Cross-Cultural Decision Making, Vol. 44, 2022, 44–51
https://doi.org/10.54941/ahfe1001854

Analysis on the Preference Intention and Its Influencing Factors of Standing Passengers in Subway Carriages

Ke Liu[1], Canqun He[1], and Zhelong Hu[2]

[1]School of Mechanical and Electrical Engineering, Hohai University, Nanjing, China
[2]KTK Group CO., LTD, China

ABSTRACT

The uneven distribution of people flow in subway carriages is a common phenomenon. Considering the influencing factors of passengers' standing position preference at the objective environment level, it can provide a theoretical basis for the optimization of subway carriage space design. In this paper, three different compartment layout factors influencing the preference intention of passenger standing area are proposed, and the multivariate ordinal Logistic model is used to empirically analyze the influence of the three factors on the preference degree of the passenger area. The results show that the number of columns in a single carriage is more than 4 and the gripping form of the door area is high bar, which are the risk factors for obtaining higher preference degree in the transition area. N + 2 type layout is the risk factor of higher preference degree of gate area. The number of columns in a single carriage is more than 4, the high ring bar in the gate area and the N + 2 seat layout are the protective factors for the middle passage area to obtain a higher degree of preference. The results confirm that the layout of carriage facilities can affect passengers' preference for different standing areas, the objective environment has an effective guiding effect on passengers' behavior path. A reasonable carriage layout can invisibly standardize the ride order and improve vehicle transport capacity and ride comfort.

Keywords: Subway compartment layout, Choice of standing position, Passenger's preference, Influencing factors

INTRODUCTION

As an important part of urban rail, the subway bears most of the public transportation capacity of the city. With the improvement of the functional expression of subway cars, researchers began to pursue a more efficient and comfortable travel experience when considering the space design of subway cars. The phenomenon of uneven density of standing seats in subway cars is a common problem in subway cars. Most passengers say that they prefer to stand near the door, and passengers near the door will be subjected to greater crowding force, which will also lead to low train transfer efficiency (Hirsch et al. 2011). Passengers are accustomed to gathering at the door, which not only reduces the capacity of the vehicle, but also affects the riding comfort.

At present, scholars have begun to pay attention to the uneven distribution of the density of standing seats in the carriage. For example, Zhao Liang et al. obtained the distribution law of the density of standing seats in the carriage by investigating the use of various facilities in the carriage (Zhao et al. 2009). Wu Qibing et al. conducted field observation on Beijing Subway Line 1 and Line 4, obtained the change rule of the density of standing seats in time and space, and proposed the evaluation standard of the density of standing seats (Wu et al. 2014). Most researchers focus on summarizing and discovering the laws of passengers' standing position selection, but few have conducted in-depth analysis of the impact mechanism behind passengers' position selection behavior.

Studies have shown that the distribution of passengers in the carriage is also affected by passenger's personal attributes, travel characteristics and environmental layout (Kim et al. 2014). The first two categories are subjective uncontrollable factors, while the third category is objective environmental factors. It is the arrangement of facilities inside the carriage that affects the distribution of passengers (Wu et al. 2013). At present, there are few related researches on the influence mechanism of objective environmental factors on passengers' position selection behavior. Therefore, understanding the mechanism of the differential physical layout inside a subway car on passenger position selection can further guide the design of subway car interior space. In order to explore the influence of objective environmental factors on passengers' choice of standing area, the preference degree of the passenger station area is used as the evaluation index, and three differentiating factors in the physical layout of the carriage are selected to explore their influence on the preference intention of the passenger station area.

THE EMPIRICAL RESEARCH

In this paper, the influencing factors of passengers' preference for standing position are focused on the carriage layout. Based on the classification and summary of the layout forms of existing subway functional facilities, three layout difference factors are proposed in advance that affect passengers' preference for standing position (Wei et al. 2016): the number of middle columns (4 or more than 4 in a single carriage), the gripping form of the door area (vertical bar and elevated area handrail), and the seat layout (N + N and N +2) (Berkovich et al. 2013).

Definition of Evaluation Index

By introducing the concept of the degree of preference for standing area, passengers' willingness to choose different standing areas was described. Passengers position preference degree can be divided into four ranks. From high to low, the preference degree of standing area is Level four, Level three, Level two and Level one.

Methods

The standing space inside subway cars is divided into three areas, namely transition area, gate area and middle passage area (see Figure 1).

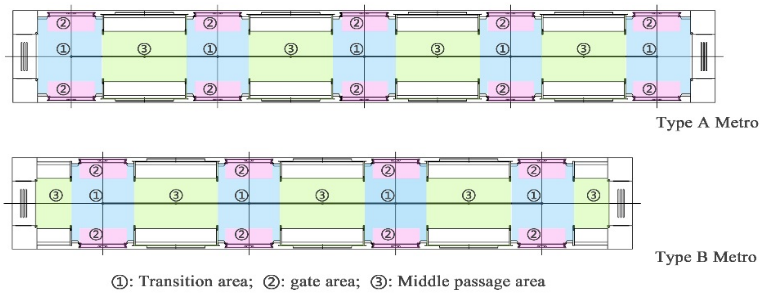

Figure 1: Schematic diagram of compartments space division.

Questionnaire survey was used to obtain the data of passengers' preference degree to different positions in different scenarios. RP survey and SP survey were used in this study. SP survey is often used in the research field of attitude tendency determining mode or route (Wardman et al. 2015). SP survey in this questionnaire is to obtain passengers' "subjective preference intention in the hypothetical carriage scenario", and paper prototype method is used to show the respondents different carriage layout scenarios. The survey content includes individual natural characteristics and travel characteristics of passengers, as well as their willingness to choose in different compartment layout scenarios.

Establishing Model

Take the degree of passengers' preference for a stand area as the explained variable, which belongs to the ordered multi-classification variable. Therefore, use the ordered classification Logistic model to analyze the relationship between the probability P of different degree of preference of fixed station area and the influencing factors. The probability that the standing area preference degree is grade is P_i, $i = 1, 2, 3, 4$, and meet $p_1, p_2, p_3, p_4 = 1$. The cumulative Logistic model is:

$$Logit(p(y \leq i)) = \ln(\frac{p(y \leq i)}{1 - p(y \leq i)}) = \alpha_i + \sum_{m=1}^{M} \beta_m X_m \qquad (1)$$

Where, in equation (1), i is 1, 2, 3; $X_m (m = 1, 2, 3)$ is the explanatory variable of this paper, the differences in the layout of the three carriages discussed above; α_j is the intercept term; β_m is the regression coefficient. According to the model, the cumulative probability that the standing area preference degree is gradecan be calculated as:

$$p(y \leq i) = \frac{\exp(\alpha_i + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}{1 + \exp(\alpha_i + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)} \qquad (2)$$

Define the definition and assignment of variables in Formula (2) (see Table 1).

Table 1. Logistic regression variable assignment table.

Category	Variable name and code	Variable assignment
Variables related to the physical layout of the carriage	Number of central columns in a single carriage ($\mathbf{X}_1$)	1: 4; 2: >4
	Holding device form of door area (X_2)	1: Middle column; 2: Annular rotary rod
	Seat arrangement (X_3)	1: N+N; 2: N + 2

Table 2. Regression results of factors influencing the degree of choice preference in area 1 (transition zone).

The independent variables	β	SE	Wald	P	OR	95%CI
Number of central columns (single carriage)						
4	0.440	0.529	28.683	0.000	1.344	1.228~1.515
>4	0				1	
Holding device for door area						
Center pillar	1.634	0.499	10.708	0.001	2.125	1.926~2.359
Annular rotary rod	0				1	
Seat arrangement type						
N+ N	0.038	0.079	0.178	0.634	1.034	0.816~1.232
N+ 2	0				1	

EMPIRICAL ANALYSIS RESULTS

SPSS software was used for econometric regression analysis of valid questionnaire data, and regression analysis of the influencing factors of explained variable – degree of passenger standing area preference.

Logistic Regression Analysis Results of Standing Area 1

Taking the preference degree of standing area 1 as the explanatory variable, the parameter estimation results of each variable were calculated (see Table 2).

In standing area 1, when the degree of passenger preference increases by at least one grade from low to high, the risk of 4 middle columns in a single carriage is 1.344 times higher than that of more than 4 middle columns. The risk of gate area with middle post was 2.125 times higher than that of ring bar. That is to say, in a column number greater than 4 and the handrail of the door area is a ring bar, passengers have a lower preference for area 1. So the single carriage in more than four pillar and ring bar is a risk factor for area 1 to obtain a higher degree of preference.

Table 3. Regression results of factors influencing the degree of choice preference in area 2 (gate area).

The independent variables	β	SE	Wald	P	OR	95%CI
Number of central columns (single carriage)						
4	0.636	0.300	3.492	0.134	1.346	1.148~1.524
>4	0				1	
Holding device for door area						
Center pillar	−0.641	0.300	4.559	0.433	0.895	0.529~1.253
Annular rotary rod	0				1	
Seat arrangement type						
N+N	1.081	0.322	41.884	0.000	2.012	1.851~2.315
N + 2	0				1	

Table 4. Regression results of factors influencing the degree of choice preference in area 3 (Middle passage area).

The independent variables	β	SE	Wald	P	OR	95%CI
Number of central columns						
4	−1.946	0.620	9.863	0.002	0.413	0.142~0.481
>4	0				1	
Holding device for door area						
Center pillar	−0.308	0.482	9.409	0.000	0.361	0.169~0.506
Annular rotary rod	0				1	
Seat arrangement type						
N+N	−1.188	0.440	19.108	0.000	0.640	0.356~0.959
N + 2	0				1	

Logistic Regression Analysis Results of Standing Area 2

Taking the preference degree of standing area 2 as the explanatory variable, the parameter estimation results of each variable were calculated (see Table 3).

The risk of N+N seat layout was 2.086 times higher than that of N + 2 seat layout when the degree of passenger preference increased by at least one grade from low to high in area 2. In other words, under the N + 2 seat layout, passengers have a lower degree of preference for standing area 2, so the N + 2 seat layout is a risk factor for area 2 to obtain a higher degree of preference.

Logistic Regression Analysis Results of Standing Area 3

Taking the preference degree of standing area 3 as the explanatory variable, the parameter estimation results of each variable were calculated (see Table 4).

In station area 3, the degree of passenger preference increases by at least one grade from low to high, the risk of a single carriage with more than 4 middle columns is 2.421 times that of 4 middle columns, and the risk of a gate area with a ring bar is 2.770 times that of middle columns. The N + 2 seat layout is 1.567 times that of the N+N seat layout. In other words, when the number of central columns is greater than 4, the handrails in the gate area are circular bars, and the seat layout is N +2, passengers have a higher preference for area 3. Therefore, more than 4 middle columns, the circular bar type in the door area and the N + 2 seat layout is the protective factor for area 3 to obtain a higher degree of preference.

DISCUSSION

The Number and Arrangement of the Middle Column can Guide the Choice Behavior of Standing Passengers

The results show that when the middle column is evenly set in the middle of the carriage, the extension of the column in the longitudinal line of sight can effectively attract standing passengers to move to the inside of the carriage, thus reducing the gathering of standing passengers near the door. Li Caifeng also came to a similar conclusion in the study of the influence of different layouts on the transfer efficiency of trains, that, the middle column as a small obstacle can play a role of drainage (Li, 2017).

Grasping Comfort of Gripping Facilities is an Important Factor Affecting Passengers' Choice Intention

When the gripping form between two pairs of side doors is circular gripping bar, the preference of passengers to choose the transition zone decreases obviously. At the same time, due to the attraction of the middle column in the middle passage area, passengers' preference for the middle transition area has increased. Jiang Liang et al. found through the study that the grip comfort of the middle column was higher than that of the high pole (Jiang et al. 2020). Combined with the results of regression analysis, it was proved that the grip comfort of the gripping facilities would affect passengers' willingness to use them. Setting up different gripping facilities in different areas will form standing areas with different attraction rates (Zhang, 2017).

Variations in the Degree of Preference for Transition Region and Middle Channel Region are Usually Complementary

In the compartmentalization of the carriage standing area in this study, the transition zone and the middle passage area are connected vertically, and the transition between the two areas is very close. It is found that the change of preference degree in the transition zone and the middle passage area is usually complementary. The preference degree in the transition zone decreases, corresponding to the preference degree in the middle passage area increases. Therefore, when considering reducing the density of passenger seats in the transition zone, we can make use of the natural connection between the transition zone and the middle passage zone to try to change the direction of thinking: how to improve the passenger attraction rate in the middle passage zone to attract passengers in the transition zone to move naturally.

CONCLUSION

Three potential factors affecting passengers' intention to choose standing area preference were proposed. 168 random survey samples were selected as the research object, and the degree of choice preference was used as the evaluation index of passengers' intention to choose standing area preference. The influence of these three variables on the degree of passenger standing area preference was analyzed by multivariate ordered Logistic model. The results show that the difference of carriage layout has a significant impact on the degree of preference of passengers in different stations, and the influence of different variables of carriage layout on different area is different. The design of the carriage space can be based on the effect of different facility layouts on the passengers' preference of standing area. The guiding effect of the environment on the passenger behavior can be used to realize the even distribution of the passenger flow in the compartment, so as to invisibly regulate the public transportation order.

ACKNOWLEDGMENTS

It is supported by Zhejiang provincial key laboratory of integration of healthy smart kitchen system (Grant No: 2014E10014) and Special funds for humanities and social sciences for central universities (Grant No: B220207017).

REFERENCES

Berkovich, A., Lu, A., Levine, B., and Reddy, A. V. (2013), "Observed Customer Seating and Standing Behavior and Seat Preferences on Board Subway Cars in New York City", *Transportation Research Record: Journal of the Transportation Research Board*, 2353 (1), 33–46.

Hirsch, L., and Thompson, K. (2011), "I can sit but I'd rather stand: Commuter's experience of crowdedness and fellow passenger behaviour in carriages on Australian metropolitan trains", *in ATRF 2011 - 34th Australasian Transport Research Forum*.

Kim, H., Kwon, S., Wu, S. K., and Sohn, K. (2014), "Why do passengers choose a specific car of a metro train during the morning peak hours?", *Transportation research. Part A, Policy and practice*, 61, 249–258.

Wardman, M., and Murphy, P. (2015), "Passengers' valuations of train seating layout, position and occupancy", *Transportation Research Part A: Policy and Practice*, 74, 222–238.

Wei, F., and Xu, B. (2016), "Application of the Human Geometry Compatibility in the Subway Interior Design".

Wu, Q. B., Chen, F., Fang, J. P., Liu, O. Y., Liu, C., and Zhai, Q. S. (2013), "Investigation and Study of the Law of Passenger Distribution in One Carriage of Subway in Beijing", *Applied Mechanics and Materials*, 2083, 361–363.

Jiang, L., Lu, X. T., He, S, J., and An, J. (2020), "Research on design status and optimization of in-car gripping system in Metro", *Design*, 33(10), 110–112.

Li, C. F. (2017), The effect of passenger room layout on passenger drop efficiency of intercity trains., Beijing Jiaotong University.

Wu, Q. B., Chen, F., Liu O. Y., Fang, J. P., and Li, X. H. (2014), "Modeling and simulation of spatial comfort of standing Passengers in subway carriages", *Transportation Systems Engineering and Information*, 14(05), 126–132.

Zhang, Y. (2017), "A brief discussion on the relationship of "man-object-space" in subway passenger room design", *Science and Technology economic Guide*, 18, 250.

Zhao, L., Chen, F., and Wu, Q. B. (2009), "Reasonable arrangement of rail transit vehicle service facilities", *Railway transportation and economy*, 31(06), 65–68.