Assessing Public Satisfaction of Freeway Closure Measures in Fog and Haze Weather: A Questionnaire-Based Study in Hubei Province, China

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Abstract. In the current work, freeway closure measures in fog and haze weather are studied from the perspective of public satisfaction, in order to improve traffic management in Hubei province, China. Through an Internet survey to collect data, a structural equation model of public satisfaction of freeway closure measures in fog and haze weather is developed with public expectations, perceived quality, perceived value, public satisfaction, public complaints, support and understanding as variables. The results show that public’s supporting degree is not very high on the freeway closure measures. However, freeway intermittent release measures are the acceptable measures in fog and haze weather, which not only ensure traffic safety but also reduce economic losses and guarantee sustainable operation of freeway. Even though freeway closure measures are frequently taken due to serious fog and haze weather, intermittent release measures should also be taken into consideration so as to enhance public satisfaction and strengthen adaptive capacity of freeway to adverse weather.

1. Introduction
Many regions of China frequently encounter serious fog and haze weather in recent years [1–2]. Road traffic is affected by both weather environment and management measures. In adverse weather, the traffic management level affects the utilization of facility resources, human’s adaptability to the climate change and their ability to resist disasters. According to the goal of China’s National Plan on Implementation of the 2030 Agenda for Sustainable Development [3], in the traffic field, on the one hand, it is necessary to “develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure.” On the other hand, it should also “strengthen resilience and adaptive capacity to climate-related hazards and natural disasters” with the specific goal of providing “access to safe, affordable, accessible and sustainable transport systems for all.”

In fog and haze weather, the visibility of freeway is poor, which is likely to cause traffic accidents [4]. In order to ensure traffic safety, traffic management department typically takes freeway closure measures, which affects public's normal trip seriously [5]. With the frequent occurrence of fog and haze weather, this problem has become increasingly prominent. Therefore, intermittent release measures have started to be used in some regions in China, where traffic management departments release a limited number of small vehicles within a specified time interval [6–7]. Tan et al. firstly proposed improved cellular automaton models of traffic to study the freeway intermittent release measures, which showed that the measures could reduce traffic accidents, as well as energy dissipation.
and emissions [8–9]. However, there is no relevant research on people's satisfaction on freeway closure measures or intermittent release measures in fog and haze weather.

Satisfaction referred to the feeling whether the sacrifices they had made were consistent with the rewards they had earned [10]. In the field of consumption, satisfaction was the customers’ feeling of using the product [11]. Woodside et al. believed that customer satisfaction was a post-purchase evaluation, which was not only the consumer's preference after consumption, but also an experience-based overall consumption attitude [12]. Fornell et al. constructed the American Customer Satisfaction Index (ACSI), which included: customer expectations, perceived quality, perceived value, customer satisfaction, customer loyalty, and customer complaints [13]. The research on public satisfaction in traffic field is mainly based on ACSI [14–15]. Some scholars have done the specific regional road traffic public satisfaction research by investigation on the social service capacity of freeway transportation [16–17].

This paper proposes a structural equation model (SEM) of freeway closure measures in fog and haze weather from the perspective of public satisfaction, in order to improve traffic management and guarantee sustainable operation of freeway in Hubei Province, China. The rest of this paper is organized as follows. In Sec. 2, a public satisfaction model of freeway closure measures is established. In Sec. 3, the empirical study is carried out. Results and discussion are presented in Sec. 4, and conclusions are given in Sec. 5.

2. Methodology
This study adopts the opinion of Howard [10], and the public satisfaction refers to their subjective reaction of the freeway closure in fog and haze weather when compared with their prior expectations. The proposed model consists of six variables: public expectations, perceived quality, perceived value, public satisfaction, public complaints, support and understanding.

2.1. Connotation of Latent Variables
In this study, public expectation is public's estimate of the impact of closure before the freeway is closed. Perceived quality represents public's actual feeling after the freeway is closed. Perceived value is defined as the public's perception of loss caused by closure, and the perceived level of hazard that may be caused by fog and haze weather when the freeway is not closed. Through the analysis of these factors, we know the disparity between public's expected level and actual feeling of closures in fog and haze weather, namely public satisfaction. The level of satisfaction will result in “public complaints” or “support and understanding”.

2.2. Observation Variable Design
As mentioned above, the variables contain several aspects within their respective scopes. This study established a public satisfaction survey scale by setting observation variables (Table 1).

| Latent variable | Observation variable |
|-----------------|----------------------|
| Public expectations ε | Expectation of the timeliness of freeway information release X₁ |
| | Expectation of the rationality of freeway closure X₂ |
| | Expectation of the attitude of staff X₃ |
| | Expectation of whether the suggestion channels are available X₄ |
| | Expectation of whether the departments accept the supervision X₅ |
| Perceived quality η | Perception of the timeliness of freeway information release Y₁ |
| | Perception of implementation of speed limit control Y₂ |
| | Perception of prohibition of dangerous goods transport vehicles Y₃ |
| | Perception of prohibition of large trucks Y₄ |
Table 1. Cont.

| Latent variable                  | Observation variable                                      |
|---------------------------------|----------------------------------------------------------|
| Perceived quality $\eta_1$      | Perception of richness of information releasing channels $Y_5$ |
|                                 | Perception of the attitude of staff $Y_6$                 |
|                                 | Perception of whether the suggestion channels are available $Y_7$ |
|                                 | Perception of whether the departments accept the supervision $Y_8$ |
| Perceived value $\eta_2$        | Influence on public’s trip $Y_9$                         |
|                                 | Perception of freeway closure measures $Y_{10}$           |
|                                 | Perception of ordinary road closure measures $Y_{11}$     |
|                                 | Understanding of the purpose of freeway closure $Y_{12}$  |
| Public satisfaction $\eta_3$     | Acceptance of freeway closure measures to ensure traffic safety $Y_{13}$ |
|                                 | Perceived disparity between actual condition and expected condition of freeway closure $Y_{14}$ |
|                                 | Perceived disparity between actual condition and best condition of closure $Y_{15}$ |
|                                 | Overall satisfaction with freeway closure $Y_{16}$        |
| Public complaints $\eta_4$       | Possibility of complaining about freeway closure $Y_{17}$ |
|                                 | Possibility of complaining about freeway closure measures $Y_{18}$ |
|                                 | Degree of public’s support if ordinary road is closed instead $Y_{19}$ |
|                                 | Degree of complaining about freeway closure $Y_{20}$      |
| Support and understanding $\eta_5$ | Degree of understanding for freeway closure measures $Y_{21}$ |
|                                 | Degree of support for freeway closure measures $Y_{22}$   |
|                                 | Degree of support and understanding for freeway departments $Y_{23}$ |
|                                 | Degree of support for intermittent release measures $Y_{24}$ |

Based on the ACSI model, the public satisfaction model of freeway closure measures (for short, PSFCM) is developed (Figure 1). The model includes two sub-models, a structural sub-model and a measurement sub-model. The structural sub-model reflects the relationship between the various latent variables. The measurement sub-model reflects the relationship between each latent variable and its corresponding observation variable. To verify the proposed model, empirical data should be collected to confirm the relationship between the latent variables, as well as the consistency degree between latent variable and its corresponding observation variable [18].

![Figure 1. Public satisfaction model framework of freeway closure measures.](image-url)
3. Empirical Study

3.1. Data Collection
The empirical data of this study is obtained by publishing a survey entitled "Survey of Public Satisfaction of Freeway Closure Measures in Fog and Haze Weather in Hubei Province" on the website https://www.wjx.cn/jq/25211604.aspx. The survey scale adopts the seven-level scoring method (the highest score of the scale is 7 and lowest score is 1), and the respondents were asked to complete the survey according to their own real situations. In this survey, 405 questionnaires were collected after removing 16 invalid questionnaires.

3.2. Reliability Test
Reliability is an indicator of the consistency or stability of measurement results [19]. Reliability test is to verify the authenticity of the survey sample and whether the data reflects the true situations of the respondents. Cronbach’s alpha coefficient is commonly used as the indicator, and when it is larger, the reliability of the data is better. When the Cronbach’s alpha coefficient is greater than (inclusive) 0.7, it can be considered that the internal consistency of the variable is high; when it is between 0.6 and 0.7, it’s also acceptable [20]. SPSS 20.0 is applied to test the reliability of the data. The results showed that the Cronbach’s alpha coefficient of the overall reliability test was 0.683, nearly 0.7, so the overall reliability was well (Table 2). Therefore, the survey data is reliable.

Table 2. Cronbach’s alpha values of the questionnaire.

| Variable name                      | Number of items | Cronbach’s alpha value |
|------------------------------------|-----------------|------------------------|
| Public expectations $E^2$          | 5 ( $X_1$ - $X_5$ ) | 0.669                  |
| Perceived quality $I^1$           | 8 ( $Y_1$ - $Y_8$ ) | 0.572                  |
| Perceived value $I^2$             | 5 ( $Y_9$ - $Y_{13}$ ) | 0.342                  |
| Public satisfaction $I^3$         | 3 ( $Y_{14}$ - $Y_{16}$ ) | 0.745                  |
| Public complaints $I^4$           | 4 ( $Y_{17}$ - $Y_{20}$ ) | 0.446                  |
| Support and understanding $I^5$   | 4 ( $Y_{21}$ - $Y_{24}$ ) | 0.502                  |
| Total                              | 29              | 0.683                  |

3.3. Validity Test
Because the latent variables contain several aspects within their respective scopes, it is difficult for the respondents to describe all of these aspects directly. Therefore, an indirect method is applied to acquire the respondents’ perception of latent variables. Undoubtedly, whether the observation variables can describe the meaning of latent variable accurately has a great impact on the results.

The "validity" is introduced to measure whether the observation variables express the meaning of the corresponding latent variable accurately. The factor loading is adopted to indicate the validity. When the coefficient is no less than 0.4, the observation variable is considered to have a high validity [20]. The higher the validity is, the more consistent the observation variables are with the content to be investigated, and vice versa. This study applies SPSS 20.0 to verify the correspondence between the variables, and the factor loading of each observation variable is obtained. The results indicate that the variable validity is acceptable.

4. Results and Discussion
The questionnaire results are shown in Table 3. Among the expectations, the highest is the expectation of timeliness of closure information release (AV=6.380, SD=1.248), and subsequently the expectation of staff attitude (AV=6.269, SD=0.990); whether the traffic management departments accept the supervision is the lowest (AV=6.042, SD=0.963). The public has the highest perceived quality of prohibiting the dangerous goods transport vehicles (AV=6.062, SD=1.110), but the feeling is not good for the richness of information releasing channels (AV=3.780, SD=1.530). It is thus clear that there is a disparity between actual situation and public's expectation.
Comparing “public complaints” with “support and understanding”, we can find that the average value of “support and understanding” is bigger than “complaints”, but the standard deviation of “support and understanding” is smaller. This result means the public supports traffic management department to take appropriate measures which can avoid losses from road closures and ensure traffic safety. What’s more, the respondents’ supporting degree is not very high on freeway closure measures (AV=4.993, SD=1.431). However, they desire the freeway intermittent release measures (AV=5.654, SD=1.220). It indicates that the freeway closure measures could be replaced by intermittent release measures under certain conditions in fog and haze weather.

In order to study the effect between variables, AMOS is applied to estimate the normalized path coefficients between latent variables of the PSFCM model (Figure 2). When the coefficient is positive (negative), the two variables are positive (negative) relationship. The following results can be obtained by analyzing the normalized path coefficients.

![Figure 2. Results of the PSFCM model.](image)

Among the three determinants affecting public satisfaction of freeway closure measures in fog and haze weather, the direct impact coefficients of perceived quality and perceived value are 0.605 and 0.618 respectively, while the public expectation is -0.012. The results indicate that public expectation has a negative impact on satisfaction. The higher the expectation, the lower the satisfaction is. Public expectation has a negative impact on the perceived quality. Due to the influence of psychological factors, the higher the expectation, the lower the perceived quality level is when people have the same experience.

Public satisfaction has a negative impact on public complaints, and the impact coefficient is -0.135, while the direct impact coefficient on support and understanding is 0.835. Public complaint has a negative impact on support and understanding, and the impact coefficient is -0.154. It goes without saying that the higher the complaints, the lower the possibility of support and understanding is, and the higher the satisfaction, the higher the possibility of support and understanding is.

The normalized path coefficients of the PSFCM model show that we could improve public satisfaction by reducing expectation or increasing perceived quality and perceived value, which also could improve public support and understanding. However, the average value of each observation variable of public satisfaction is less than 4.8, and it's hard to become higher. That's because freeway closure measure is not the best way of human adaptation to frequent fog and haze weather. Freeway closure measures will bring a great deal of economic losses [4]. Take Shanghai-Nanjing freeway as an example, the mileage is 274.35 km, and there were 57 closures due to fog weather from 2006 to 2009, resulting in direct economic losses of more than RMB67.81 million [6]. In addition, drivers who are forbidden to drive on freeway have to drive on ordinary road where traffic accidents also easily happen in fog and haze weather [5]. Therefore, intermittent release measures are more applicable which could guarantee that no rear-end collisions occur and avoid losses [9].
Table 3. The average value and standard deviation of the observation variables.

| Latent variable          | Observation variable | Average value (AV) | Standard deviation (SD) |
|--------------------------|----------------------|--------------------|-------------------------|
| Public expectations ε    | X₁                   | 6.380              | 1.248                   |
|                          | X₂                   | 6.257              | 0.997                   |
|                          | X₃                   | 6.269              | 0.990                   |
|                          | X₄                   | 6.094              | 1.054                   |
|                          | X₅                   | 6.042              | 0.963                   |
| Perceived quality η₁    | Y₁                   | 4.333              | 1.706                   |
|                          | Y₂                   | 5.398              | 1.161                   |
|                          | Y₃                   | 6.062              | 1.110                   |
|                          | Y₄                   | 5.667              | 1.257                   |
|                          | Y₅                   | 3.780              | 1.530                   |
|                          | Y₆                   | 4.733              | 1.232                   |
|                          | Y₇                   | 4.133              | 1.376                   |
|                          | Y₈                   | 4.309              | 1.386                   |
| Perceived value η₂      | Y₉                   | 2.331              | 1.220                   |
|                          | Y₁₀                  | 3.672              | 1.518                   |
|                          | Y₁₁                  | 4.121              | 1.443                   |
|                          | Y₁₂                  | 4.652              | 1.867                   |
|                          | Y₁₃                  | 5.938              | 1.175                   |
| Public satisfaction η₃  | Y₁₄                  | 4.620              | 1.196                   |
|                          | Y₁₅                  | 4.501              | 1.310                   |
|                          | Y₁₆                  | 4.798              | 1.270                   |
| Public complaints η₄    | Y₁₇                  | 4.017              | 1.686                   |
|                          | Y₁₈                  | 5.728              | 1.229                   |
|                          | Y₁₉                  | 4.425              | 1.485                   |
|                          | Y₂₀                  | 4.262              | 1.570                   |
| Support and understanding η₅ | Y₂₁              | 5.743              | 1.155                   |
|                          | Y₂₂                  | 4.993              | 1.431                   |
|                          | Y₂₃                  | 4.990              | 1.284                   |
|                          | Y₂₄                  | 5.654              | 1.220                   |

5. Conclusions
In this paper, the PSFCM model is proposed to study public satisfaction of freeway closure measures in fog and haze weather in Hubei Province, China. We find that although freeway closure measures are frequently taken by the traffic management department in recent years, the respondents’ supporting degree is not very high on the measures. Furthermore, freeway intermittent release measures are the acceptable measures in fog and haze weather, which not only ensure traffic safety but also reduce economic losses and guarantee sustainable operation of freeway. In order to strengthen adaptive capacity of freeway to frequent fog and haze weather, we will do further research on intermittent release measures to promote sustainable development of traffic in the future.

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