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How does commuting behavior change due to incentives? An empirical study of the Beijing Subway System

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ABSTRACT

This study examines the impact of incentives on commuters' travel behavior based upon a questionnaire survey conducted with respect to the Beijing Subway System. Overall, we find that offering incentives to commuters, particularly fast food restaurant-related services and reduced ticket fares, has a positive influence on avoiding the morning rush hour. Furthermore, by using an interaction analysis, we discover that a flexible work schedule has an impact on commuters' behavior and the efficiency of the subway system. Finally, we recommend two possible policies to maximize the utility of the subway system and to reduce congestion at the peak of morning service: (1) a set of incentives that includes free wireless internet service with a coupon for breakfast and a discount on ticket fares before the morning peak and (2) the introduction of a flexible work schedule.

1. Introduction and background

As a result of rapid economic development and urbanization, transportation-related environmental problems—including congestion, pollution from automobile exhaust, and noise pollution—have plagued many large cities in China. According to the Chinese Academy of Social Sciences, the social costs incurred as a result of overcrowding in Beijing in 2010 amounted to 14.6 billion Yuan, which represents more than 1% of China's GDP (Zhang, 2006).

Subway systems are considered effective tools for mitigating and even remedying transportation-related environmental problems (Tang & Lo, 2008) and have been developed extensively in recent years in China (Jiang, 2008; Jong, Rui, Stead, Ma, & Xi, 2010). To encourage people to choose the subway over other means of transportation, such as automobiles, Beijing has set the price of traveling by subway at 2 Yuan per trip since November 7, 2007. The same price is charged regardless of the distance traveled or the number of transfers, and this price is lower than that in other cities in China. However, the affordable ticket has also resulted in significant crowds during rush hours. More than 30 stations in the Beijing Subway System have restricted passenger flows boarding trains to ensure safety and to leave enough space for the next stations. Consequently, dozens of commuters choose other ways to travel to their places of work so that they do not have to wait for a long time or take a crowded train.

The load rate of the trains is approximately 135%, which is the same as that of Sydney and Osaka. Excess demands on the transportation system and crowding on the platform staircases of subway stations create considerable negative externalities such as noise pollution, subway user safety, and psychological problems, such as commuting stress (Jiang, Deng, Hu, Ding, & Chow, 2009; Mahudin, Cox, & Griffiths, 2012; Mayeres, Ochelen, & Proost, 1996; Sposato, Röderer, & Cervinka, 2012).

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Although increasing the number of cars and expanding the subway network might enhance subway capacity, these solutions are limited because of the existing lines, the system's limited space, and technical limitations. In addition, such methods require extensive capital investment and time to accomplish after appropriate feasibility studies have been undertaken. There are cases in other cities that encourage commuters to take early subway trips, such as the Early Bird Ticket in Melbourne, Australia, that has been available since 2007 and the Breakfast-Exchange Certificate in Shenzhen, China, that was introduced in 2011. Under these policies, peak commuter flow has flattened to an extent. Thus, promoting off-peak commuting is considered a quicker method to address this problem and requires less investment.

Encouraging off-peak commuting might be considered a conversion of commuting time and behavior modification for a commuting individual. Some pricing mechanisms that have emerged in primary studies of managing peak demand for transportation are shown in Table 1; these mechanisms mostly involve stated preference (SP) experiments.

Money and other forms of rewards have been used as incentives to avoid rush hour travel (Ben-Elia & Ettema, 2011). Different levels and types of rewards have been applied, and behavior has been tracked with the latest detection equipment by Ben-Elia and Ettema (2011). Specific incentives (including those based on socio-demographic characteristics, scheduling constraints and flexible working hours), habitual behavior, attitudes toward commuting alternatives, the availability of tourist information, and even the weather have contributed to reducing traffic, encouraging travel during off-peak hours and increasing public transportation's stock. Several publications focus on the psychological models of decision making (Chen & Chao, 2011; Devarasetty, Burris, Arthur, McDonald, & Muñoz, 2014; Gardner & Abraham, 2008).

There are also services that have been provided as incentives, such as providing grocery stores and childcare near stations (Bhat & Sardesai, 2006). Bhat and Sardesai (2006) show four different travel modes in a form for each alternative part. Such services near a station are effective—to a limited extent—in encouraging commuters to choose railway for their travel.

These studies are based on the factors that affect a traveler's traffic time choices (see Fig. 1). Due to the complexity of these factors, several researchers have divided the factors into three categories: personal information, travel information and incentives (Bates, Polak, Jones, & Cook, 2001; Ben-Elia & Ettema, 2011; Bhat & Sardesai, 2006; Douglas & Karpouzis, 2006; Hollander, 2006; Whelan & Crockett, 2009). The same division will be used in this research.

Previous studies indicate that a shift in the departure time of commuters is frequently strongly influenced by the commuters' work schedule flexibility. A number of researchers have noted that a good approach might be to focus on the relationship between work schedule flexibility and traffic management (Brewer, 1998; D'Ariano et al., 2008; Saleh & Farrell, 2005). Therefore, we must determine whether commuters are using flexible time schedules and what role such flexibility might play in the choice of a time shift based on incentives. Additionally, as discussed previously, there are several studies that focus on the utility of monetary rewards (Ben-Elia & Ettema, 2011), time reliability (i.e., Hollander, 2006), and other types of incentives (i.e., Bhat & Sardesai, 2006).

However, these studies have rarely addressed combining the different types of incentives. Thus, it is hard to provide an easy prediction of which works best. Overall, we think that more people will want to take earlier subway trips and avoid the morning peak if they can benefit from several incentives. Meanwhile, the performance of each incentive might be different. For instance, commuters might be easily influenced by a commuting allowance with respect to a financial incentive and by saving time spent waiting for the train with respect to a time and congestion incentive. To date, there remains a lack of understanding and knowledge as to how these incentives can be grouped while taking into account their interdependence to form the best combination of policies to smooth the peak-hour rush. Therefore, the objective of this paper is to identify the mediating factors and the possible moderators.

The remainder of the paper is organized as follows: Section 2 explains the methodology and modeling of commuters' choice behavior; Section 3 describes the design of the pilot study and data collection procedures; Section 4 presents the results of the analyses; and Section 5 concludes with policy implications and directions for further research.

Table 1
Literature review.

Study	Incentive(s)	Mode	Location	Trip purpose	SP	Information shown in survey
Hollander (2006)	Time	Bus	UK	Commute	SP	Fare, preferred arrival time, travel time variation
Bates et al. (2001)	Time	Train	UK	n/a	RP/SP	Fare, scheduled departure time and arrival time, preferred arrival time
Bhat and Sardesai (2006)	Time and service	Multi-modes	US	Commute	SP	Fare, travel time variation, grocery store and child care near station
Douglas and Karpouzis (2006)	Congestion	Train	Australia	Commute mainly	SP	Seat (uncrowded or crowded) or stand for a number of minutes
Whelan and Crockett (2009)	Congestion	Train	UK	Commute, business, education, other	SP	Number of standing passengers and the proportion seated
Ben-Elia and Ettema (2011)	Financial	Car	Netherlands	Commute	SP	Reward of Money, Yeti (Mobile phone) of rush hour

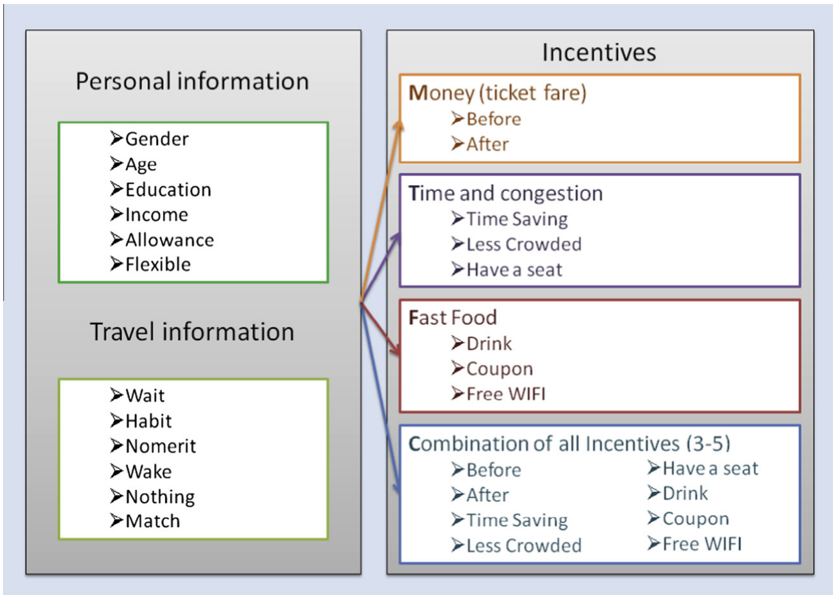

Fig. 1. Research framework.

2. Methodology and model

Our study examines a set of interrelated conservation practices in which it is likely that the decision to adopt one practice is correlated with other conservation-management decisions. Here, we examine M (Money, including ticket fare before 6:30 a.m. and ticket fare between 6:30 a.m. and 9:00 a.m.), T (Time and Congestion, including time saving, less crowded and with a seat), F (Fast Food Restaurant Service, including free drink, coupon for breakfast and free wireless internet or WIFI), and C (a combination of three types of incentives).

To determine the relationship between the different types of incentives and the most significant factors impacting commuters, we must build a model to make a quantitative analysis. Previous studies have utilized a multivariate probit model that aims to determine how people respond to congestion mitigation policies due to three travel-related strategy bundles (Choo & Mokhtarian, 2008), how environmental stringency influences the adoption of best management practice in agriculture in eight different cases (Kara, Ribaudo, & Johansson, 2008), and how interviewing impacts the domestic-violence reporting in three cases (Allen, 2009).

In our case, we estimate the following multivariate probit regression model for each commuter "*i*" choosing different incentives "*j*",

$$Y^*_{ij} = \beta'_j X_{ij} + \varepsilon_{ij}, \quad i = 1, \ldots, n; \quad j = M, T, F, C \tag{1}$$

$$Y_{ij} = 1 \ if \ Y^*_{ij} > 0 \ and \ Y_{ij} = 0 \ otherwise \tag{2}$$

Here, Y_{ij} is an unobserved variable representing the latent utility of each set of incentives (money, time and congestion, fast food restaurant service, and the combination of the foregoing). X is the matrix of independent variables hypothesized to be relevant factors (i.e., gender, age, income, education, allowance, flexible work schedule, duration of wait, and psychological factors influencing commuters' behavior, such as habits and attitude toward perceived benefits). β_j is a vector of unknown coefficients to be estimated. ε_{ij} denotes the error terms with multivariate normal distribution with a mean of 0 and a variance of 1.

We have four equations that are individual probit models with the same functional form and the same set of independent variables. The error terms of conservation practices are assumed to be related to one another. In this way, a multivariate probit model can be regarded as a system of four seemingly unrelated probit models.

The simulated maximum likelihood (SML) technique is used to estimate our model. As Greene (2002) emphasized, SML estimation has been used by an increasing number of studies (e.g., Belderbos, Carree, Diederen, Lokshin, & Veugelers, 2004; Cooper, 2001). Following Cappellari and Jenkins (2003), our multivariate probit models are estimated using the Geweke–Hajivassiliou–Keane (GHK) simulator in Stata. Four-dimensional normal probability distribution functions are simulated to evaluate multivariate probit likelihood functions. Multivariate normal probabilities are calculated after several iteration steps of the simulation using the GHK simulator. As with the maximum likelihood estimator, the SML estimator is asymptotically consistent. Simulation bias will be minimized as the number of observations and the numbers of random draws increase (Cappellari & Jenkins, 2003).

3. Data

We utilized an Internet-based method to conduct this experiment with random sampling. The data can be entered through the questionnaire survey website and the link posted on other subway-related sites and forums. A total of 742 valid samples were collected from 2099 website views from February to May 2012. The collection rate was 35.35%. Additionally, 689 out of the 742 persons who depart after 6:30 a.m. provided valid responses for analysis in this research.

By conducting field research via the questionnaire survey, we have collected three types of information from commuters: (1) personal information, (2) time information, and (3) incentives. The objective of the first part is to obtain personal information from commuters such as gender, age, annual income, commuting allowance, and schedule flexibility.

The second part includes travel time information and the reasons for not taking earlier subway trains. The respondents were asked about the times at which they begin work, wake up, arrive at the departure station, board the train, and arrive at their workplace. They would be divided into two groups based on whether they get on the train before 6:30 a.m. Based on the actual situation in Beijing, most commuters take the subway after this time. Only those who board the train after 6:30 a.m. would be asked to answer the multiple choice question about why they do not take an earlier train, with the following possible responses: hate to get up earlier, have nothing to do if arriving at their workplace too early, no buses or subways if departing too early, and needing to coordinate with other family members. These answers would be listed as alternatives to provide a proof of travel-time-shifting behavior.

The last part involves incentives, which is the core of this research. There are cases in other cities that encourage commuters to take early subway trains, such as the Early Bird Ticket in Melbourne and the Breakfast-Exchange Certificate in Shenzhen. According to prior research—and based on the specific conditions in Beijing—four incentives will be offered in this survey.

Asking too many questions might bore respondents and make them answer questions at random; therefore, we put respondents into four groups to obtain more accurate results. We define several sectors in each type of incentive. Table 2 shows the description of each incentive sector for M, T, F, and C.

As of December 30, 2011, there are 36 passenger-flow-limited stations out of 172 total stations in Beijing. Most of the limited time is between 7:00 a.m. and 9:00 a.m. Although commuting at peak time includes departure before and after peak time (Ben-Elia & Ettema, 2011), it is difficult to arrive at a work place later without a flexible working system. Thus, respondents who get on the train after 6:30 a.m. would be asked in this research if they want to take the subway to work before 6:30 a.m. Meanwhile, the incentives of money and services would last until 9:00 a.m.

Tables 3 and 4 show the descriptive statistics on personal information, travel information and incentive choices. More than half the respondents consider the most difficult thing for them in taking earlier trains to be that they dislike getting up earlier. The fewest people believe it is simply difficult for them to change their habits. In general, more people want to take earlier subways to avoid the morning peak if they receive incentives.

Case M is defined as the differentiation of ticket fare for off-peak and peak trains. The ticket fare can affect ridership (Chen, Chen, & Barry, 2009; Voith, 1997). Because the subway ticket fare is relatively low in Beijing (2 Yuan), we will discuss the effect of an increase in fare, examining whether such an increase will encourage more commuters to use the subway or not. From the perspective of price elasticity, if we decrease the price by 1/2 or increase it to 2 or 3 times the original price, it will be easier to determine the influence of the ticket price on commuters making transportation choices.

There are two sides of the T case: the time spent waiting for trains and the reduced train congestion. Time is valuable to commuters (Douglas & Karpouzis, 2006; Whelan & Crockett, 2009). One of the most significant advantages of the subway

Table 2
Description of each incentive sector in case M, T, F, and C.

Variable name	Description
mafter_bef	It is more attractive to change ticket fare after 6:30 than before 6:30 in case M (mafter_bef = 1)
ttime_cro	It is more attractive to save time than lessen overcrowding in case T (ttime_cro = 1)
tcrowd_seat	It is more attractive to take a seat than lessen overcrowding only in case T (tcrowd_tseat = 1)
fdrink_coupon	It is more attractive to offer free drink with coupon in case F (fdrink_coupon = 1)
fWIFI_coupon	It is more attractive to offer free WIFI with coupon in case F (fWIFI_coupon = 1)
cafter_bef	It is more attractive to change ticket fare after 6:30 than before 6:30 in case C (cafter_bef = 1)
ccrowd_seat	It is more attractive to take a seat than lessen overcrowding only in case C (ccrowd_tseat = 1)
fdrink_coupon	It is more attractive to offer free drink with coupon in case F (fdrink_coupon = 1)
cWIFI_coupon	It is more attractive to offer free WIFI with coupon in case C (cWIFI_coupon = 1)

Table 3
Descriptive statistics on personal information, travel information.

Variable	Description	Sample/mean	Proportion/SD
Personal information			
Gender	Male (gender = 1)	390	57%
	Female (gender = 0)	299	43%
Age	Age	34.73	8.08
Income	Annual income	65809.87	34155.98
Education	Under college	202	29%
	College	186	27%
	Bachelor	205	30%
	Over bachelor	96	14%
Allowance	Have (allowance = 1)	108	16%
	Not have (allowance = 0)	581	84%
Flexible	Flexible work schedule (flexible = 1)	70	10%
	Fixed work schedule (flexible = 0)	619	90%
Travel information			
Wait	Time waiting for the train	8.23	3.57
Habit	I find it is difficult for me to change my habit (Yes = 1)	62	9%
	I find it is difficult for me to change my habit (No = 0)	627	91%
Nomerit	No merits even if getting up earlier (Yes = 1)	76	11%
	No merits even if getting up earlier (No = 0)	613	89%
Wake	Hate to get up earlier (Yes = 1)	352	51%
	Hate to get up earlier (No = 0)	337	49%
Nothing	Closed or have nothing to do if arrived too early (Yes = 1)	148	21%
	Closed or have nothing to do if arrived too early (No = 0)	541	79%
Match	Need to consider of other family members' time (Yes = 1)	171	25%
	Need to consider of other family members' time (No = 0)	518	75%

Table 4
Descriptive statistics on incentive sectors.

Variable	Description	Sample	Proportion (%)
Incentive sectors			
M	Change depart time in Money case ($m = 1$)	404	59
	Not change in Money case ($m = 0$)	285	41
T	Change depart time in Time and Congestion case ($t = 1$)	303	44
	Not change in Time and Congestion case ($t = 0$)	386	56
F	Change depart time in Fast Food Restaurant Service case ($f = 1$)	439	64
	Not change in Fast Food Restaurant Service case ($f = 0$)	250	36
C	Change depart time in Combination of all Incentives ($c = 1$)	420	61
	Not change in Combination of all Incentives case ($c = 0$)	269	39

system is time reliability. Currently, passengers at the passenger-flow-limited stations must wait a long time for their trains. Guaranteeing a shorter waiting time for trains during off-peak hours might serve as another incentive for them to commute earlier.

Crowding is typically accepted as a possible threat to the health of both the rail industry and the passengers (Cox, Houdmont, & Griffiths, 2006). Cases can be found in which passengers are willing to pay more in exchange for less congestion and greater comfort while traveling (Bates et al., 2001; Bhat & Sardesai, 2006; Hollander, 2006).

Case F focuses on fast food restaurant service at the arrival station. Adapting from the case in Shenzhen, it might be helpful to cooperate with fast food restaurants to offer special service to those who depart before peak time near the subway stations in Beijing. In this research, they can receive a free drink, a coupon for breakfast (only available for this particular morning) and free WIFI until 9 a.m.

Case C analyzes the combination of all incentives. In this case, we choose four or five incentives and make the strength of all of the choices similar to respondents by adjusting their levels (such as 30%, 50%, and 70% of the coupon discount).

In this study, each respondent would be asked to answer four difficult cases (Money, Time and Congestion, Fast Food Restaurant Service and Combination of all incentives). Respondents must answer whether they would change their time of day for commuting based on each question.

Commuters who are taking the subway to their workplace are the targets of this research. Because the network of the Beijing Subway System is not extremely large and it is difficult to smooth passenger flows by only focusing on a few stations or one line, the questionnaires were set to include all of the stations of the Beijing Subway System.

Table 5
Multivariate probit analysis of each case: no interactions.

	Money		Time and congestion		Fast food restaurant		Combination	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Personal information								
Gender	−0.012	0.107	0.211	0.101**	0.412	0.099***	0.424	0.100***
Age	0.032	0.008***	0.006	0.007	0.027	0.007***	0.019	0.007***
Income	5E−6	2E−6**	−3E−6	2E−6	3E−7	2E−6	−1E−6	2E−6
Education	−0.260	0.065***	−0.125	0.065*	−0.045	0.060	−0.112	0.062*
Allowance	−0.413	0.150***	0.025	0.144	−0.159	0.138	−0.480	0.140***
Flexible	−0.784	0.180***	−0.485	0.187***	−0.326	0.173*	−0.543	0.172***
Travel information								
Wait	0.040	0.015***	−0.019	0.015	0.016	0.015	0.026	0.015*
Habit	−0.241	0.200	−0.342	0.189*	−0.580	0.180***	−0.270	0.179
Nomerit	0.639	0.192***	0.268	0.162*	0.449	0.176**	0.425	0.176**
Wake	−0.119	0.123	−0.015	0.119	0.259	0.121**	0.170	0.117
Nothing	0.007	0.141	0.584	0.137***	0.359	0.140***	−0.077	0.134
Match	0.247	0.140*	0.442	0.132***	0.638	0.143***	0.228	0.134*
Incentive sectors								
mafter_bef (cafter_bef)	−0.709	0.110***	–	–	–	–	−0.159	0.146
ttime_cro	–	–	–	−0.054	0.117		–	–
tcrowd_seat (ccrowd_seat)	–	–	–	0.059	0.145	–	0.356	0.146**
fdrink_coupon	–	–	–	–	−0.191	0.128	–	–
fWIFI_coupon (cWIFI_coupon)	–	–	–	–	0.379	0.117***	0.446	0.204**
ρ_{21}					0.224***			
ρ_{31}					0.577***			
ρ_{41}					0.495***			
ρ_{32}					0.615***			
ρ_{42}					0.419***			
ρ_{43}					0.655***			

* Statistical significance at the 10% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

4. Results and discussion

Table 5 shows the estimation results. Basically, the older male subjects with less education are easily influenced by the incentives. The coefficient of allowance is negative and significant in cases M and C. This result implies that Commuter departure time is hard to shift in cases M and C because commuters might receive commuting allowances from their workplace. People with a flexible time schedule are not attracted by such incentives more than any other; thus, they believe they receive few benefits from this shifting. Additionally, C is more effective for commuters to shift their departure time than T if they take a seat because coefficient of ccrowd_seat is significantly positive even though coefficient of tcrowd_seat is not significant.

From Table 4, we find that the preference is for incentive group F (64%) > C (61%) > M (59%) > T (44%); commuters prefer fast food restaurant service rather than other services. Case F is so attractive that commuters prefer it to the combination case that makes the fast food restaurant less significant and the other types of incentive more substantial. With today's faster pace of life, a growing number of Chinese people eat their breakfast out instead of at home. There are many different breakfast carts and restaurants that offer fast food in the morning in Beijing. Thus, offering a set of fast food restaurant services is an effective incentive.

Money-related incentives always become an important factor for people's activity (Ben-Elia & Ettema, 2011); however, this effect is not so obvious in Beijing because the ticket fare in Beijing is relatively low compared with that of other cities. Thus, even increasing the ticket fare to three times its original price is not a sizeable expenditure for dozens of commuters. The time and congestion case alone is preferred by less than half of the respondents. Although it is time consuming to wait for the train at the station, commuters still know the total time it should take to arrive at their workplace. In addition, because the average wait time for a train is not particularly long at 8.23 min (see Table 3), commuters do not seem to mind the wait. As a high-capacity mode of transportation, a subway system is built for substantial passenger flows. Thus, commuters frequently do not expect that they will be comfortable in most cities in the world.

The variables "mafter_bef" and "cafter_bef" stand for whether it is more attractive to change ticket fares after 6:30 a.m. rather than before 6:30 a.m. for cases M and C (with similar notation for all cases hereafter). From the coefficient number and

p-value, we know that it is not more attractive to change the ticket fare after 6:30 a.m. (until 9:00 a.m.) than before 6:30 a.m. in case M, but there is no clear connection in case C. It is generally understood that the ticket fare in Beijing is too low to make the market mechanism work smoothly, and our results do not suggest that increasing the ticket fare during the morning peak (from 6:30 to 9:00 a.m.) is a good method. At first, our results indicate that people are more motivated in this study when rewarded rather than punished. Moreover, some passengers might decide to use a different mode of transportation for commuting instead of taking an earlier subway trip, which would be a negative result for morning transportation.

The relationship between waiting time and reducing overcrowding is not significant in case T. A decrease in the waiting time and the degree of crowdedness might be considered contradictory factors. If people want to save time waiting for the train, they must share the train with more people during the morning peak. In this study, neither of these factors gains preference; this type of time-shifting incentive is not attractive to commuters.

It is more effective to assure a seat for commuters than to reduce overcrowding in the train for case C, but there is no clear connection for case T. On the other hand, commuters are attracted by having a seat rather than by reducing overcrowding only. People do not consider a seat an important factor for changing time and congestion only, but they do in the combination case that includes all incentives. When taking trains, having a seat can make passengers feel much better and more comfortable than reducing overcrowding only (Cox et al., 2006). However, it is somewhat difficult for the Beijing Subway System to provide this service by shortening the start interval or by designating a particular train car with a special ticket (such as the "Green Car" in Japan) because of the limited number of train cars.

Table 6
Multivariate probit analysis of each case: interactions based on flexibility.

	Money		Time and congestion		Fast food restaurant		Combination	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Personal information								
Gender	−0.008	0.108	0.246	0.103**	0.439	0.101***	0.438	0.101***
Age	0.031	0.008***	0.005	0.007	0.028	0.007***	0.019	0.007***
Income	5E−6	2E−6**	−3E−6	2E−6	6E−7	2E−6	−8E−7	2E−6
Education	−0.277	0.066***	−0.135	0.066**	−0.052	0.062	−0.120	0.062*
Allowance	−0.436	0.156***	0.009	0.150	−0.252	0.143*	−0.537	0.144***
Flexible	0.290	0.475	−0.301	0.613	0.952	0.478**	−0.150	0.467
Travel information (no interactions)								
Wait	0.053	0.017***	−0.009	0.016	0.021	0.016	0.030	0.016*
Habit	−0.106	0.223	−0.513	0.214**	−0.535	0.205***	−0.390	0.200*
Nomerit	0.737	0.228***	0.311	0.181*	0.833	0.223***	0.515	0.201***
Wake	−0.048	0.135	−0.101	0.126	0.410	0.138***	0.194	0.126
Nothing	0.029	0.157	0.606	0.147***	0.516	0.162***	−0.088	0.145
Match	0.257	0.147*	0.361	0.138***	0.674	0.156***	0.193	0.139
Travel information (interactions with flexible)								
flx_wait	−0.083	0.044*	−0.139	0.060**	−0.072	0.045	−0.046	0.042
flx_habit	−0.622	0.586	0.959	0.522*	0.209	0.459	0.828	0.446**
flx_nomerit	−0.619	0.447	−0.867	0.530	−1.581	0.448***	−0.581	0.418
flx_wake	−0.475	0.378	1.065	0.463**	−0.676	0.379*	−0.319	0.352
flx_nothing	0.086	0.408	−0.079	0.451	−0.403	0.422	0.284	0.390
flx_match	0.574	0.568	1.379	0.730	3.509	83.773	0.853	0.588
Incentive sectors								
mafter_bef (cafter_bef)	−0.707	0.111***	–	–	–	–	−0.137	0.147
ttime_cro	–	–	−0.019	0.118	–	–	–	–
tcrowd_seat (ccrowd_seat)	–	–	0.025	0.147	–	–	0.356	0.147**
fdrink_coupon	–	–	–	–	−0.176	0.130	–	–
fWIFI_coupon (cWIFI_coupon)	–	–	–	–	0.452	0.120***	0.434	0.205**
ρ_{21}					0.223***			
ρ_{31}					0.572***			
ρ_{41}					0.490***			
ρ_{32}					0.629***			
ρ_{42}					0.419***			
ρ_{43}					0.650***			

* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.

We cannot see an obvious difference between offering a free drink with a coupon and giving only a coupon for case F. A small free drink is not attractive for commuters. Although people can rest easily in the restaurant after getting a free drink until they go to work, they still do not have enough to do there.

Providing free WIFI with a coupon creates a good effect for both case F and case C. Since 2011, free WIFI has no longer been offered in fast food restaurants in Beijing. Therefore, free WIFI is one of the most attractive incentives for commuters to shift their departure time. This incentive is similar to a lounge for commuters not only to have breakfast but also to relax for a moment. Thus, WIFI is an attractive incentive for both the fast food and the combination cases.

The ρ value shows the relationship between two incentives. For example, if ρ_{ab} is negative, it indicates that people who choose "a" will hardly choose "b". Table 5 shows that there are no conflicts among all incentives (all are positive). The weakest relationship is between the money case and the time and congestion case, whereas the strongest is between the fast food restaurant case and the combination case.

It has been noted that a shift in the departure time of a commuter is often strongly influenced by whether a commuter has a flexible work schedule. Some results are not sufficiently explained without considering the effect of flexibility. Therefore, a new scenario has been conducted in this study by putting interaction variables based on flexibility into the model (see Table 6).

We had predicted that commuters are easily affected by the time spent waiting for the train in the time and congestion case before conducting the questionnaire. However, from the no-interaction results, the time spent waiting for trains is not a significant motivator for commuters to shift their departure time. In contrast to the interaction results, commuters that have a flexible schedule are easily impacted by this factor. A reasonable explanation for the negative value is that commuters using flexible work time schedules have previously chosen an appropriate travel time to avoid the peak. If they still have to wait for a long time for the train at that moment, it is likely that they are less able to change their time schedule. Thus, the more time they typically wait, the less the incentive works. This is not simply a reasonable interpretation of this issue; it also shows that making their work schedules flexible may lead commuters to avoid the morning peak altogether to shorten the time spent waiting for trains.

On the questionnaire, respondents were asked to choose yes or no based on whether they think it is difficult to take an earlier train because there are no benefits to doing so. Under the no-interaction condition, most people believe it is an important factor for them. However, under the interaction condition, people with a flexible work schedule do not consider the lack of benefits when making a choice because they can start and finish their work earlier without any loss.

Similarly, this reasoning has a divided effect on whether commuters must coordinate their morning schedule with other family members' time. Commuters with a flexible work schedule can coordinate with their family members' time far more easily.

5. Concluding remarks

In this study, we examined the impact of a variety of incentives on commuters' travel behavior based on an empirical analysis of the Beijing Subway System during the morning peak. Although each incentive is different, we find that these incentives have a relatively positive impact on avoiding the morning rush hour. Furthermore, we find that a flexible work schedule has a significant impact on commuters' behavior, as shown by an interaction analysis.

We already know that the subway system is an effective way to solve certain overcrowding and transportation-related environmental problems. Nevertheless, simply expanding the system but not considering the supporting policies may tend to yield an unsatisfactory result. To achieve the goal of maximizing utility on the subway system and to smooth congestion during the morning peak, we make the following policy recommendations.

First, free WIFI with a coupon and a discount on the ticket fare might be an attractive set of incentives to commuters. From the results of this study, giving incentives such as a coupon, free WIFI and a discount on ticket fare is a good way to encourage Beijing commuters to shift their departure times. Because the necessary resources might not be sufficient, the coupon and free WIFI could be offered in a limited quantity to earlier users, depending on the scale of the station and the availability of fast food restaurants.

Second, the introduction of a flexible work schedule might be another approach to solve this problem. Commuting is strongly impacted by the commuter's flexibility. By introducing a flexible system, the subway system might become more efficient. Incentives and flexibility are two different ways to solve the same problem of the morning peak in the Beijing subway. Therefore, it may be a good strategy to consider a set of policies that incorporate these two options.

Appendix A

Questionnaire Survey (Group 1, Brief Version)

1Your Gender ① M ② F

2Your Age ___________

3 Your Occupation ① Government and institution personnel ② Business management personnel

③ Project management personnel ④ Enterprise staff

⑤ Worker ⑥ Freelancer

⑦ Other___________

4 Your Education Background ① Under College ② College ③ Bachelor ④ Over Bachelor

5 Your Annual Income ___________

6 Does your workplace provide commuting allowance? ① Yes ② No

7 Does your workplace use flexible work schedule? ① Yes ② No

8 Name of departure station _________; Name of arrival station_________

9 Please write down the time you…

Begin to work	Get up	Arrive at subway station	Get on train	Arrive at workplace
Number of days you work every week	Number of days you commute by the schedule	Are the two days above accordance?		
1 2 3 4 5 6 7 Not fixed	1 2 3 4 5 6 7 Not fixed	Yes No, using cars No, taking buses No, riding bike or walking No, different schedule in different days No, not regularly No, other_____________		

10 Your reason for not taking earlier subways (Please choose all that apply)

① I find it is difficult for me to change my habit ② No benefits even if getting up earlier ③ Hate to get up earlier

④ Workplace is closed or have nothing to do if arrived at workplace too early ⑤ No earlier bus or subway available

⑥ Need to take into account of other family members ⑦ Other ____________

11 Please indicate whether you will take subway before 6:30 am in each of the following cases. ① Yes ② No

Code	Ticket fare before 6:30	Ticket fare from 6:30 to 9:00	Time of Waiting for train	Congestion	Free drink from fast food restaurant (FFR)	Coupon for breakfast that morning in FFR	Free WIFI until 9:00 in FFR	Yes or No
T2222000	￥2	￥2	50% Saving	Have a seat	No	No	No	
C2400051	￥2	￥4	No	No	No	50% discount	Yes	
M2600000	￥2	￥6	No	No	No	No	No	
F2200130	￥2	￥2	No	No	100 ml	70% discount	No	

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