THE EFFECT OF SMOG POLLUTION ON TRANSPORT MODE CHOICE: A CASE STUDY OF XI'AN, CHINA

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ABSTRACT

This study makes use of an online survey from 363 residents living in Xi'an, China, to explore whether smog pollution has an influence on travel behaviour and whether people will take the environment, health, and safety into consideration to choose pro-environmental modes such as public transport, cycling and walking rather than personal vehicles during smog weather. A structural equation model (SEM) is built based on an extended Theory of Planned Behaviour (TPB) involving awareness of smog pollution, attitude towards travel mode, perceived behaviour control, subjective norms and an individual's past experience. The results indicate that past experience has the most positive effect on an individual's travel behaviour on smog days, while the attitude towards travel mode and perceived behaviour control are the important factors to encourage residents to change travel behaviour and choose environmentally friendly transport modes. In addition, almost all respondents are concerned about smog; many of them agree that using non-car modes is beneficial for smog reduction, and they are willing to select public transport or bicycle. However, some car owners have more difficulty in giving up cars unless public transport services are improved and the air quality is good.

1 INTRODUCTION

Since 2013, China has entered a period with a high incidence of smog, and this situation has aroused widespread public concern (Zhang and Cao, 2015). According to the China National Environmental Monitoring Centre, smog in Xi'an accounted for 36.2% of the total number of days in 2017 (24.2% in Shanghai, 14.1% in Guangzhou, 0.01% in Haikou), and Xi'an is ranked fourth from last among 74 cities. Smog is mainly produced by anthropogenic emissions and unfavourable diffusion conditions (meteorology, terrain) (Kang, et al., 2013). Among man-made emissions that can be controlled, traffic sources account for 17%. Smog can reduce visibility and adversely affect traffic safety and operational efficiency (Yu, et al., 2016). Vehicles running at low efficiency emit more exhaust gas, which aggravates smog. Many cities have adopted traffic-related measures to alleviate the smog phenomenon (Wang, et al., 2017a). For example, the implementation of driving restriction policies in Xi'an, the

subsidisation of electric vehicles, and the encouragement to share bicycles are all aimed at inducing people to choose more energy-saving and emission-reducing modes of transportation. However, with socio-economic development, the growth of private car ownership and the emergence of new travel modes such as online car-hailing and shared cars have brought about an impact on public transport. Currently, it is necessary to study whether people will take environment, health, safety and efficiency into consideration to choose pro-environmental modes such as public transport, cycling and walking rather than personal cars under the common hazy weather and diversified travel modes. This choice will provide the basis for the formulation and improvement of smog mitigation and congestion alleviation related policies.

The psychological impact on travel mode choice is based mainly on psychology theory (Theory of Planned Behaviour, norm Activation Model). Further, SP (Stated Preference) and RP (Revealed Preference) surveys (Liu, et al., 2017;Yadav and Pathak, 2016) have often been conducted. In addition, the travel conditions referred to occasionally adverse weather, such as rain, snow, and extreme hot or cold temperatures (Anta, et al., 2015;Zanni and Ryley, 2015). However, long-term smog weather has been considered less. The purpose of this study is to explore the effect of smog pollution on the choice of transport mode. Taking Xi'an as an example, extended TPB is adopted to synthetically consider awareness of smog pollution, attitude towards travel mode, perceived behaviour control, subject norm, individual's experience and other factors to establish a structural equation model of travel mode preference and actual behaviour on smog days.

2 METHODOLOGY

2.1 Theory of planned behaviour

The TPB was developed by the Theory of Reasoned Action (TRA) and has become one of the most popular theories to explain individual behaviour (Zhang, et al., 2017). It is stated that a person’s behaviour is directly determined by only his intention, and the intention is influenced by three psychological factors: attitude towards behaviour (the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question), subjective norm (the perceived social pressure to perform or not to perform the behaviour) and perceived behaviour control (the perceived ease or difficulty of performing the behaviour) (Ajzen, 1991), as shown in Fig. 1(a).

The TPB has been applied to many fields, including transport facilities, public transportation, vehicle emissions, clean energy, recycling and environmental protection. Although the TPB has great advantages in explaining behaviour, some other independent variables have been proposed to provide better explanations, such as moral norms, self-efficacy, past experience, habits, knowledge and awareness (Oztekin, et al., 2017). However, these factors are potential variables and cannot be directly measured. They need to be described by obvious variables that can be directly observed. The common method is to construct a relational model of potential variables by hypothesis and then investigate the obvious variables that can reflect the potential variables. After this step, analysis software is used to verify the relationships among the variables and the correctness of the model.

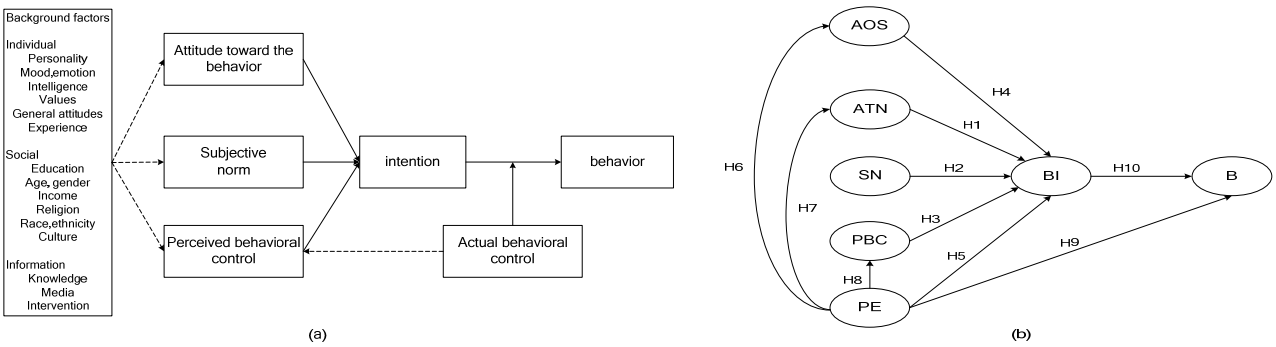

Fig. 1 (a) The structure of TPB. (b) The extended TPB in this study.

2.2 Hypotheses

The attitude towards non-car modes (pro-environmental modes, such as public transport, cycling and walking) indicates the evaluation of the public regarding pro-environmental transport modes. If travellers are satisfied with public transport and think it is beneficial to take, they would like to take public transport more frequently. Thus, the smog would be improved due to the increased usage of public transportation, which produces fewer emissions than cars (Liu, et al., 2016).

The higher pressure from the outside is, especially from the people who are closest or most trusted, the greater the impact on one's intention and behaviour. That is, the behaviour is influenced by subjective norm. This result occurs mainly because everyone needs to be approved so that proposals by significant people will be considered before an actual behaviour.

Perceived behavioural control implies whether a person has the ability to do something and how much the confidence the person has. If travellers have more confidence, they will try their best to do; that is to say, their intention will be increased. In contrast, if they are disappointed with things, they may give up at the beginning.

The awareness of smog refers to people's understanding of smog. It is easier for people who recognize the composition and harm of smog to consider pro-environmental behaviours for environmental protection and health and to know how to contribute to mitigating smog through reasonable traffic behaviour. In contrast, people who believe that smog has nothing to do with traffic and does not harm the body will not consider what kind of traffic behaviour should be taken to mitigate smog.

Past experience refers to the perception of smog and ride experience. The main component of smog is particulate matter, which does great harm to the human respiratory tract and lungs (Guo, et al., 2016). Some people may feel uncomfortable on hazy days, especially those who have respiratory and lung diseases. On foggy days, efficient travel modes may be chosen to reduce the time spent outdoors; hence, they intend to take public transport or cars. For example, smog reduces visibility and may cause traffic congestion. Taking the metro or buses with a mask may be more efficient than driving private cars on weekdays so that some people prefer public traffic to cars. Therefore, the individual's past experience is the general perception of life, travel, and health awareness, which gradually changes one's awareness of smog, attitude towards non-car modes and perceived behavioural control.

A good travel experience increases the probability of choosing the same travel mode, so some people choose their travel mode directly based on experience, regardless of other

factors; that is, past experience has a direct impact on actual behaviour. In addition, according to the TPB, travellers' behaviours are determined by their intentions. Therefore, 10 hypotheses were proposed according to above analysis, as shown in Fig. 1(b). Hypothesis 1 (H1): Attitude towards non-car modes has a positive impact on public intention to use non-car modes during smog. Hypothesis 2 (H2): Subjective norm has a positive impact on public intention to use of non-car modes during smog. Hypothesis 3 (H3): Perceived behavioural control has a positive impact on public intention to use non-car modes during smog. Hypothesis 4 (H4): Awareness of smog has a positive impact on public intention to use non-car modes during smog. Hypothesis 5 (H5): Past experience has a positive impact on individuals' intention to use non-car modes during smog. Hypothesis 6 (H6): Past experience has a positive impact on awareness of smog. Hypothesis 7 (H7): Past experience has a positive impact on attitude towards non-car modes. Hypothesis 8 (H8): Past experience has a positive impact on perceived behavioural control. Hypothesis 9 (H9): Past experience has a positive impact on behaviour. Hypothesis 10 (H10): Behaviour intention has a positive impact on behaviour.

2.3 Questionnaire survey

To verify the hypotheses, a questionnaire survey about the cognitive and psychological thoughts of travellers was conducted on the Internet in January 2017, which coincided with continuous extreme smog pollution. The residents in Xi'an were chosen, and the questionnaires were randomly distributed. Finally, 410 copies were received, and invalid questionnaires were excluded due to missing items; 363 were valid with an effective rate of 88.5%.

The questionnaire was divided into three parts. The first part was the socio-economic attributes of the respondents, as shown in Table 1. The second part was a survey of mode choice preference and actual behaviour on smog days. Questions were investigated to represent seven latent variables, and a 5-point Likert scale (1 = strongly disagree; 2 = disagree, 3 = neutral; 4 = agree; 5 = strongly agree) was introduced as shown in Table 2. The third part was to investigate the reasons for the choice of travel mode during smog days, such as the reason for choosing car and non-car modes.

Table 1 Demographic profiles of participants.

Item	Categories (percent %)
Gender	Female (54.5)，Male (45.5)
Age	＜25 (31.9)，26~40 (38.7)，41~55 (21.8)，＞56 (7.7)
Monthly income (RMB)	＜3000 (33.0)，3000~6000 (38.9), 6000~9000 (21.2), ＞9000 (6.9)
IC card owned	No (17.1)，Yes (82.9)
Non-cars owned	No (54.8)，Yes (45.2)
Cars owned	No (62.6)，Yes (37.5)
Respiratory disease	No (80.4)，Yes (19.6)
Travel purpose	Flexible travel needs (shopping, entertainment, fitness) (16. 3)，Rigid travel needs (work, school, business) (83.7)
Travel distance (km)	＜1 (12.1), 1~5 (52.7)，6~10 (25.3)，＞10 (9.9)
Travel time (min)	1~15 (11.8)，16~30 (36.1)，31~45 (26.7), 46~60 (8.6)，＞60 (16.8)

Table 2 Latent variables and measurement items.

Variables	Item description
Awareness of smog (AOS)	Smog is mainly a manmade phenomenon rather than a natural phenomenon. (AOS1) Smog is due mainly to automobile exhaust. (AOS2) Not using cars is beneficial to reduce smog. (AOS3) Taking non-car modes is beneficial to reduce smog. (AOS4)
Attitude towards non-car (ATN)	I like taking non-car modes. (ATN1) I prefer to non-car modes rather than cars. (ATN2) It is pleasant to take non-car modes. (ATN3) I think the infrastructure for non-car modes is complete. (ATN4)
Subjective norms (SN)	My family often discuss the impact of smog on transportation. (SN1) My peers often discuss the impact of smog on transportation. (SN2) My family encourage me to use non-car modes to reduce smog. (SN3) My peers encourage me to use non-car modes to reduce smog. (SN4)
Perceived behavioural control (PBC)	It is easy to obtain information about the smog level. (PBC1) It is easy obtain information on how to reduce smog by individual travel activity. (PBC2) It is easy to access the stations for non-car modes. (PBC3) It is easier to take non-car modes than cars during smog. (PBC4)
Past experience (PE)	I usually feel uncomfortable during smog. (PE1) Smog usually causes poor visibility. (PE2) Smog usually causes traffic jams. (PE3) Taking non-car modes is safer than cars in smog weather. (PE4) Taking non-car modes is more efficient than cars in smog. (PE5)
Behaviour intention (BI)	I am willing to limit using cars to help reduce smog. (BI1) I am willing to take non-car modes frequently to reduce smog. (BI2) I am willing to look up information about non-car modes. (BI3) I tend to limit using cars to help reduce smog. (BI4) I tend to take non-car modes frequently to reduce smog. (BI5)
Behaviour (B)	The times of travel were reduced on recent smog days. (B1) The total time of travel was reduced on recent smog days. (B2) The frequency of taking non-car modes was increased. (B3) The frequency of taking cars was reduced on recent smog days. (B4)

2.4 Data analysis

A structural equation model (SEM) integrates the two methods of factor analysis and path analysis and can obtain the direct effect, indirect effect and total effect of independent variables on dependent variables; such a model can also evaluate the reliability and validity of measurement. To pursue a stable analysis, the number of samples is preferably greater than 200. The SEM is composed of the measurement model and the structural model; the former implies the relationship between measurement items and latent variables, and the latter indicates the relationship among latent variables. Thus, the SEM technique was introduced to test the hypotheses in this study. Moreover, AMOS 17.0 and SPSS 21.0 were used to conduct data analysis.

3 RESULTS AND DISCUSSION

3.1 Measurement model

The reliability and validity were verified by using confirmatory factor analysis (CFA). Construct reliability implies the consistency of the indicators, which can be measured by Cronbach's alpha and composite reliability; both should exceed 0.70 (Shi, et al., 2017). All the constructs in Table 3 met the requirement. Convergent validity indicates the constructs should be related to each other, and it can be illustrated by standardized item loadings and average variance extracted (AVE). The former were close to or above 0.7, and the latter were more than 0.5 as the suggested thresholds.

Table 3 Results of CFA.

Latent variables	Items	Standardised loading	Cronbach's alpha	Composite reliability	AVE
Awareness of smog（AOS）	AOS1	0.70	0.71	0.85	0.59
	AOS2	0.78			
	AOS3	0.82			
	AOS4	0.77			
Attitude toward non-cars modes（ATN）	ATN1	0.81	0.75	0.85	0.58
	ATN2	0.71			
	ATN3	0.74			
	ATN4	0.79			
Subjective norms（SN）	SN1	0.83	0.70	0.88	0.67
	SN2	0.77			
	SN3	0.85			
	SN4	0.82			
Perceived behavioural control（PBC）	PBC1	0.68	0.76	0.83	0.59
	PBC2	0.72			
	PBC3	0.83			
	PBC4	0.75			
（PE）	PE1	0.69	0.71	0.85	0.53
	PE2	0.81			
	PE3	0.74			
	PE4	0.71			
	PE5	0.70			
Behaviour intention（BI）	BI1	0.78	0.88	0.89	0.62
	BI2	0.76			
	BI3	0.85			
	BI4	0.83			
	BI5	0.72			
Behaviour（B）	B1	0.80	0.78	0.84	0.57
	B2	0.80			
	B3	0.69			
	B4	0.73			

Furthermore, the discriminant validity was examined. It was different from the convergent validity that suggests the constructs were disconnected from each other (Wang, et al., 2017b). This result supported that the square root of the AVE for each latent construct was larger than its correlation with other constructs, as implied in Table 4. To summarize, the above results showed that the measurement model possessed adequate reliability and validity.

Table 4 Means, standard deviations and correlations.

Constructs	AOS	ATN	SN	PBC	PE	BI	B
AOS	**0.77**						
ATN	0.41**	**0.76**					
SN	0.29**	0.29**	**0.82**				
PBC	0.19**	0.277**	0.34**	**0.75**			
PE	0.37**	0.46**	0.41**	0.40**	**0.73**		
BI	0.37**	0.52**	0.37**	0.39**	0.53**	**0.79**	
B	0.02	0.12*	0.18**	0.11*	0.20**	0.17**	**0.76**
Mean	3.69	3.40	3.40	3.45	3.71	3.76	2.82
SD	0.68	0.73	0.61	0.56	0.57	0.73	0.76

Notes: Significance: *p < 0.05 and **p < 0.01. The square roots of the AVE values are in **bold** font on the diagonal values.

3.2 Structural model

The results of structural model are shown in Fig. 2, and the evaluation of SEM model is given in Table 5. All the indicators reach the standard, indicating that the established model is a good fit and all assumptions are valid. It is revealed that past experience indeed has a significantly positive impact on human travel attention and actual behaviour. Awareness, attitude and perceived behavioural control remain as intermediary variables, which indirectly contributed to the past experience and then to intention.

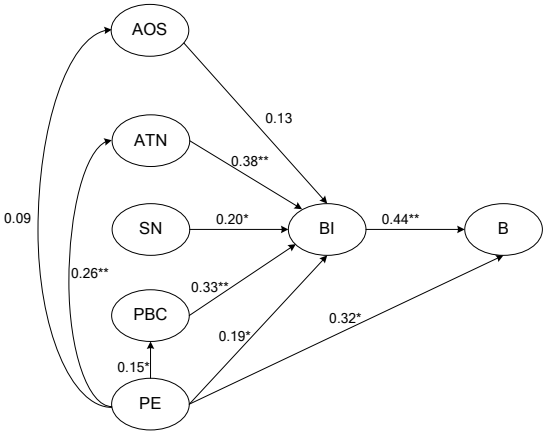

Fig. 2 The results of the SEM model.

Attitude and perceived behavioural control have the strongest positive impacts on behaviour intention, indicating that the travellers' attitude to the traffic mode is the primary factor in the choice intention. If the car preference is adopted, they tend to choose a car. Then, perceived behavioural control is another main factor to be considered. Based on traffic infrastructure, traffic conditions, travel experiences, etc., travellers are aware of how easy it is to choose a

certain transport mode, and this perception has a direct impact on the choice intention of the later travel mode. Past experience affects awareness of smog, attitude towards non-car modes and perceived behavioural control and thus indirectly affects intention. People's travel experiences change their views on smog, traffic and efficiency, thus indirectly adjusting their intention to choose a mode. Therefore, among the total effects of travel mode intention, the value of attitude is the largest (0.38), and past experience is the second largest factor due to the direct effect and indirect influence (0.35), followed by perceived behavioural control.

Table 5 The evaluation of the SEM model.

	Indicators	Criterion	Results	Judgment
Absolute fit measure	χ^2/df	1~3	2.063	Yes
	GFI	＞0.9	0.903	Yes
	RMR	＜0.05	0.046	Yes
	SRMR	＜0.05	0.049	Yes
	RMSEA	＜0.1	0.054	Yes
Incremental fit measures	NFI	0.9~1	0.912	Yes
	IFI	0.9~1	0.901	Yes
	CFI	0.9~1	0.900	Yes

Among the factors that influence actual choosing behaviour, past experience and intention exert direct impacts. Travel time and travel conditions are not easy to estimate due to various unfavourable factors on smog days, and an efficient travel experience impresses travellers and provides the most direct reference to them. Therefore, some people select the transport mode based only on their recent trip experience. Intention, indirectly affected by awareness, attitude, subjective norms, perceived behavioural control and experience, has the greatest immediate impact on behaviour, which also addresses the classical TPB theory. However, the direct and indirect effects of past experience make it a primary factor that affects the mode choice behaviour. The above discussion illustrates the importance of past experience for the travellers' mode choice in foggy weather. Travellers comprehensively consider smog, efficiency, health and other factors, combined with recent trip experience to select the most suitable and efficient travel mode for themselves.

3.3 The findings of the survey

In addition to verifying the proposed extended TPB, this study also analysed deeply for the reasons behind the actual behaviour. It is found that travellers with a history of respiratory tract and lung disease are more likely to pay attention to the length of time that they are exposed to the smog weather and give preference to efficient modes of transportation. Among the travellers owning cars, 37% used cars frequently, and 22% used cars almost as often as they needed to travel, regardless of weather conditions, road conditions, and parking availability. The reason for this behaviour is that they think the public transport is not convenient for its long travel time, as shown in Fig. 3(a). This result indicates that private car owners rely more on cars. If the convenience and accessibility of public transport cannot be greatly improved, it is hard to induce these travellers to abandon their cars and adopt a more environmentally friendly way of travelling. For those who use public transport for a long time, the short distance to boarding stations and medium fare are the maximum attractions.

In particular, the emergence of shared bicycles has greatly alleviated the problem of "the last mile". Coupled with the completion of the subway, it is greatly attractive for commuting and long-distance trips, as shown in Fig. 3(b). The last two rows in Table 4 show the mean and standard deviation of the latent variables, with the average value of behaviour intention being significantly lower than those of the other variables, indicating that while travellers have a certain understanding of smog and recognize that the car is harmful to the environment, environmentally friendly trips may not be selected when travelling. One reason is that car users rely on cars, and another reason is that public transport is less efficient than cars on average, so for those who can drive car or take a bus, the probability of choosing a car is usually greater, especially with the popularity of the ride-sharing services, carpools and so on. However, 73% of respondents said that travel efficiency should be considered first on smog days because of the harm of smog for human health and also not staying outdoors for too long but that on future non-smog days they would choose public transport more to reduce the environmental pollution caused by car trips.

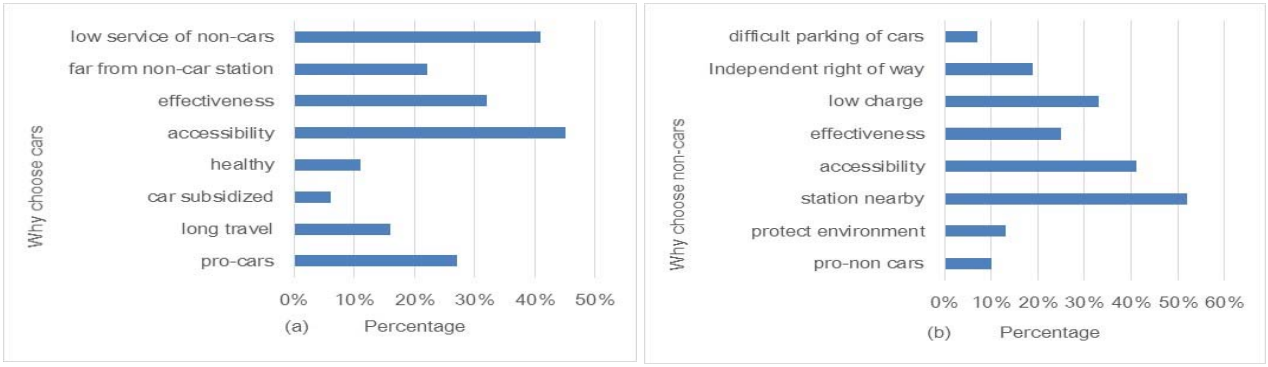

Fig. 3 The reasons why people choose cars (a) and non-car modes (b).

4 CONCLUSION

The objective of this research is to determine whether travellers will choose environmentally friendly transport modes, such as public transport, in consideration of environmental protection, health, and travel efficiency during smog days. The attitude towards non-car modes and perceived behaviour control have greater effects on intention than awareness of smog and subjective norms. Travellers will give preference to efficient travel modes to reduce the time spent outdoors. However, some car loyalists have more difficulty in giving up cars unless public transport services are improved greatly and the air quality is good. This result shows that although travellers have a certain understanding of smog and most agree that reducing the use of cars will help to alleviate the smog, whether to use pro-environmental transport depends mainly on past traffic experience. It is found that past experience has a direct influence on the traffic mode preference and actual behaviour and an indirect influence on them by affecting awareness of smog, attitude towards non-car modes and perceived behaviour control. Therefore, some traffic policies should be considered, such as normally implementing a license number restriction policy to force reductions in the use of cars; encouraging units to use shuttles for employees; encouraging carpooling services; implementing a charging policy on congested roads; and introducing preferential public transport interchange policies. Only by combining compulsory restrictions on the use of cars with the improvement of non-car mode services can we achieve the goal of reducing traffic pollution in the near and long-term future. This study still has deficiencies;

future studies will consider smog exposure and introduce personal socio-economic foundations into the model.

REFERENCES

Ajzen, I, 1991. The theory of planned behaviour. Organizational Behaviour and Human Decision Processes, 50 p.179.

Anta, J, Pérez-López, JB, Martínez-Pardo, A, Novales, M and Orro, A, 2015. Influence of the weather on mode choice in corridors with time-varying congestion: a mixed data study. Transportation, 43 p.337.

Guo, Y, Zeng, H, Zheng, R, Li, S, Barnett, AG, Zhang, S, et al., 2016. The association between lung cancer incidence and ambient air pollution in China: A spatiotemporal analysis. Environmental Research, 144 p.60.

Kang, H, Zhu, B, Su, J, Wang, H, Zhang, Q and Wang, F, 2013. Analysis of a long-lasting haze episode in Nanjing, China. Atmospheric Research, 120-121 p.78.

Liu, D, Du, H, Southworth, F and Ma, S, 2017. The influence of social-psychological factors on the intention to choose low-carbon travel modes in Tianjin, China. Transportation Research Part A: Policy and Practice, 105 p.42.

Liu, Y, Hong, Z and Liu, Y, 2016. Do driving restriction policies effectively motivate commuters to use public transportation? Energy Policy, 90 p.253.

Oztekin, C, Teksoz, G, Pamuk, S, Sahin, E and Kilic, DS, 2017. Gender perspective on the factors predicting recycling behaviour: Implications from the theory of planned behaviour. Waste Manag, 62 p.290.

Shi, H, Wang, S and Zhao, D, 2017. Exploring urban resident's vehicular $PM_{2.5}$ reduction behaviour intention: An application of the extended theory of planned behaviour. Journal of Cleaner Production, 147 p.603.

Wang, J, Zhao, B, Wang, S, Yang, F, Xing, J, Morawska, L, et al., 2017a. Particulate matter pollution over China and the effects of control policies. Science of the Total Environment, 584-585 p.426.

Wang, S, Li, J and Zhao, D, 2017b. The impact of policy measures on consumer intention to adopt electric vehicles: Evidence from China. Transportation Research Part A: Policy and Practice, 105 p.14.

Yadav, R and Pathak, GS, 2016. Young consumers' intention towards buying green products in a developing nation: Extending the theory of planned behaviour. Journal of Cleaner Production, 135 p.732.

Yu, X, Ma, J, An, J, Yuan, L, Zhu, B, Liu, D, et al., 2016. Impacts of meteorological condition and aerosol chemical compositions on visibility impairment in Nanjing, China. Journal of Cleaner Production, 131 p.112.

Zanni, AM and Ryley, TJ, 2015. The impact of extreme weather conditions on long distance travel behaviour. Transportation Research Part A: Policy and Practice, 77 p.305.

Zhang, X, Geng, G and Sun, P, 2017. Determinants and implications of citizens' environmental complaint in China: Integrating theory of planned behaviour and norm activation model. Journal of Cleaner Production, 166 p.148.

Zhang, YL and Cao, F, 2015. Fine particulate matter ($PM_{2.5}$) in China at a city level. Scientific Reports, 5 p.14884.