Research on Travel Behavior in Hazy Weather Based on Structural Equation Model

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Abstract

Haze has great influence on human health and daily travel, so it is necessary to study the influence of hazy weather on people's travel activities. Based on the questionnaire survey, the structural equation model was established to simulate the college students' travel behavior in hazy weather with AMOS and SPSS software. The results show that the psychological status of travelers and their sensitivity to hazy weather are the key factors affecting the students' travel. Therefore, hazy weather can lead to changes in travel behavior: the hazy weather had the greatest impact on travel time, followed by travel frequency, and the least impact on travel mode. This paper studies the influence of haze weather on college students' travel behaviors, and proposes a rational understanding of haze, a pleasant mood to go out and a corresponding protective measure, and proposes different measures for the traffic management department in the haze weather. Traffic management measures, priority to ensure the recommendations of bus traffic; for the traffic management department, put forward the propaganda to increase the pros and cons of smog weather and road traffic conditions, and strengthen the traveler's rational understanding of travel in smog weather.

Keywords: Urban traffic, Travel behavior, Structural equation model, Hazy weather

1 Introduction

Haze has become the ten most important words of the year in 2013, and appeared more and more frequently in the public eye. According to relevant data, at the end of 2016, a large area of heavily polluted weather continued to occur in the central and eastern part of China, with a total of 71 cities with daily average concentrations of severe pollution or above [1]. Haze has great influence on human health and traffic travel, so it is necessary to study the influence of hazy weather on people's daily travel activities. Liu [2] believes that hazy weather has a greater impact on residents who choose to travel slowly, and has a greater impact on female residents. When the haze is severe, it can seriously affects the flexible travel of residents; and the residents can accept the shorter exposure time, which will make some of the potential groups who are interested in taking public transport to travel on rail or taxi. Du [3] analyzed the influence of hazy weather on the behavior of private car owners in the city. The results showed that with the increase of air pollution, the proportion of private car owners choosing public transport gradually increased. Especially when the air quality index exceeds 200, the proportion of private car travel continues to decrease rapidly, while the proportion of public transport travel increases rapidly.

Existing studies have shown that, when studying the effects of hazy weather on people's travel, most of them are private car owners or other people. There is less research on college students, the particularity of college students is that they do not have private cars, so they choose public transportation mode to travel. College students are more active travel groups, and more flexible travel, such as entertainment activities, shopping, and its travel behavior is easily affected by haze and other factors.

The theory of planned behavior believes that behavioral intention is the most direct influencing factor of individual behavior, and behavior itself is the result of the combined effect of three factors: attitude, subjective norms, and perceived behavior control. The subjective norm refers to the pressure of other important related persons when an individual performs a certain behavior. Views such as family or friends in haze weather can affect traveler decisions. Therefore, this article chooses the attitudes of parents and friends as the actual embodiment of subjective norms in the theory of planned behavior. In the study of residents' travel mode choice behavior, the commonly models are divided into two categories: the aggregate model and the disaggregate model. The aggregate model usually makes statistical analysis of everyone's traffic

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activities according to the traffic area, and obtains the model based on the traffic area, such as gravity model, regression model, etc. This model ignores the differences between individuals. The disaggregate model is used to build the model directly in the form of individuals who actually generate traffic, don't according to the traffic area for statistical treatment, such as MNP model, Logit model, ML model. Li and Xu [4] used Multiple Logit models to analyze the relationship between the four travel modes and the individual characteristics of commuters, family characteristics and travel characteristics. Yin and Zhang [5] built a ML model to study the main factors affecting residents' choice of green travel mode. In order to describe the travel chain, travel mode and departure time, Yang and Li [6] constructed a cross-nested logit model, and QiuTing Xie [7] established the multiple logit models to quantify the key factors that affect the choice of travel mode of satellite city residents.

These models have some limitations, so it is difficult to define the internal relationship between the factors. The structural equation model (SEM) can solve this problem. The research of SEM for travel behavior modeling first appeared in 1980. It established a joint model of vehicle ownership and use, as well as a dynamic model of travel mode and attitude choice [8], and SEM can consider and deal with multiple dependent variables at the same time [9]. Kamargianni et al. [10] use SEM to study students' behavior choice in school. Ding and Lu [11] by comparing two SEM to verify the relationship between land use and travel behavior and activity participation. Zhou [12] established a travel behavior impact analysis model based on SEM Chengdu traffic trip survey data. Chen et al. [13-15] used SEM to analyze the causality between various factors influencing the choice of public transport mode, and established a method of analysis of choice behavior. Combined with the theory of planned behavior, the influence of psychological factors on travel choice behavior is described quantitatively, the residential and travel behaviors of middle and low income groups were studied. Lu et al. [16] studied the interaction between people's travel behavior and their places of work and residence in 14 cities in Bangladesh, including coastal and inland areas, under flood disasters through SEM. Yang et al. [17] taking the travel chain as the analysis unit, the SEM of residents' choice of travel mode in the process of rapid urbanization is established, and the relationship between influencing factors and travel mode is analyzed. Cheng and Chen [18] used SEM to establish a low income commuter travel model, and analyzed the factors that affect the low income commuting travel.

The college student group is a relatively special group. It has almost no private cars, and it uses public transportation. It is mostly flexible and more susceptible to external factors such as haze. It is clear that the haze weather will affect the aspects of the travellers. The structural equation model is used to qualitatively and quantitatively analyze the influence degree of each influencing factor, and the relationship between the influencing factors and the travel behavior of the traveler is determined through the analysis of the importance degree of the influencing factors. This will provide a basis for transportation planning and management, and through the study of college students, it will provide reference and basis for future research on the travel of all residents in smoggy weather.

This paper studies the influence of haze weather on college students' travel behaviors, and proposes a rational understanding of haze, a pleasant mood to go out and a corresponding protective measure, and proposes different measures for the traffic management department in the haze weather. Traffic management measures, priority to ensure the recommendations of bus traffic; for the traffic management department, put forward the propaganda to increase the pros and cons of smog weather and road traffic conditions, and strengthen the traveler's rational understanding of travel in smog weather.

2 Related Work

2.1 Structural Equation Model

Model brief introduction SEM is a statistical method to analyze the relationship between variables based on the covariance matrix of variables [19].

The structural model reflects the causality between latent variables, and its model forms is

$$\eta = B\eta + \Gamma\xi + \varsigma \quad \textbf{(1)}$$

where η is an endogenous latent variable, ξ is an exogenous latent variable, ς is a random disturbance term, which reflects the part of formula (1) in which η is not explained.

B is an endogenous latent variable coefficient matrix, and the interaction between the endogenous latent variables η and Γ is an exogenous latent variable coefficient matrix, and the influence of the exogenous latent variable ξ on the endogenous latent variable is described.

The measurement model reflects the relationship between latent variables and measurable variables. Its forms such as formula (2) and formula (3).

$$X = \Lambda_x\xi + \delta \quad \textbf{(2)}$$

$$Y = \Lambda_y\eta + \quad \textbf{(3)}$$

where X is the observational index of δ, Y is the observational index of ε, δ is the measurement error of X. ε is the measurement error of Y. Λ_x is a

coefficient matrix consisting of a factor load on X on δ. Λ_y is a coefficient matrix consisting of a factor load on Y on ε.

2.2 Model Advantage

Unlike traditional regression analysis, structural equation analysis can simultaneously process multiple dependent variables and compare and evaluate different theoretical models. Compared with other analytical methods, specifically:

Linear correlation analysis. Linear correlation analysis indicates a statistical link between two random variables. The two variables are equal in status and have no dependent variable and independent variable. Therefore, the correlation coefficient does not reflect the causal relationship between the single indicator and the population.

Linear regression analysis. Linear regression is a more complex method than linear correlation, which defines dependent and independent variables in the model. But it can only provide direct effects between variables and not show possible indirect effects. Moreover, due to collinearity, there is an unexplained data analysis result such as a single indicator and a negative correlation.

Structural equation model analysis. Structural Equation Model is a method for establishing, estimating, and testing causality models. The model contains both observable explicit variables and potential variables that cannot be directly observed. The structural equation model can replace multiple regression, path analysis, factor analysis, covariance analysis and other methods to clearly analyze the relationship between individual indicators and the individual indicators.

(1) SEM can deal with measurement and analysis problems at the same time.

Compared with the traditional statistical method, SEM is a kind of econometric research technology which can integrate measurement and analysis into one. It can not only estimate the error of index variables, but also evaluate the reliability and validity of measurement. The potential variables can not be directly measured, the indicators used in this paper, such as travel behavior, sensitivity to hazy weather, hazy weather traveler's psychological condition, etc. These unobservable constructs can be measured with a set of observation variables.

(2) Statistical Analysis of SEM for large samples.

SEM is suitable for the analysis of large samples. The more the sample number is, the better the stability of the statistical analysis and the adaptability of various indexes are. The sample size of this paper is 400, which is suitable for SEM.

(3) SEM has a theoretical transcendence.

A characteristic of SEM analysis is that it is assumed that the causal model must be based on a certain theoretical basis, so that SEM is a statistical technique used to verify the appropriateness of a theoretical model or hypothesis model, and the SEM of this article is based on the theory of planned behavior [20]. In addition, the optimization algorithms [21-27] in the following papers are instructive for solving models.

2.3 Theory of Planned Behavior

The Theory of Planned Behavior (TPB) from the perspective of information processing, explains the general decision-making process of individual behavior from the perspective of information processing and taking the theory of expected value as the starting point [28]. It is one of the most important theories about the formation of individual behavior in social psychology.The theory holds that behavior intention is the most direct influence factor of individual behavior, and behavior itself is the result of the comprehensive action of attitude, subjective norm and perceived behavior control. Subjective norms refer to the pressure of other important people when they perform certain behaviors. Views of family or friends in smoggy weather can affect traveler decisions [29].

Based on TPB, this paper studies the influence of hazy weather on the traffic behavior of college students, Including the sensitivity of travellers to smog weather, the haze weather, the number of trips by travellers, and the way they travel. Furthermore, transportation big data [30], data mining [31-32] and value capture [33] were also applied in such analysis.

3 Data Sources and Statistical Analysis

3.1 Data Sources

The data are based on the traffic survey of some college students in Yangpu District, Shanghai. Through this investigation, we can find out the daily travel habits, travel patterns, attention to haze, sensitivity and the influence of hazy weather on college students' travel. The survey is divided into the following categories:

(1) The basic personal attributes of college students. Including whether to live in school, what kind of transportation they have.

(2) Travel intention survey. Including the working day, the rest day respectively uses the transportation mode, the single trip time, the travel purpose; attention to haze, the haze influence degree to the trip, etc.

(3) Travel psychology survey. Parents, family, classmates and friends of the attitude of the traveler's influence degree, the traveler's psychological condition, etc. That is, the content of the subjective attitude in the theory of planned behavior

(4) The change of travel mode in hazy weather. Including travel mode, travel times and travel time

changes and so on.

(5) A survey of the psychological state of travelers in smog weather. Studies have shown that the psychological state of travelers in haze weather mainly includes irritability, tension, fatigue, feelings of depression and fear. The main physical conditions are symptoms of respiratory diseases, symptoms of cardiovascular diseases and various infections. 3 symptoms of illness. Therefore, this article divides the psychological status of travelers into four categories: irritability, fatigue, tension, and depression.

The form of questionnaire is a five-level scale, from 1 to 5 respectively means "very dissenting" to "very agree" semantic progression.

The questionnaire is based on the combination of field questionnaire and network questionnaire, and 400 questionnaires are sent out, 271 valid questionnaires are returned, and the effective recovery rate is 67.75.

3.2 Statistical Analysis

Figure 1 is a comparison of travel purposes under different weather conditions. Figure 1 shows that when the weather is in good condition (as shown in the inner ring), the interviewees prefer to go out to play and take part in recreational activities. However, among the interviewees who still choose to travel on hazy weather (as shown in the outer ring), the proportion of intern and part-time travelers has slightly increased, the number of people participating in recreational activities has decreased significantly, and the proportion of travelers visiting relatives and friends has also decreased slightly. It shows that hazy weather will have a significant impact on the travel behavior of college students.

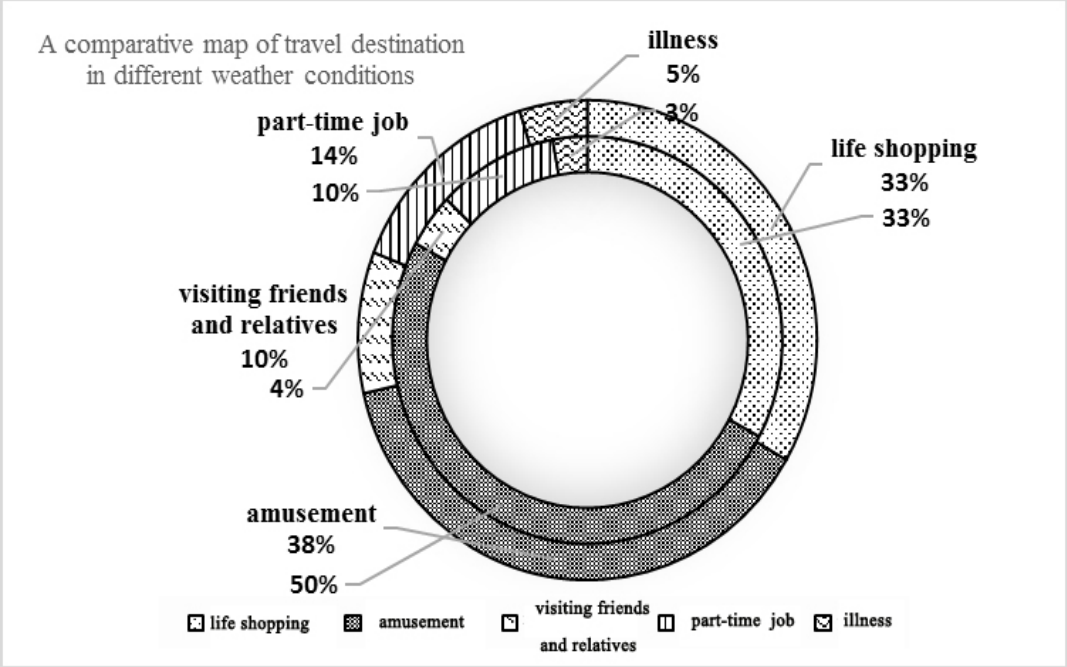

Figure 1. Comparative map of travel destination in different weather conditions

Table 1 is a survey of college students' travel. As can be seen from Table 1, more than half of the college students surveyed believed that hazy weather would lead to a change in travel patterns, and that they would be somewhat affected by their parents' families. More than half of the respondents thought hazy weather would make them feel irritable, tired, etc.

Table 1. Statistical table of partial survey results

Statistical item	Scene description	Very disapprove	Disapprove	Neutral	Approve	Very approve
Travel mode	From outdoor to indoor	12.50%	5%	10%	40%	32.5%
Attitudes	Parents and family members	17.50%	32.50%	40%	2.50%	7.50%
	Schoolmates and friends	12.50%	42.50%	37.50%	2.50%	5%
State of mind	Irritable	2.50%	7.50%	27.50%	37.50%	25%
	Tired	5%	10%	25%	42.50%	17.50%
	Nervous	0%	7.50%	32.50%	40%	20%
	Depressed	0%	5%	17.50%	47.50%	30%

4 Model Construction and Fitting Evaluation

4.1 Selection of Model Variables

The SEM hypothesis of this article is as follows:

Measurement model. The assumption of the model in this paper is shown in Table 2.

Structural model. The structure model of this article is shown in Figure 2 and Figure 3.

Table 2. Each index of Structural Equation Model and its description

Latent variable η	Observation variable	Latent variable ξ_1	Observation variable	Latent variable ξ_2	Observation variable	Latent variable ξ_3	Observation variable
Travel behavior	Travel times TR_1	Subjective norm	Family attitude SU_1	Sensitivity	Attention degree SE_1	Psychological condition	ImpatienceMI_1
	Travel time TR_2		Students' attitude SU_2		Acceptability SE_2		Fatigue senseMI_2
	Travel mode TR_3				Influence degree SE_3		Thrill MI_3
							Feel depressedMI_4

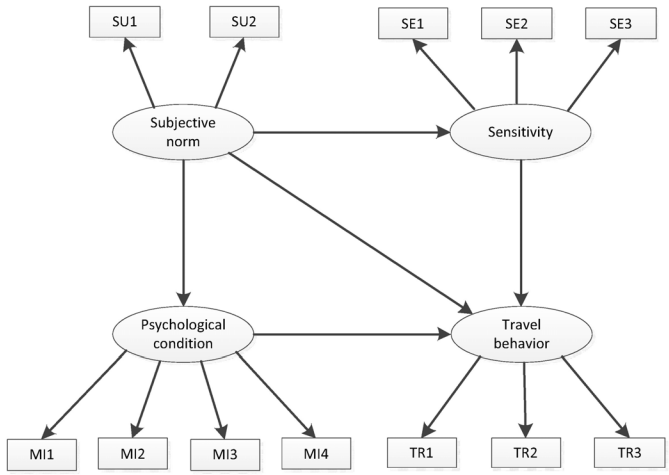

Figure 2. Structural Equation Model of travel behavior of college students

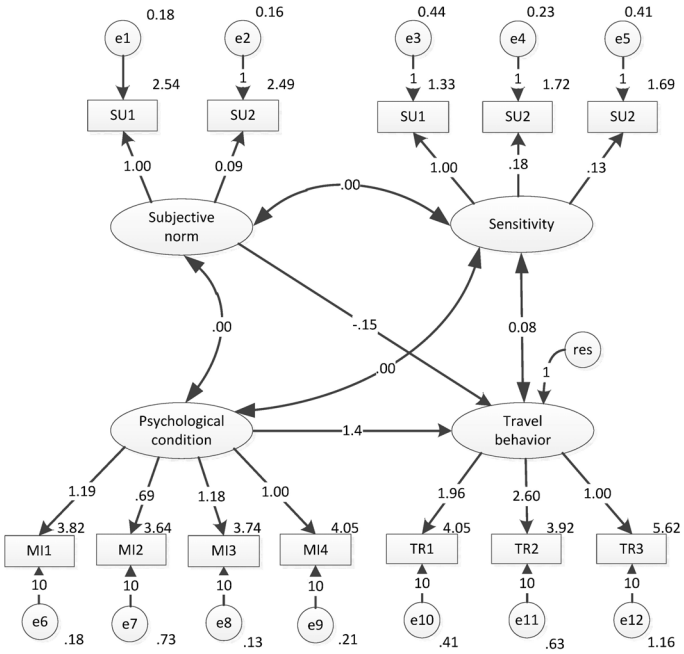

Figure 3. SEM image of the impact of optimized haze weather on college students' travel

4.2 The Fitting Evaluation of the Measurement Model

In this paper, AMOS21.0 is used to analyze the model results based on maximum likelihood estimation. The estimated results are as follows. The suitability of the model is shown in Table 3. The regression weight of the measurement model is shown in Table 4, which shows the quantitative relationship between the observed variables and the corresponding latent variables. For "subjective norm", the parameter value of SU_2 (classmate attitude) is 0.566; for "sensitivity", the parameter value of SE_2 (acceptance) is 0.124, which is the highest in other observational indexes. For "psychological condition", the parameters of MI_3 (tension) and MI_1 (irritable feeling) are the highest and 1.186; for "travel behavior", the parameter value of TR_2 (travel time) is 0.95.

Table 3. Model fitness index

Index	Description	model results
χ^2	The smaller the significant probability value, the more appropriate the causal path of the model is to the actual data.	223 p=0.000
RMESA	The approximate error root mean square between 0.05 and 0.08 indicates that the model is good and reasonable, and the value is less than 0.05, which indicates that the fitness is very good.	0.049

Table 4. Regression weight of the measurement model

Latent variable	Observation variable	Estimated value
Subjective norm	SU_1	1
	SU_2	0.566*
Sensitivity	SE_1	1
	SE_2	0.124**
	SE_3	0.075*
Psychological condition	MI_1	1.186***
	MI_2	0.692**
	MI_3	1.186***
	MI_4	1
Travel behavior	TR_1	0.68***
	TR_2	0.95***
	TR_3	1

Note. Level of significance.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

The results show that college students are more likely to be influenced by classmates or friends when they travel in hazy weather than their parents or family members. The sensitivity of college students to fog and haze is generally not high, but hazy weather has a greater impact on College Students' psychological status, making it easier for people to become impatient and nervous. Hazy weather will greatly affect the travel time of college students, which shows that college students generally understand the harm of fog and haze, and will reduce the risk of haze to their own health by reducing travel time.

4.3 Fitting Evaluation of Structural Model

Table 5 is the total influence matrix under standardization, showing the relationship between latent variables and observed variables and their influence degree.

Table 5. The total influence matrix under standardization

	Subjective norm	Psychological condition	Sensitivity	Travel behavior
Psychological condition	-0.134	0	0	0
Sensitivity	0.107	0	0	0
Travel behavior	-0.183	0.163	0.124	-
TR_1	-0.132	0.118	0.09	0.724
TR_2	-0.142	0.126	0.096	0.776
TR_3	-0.126	0.112	0.085	0.688
MI_1	-0.118	0.883	0	0
MI_2	-0.064	0.477	0	0
MI_3	-0.123	0.917	0	0
MI_4	-0.11	0.824	0	0
SE_1	0.224	0	2.101	0
SE_2	0.027	0	0.249	0
SE_3	0.012	0	0.117	0
SU_1	1.123	0	0	0
SU_2	0.728	0	0	0

For the explanatory power of college students' travel behavior in hazy weather, the path coefficient of psychological condition is 0.163, and the path coefficient of sensitivity degree is 0.124. It shows that psychological status and sensitivity are positively related to traveler's travel behavior. Moreover, the psychological state has the greatest explanatory power for this change, which indicates that the psychological condition of travelers is the main factor affecting their travel behavior in hazy weather.

For "subjective norms", the parameters of SU_1 (family attitude) and SU_2 (students' attitude) were 1.123 and 0.728 respectively, indicating that the attitude of classmates and friends and other peers had greater impact on the travel of college students than their parents and family. The sensitivity of college students to haze will affect the decision of travel or not in hazy weather to some extent. This is because the parameters of SE_1, SE_2 and SE_3 are positive, of which SE_1 is the largest, and the parameter value is 0.224.

For the latent variable of "psychological condition", the parameter value of MI_3 (tension) is the highest, which is 0.917, indicating that the stress caused by hazy weather has the greatest impact on travel behavior, followed by MI_1 (irritable feeling) and MI_4 (low emotion), and the parameter values are 0.883 and 0.824 respectively, and MI_2 (tiredness) had the least effect on travel behavior, with a parameter value of 0.477. Psychological conditions had the greatest impact on TR_2 (travel time), followed by TR_1 (travel times), and the least impact on TR_3 (travel mode). The parameter values were 0.126, 0.118 and 0.112 respectively.

For the latent variable of "sensitivity", the sensitivity of hazy weather also affects the travel behavior of college students. The path coefficient is 0.124. Among them, SE_1 (the degree of attention to hazy weather) has the greatest impact on College Students' travel behavior, the parameter value is 2.101, SE_2 (the maximum acceptable level for haze) and SE_3 (the influence of haze on their daily life and travel) are relatively small. The sensitivity degree of hazy weather has the biggest impact on TR_2 (travel time), the second largest impact on TR_1 (travel times) and the least impact on TR_3 (travel mode).

In the hazy weather, travel time and frequency of college students decreased significantly, indicating that the understanding and self protection for college students on hazy are generally high. This can be explained as that in the hazy weather, the first choice for college students is to reduce travel time, which means, to be less exposed to the haze; secondly, reduce the number of trips to reduce the possibility of exposure to haze. Few people choose to change travel mode, because most travelers go out by public transport that is hard to transfer to private transport.

5 Conclusion

This paper screens, integrates, and analyzes traffic survey data, and combines the theory of planned behavior with actual conditions to construct a structural equation model. The factors influencing college students' tourism and their degree of influence are analyzed. Finally, different suggestions are put forward for different groups. For travellers, it is proposed to rationally understand the haze, go out to maintain a happy mood, and make corresponding protective measures; for the traffic management department, it is proposed to take different traffic management measures in haze weather to give priority to ensuring the passage of buses Suggestions: For other government departments, put forward suggestions to increase publicity on the advantages and disadvantages of haze weather travel and road traffic conditions, and strengthen the rational understanding of travelers on haze weather travel.

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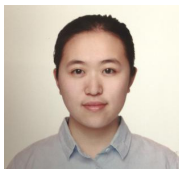

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