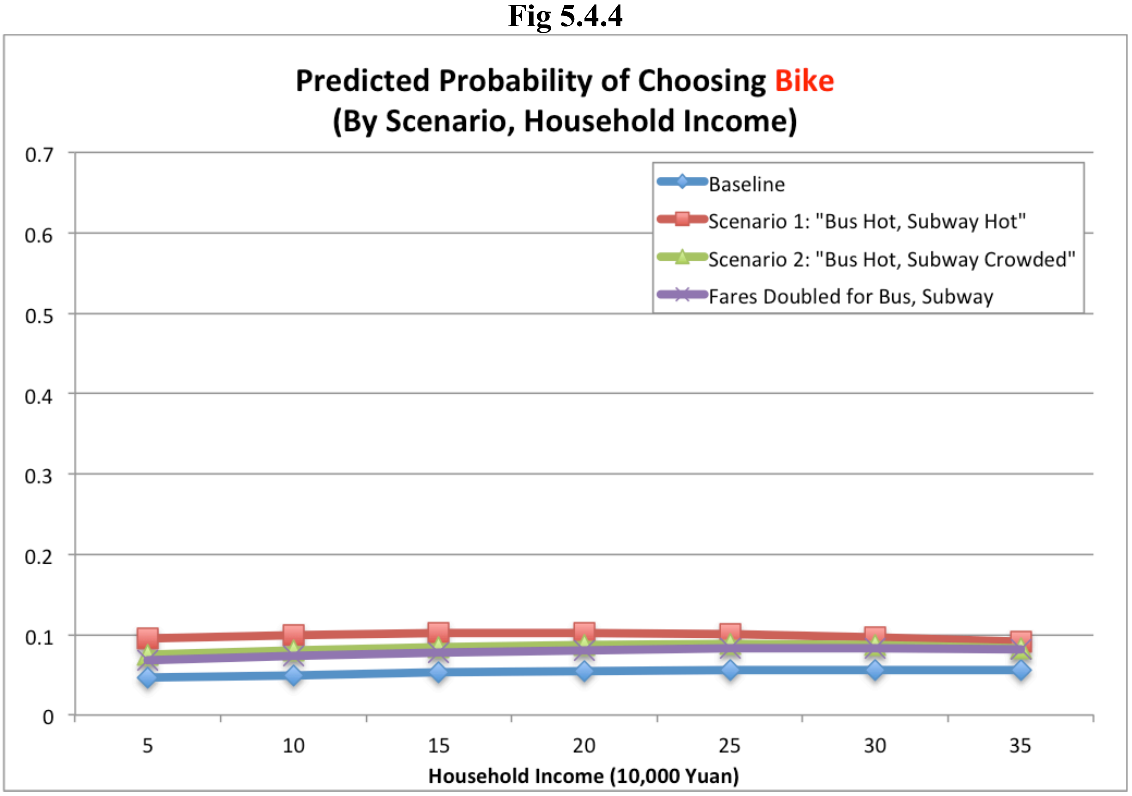


Fig 5.4.4



5.5 Discussion

Overall, the stated preference approach reveals statistically significant effects on ridership when thermal comfort and crowding levels are altered. In general, the effect of crowding is higher than the effect of thermal comfort, which agrees with results from literature. Interestingly, the affect of temperatures and crowding combined are sometimes comparable or even more pronounced than the effect of price hikes.

There are several important limitations. First of all, there are not enough games to provide sufficient variability in temperatures, crowding, prices and other factors such as travel times and prices. This limits the set of coefficients I am able to estimate, and I could only estimate the effect of combined scenarios rather than individual effects of each variable. The original questionnaire had up to 3 levels for each variable but not enough game variations, which prompted me to change a 3 level scale for temperatures and crowding into binary variables ("hot", "cool"; "crowded", "not crowded"). Finally, the stated preference game was the last section of the questionnaire and likely led to biased responses.

The stated-preference game nevertheless revealed differentiated responses between different scenarios, as well as different effects of crowding and thermal comfort between different modes as well as for different socioeconomic groups. These results largely agree with literature in that the effect of "soft" service quality factors are highly subjective and context specific. Although limitations exist, the results provide some indication of the potential disutility of crowding and thermal discomfort and their potentially large effect on transit ridership if onboard crowding and temperatures depart largely from riders' expectations.

PART 6: Conclusion & Discussion

6.1 Conclusion & Discussion

In this paper I have first summarized observed and preferred levels of crowding and thermal on transit among the sample of Beijing residents. Along with travel data, and socioeconomic variables, I have developed multinomial logit models predicting mode choice using both revealed preference and stated preference approaches.

Data summary shows high levels of dissatisfaction in terms of crowding and thermal comfort, especially for transit riders. The revealed preference approach, however, found statistically significant effects of crowding for car-owners only, while other coefficient estimates were either non significant or counterintuitive due. The stated preference approach found statistically significant effects on travel mode choice for different combinations of high temperatures and high crowding levels, and these effects are usually even larger than the effect of "doubling fare prices". This method also found that the impact of high crowding is generally larger than high temperatures. The validity of these results is limited by data quality and survey design constraints.

Overall, the regression results largely agree with literature in that the effects of such "soft" service quality variables vary between people and context. More on, if crowding, thermal discomfort, or the disutility from the lack of any other "soft" service quality factor are at very high levels, their impacts on transit ridership can be very significant and costly. Transit agencies should first guarantee basic levels of service in terms of fares, travel times, and reliability, but sufficient attention and funds into transit comfort should be in place. While these agencies are usually monopolies in their respective travel mode, they do not have dominant power over how people travel and must compete with other travel modes. Policies that seek to increase ridership through fare prices or other "hard" service quality factors would likely see diminished effects if "soft" service quality factors such as crowding and thermal comfort are sacrifice or ignored. The key would be how limited transit agency budgets should be allocated to satisfy passenger needs in both “hard” and “soft” service quality factors. Differentiated services that cater to the needs in costs and service quality of different groups along with a certain degree of privatization and competition in transit could be required.

Alternatives methodologies might include conducting in-person household surveys rather than intercept surveys such that respondents can more accurately recall information, and changing self-reported crowding and temperatures to actual field measurements. Further research should seek to improve survey design issues and improve data quality on this, evidently, very subjective topic.

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Appendix

Appendix 1: Summary of Citywide Data (2000-2012)

Category	Yr	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Basic Stats	Resident Population (10K)		1385	1423	1456	1493	1538	1581	1633	1695	1755	1961	2019	2069
	Urban Disposable Income (Yuan)		11578	12463	13882	15637	17653	19978	21989	24725	26738	29073	32903	36468
	CPI Change (%)		0.7	-0.8	1.2	3.9	1.8	1.5	4.8	5.9	-0.7	3.3	5.4	2.6
	Daily Total Person-Times Travelled (10K Person-Times)		1605	1759	1832	1901	2015	2164	2275	2637	2746	2904	2873	3033
	Average Traffic Speed (km/h) - 3rd Ring Road (Daily)/City Area Expressways (Inner 5th Ring Road) (Peak Hours)			59.9	59.4	57.8	57.75	53.8/33	28.95	33	33	32.65	33.4	
	Downtown Total Road Length (km)		2492.9	2503.8	3055	4067	4073	4419	4460	6186	6247	6355	6258	
	Total Cars (10K)	157.8	169.9	189.9	212.4	229.6	258.3	287.6	312.8	350.4	401.9	480.9	498.3	520
	Downtown Benchmark Daily Traffic Flow (10K Vehicles/Day)			353.9			507.9							
	Car (%)	23.2		26.2		26	29.8	31.6	32.6	33.6	34	34.2	33	32.6
Fiscal Budget	Fiscal Expenditure (100M Yuan)	490.34	614.92	683.98	809.39	974.17	1137.28	1411.58	2067.65	2400.93	2820.86	4064.97	4574.94	4803.75
	Fiscal Revenue (100M Yuan)		454.2	534	592.5	744.5	919.2	1117.2	1492.6	1837.3	2026.8	2353.9	3006.3	3314.9
	Public Transit Subsidy (100M Yuan)	8.8	8.6	9.6	14.6	16.92	16.9	36.7	49.8	99.2	112.0	135.3	156.9	175.0
	Public Transit Subsidy (%)	1.80%	1.40%	1.40%	1.80%	1.7%	1.5%	2.6%	2.4%	4.1%	4.0%	3.3%	3.4%	3.6%
Ridership	Bus (100M Yuan)					11.92	13.1	31.4	39.5	91.5	104.2	90.0	110.0	138.2
	Subway (100M Yuan)					6.5	5.7	5.4	10.3	7.9	15.2	30.0	40.0	36.9
	Bus (100M Rides)		40.73	44.39	37.94	43.91	45.68	40.1	42.3	47.1	51.7	50.5	50.3	52
	Bus (%)	22.9		23.5		26.5	24.1	24.4	27.5	28.8	28.9	28.2	28.2	29.9
	Total Bus Route Length (km)		13126	15760	16017	15133	18214	18468	17353	17857	18270	18743	19,460.00	19547
	Subway (100M Rides)		4.69	4.82	4.72	6.07	6.80	7.03	6.55	12.17	14.23	18.46	21.93	24.60
	Subway (%)	3.6		4.5		5	5.7	5.8	7.0	8.0	10.0	11.5	13.8	14.1
	Total Subway Route Length (km)		54	75	114	114	114	114	142	200	228	336	372	442
	Taxi (100M Rides)		5.98	5.98	5.18	5.88	6.5	6.41	6.4	6.9	6.8	6.9	6.96	6.99
	Taxi (%)	8.8		8.2			7.6	8.1	7.7	7.4	7.1	6.7	6.9	6.7
	Bicycles (%)	38.5		34.7		31.5	30.3	27.7	23.0	20.3	18.1	16.4	15.1	13.9
Price Indices	Consumer Price Index	97.6	100.6	98.8	99.0	100.0	101.5	102.4	104.9	110.2	108.6	111.2	117.4	121.3
	Traffic Price Index	98.3	100.8	104.3	105.4	100.0	99.1	102.1	98.2	97.9	94.8	97.9	102.3	103.0
	Fuels and Parts Price Index					100.0	112.6	132.6	136.5	158.1	151.9	171.2	192.2	197.6
	In-city Public Transit Price Index					100.0	100.0	110.2	99.8	97.9	98.1	99.8	101.0	102.1
Wages & Employment	Average Wage of Fully Employed: City		19155	21852	25312	29674	34191	40117	46507	54913	58140	65683	75834	85307
	Public Transit Sector				19976.7	24628	18687	20887	23485	29541	29475	32147	35889	
	Transportation, Storage & Post Sector				14922.8	16608	27655	34054	38949	46043	46109	51443	59113	
Public Transit Sector	Public Transit Year End Employed Persons				152131	151732	160137	175786	174992	181608	210762	215052	212673	
	Public Transit: Revenue of Main Business						902183	1029560	927100	1040120	998065	1074846	1114986	
	Public Transit: Cost of Main Business						818920	1041800	1164699	1619302	1666015	1879688	2089408	
Transportation Expenditures	Total Average	171.51	190.2	300.12		321.5	338.88	394	338	341	367	411	424	
	0-20% Income Percentile	98.11	121.8	138.3		134.4	161.99	196	190	127	150	172	169	
	20-40% Income Percentile	134.83	126.7	189.2		212.6	252.3	289	235	217	264	314	262	
	40-60% Income Percentile	143.19	162.7	287.1		266	306.35	377	321	271	320	339	349	
	60-80% Income Percentile	181.02	207.7	351.1		400	415.59	421	380	388	399	454	497	
	80-100% Income Percentile	322.99	366.3	575.2		653.5	607.6	735	593	723	730	796	825	
Annual Living Expenditures Per Capita	Total Average	8493.5	8922.7	10285.8		12200.4	13244.2	14825	15330	16460	17893	19934	21984	
	0-20% Income Percentile	5412.7	5954.5	6837.5		7395.4	7863.5	8911	9183	8985	10009	11478	11308	
	20-40% Income Percentile	6763.1	7192.7	8230.5		10009.4	10939	12436	12196	12776	14538	16611	16573	
	40-60% Income Percentile	8369.4	8612.8	9777.3		11115.4	11772.5	14080	15094	15380	16752	18683	19885	
	60-80% Income Percentile	9687.2	10310.2	12021.1		13907	15813.8	16452	17747	19109	20529	22433	25213	
	80-100% Income Percentile		13381.2	15354.3		19969.7	21325.2	23520	23415	26589	28541	31085	36264	

Sources: Beijing Statistical Yearbook (2000-2013); BTRC (2006-2013); Report of the Beijing 5th Transport Comprehensive Survey (2012).

Appendix 2: Questionnaire

Travel Mode Shift Since the 2007 Beijing Public Transit Fare Reform – Questionnaire
CPHS Exempt 2014-03-618

Hello, we are student researchers from UC Berkeley and Renmin University, currently conducting a survey on transit reform in Beijing. Jan 1, 2007, Beijing implemented the Public Transit Fare Reform, cutting bus fares by 60%, and bringing subway fares down to 2 Yuan. We wish to understand how the reform has affected residents' travel behavior and attitudes.

1. Were you in Beijing around Jan 1, 2007 when the reform took place?
   【□ I was employed in Beijing in 2006
   □ I was a student in Beijing in 2006
   □ I was not in Beijing in 2006, I came to Beijing in _____ 】

2. Your current occupation: 【□ Full Time □ Part Time □ Student □ Other: _________】

3. We wish to know how you usual commute back home from work/school currently.

(a) Days of work/school per month	【______ Days】
(b) Time of day work/school finishes	【______:______ AM/PM】
(c) Origin/destination of commute back home	From 【_____________ to _____________】 (ex."Guomao"至"Tiantongyuan")
(d) Your primary travel mode (choose 1, based on longest distance travelled. If cannot distinguish, select most recent mode) 【□ car □ taxi □ bike □ subway □ bus: route _____ □ walk □ other: _______】	
(e) Single journey duration using this mode	【_______ min】
(f) Monthly travel cost	【_______ Yuan/Mo】 (# daily commutes x # work days, suppose use same mode each journey, include fares, fuel, parking etc.)
(g) When did you start using this mode?	【Year ________】

4. Besides the above, what is your alternative travel mode for your usual commute back home from work/school? (such as when car plate is restricted or bad weather)

(a) Your primary travel mode (choose 1, based on longest distance travelled. If cannot distinguish, select most recent mode) 【□ car □ taxi □ bike □ subway □ bus: route _____ □ walk □ other: _______】	
(b) Single journey duration using this mode	【_______ min】
(c) Monthly travel cost	【_______ Yuan/Mo】 (# daily commutes x # work days, suppose use same mode each journey, include fares, fuel, parking etc.)

5. Please recall your usual commute back home from work/school in 2006 (before bus, subway fares were cut).(If you were not in Beijing in 2006, recall your commute when you first came to Beijing)

(a) Days of work/school per month	【______ Days】
(b) Time of day work/school finishes	【______:______ AM/PM】
(c) Origin/destination of commute back home	From 【_____________ to _____________】 (ex."Guomao"至"Tiantongyuan")
(d) Your primary travel mode (choose 1, based on longest distance travelled. If cannot distinguish, select most recent mode)	

[Official Use] Survey Worker: _____ Respondent #: _____ Time: _____ Date: _____ Loc: _________

【□ car □ taxi □ bike □ subway □ bus: route _____ □ walk □ other: ________】	
(e) Single journey duration using this mode	【_______ min】
(f) Monthly travel cost	【_______ Yuan/Mo】 （# daily commutes x # work days, suppose use same mode each journey, include fares, fuel, parking etc.）

6. If your current primary travel mode is different from in 2006, your reason for switching is: (choose 1)
【□ Cost □ Route/Walking Distance □ Time/Hassle □ Reliability (Intervals/Delays/Breakdown)
□ Service □ Comfort (Cleanliness/Crowdedness/Air-Conditioning)
□ Personal Preference/Lack of info of other modes □ No change】

7. Other than the travel modes above, have you ever switched to other modes not mentioned above between 2006-2014? (If many occasions, recall 1)

【Year ______】 to 【Year ______】 or: □ None	Occupation: 【□ Full Time □ Part Time □ Student □ Other: _____】 Work/School Days Per Mo: _____, Finish Time: 【______:______ AM/PM】 Origin/Destination: 【From _________ To _________(Home)】 【□ car □ taxi □ bike □ subway □ bus: route _____ □ walk □ other: _______】 Duration: 【______ min】,Cost 【____________ Yuan/Mo】

8. Attitudinal Questions:

(a) Rate your satisfaction on your current public transit options:
【□ Very unsatisfied □ Somewhat Unsatisfied □ Indifferent □ Somewhat satisfied □ Very satisfied】

(b) Your current satisfaction compared to in 2006 (Before fare cuts) is:
【□ Much worse □ Somewhat worse □ About the same □ Somewhat better □ Much better】

(c) The crowdedness of your current primary travel option is: (See Attachment for Pictures)
【□ Seated □ Not Crowded (pic 1) □ Somewhat Crowded (pic 2) □ Very Crowded (pic 3)
□ Do not take public transit】

(d) The inside temperature onboard (bus/subway given above crowdedness or car/taxi/other) is usually:
【□ Much lower than 26℃(very cool) □ Somewhat lower than 26℃
□ Around 26℃ (approximately comfortable) □ Somewhat higher than 26℃
□ Much higher than 26℃(very hot)】

(e) Your preferred air-conditioning temperature at home/work is: 【__________ ℃】

9. Other Information:

(a) Your gender 【□ M □ F】 (b) Your age 【_____ Yrs】

(c) Your total household population 【_____】

(d) Does your school/work provide traffic allowance? 【□ Y □ N】

(e) Total number of cars in your household 【________】, Purchase Time 【Year(s) _______________】

(f) Your Education Level:
【□ None □ Primary/Junior High □ Senior High □ Occupational High □ Undergraduate
□ Occupational Undergraduate □ Graduate or Above】

(g) Your expected total household income this year: (pre-tax, include all sources such as bonuses)
【Annual Household Total (Unit: 10K): □ <5 □ 5-10 □ 10-15 □ 15-20 □ 20-25 □ 25-30 □ >30】

[Official Use] Survey Worker: _____ Respondent #: _____ Time: _____ Date: _____ Loc: _________

(h) Since 2006, your total household income level growth is：

【□ Much slower than inflation □ Somewhat slower than inflation □ Similar to Inflation
□ Somewhat higher than inflation □ Much higher than inflation 】

10. Scenario Simulation Games (See attachment for game cards)

- Below are 6 scenario simulation games. Suppose your purpose for travel is still from work/school to home, travel distance is 8km.
- In each game, please consider the (1) travel time, (2) travel cost, (3) air-conditioning status, and (4) crowdedness level we have provided. Combining with your personal reality and preference, consider how you would chose to travel.

Note: 1=bus, 2=subway, 3=car/taxi, 4=Bike

Game 1	Game 2	Game 3	Game 4	Game 5	Game 6
Your Choice: 【______】	Your Choice: 【______】	Your Choice: 【______】	Your Choice: 【______】	Your Choice: 【______】	Your Choice: 【______】

11. What other factors affect your decision on how you would commute? 【________________】

This is the end of this questionnaire, thank you for your support! All information will be held strictly confidential. Data usage will be limited to research and will not be released to personnel or organizations other than our research team. Please address any questions to the primary student investigator Diwen SHEN (UC Berkeley Junior Economics and Statistics Major, Minor in City and Regional Planning). Contact: 15910885132 or stevendshen@berkeley.edu.

[Official Use] Survey Worker: _____ Respondent #: _____ Time: _____ Date: _____ Loc: _________

Appendix 3: Stated Preference Game Cards

Game 1: Suppose travel distance is 8km. Given the information provided below, choose your most preferred travel mode for commuting from work/school back to your residence.

Option (1) Bus	Option (2) Subway	Option (3) Car/Taxi	Option (4) Bike
60 min (Single Journey)	36 min (Single Journey)	30 min (Single Journey)	64 min (Single Journey)
0.8 Yuan (Single Journey)	2 Yuan (Single Journey)	19 Yuan (Single Journey, Including Gas, Parking)	0 Yuan (Single Journey)
Very Hot (Much higher than 26 C)	Very Hot (Much higher than 26 C)	Air-conditioning set to your preferred temperature	-
Somewhat Crowded (5 people/ squared meter)	Somewhat Crowded (5 people/ squared meter)	-	-
			

Game 2: Suppose bus fares rise to 1.6 Yuan (doubled), subway fares rise to 4 Yuan (doubled). Keeping all other factors the same as in Game 1, choose your most preferred travel mode for commuting from work/school back to our residence.

Game 3: Suppose travel distance is 8km. Given the information provided below, choose your most preferred travel mode for commuting from work/school back to your residence.

Option (1) Bus	Option (2) Subway	Option (3) Car/Taxi	Option (4) Bike
60 min (Single Journey)	36 min (Single Journey)	30 min (Single Journey)	64 min (Single Journey)
0.8 Yuan (Single Journey)	2 Yuan (Single Journey)	19 Yuan (Single Journey, Including Gas, Parking)	0 Yuan (Single Journey)
Very Hot (Much higher than 26 C)	Cool (No higher than 26 C)	Air-conditioning set to your preferred temperature	-
Not Crowded (1 person/ square meter)	Very Crowded (12 people/ square meter)	-	-
			

Game 4: Suppose bus fares rise to 1.6 Yuan (doubled), subway fares rise to 4 Yuan (doubled). Keeping all other factors the same as in Game 3, choose your most preferred travel mode for commuting from work/school back to our residence.

Game 5: Suppose travel distance is 8km. Given the information provided below, choose your most preferred travel mode for commuting from work/school back to your residence.

Option (1) Bus	Option (2) Subway	Option (3) Car/Taxi	Option (4) Bike
60 min (Single Journey)	36 min (Single Journey)	30 min (Single Journey)	64 min (Single Journey)
0.8 Yuan (Single Journey)	2 Yuan (Single Journey)	19 Yuan (Single Journey, Including Gas, Parking)	0 Yuan (Single Journey)
Cool (No higher than 26 C)	Slightly higher than 26 C	Air-conditioning set to your preferred temperature	-
Somewhat Crowded (5 people/ square meter)	Not Crowded (1 person/ square meter)	-	-
			

Game 6: Suppose bus fares rise to 1.6 Yuan (doubled), subway fares rise to 4 Yuan (doubled). Keeping all other factors the same as in Game 5, choose your most preferred travel mode for commuting from work/school back to our residence.

Appendix 4: Survey Logistics

Fig. A4: Survey Logistics

Month		July																	August		
Date		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
Survey Worker	Location/ ~Amount	XD	XD	ZG	ZG	BC ZG	GM	WJ	GM	GM	XD CY	SJ	XD	SJ WD	XD ZG	CY ZG	SJ	SJ	CY		
#1	150													SJ	XD	CY					
#2	70													SJ	XD						
#3	150																				
#4	30														XD						
#5	100													SJ							
#6	7																				
#7	150													SJ	XD	CY					
#8	24																				
#9	65													WD	ZG	ZG					
#10	15																				

Appendix 5: Modeling Mode Shift Between 2006 & 2014

Fig A5.1: Mode Shift for Transit (Bus/Subway) Riders 2006-2014 (Rel to Switching to Auto)

Variable	Alternative	Coefficient	SE
Intercept	Switch to Bike	-4.652	(6.114)
	No Switch	2.245	(2.362)
Travel Distance	Switch to Bike	0.324	(0.263)
	No Switch	-0.026	(0.053)
Δ Travel Distance	Switch to Bike	-0.083	(0.120)
	No Switch	0.049	(0.031)
Travel Time on Transit	Switch to Bike	-0.279	(0.218)
	No Switch	0.032	(0.031)
Δ Travel Time on Transit	Switch to Bike	-0.057	(0.091)
	No Switch	-0.013	(0.024)
Travel Time on Transit Less	Switch to Bike	0.138	(0.166)
Travel Time in Auto	No Switch	0.007	(0.026)
Δ Travel Time on Transit Less	Switch to Bike	0.042	(0.096)
Travel Time in Auto	No Switch	0.013	(0.025)
Travel Cost on Transit	Switch to Bike	-0.033	(0.028)
	No Switch	-0.002	(0.004)
Δ Travel Cost on Transit	Switch to Bike	0.012	(0.017)
	No Switch	0.0002	(0.004)
Crowding on Transit	Switch to Bike	-0.003	(0.241)
	No Switch	0.069	(0.067)
Onboard Temperature on Transit	Switch to Bike	-0.010	(0.148)
Less Preferred Temperature	No Switch	0.016	(0.057)
Transit Satisfaction	Switch to Bike	-0.714	(0.860)
	No Switch	0.039	(0.324)
Δ Transit Satisfaction	Switch to Bike	1.116	(0.888)
	No Switch	0.153	(0.301)
Gender	Switch to Bike	5.199*	(3.027)
	No Switch	1.250**	(0.595)
Age	Switch to Bike	0.005	(0.064)
	No Switch	-0.049*	(0.026)
Education	Switch to Bike	-0.337	(0.382)
	No Switch	-0.018	(0.112)
Household Income	Switch to Bike	-0.146	(0.112)
	No Switch	-0.026	(0.037)
Δ Household Income	Switch to Bike	3.001**	(1.504)
	No Switch	-0.133	(0.245)
Observations	314		
Log Likelihood	-66.966		
LR Test	49.038* (df = 36)		

Note: *p<0.1; **p<0.05; ***p<0.01. This model was not included in Part 4 because of missing thermal comfort and crowding data in 2006.

Fig A5.2: Mode Shift for Auto (Car/Taxi) Riders 2006-2014 (Rel to No Switch)

Variable	Alternative	Coefficient	SE
Intercept	Switch to Bike	19.658	(56,580.520)
	Switch to Transit	-1.719	(5.563)
Travel Distance	Switch to Bike	0.868	(1,684.084)
	Switch to Transit	-0.401**	(0.194)
Δ Travel Distance	Switch to Bike	-3.341	(2,063.934)
	Switch to Transit	0.722*	(0.391)
Travel Time on Transit	Switch to Bike	-1.077	(677.042)
	Switch to Transit	0.152*	(0.086)
Δ Travel Time on Transit	Switch to Bike	0.679	(788.378)
	Switch to Transit	-0.236**	(0.111)
Travel Time on Transit Less	Switch to Bike	0.391	(329.814)
Travel Time in Auto	Switch to Transit	-0.013	(0.054)
Δ Travel Time on Transit Less	Switch to Bike	0.180	(391.022)
Travel Time in Auto	Switch to Transit	0.053	(0.039)
Travel Cost on Transit	Switch to Bike	0.008	(77.818)
	Switch to Transit	-0.003	(0.017)
Δ Travel Cost on Transit	Switch to Bike	-0.014	(83.666)
	Switch to Transit	0.012	(0.016)
Crowding on Transit	Switch to Bike	0.192	(2,178.847)
	Switch to Transit	0.179	(0.173)
Onboard Temperature on Transit	Switch to Bike	-0.938	(1,056.629)
Less Preferred Temperature	Switch to Transit	0.339**	(0.165)
Transit Satisfaction	Switch to Bike	2.085	(4,780.815)
	Switch to Transit	-0.183	(0.708)
Δ Transit Satisfaction	Switch to Bike	-5.529	(3,563.015)
	Switch to Transit	0.563	(0.570)
Gender	Switch to Bike	-20.346	(12,488.690)
	Switch to Transit	2.492	(1.857)
Age	Switch to Bike	0.703	(609.036)
	Switch to Transit	-0.180**	(0.086)
Education	Switch to Bike	-1.243	(3,705.685)
	Switch to Transit	0.233	(0.222)
Household Income	Switch to Bike	-0.346	(1,409.190)
	Switch to Transit	-0.018	(0.102)
Δ Household Income	Switch to Bike	-0.006	(4,080.591)
	Switch to Transit	-1.419	(0.990)
Observations	51		
Log Likelihood	-15.083		
LR Test	51.148^{**} (df = 36)		

Note: *p<0.1; **p<0.05; ***p<0.01. This model was not included in Part 4 because of missing thermal comfort and crowding data in 2006.