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# Road traffic congestion measurement considering impacts on travelers

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**Abstract** The article intends to find a method to quantify traffic congestion's impacts on travelers to help transportation planners and policy decision makers well understand congestion situations. Three new congestion indicators, including transportation environment satisfaction (TES), travel time satisfaction (TTS), and traffic congestion frequency and feeling (TCFF), are defined to estimate urban traffic congestion based on travelers' feelings. Data of travelers' attitude about congestion and trip information were collected from a survey in Shanghai, China. Based on the survey data, we estimated the value of the three indicators. Then, the principal components analysis was used to derive a small number of linear combinations of a set of variables to estimate the whole congestion status. A linear regression model was used to find out the significant variables which impact respondents' feelings. Two ordered logit models were used to select significant variables of TES and TTS. Attitudinal factor variables were also used in these models. The results show that attitudinal factor variables and cluster category variables are as important as sociodemographic variables in the models. Using the three congestion indicators, the government can collect travelers' feeling about traffic congestion and estimate the transportation policy that might be applied to cope with traffic congestion.

**Keywords** Traffic congestion indicator · Attitudinal factor variable · Linear regression model · Ordered logit model

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## 1 Introduction

Traffic congestion is one of the worst problems in China, especially in those metropolises, such as Shanghai, Beijing, and Shenzhen. After long-time struggling with traffic congestion, most of researchers realize it is not easy to eliminate congestion but it is possible to relieve it. A number of traffic congestion studies [1–3] focused on improving transportation system but not transportation users' feelings. Presently, more and more researchers [4, 5] realize that it is not enough to just study transportation system capacity, and transportation users' feelings and reactions are also important to decide how to relieve traffic congestion. It is an important point to know transportation users' feelings and reactions about urban road traffic congestion, which can help decision makers to make more efficient and useful policies and strategies. A method should be found to quantify traffic congestion's impacts on travelers to help transportation planners and policy decision makers well understand congestion situations standing on travelers' side. Some prior studies [6, 7] revealed that traffic conditions especially traffic congestion may impact people's travel-related decisions and behaviors.

Under this background, we study the traffic congestion impacts on travelers and their reactions to congestion. A random sampling survey was taken in Shanghai, China during August 1st to August 31st in 2009 to collect data for this research, including transportation users' attitudes about road traffic congestion, baseline transportation characteristics of transportation users, their reactions to traffic congestion and sociodemographics. Totally, 274 valid samples were collected, covering most of districts of Shanghai.

In order to quantify traffic congestion impacts, we found a way to evaluate the service level of transportation system. It is a hotspot to study traffic congestion relieving policies in China. Most of these studies focus on seeking sources of congestion and qualitative analysis of policies to relieve congestion. However, study on quantitative indicators for congestion impacts is as important as study on congestion-estimating policies. Study of traffic congestion impacts on travelers and their reactions can provide some supports for setting the target of urban transportation system service level, also for choosing congestion policies.

Three travelers' feeling indicators, namely, transportation environment satisfaction (TES), traffic congestion feeling and frequency (TCFF), and travel time satisfaction (TTS) were selected to quantify congestion impacts on travelers. The "likert-type scale" is used to get data of TES and TTS. A series of questions were asked to get the information of travelers' feelings and the frequency they suffer congestion in a typical month about 9 traffic congestion situations which were designed based on previous studies and our hypothesis. A merged indicator was created based on both travelers' feelings and frequency they met from the nine congestion situations using factor analysis. Ordered logit models and linear regressive model were set up to analyze impact factors of the three indicators, respectively.

The remainder of the article is organized as follows. Section 2 briefly reviews previous related research. Section 3 describes the data collection and survey contents in this study. Then Sect. 4 presents the reason for select the three traffic congestion indicators and their values in Shanghai, China. Models were built to analyze the impact factors of each indicator in Sect. 5. Finally, Sect. 6 summarizes the study and suggests future research directions.

## 2 Literature review

Definitions of traffic congestion could differ with different organizations and purposes. The Federal Highway Administration [8] defines traffic congestion as "the level at which transportation system performance is no longer acceptable due to traffic interference." They also state that "the level of system performance may vary by type of transportation facility, geographic location (metropolitan area or sub-area, rural area), and/or time of day." The regional council of governments in Tulsa, Oklahoma [1] defines congestion as "travel time or delay in excess of that normally incurred under light or free-flow travel conditions." In Minnesota [8], when the traffic speed is below 45 mph in peak hours, freeway congestion could be defined. Michigan also defines freeway congestion using level of service.

By user expectation, "unacceptable congestion" was defined using travel time in excess of an agreed-upon norm, which might vary by type of transportation facility, travel mode, geographic location, and time of day. Lomax et al. [9] realized that "A key aspect of a congestion management strategy is identifying the level of 'acceptable' congestion and developing plans and programs to achieve that target." Pisarski [10] used the U.S. Census data to conduct the commuting patterns, and defined the unacceptable congestion as "if less than half of the population can commute to work in less than 20 min or if more than 10 % of the population can commute to work in more than 60 min." The Metropolitan Washington Council of Governments [11] developed a "user satisfaction" transportation system performance measure based on acceptable travel time and delay. The measure incorporated a set of curves that show the percentage of users satisfied for a given trip length and time.

Some more studies about traffic congestion indicators are listed in Table 1. In those studies, we can find that most of traffic congestion indicators are focused on transportation capacity, travel time, delay, travel speed, et al., which could be classified as transportation system performance indicators. A few indicators are based on user expectation and satisfaction, which concern users' acceptable travel time or delay.

Attitude data analysis in travel behavior researches were started from 1970s, and became more popular ever since [12]. Attitudinal surveys provide a means for measuring the importance of qualitative factors in travel behavior. Factor analysis was often used to collapse the questions into a smaller set of factors as explanatory variables in travel behavioral models [13]. A significant amount of studies used factor analysis, cluster analysis, and discrete model to study traveler's behavior under specific situations or policies. Redmond [14] used factor analysis to identify the fundamental dimensions of attitude, personality, and lifestyle characteristics; then used cluster analysis to group respondents with similar profiles. Mokhtarian [15] used the discrete model to describe the choice of increasing transit use during the Fix I-5 project. She also used the discrete model to estimate the preference to telecommute from home [16]. Factor analysis is performed on two groups of attitudinal questions, identifying a total of 17 factors in that article.

## 3 Data collection and survey

### 3.1 Data collection

A random sampling household survey was taken in Shanghai during August 1st to August 31st in 2009 to collect data for this research. The data were collected from

**Table 1** Traffic congestion indicators in different research

| Author/ organization | Years | Purpose | Indicators | Note |
|---|---|---|---|---|
| Texas transportation institute [11] | 2007 | Used in both the public and private sectors as a means of communicating the congestion trends in the larger U.S. urban areas | Roadway congestion index (RCI) | The RCI is an empirically derived formula that combines the indicator of urban area daily vehicle kilometers of travel (DVKT) per lane of roadway for both freeways and principal arterial streets |
| Chicago's freeway management system [11] | 1996 | Quantify freeway congestion | Lane occupancy rates | Using lane occupancy rates requires the installation of a freeway detector network |
| The metropolitan Washington council of governments [11] | 1996 | Measure transportation system performance based on acceptable travel time and delay | User satisfaction | The measure incorporates a set of curves that show the percentage of users satisfied for a given trip length and time |
| Herbertlevinson, timothyj. lomax [11] | 1996 | Consistent with the myriad analytical requirements | Delay rate index (DRI) | DRI combines the beneficial effects of using travel time and speed data with the ability to relate congestion and mobility information |
| Highway capacity manual [9, 11] | 1985 | Reflect traffic volume counts and peaking, roadway characteristics, and traffic signal timing | Level-of-service (LOS) | The LOS is defined in terms of density for freeways, average stopped delay for intersections, and average speed for arterials |
| Department of Transportation in UK [17] | 2001 | To well understand congestion and cope with it | Extra time taken compared with free-flow time risk of serious delay average speed on different road types amount of Time stationaryor less than 10 mph | Four measures people would find most helpful to measure congestion by publish information |
| The federal highway administration (FHWA) [3, 8] | 2005 | To measure travel time in a mobility monitoring program | Travel time index average duration of congested travel per day (hours) buffer index | They are trying to answer a mobility question: "how easy is it to move around?" and a reliability question": how much does the ease of movement vary?" |

a mixed internet-based survey and mail survey in Shanghai. We sent 15,000 letters by mails to invite people taking part into the survey, and the survey website link was provided in the letter for those who were willing to attend the survey by internet. We also provided four ways for people to ask for the paper questionnaires: our survey service phone number, email address, text message to cell phone, and mail back the postcard which is paid by us. Totally, 274 valid samples were collected, covering most of districts of Shanghai, including 233 internet-based respondents and 21 paper questionnaire-based respondents.

Table 2 presents the sample statistics for some selected characteristics. A majority of the respondents (59 %) are less than 40 years old; 79 % respondents' education level is higher than high school graduate; company employees form the largest part in whole respondents, the proportion is 45 %; more respondents (34.4 %) have an annual income of 60,000–119,999 Yuan.

### 3.2 Survey contents

There are six parts in the survey:

Part *A* collects respondents' characteristics and attitudes, including satisfaction about current life, the city and neighborhood, the transportation system, personal characteristics, and general attitudinal statements.

Part *B* offers attitudinal statements to seek transportation-related attitudes under the traffic congestion.

Part *C* collects the information about most frequent trips of respondents, including trip purpose, travel mode, trip OD, departure time, frequency, and feeling about different traffic congestion statements.

Part *D* collects the general trip information of respondents, including trip purpose, travel mode, and total travel time per week.

Part *E* explores the active choices and reactions to traffic congestion.

**Table 2** Selected characteristics of the sample

| Characteristic | Number of cases | Percentage (%) | Sample sizes |
|---|---|---|---|
| Number of females | 133 | 48.9 | 272 |
| Age group | | | |
| 16–20 years old | 29 | 10.7 | 272 |
| 21–30 years old | 106 | 39.0 | |
| 31–40 years old | 54 | 20.0 | |
| 41–50 years old | 33 | 12.1 | |
| >50 years old | 50 | 18.4 | |
| Education background | | | |
| Doctoral degree | 7 | 2.6 | 274 |
| Master's degree | 23 | 8.4 | |
| Four-year college, university, or technical school graduate | 115 | 42.0 | |
| Some college or technical school | 71 | 25.9 | |
| High school graduate | 29 | 10.6 | |
| Some grade or high school | 18 | 6.6 | |
| Other | 11 | 4.0 | |
| Occupation | | | |
| Officer | 28 | 10.2 | 274 |
| Company employee | 123 | 44.9 | |
| Student | 44 | 16.1 | |
| Business man | 6 | 2.2 | |
| Teacher | 14 | 5.1 | |
| Retiree | 30 | 10.9 | |
| Production/construction/crafts | 16 | 5.8 | |
| Other | 13 | 4.8 | |
| Annual household income | | | |
| Less than 24,999 yuan | 32 | 11.7 | 273 |
| 25,000–59,999 yuan | 76 | 27.8 | |
| 60,000–119,999 yuan | 94 | 34.4 | |
| 120,000–249,999 yuan | 59 | 21.6 | |
| 250,000–399,999 yuan | 8 | 2.9 | |
| 400,000–599,999 yuan | 1 | 0.4 | |
| 600,000 yuan or more | 3 | 1.1 | |

Part *F* collects information on sociodemographic characteristics, including age, gender, income, occupation, and education.

## 4 Road traffic congestion indicators based on the impacts by travelers

### 4.1 Road traffic congestion indicators selection

Based on previous studies [9, 18] and our hypothesis, three traffic congestion indicators based on the impacts by travelers were created in this article. They are

(1) TES. This indicator presents people's satisfaction of total transportation environment, not only for evaluating traffic congestion. However, we can set it as an indicator to show situations at the macro-level about transportation system.

(2) TCFF. It is a new indicator created by the author to present travelers' feelings of different traffic congestion situations by considering both frequency of congestion happening and travelers' feelings about the congestion. In our survey, we designed nine congestion situations[1] to present congestions in our daily life. TCFF integrated these 9 situations.

(3) TTS. It is a popular indicator in some previous studies based on traveler's feelings. In our survey, we also asked a question for traveler's satisfaction of their travel time. This indicator was also used to present travelers' particular feelings of travel time.

### 4.2 The value of congestion indicators in Shanghai, China

A question was asked in our survey about the TES: "How satisfied do you feel with your current life,…, and the transportation system?" One statement is "Travel environment in the city." The options are "Not satisfied at all," "Not satisfied," "Slightly satisfied," "Moderately satisfied," and "Extremely satisfied." About 30 % respondents presented their dissatisfaction of transportation environment, and 24 % respondents felt satisfied. The following question was asked about the TTS: "Are you satisfied with your usual travel time for your most frequent trips?" The options are the same as the former one. The information of travelers' most frequent trips were required. The most frequent trips could be a trip from home to work (or work to home), or a non-work trip, but it should always have the same trip purpose and the same (single) origin and destination. The reason to ask for the most frequent trips information is that, we want to get more exact information like departure time, trip origin, and destination for a special trip which will not change by different purpose or trip distance. And the most frequent trip will be the most familiar trip in travelers' daily trips which impact them most. For this question, about 20 % respondents report that

[1] 9 congestion situations: (a) You are delayed about 30 min because of traffic congestion; (b) The traffic you are in basically stops for more than 5 min because of traffic congestion; (c) The traffic you are in always stops but restarts soon; (d) Your speed is slower than a bicycle; (e) Although you can move smoothly, the road is full of vehicles and people; (f) The trip takes longer than you expected; (g) It takes at least two green lights before you can get through the intersection; (h) You can't estimate travel time because of traffic congestion; (i) You are stacked behind people who are slower than you like.

they are satisfied or unsatisfied with their travel time for the most frequent trips, respectively.

TCFF is a new indicator which was not designed directly in the questionnaire. Instead, we set a series of situations (see the footnote on the last page) to describe traffic congestion, and ask for the frequency respondents meet the similar situation in a typical month, and how it makes them feel. Even if a certain event never happens, the respondent would be also asked to image the feeling. The statistical results indicate that most respondents (76.2 %) feel moderately bad or extremely bad when they are delayed about 30 min because of traffic congestion, which is consistent with the previous study results of Al-Mosaind [19]. However, in Shanghai, 14.3 % of respondents indicate that they meet this kind of situation more than once a week in a typical month. The situations that the speed is slower than a bicycle and cannot estimate travel time because of traffic congestion are the following two events which make respondents feel moderately bad or extremely bad, about 67.5 % and 66.7 % respectively. 24 % and 26 % of respondents said that they meet these two situations more than once a week in a typical month. The frequencies of the situations such as that taking at least two green lights to get through the intersection, being stacked by slower people, and travel time being longer than expected occur more often than other situations. More than 40 % of respondents suffered these three situations more than once a week in a typical month.

We hypothesize that the frequency of a congestion situation will impact travelers' integrate feeling about congestion. In other words, if two travelers have the same feeling to one congestion situation itself, such as slightly bad, but one traveler suffers it once a week and another one just meet it once a month, we assume that the traveler who suffers more often would feel worse than the low frequency one in their true life. Therefore, we set a integrate index to describe this relationship which we call as TCFF. The formula of TCFF is as follows:

TCFF = Traffic congestion frequency × Traveler's feeling

In order to calculate the index, in this study, we transferred the survey options of frequency to the exact number of value:

"Never" → 0 per month;
"Less than once a month" → 0.5 per month;
"1–3 times a month" → 2 per month;
"1–2 times a week" → 6 per month;
"3–4 times a week" → 14 per month;
"5 or more times a week" → 20 per month.

At the same time, we set the value of travelers' feeling as

"Not a problem" → 0;
"Slightly bad" → 1;
"Moderately bad" → 2;
"Extremely bad" → 3.

After calculated, the average value of TCFF is shown in Fig. 1. The value of the situation that traffic flow always stops is the highest one (10.66) in the 9 congestion situations, with high share rate of respondents who suffered it more than once a week and feeling moderately or extremely bad.

TCFF is a kind of indicator that combines the frequency of respondents suffered congestion and their feeling. It presents the real and integrated feeling of congestion situations in the true life. The value of this index can be used to evaluate travelers' feeling and their experiences of traffic congestion.

## 5 Models of road traffic congestion indicators

### 5.1 Methodology and variables

#### *5.1.1 Methodology*

The purpose of this study is to estimate how traffic congestion impacts travelers' feeling. The relationship of congestion indicators and impact factors needs to be studied through models to help understand which make travelers feel bad or not. As the type of data for TES and TTS are ordered data, the ordered logit model is selected to analyze the relationship between impact factors and indicators. The linear regression (LR) model is used for TCFF calculation.

#### *5.1.2 Dependent variables*

Two dependent variables—TES and TTS—are created from the survey question which asks "How satisfied do you feel with your current life,…, and the transportation system?" One statement is "Travel environment in the city." And the question asks "Are you satisfied with your usual travel time for your most frequent trips?" The options are the same: "Not satisfied at all," "Not satisfied," "Slightly satisfied," "Moderately satisfied," and "Extremely satisfied."

The dependent variable of TCFF model is calculated from the integrated value of the index in 9 congestion situations. The factor analysis is used to obtain the integrated value by setting just one factor number. The 9 congestion situations can be set as 9 statements in factor analysis after the value of statements are standardized by dividing 10 (from 0–60 to 0–6). The principal components analysis (PCA) is used in this study to derive a small number of linear combinations of a set of variables that retain as much of the information in the original variables as possible, using the SPSS statistical software package. For the result, the main factor explained 62 % of the total variance in the statements which could be seemed as a high value and able to present most of information for those variables [20]. The factor score was used in the subsequent model as the dependent variable.

### 5.1.3 Explanatory variables

Based on literature review and previous empirical studies [2, 6, 9, 15, 19, 21–23], the explanatory variables obtained from the survey fall into five main categories, each described as below.

General attitude and transportation-related attitude: in survey Part *A* and Part *B*, we asked a series of general attitude and transportation-related attitude statements on a 5-point scale from "strongly disagree" (1) to "strongly agree" (5). Common factor analysis was used to extract the 4 general attitude factors and 6 transportation-related attitude factors. Table 3 presents the factor loadings by general attitudinal statements, and Table 4 presents the factor loading by transportation-related attitudinal statements.

General attitude and transportation-related attitude cluster variables: a cluster analysis was used to classify the categories of respondents based on their general attitudinal factors and transportation-related attitudinal factors. We produced solutions for predefined cluster numbers of 2 and 3. For the criteria of interpretability and maintenance of statistically robust segment sizes, we selected the two-cluster solution. Table 5 presents the cluster results for each of them.

Baseline travel characteristics: Part *C* and Part *D* of the survey collected the information of respondents about their general trips and the most frequent trips including trip purpose, travel mode, travel time, and so on.

Other traffic congestion indicators: other traffic congestion indicators were added to estimate the relationship between them and the dependent variable.

Sociodemographic characteristics: Part *F* of the survey captured an extensive list of sociodemographic variables such as gender, age, educational background, household income, household size, and so on.

## 5.2 Model results

### 5.2.1 TES model results

Due to missing data, the final TES model (Table 6) has 239 respondents. The $\rho^2$ goodness-of-fit measure [24] with the market-share model as base is 0.145, which shows that the true explanatory variables add 0.145 to the goodness-of-fit.

Nine variables besides the constant are retained in the model: three sociodemographic variables, three additional factors, and three other congestion indicators.

Three sociodemographic variables are gender, owning the current residence, and annual household income. Women are more likely to be satisfied with transportation environment than men, which could be explained using

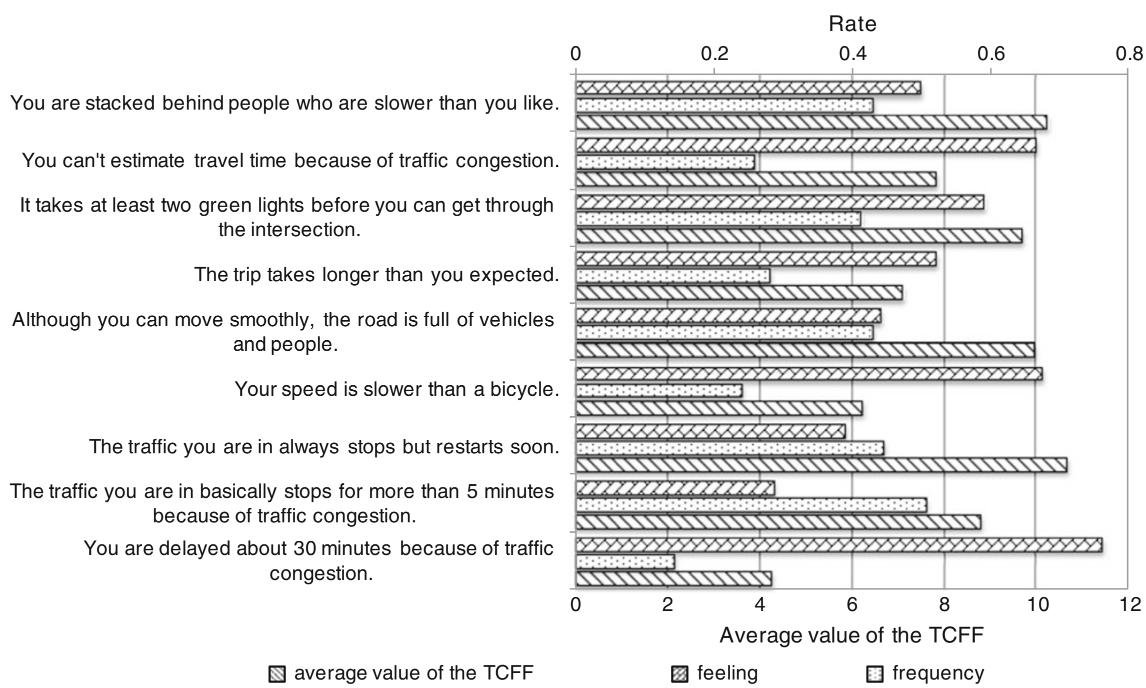


**Fig. 1** Average value of TCFF and share rate of respondents for congestion frequency and feeling. Note The "frequency" bar presents the share rate of respondents who suffered the situation more than once a week week; the "feeling" bar presents the share rate of respondents whose feeling to the situation is moderately bad or extremely bad

results of the previous study of Mokhtarian [15] that women are easier to adjust themselves to the external changes. Respondents who own the current residence are more likely to be satisfied with transportation environment, for they may have more acceptances with the city when they decided to buy the house or apartment. Respondents with higher income show their less satisfaction with transportation environment. Maybe it is because people with more money will have higher requirements to the city.

We got attitudinal factors from a series of statements using factor analysis, and more details could be seen in the author's another article [25]. Three significant attitudinal factors are hates wasting time, contend with travel conditions, and dislikes travel. It is easy to understand that people who hate wasting time will be more likely to feel dissatisfied with transportation when they are stacked on the road. People who can contend with travel conditions are more likely to feel satisfied with transportation. If people dislike travel, then it means there are some aspects with trips which make them uncomfortable, and so they will feel less likely to be satisfied with transportation environment.

Other congestion indicators also involved in the model to estimate the relationship between TES and other congestion indicators. Three other congestion indicators are significant in the model. TTS is a major index to present whether travelers are satisfied with their travel time. Respondents who are satisfied with their travel time are more likely to be satisfied with the total transportation environment. The 30-min-delay frequency and feeling and slower than bicycle frequency and feeling are indicators presenting the frequency and respondents' feelings with two congestion situations. If travelers meet these two congestion situations more frequently or they feel worse than other people, then they will less likely to be satisfied with the urban transportation environment. The results also indicate that travel time and travel speed are the two important aspects for travelers when they do the daily trips, which will impact their feeling to the total transportation environment.

### 5.2.2 *TTS model results*

TTS model (Table 6) has 235 valid respondents. The $\rho^2$ goodness-of-fit measure with the market-share model as base is 0.271, which shows that the true explanatory variables add 0.271 to the goodness-of-fit. Eleven variables

**Table 3** Rotated factor loadings (pattern matrix) by general attitudinal statements ($N = 271$)

| Survey statement | Hates wasting time | In a hurry and out of control | Confident | Likes quiet living | Communalities |
|---|---|---|---|---|---|
| Even if I have something else pleasant or useful to do while traveling for routine activities, it often bothers me if the trip takes a long time | 0.579 | – | – | – | 0.352 |
| In my daily life, I have to spend too much time waiting | 0.435 | – | – | – | 0.412 |
| I make productive use of the time I spend on daily traveling | −0.393 | – | – | – | 0.249 |
| If the line is moving, waiting is OK for me | −0.357 | – | – | – | 0.144 |
| In general, waiting is unpleasant even if I have an interesting way to pass the time | 0.351 | – | – | – | 0.142 |
| Work and family do not leave me enough time for myself | 0.268 | – | – | – | 0.129 |
| I'm often in a hurry to be somewhere else | – | 0.703 | – | – | 0.461 |
| I have to admit that sometimes I make other people wait for me | – | 0.499 | – | – | 0.267 |
| I will do something humiliating, if you give me enough money | – | 0.439 | – | – | 0.271 |
| I often feel like I don't have much control over my life | – | 0.325 | – | – | 0.423 |
| In choosing where to live, there are many factors much more important than transportation conditions | – | 0.224 | – | – | 0.065 |
| It is understandable for someone to be a bit late | – | 0.180 | – | – | 0.043 |
| I am confident that I can deal with unexpected events effectively | – | – | 0.583 | – | 0.323 |
| I can always rely on my own ability to handle difficult situations | – | – | 0.500 | – | 0.261 |
| Even when I have a lot of things to do, I seldom feel pressure | – | – | 0.254 | – | 0.093 |
| I like living in a small and quiet city instead of a bustling city | – | – | – | 0.617 | 0.393 |
| I like the idea of having different types of businesses (such as stores, offices, post office, bank, and library) mixed crowdedly in with the homes in my neighborhood | – | – | – | −0.392 | 0.289 |
| I like to live in a crowded neighborhood with lots of people | – | – | – | −0.357 | 0.212 |

**Table 4** Rotated factor loadings (pattern matrix) by transportation-related attitudinal statements ($N = 271$)

| Survey statement | Contend with travel conditions | Likes driving | Travel planner | Transportation aware | Travel constraint | Dislikes travel | Communalities |
|---|---|---|---|---|---|---|---|
| Thinking about both good and bad aspects, overall the public transportation system is pretty good | 0.736 | | – | – | – | – | 0.532 |
| It's convenient to travel from one place to another in my city | 0.609 | – | – | – | – | – | 0.411 |
| Getting stuck in traffic doesn't bother me too much | 0.494 | – | – | – | – | – | 0.257 |
| Some amount of traffic congestion is inevitable, no matter what we do | 0.358 | – | – | – | – | – | 0.153 |
| I prefer to drive rather than travel by any other means | – | 0.731 | – | – | – | – | 0.520 |
| I like driving itself, without having any other reason | – | 0.584 | – | – | – | – | 0.404 |
| To me, a car is a status symbol | – | 0.436 | – | – | – | – | 0.247 |
| I like the idea of walking or biking as a means of transportation | – | −0.430 | – | – | – | – | 0.249 |
| I get where I'm going more quickly than other people because I know how to choose my departure time and route to avoid congestion | – | – | 0.747 | – | – | – | 0.463 |
| It is important for me to organize my errands so that I make as few trips as possible | – | – | 0.542 | – | – | – | 0.433 |
| I really need to get more information about traffic conditions before I make a trip | – | – | 0.416 | – | – | – | 0.362 |
| Even though I'm only one person, my actions can make a difference to the transportation system | – | – | – | 0.519 | – | – | 0.246 |
| Transportation condition plays an important role when I choose my job | – | – | – | 0.504 | – | – | 0.187 |
| I like the idea of using public transportation whenever possible | – | – | – | 0.443 | – | – | 0.231 |
| When I choose the means of transportation for a certain trip, I consider traffic congestion | – | – | – | 0.369 | – | – | 0.417 |
| It's unfair to expect me to sacrifice to help reduce traffic congestion, if other people aren't doing it too | – | – | – | 0.215 | – | – | 0.229 |
| It's really hard to estimate my travel time before leaving because of congestion | – | – | – | – | 0.522 | – | 0.365 |
| I know very little about the transportation system of this city | – | – | – | – | 0.433 | – | 0.341 |
| The only good thing about traveling is arriving at your destination | – | – | – | – | 0.393 | – | 0.185 |
| I generally know when and where Congestion will happen in the city | – | – | – | – | −0.383 | – | 0.306 |
| The traveling that I need to do interferes with doing other things I like | – | – | – | – | 0.282 | – | 0.101 |
| Sometimes I would enjoy staying at home for the whole day and not having to go anywhere | – | – | – | – | – | 0.607 | 0.366 |
| I want to go somewhere at least once a day, even if I have nothing particular to do | – | – | – | – | – | −0.569 | 0.357 |
| I prefer to shop near where I live, in order to make fewer trips | – | – | – | – | – | 0.322 | 0.212 |

**Table 5** Cluster centroids and between-cluster mean sum of squares ($N = 274$)

| General attitudinal factor | Cluster centers | | Between-cluster MSS |
|---|---|---|---|
| | Stressed | Executive | |
| Hates waiting time | 0.363 | −0.502 | 50.029 (HH) |
| In a hurry and out of control | −0.392 | 0.543 | 58.342 (HH) |
| In control | 0.073 | −0.010 | 1.986 (BB) |
| Likes quiet living | 0.259 | −0.357 | 25.295 (B) |
| No. (%) of observations in each cluster | 159 (58.0) | 115 (42.0) | – |
| **Transportation-related attitudinal factor** | **Savvy traveler** | **Travel planner** | **Between-cluster MSS** |
| Contend with travel conditions | 0.193 | −0.377 | 19.973 (B) |
| Likes driving | 0.088 | −0.171 | 4.130 (BB) |
| Travel planner | −0.356 | 0.694 | 67.653 (HH) |
| Transportation aware | 0.362 | −0.707 | 70.183 (HH) |
| Travel constraint | −0.153 | 0.298 | 12.475 (B) |
| Dislikes travel | 0.039 | −0.077 | 0.831 (BB) |
| No. (%) of observations in each cluster | 181 (66.1) | 93 (33.9) | – |

The average BMSS of 33.913 for general attitudinal factors and 29.208 for transportation-related attitudinal factors. BB and B means much below and below, respectively; M means the value is about equal to the mean BMSS; H and HH means above and much above mean BMSS, respectively

besides constant variable are significant in the model, including three sociodemographic variables, four attitudinal factors, two trip characteristics, and two other congestion indicators.

Three significant sociodemographic variables are gender, government employee, and company employee. Inconsistent with the TES model, women are more likely to be unsatisfied with travel time for their most-frequent trips which is the same as previous study [15]. The reason could be due to gender differences in response style: women could be more inclined than men to use the extreme ends of a scale [26]. TES is a kind of overall indicator to describe the total transportation status of a city, however, TTS indicator more focuses on the most frequent trips. Therefore, they may have lower level acceptance in travel time than men but more of them like the total transportation system. Government employee and company employee are more likely to be satisfied with travel time which may be because generally, their-most frequent trips are commuted trips for which they are already used to the travel time. So they may be more satisfied with travel time than other respondents whose most frequent trips' purposes are not commuting.

Four attitudinal factors are residence satisfaction, satisfaction of urban transportation system, in a hurry and out of control, and likes quiet living. Respondents who are satisfied with their residence and transportation system will obviously more likely to be satisfied with the travel time of the most frequent trips. Respondents who are always in a hurry and out of control will be more likely to be unsatisfied with travel time. That is because these kinds of people do not have the ability to organize or plan their errands, and so they will more likely feel to be hurrying with everything including their trips. People who like quiet living are more likely to be unsatisfied with travel time either. The reason is that such people do not like the busy life and traveling itself, so they will be less likely to take long time on traveling.

The longer travel time of the most frequent trips is, the less likely the respondents are to be satisfied with the travel time. Accordingly, the longer the total travel time in a week is, the less likely the respondents are to be satisfied with the travel time. Two congestion indicators are also significant in the model. If the road is full of vehicles, then respondents will be less likely to feel satisfied with travel time. And if respondents need to wait for two green lights to go through the intersection, it means the travel time is longer than usual, so they will be less likely to feel satisfied with the travel time.

### 5.2.3 *TCFF model results*

The LR model was used here. In the model, 220 respondents are valid (see Table 7); the $\rho^2$ is 0.345, and the adjusted $\rho^2$ is 0.300, which could be deemed as acceptable [27].

There are fifteen variables significant in the model, including two sociodemographic variables, five attitudinal factors, one cluster category, and seven trip characteristics variables. Two sociodemographic variables are currently owning residence and annual household income. Different from the TES model results, respondents who currently

**Table 6** Ordered logit models of TES and TTS (0 = strongly disagree, 1 = disagree, 2 = neutral, 3 = agree, 4 = strongly agree)

| Variable name | TES | | TTS | |
|---|---|---|---|---|
| | Coefficient | *P* value | Coefficient | *P* value |
| | 2.765 | 0.001 | 7.503 | 0.000 |
| Socio-demographics | | | | |
| Female (dummy variable-DV) | 0.478 | 0.067 | −0.643 | 0.030 |
| Annual household income | −0.266 | 0.030 | | |
| Own the current residence (DV) | 0.794 | 0.050 | | |
| Government employee (DV) | | | 0.982 | 0.048 |
| Company employee (DV) | | | 0.948 | 0.005 |
| Attitudinal factors | | | | |
| Residence satisfaction | | | 0.757 | 0.000 |
| Satisfaction of urban transportation system | | | 0.685 | 0.000 |
| In a hurry and out of control | | | −0.584 | 0.000 |
| Likes quiet living | | | −0.533 | 0.011 |
| Hates wasting time | −0.287 | 0.059 | | |
| Contend with travel conditions | 0.600 | 0.000 | | |
| Dislikes travel | −0.320 | 0.036 | | |
| Trip characteristics | | | | |
| Travel time of the most frequent trips (minutes) | | | −0.163 | 0.001 |
| Total travel time of a typical week for commuting (hours) | | | −0.228 | 0.019 |
| Other congestion indicators | | | | |
| TTS | 0.459 | 0.016 | | |
| 30 min delayed frequency and feeling | −0.257 | 0.026 | | |
| Slower than bicycle frequency and feeling | −0.218 | 0.057 | | |
| Full with vehicles on the road frequency and feeling | | | −0.527 | 0.000 |
| Waiting for more than one green lights frequency and feeling | | | −0.405 | 0.001 |
| Valid number of cases, $N$ | 239 | | 235 | |
| Final log-likelihood, $LL(\beta)$ | −263.298 | | −188.877 | |
| Log-likelihood for market share model, $LL(MS)$ | −307.953 | | −259.095 | |
| No. of explanatory variables, $K$ (including constant) | 10 | | 12 | |
| $\rho^2_{\mathrm{MSbase}} = 1 - LL(\beta)/LL(MS)$ | 0.145 | | 0.271 | |
| $\chi^2$ (between final and MS models) | 89.310 | | 140.436 | |

own their residences have higher value of TCFF. This may be due to the differences between these two indicators. TCFF presents the real statuses of the respondents in their most-frequent trips—frequency at which they meet the congestion situations and their feelings about these congestion situations. The same thing happens to the annual household income: respondents with higher income have less satisfaction of transportation environment but also meet less-frequent congestion situations or feel better with those congestion situations. The interpretation is that people with higher income levels have higher requirements with urban transportation system. At the same time, they also have higher ability to cope with the traffic congestion.

Five attitudinal factors are satisfaction of urban transportation system, hating wasting time, contending with travel conditions, disliking travel, and transportation awareness. Respondents who are satisfied with transportation system are less likely to meet the congestion situations or have better feeling with congestion. For those who hate wasting time, they are more likely to feel worse with congestion. Respondents who have higher awareness of transportation are more sensitive to congestion that makes them easier to point out congestion or feel worse about congestion. If travelers who can contend with travel conditions, then they will be less likely to suffer congestion situations or feel bad with congestion. And for those who dislike travel respondents, they will make as fewer trips as they can, and the frequency of meeting congestion will be less than others, and their TCFF value will be lower.

One cluster category variable became significant in the model which indicates that different people group will have

**Table 7** LR models of TCFF

| Variable name | TCFF index | |
|---|---|---|
| | Coefficient | *P* value |
| | −2.415 | 0.000 |
| Sociodemographics | | |
| Annual household income | −0.103 | 0.054 |
| Own the current residence (DV) | 0.482 | 0.005 |
| Attitudinal factors | | |
| Satisfaction of urban transportation system | −0.129 | 0.062 |
| Hates wasting time | 0.268 | 0.002 |
| Contend with travel conditions | −0.401 | 0.000 |
| Dislikes travel | −0.122 | 0.102 |
| Transportation aware | 0.232 | 0.001 |
| Executive (DV) | 0.606 | 0.000 |
| Trip characteristics | | |
| Total travel time of a typical week for commuting (hours) | 0.091 | 0.021 |
| Total travel time of a typical week for recreation or social activities (hours) | 0.107 | 0.050 |
| Trip purpose of the most frequent trips commute (DV) | 1.479 | 0.017 |
| Trip purpose of the most frequent trips work related (DV) | 1.545 | 0.016 |
| Trip purpose of the most frequent trips grocery shopping (DV) | 1.704 | 0.012 |
| Trip purpose of the most frequent trips recreation or social activities (DV) | 1.961 | 0.003 |
| Trip purpose of the most frequent trips picking up other people (DV) | 1.914 | 0.007 |
| Valid number of cases, *N* | 220 | |
| No. of explanatory variables, *K* (including constant) | 15 | |
| $\rho^2$ | 0.345 | |
| Adjusted $\rho^2$ | 0.300 | |

different feelings of congestion. Executive travelers will meet more frequent congestion situations or feel worse about congestion than stressed people (cluster results shown in Table 5).

Different from TES model, several trip characteristic variables are significant in the model. Besides, two travel time-related variables—total travel time of a typical week for commuting and total travel time of a typical week for recreation or social activities, other five variables are all about the trip purpose of the most frequent trips. In general, if the travel time of respondents' daily trips is longer, they are more likely to suffer more congestion and feel worse. The significant variables of trip purposes are commuting, work-related trips, grocery shop, recreation, or social activities, and picking up other people. During trips with these five purposes, respondents will be more likely to meet more congestion or feel worse than those with other trip objectives.

## 6 Conclusions and suggestions for future research

The article uses three new congestion indicators to estimate urban traffic congestion based on travelers' feelings. They are TES, TTS, and TCFF. A survey was taken in Shanghai China to collect travelers' attitudes about congestion and trip information. Based on the survey data, we estimated the three indicators' value of travelers in Shanghai. About 30 % respondents showed they were unsatisfied with transportation environment and 23 % respondents said they were unsatisfied with the travel time of the most frequent trips. Nine congestion situations were designed in the survey to collect the frequency that travelers meet in their most frequent trips and the feelings when meet these situations. In the nine congestion situations, most respondents (76.2 %) feel moderately bad or extremely bad when they are delayed about 30 min. The situations that the speed is slower than a bicycle and cannot estimate travel time because of traffic congestion are the two events which make about 67.5 % and 66.7 % respondents feeling moderately bad or extremely bad, respectively. TCFF was created by multiplying the frequency with the feeling value.

Subsequently, in order to estimate the whole congestion status, the PCA was used to derive a small number of linear combinations of a set of variables. We set the factor as the dependent variable in TCFF model. The LR model was used to find out the significant variables which will impact respondents' feelings. The ordered logit model was also used to select significant variables of TES and TTS. Nine variables are significant in the TES model, eleven variables are significant in the TTS model, and fifteen variables are significant in the TCFF model. The results show that attitudinal factor variables and cluster category variables are as important as sociodemographic variables in models. Three congestion indicators can describe travelers' feelings of congestion from three different levels. Using these congestion indicators, the government can collect travelers' feelings about congestion besides traffic condition index.

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