Evaluation about Passenger Satisfaction Degree of Wuhan-Guangzhou High-speed Rail Based on SPA

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Abstract. As far as Wuhan-Guangzhou high-speed rail put in operation, except for holidays, the passenger load rate is low, facing huge market risk. This paper explores the passenger satisfaction of Wuhan-Guangzhou high-speed rail, based on SPA(Set Pair Analysis) theory and combined with practice. To analyze the impact factors of passenger satisfaction, a in-depth investigations was made on Wuhan-Guangzhou high-speed rail. After the investigations, the date collected is processed by software named SPSS. Then, through using the method of SPA, passenger satisfaction evaluation model is built. Therefore, we can estimate the passenger satisfaction levels of Wuhan-Guangzhou high-speed rail by the model. The results can provide a reference for the management of Wuhan-Guangzhou high-speed rail, but also a basis for scientific decisions.

Introduction

Wuhan-Guangzhou high-speed railway was put into operation in September 2009. Over the past years, except for holidays, the passenger load rate is low, facing huge market risk. The development level of Wuhan-Guangzhou high-speed rail transport system is directly related to the whole functions of the city along the line. So passenger satisfaction level affects the Wuhan-Guangzhou high-speed rail operating conditions directly. Therefore, the comprehensive evaluation to passenger satisfaction levels of Wuhan-Guangzhou high-speed rail is important to promote the rapid development of the Wuhan-Guangzhou high-speed rail.

Set Pair analysis (SPA) is a system analysis method that deals with the uncertainty problem. It is proposed by China scholar Zhao Keqin in 1989[1]. Currently, the method has been widely used in engineering, systems management decision-making, evaluation of groundwater quality, atmospheric environmental assessment, safety evaluation, integrated forecasting and detection of power, urban public transportation. But SPA has not been applied in passenger satisfaction evaluation issues of railway[2].Through analyzing various impact indicators factors, this paper sets up passenger satisfaction evaluation model of Wuhan-Guangzhou high-speed rail based on set pair analysis theory .Then through field research and collecting data, it gets the evaluation value.

The General Introduction of Set Pair Analysis

The profile of Set Pair Analysis. SPA is a system analysis technology that research the certainty and uncertainty and a transfer regular widely existed in system. Set Pair is a set of pairs that is composed by two sets which have a certain link, Set Pair Analysis is the characterization of contact and confrontation in some feature, it can be represented by a simple and complete connection degree μ, the formula can represent expressions dialectical relationship of the set.

$$\mu=a+bi+cj \quad (1)$$

In this formula, a, b, c are respectively called same degree, different degree,opposite degrees of the set pair. i, j are respectively the sign or the appropriate factor of the different degree and opposite degree, suppose $i \in [-1,1]$, $j = -1$, $a + b + c = 1$.

The connection degree formula is the basic of Set Pair Analysis. In the connection degree, a and c, respectively refers to the same and opposing sides of things' certainty and the uncertainty. while item b

refer to the uncertainty of the system, and reflect the complete information. Compared to traditional methods of evaluation, the evaluation results of Set Pair Analysis is more reasonable.

The basic method of Set Pair Analysis. The core of SPA is the calculation of connection degree. The basic idea of the calculation is: when the evaluation indictor is in the grade, then the connection degree of this grade is 1,if the evaluation indictor is in the interval grade, then the connection degree of this grade is -1 or 0.Because the satisfaction degree is non-negative, the connection degree take 0 in this paper, if the evaluation indictor is in the adjacent grade, the connection degree is determined by a functional. Specific calculations for each grade are as follows: from formula (2) to (6) [3].

1)When the evaluation indictor is in grade (Ⅰ)

$$m_{i1}=\begin{cases}1 & x\in[U_1,U_0]\\ \dfrac{x-U_2}{U_1-U_2} & x\in[U_2,U_1]\\ 0 & x\in(0,\ U_2]\end{cases} \tag{2}$$

2)When the evaluation indictor is in grade (Ⅱ)

$$m_{i2}=\begin{cases}\dfrac{U_0-x}{U_0-U_1} & x\in[U_1,U_2]\\ 1 & x\in[U_2,U_1]\\ \dfrac{x-U_3}{U_2-U_3} & x\in[U_3,U_2]\\ 0 & x\in(0,\ U_3]\end{cases} \tag{3}$$

3)When the evaluation indictor is in grade (Ⅲ)

$$m_{i3}=\begin{cases}0 & x\in(0,\ U_4]\cup[U_1,U_0)\\ \dfrac{U_1-x}{U_1-U_2} & x\in[U_2,U_1]\\ 1 & x\in(U_3,U_2]\\ \dfrac{x-U_4}{U_3-U_4} & x\in(U_4,U_3]\end{cases} \tag{4}$$

4)When the evaluation indictor is in grade (Ⅳ)

$$m_{i4}=\begin{cases}0 & x\in(0,\ U_5]\cup[U_2,U_0)\\ \dfrac{U_2-x}{U_2-U_3} & x\in[U_3,U_2]\\ 1 & x\in(U_4,U_3]\\ \dfrac{x-U_5}{U_4-U_5} & x\in(U_5,U_4]\end{cases} \tag{5}$$

5)When the evaluation indictor is in grade (Ⅴ)

$$m_{i5}=\begin{cases} 0 & x\in(0,\ U_4]\cup[U_1,U_0) \\ \dfrac{U_3-x}{U_3-U_4} & x\in(U_3,U_1] \\ 1 & x\in(U_4,\ U_3] \end{cases} \quad (6)$$

From formula (2) to formula (6), U_0~U_5 refer to respectively the limit value of the evaluation indictor for five grade(Ⅰ-Ⅴ); x is the actual value of the evaluation indictor,μ_{i1}, μ_{i2}, μ_{i3}, μ_{i4}, μ_{i5} are the connection degree for each grade.

If $\mu_p=\max\mu_j$, $1 \le j \le m$, $p \in [1,2,...,m]$,which is said that the evaluation grade level is p, m is the number of the grades.

The Passenger Satisfaction Evaluation Index System of Wuhan-Guangzhou High-speed Rail

Passenger satisfaction refers to the visitors' feeling status level, this level is the comparison result between rail passenger services and tourists expected performance [1].Railway passenger satisfaction evaluation system focus on improving rail passenger satisfaction. By the use of the system- perspective, in the rail passenger service system, the major impact factors of passenger satisfaction are linked. Ultimately, a comprehensive evaluation index system is formed [4].

Wuhan-Guangzhou high-speed rail system is a complex system, and its comprehensive evaluation factors are complex. So the evaluation system should not only be feasible, comprehensive, objective, but also can truly reflect the actual situation of the urban public transport system. Therefore, applying systems-perspective and enterprise management method, this paper combines the main factors together, which affect passenger satisfaction that in all aspects and in various stages of the Wuhan-Guangzhou high-speed rail passenger service systems. At last, based on the structure of passenger demand and the characteristics of transport products and services, passenger satisfaction evaluation index system is established.

The major factors that affect the railway passenger satisfaction include seven aspects: 1) Security 2) economy 3) rapidity 4) comforts 5) convenience 6) Service 7) hardware. Based on the seven factors, combined with the special nature of stations and trains (U_1,U_2), 16 indicators are determined to assess the passenger satisfaction of Wuhan-Guangzhou high-speed rail. The passenger satisfaction evaluation index system of Wuhan-Guangzhou high-speed rail is shown in Table 1.

Table 1 The passenger satisfaction degree evaluation system

		Indictor code	evaluation indictor
The passenger satisfaction evaluation index system	station (U_1)	I_1	convenience of public bus transfer
		I_2	Information propaganda of station and train
		I_3	ticket service
		I_4	reasonable degree of ticket price
		I_5	signs for instruction
		I_6	business environment
		I_7	convenience of parking
		I_8	order and security
	train (U_2)	I_9	punctuality and quick
		I_{10}	clean and comfortable
		I_{11}	safety in operation
		I_{12}	service of crew

		I_{13}	catering
		I_{14}	facilities and equipment
		I_{15}	leisure and entertainment
		I_{16}	Information service

Measure Passenger Satisfaction Evaluation Indictor of Wuhan-Guangzhou High-speed Rail

The nature of passenger satisfaction measure is a process of quantitative analysis. In other words, the measure uses data to reflect passengers' attitude on assessment objects quantitatively. Through the field surveys of Wuhan-Guangzhou high-speed rail stations and trains, using the method of questionnaires, we can get passengers' attitude on the consuming process of transportation service. Finally, after collecting questionnaire data, we can measure satisfaction degree values of 16 by using the method of probability multiplication.

To make the survey results more intuitive, this paper selects the five grade Likert scale. the five attitudes are: very satisfied, satisfied, satisfied in general, dissatisfied, very dissatisfied, the value are respectively 9,7,5, 3,1. The survey statistics are shown in Table 2.

Table 2 The result of passenger satisfaction survey

	Indictor	passenger rate(%) Very satisfied (9)	Satisfied (7)	Satisfied in general (5)	Dissatisfied (3)	Very Dissatisfied (1)
U_1	I_1	8	24	41	25	3
	I_2	32	43	17	6	2
	I_3	36	46	14	3	1
	I_4	10	13	40	15	22
	I_5	52	22	20	5	1
	I_6	18	32	37	10	3
	I_7	34	44	19	2	1
	I_8	67	20	10	2	1
	I_9	80	16	4	0	0
	I_{10}	51	40	8	1	0
	I_{11}	31	40	21	6	2
	I_{12}	32	43	22	1	1
U_2	I_{13}	14	19	36	25	6
	I_{14}	15	4/	25	16	4
	I_{15}	7	12	60	16	5
	I_{16}	16	20	42	15	7

passenger satisfaction degree evaluation indictor is measured by formula (7) :

$$I = \sum_{n=1}^{5} P_n w_{in} \qquad (7)$$

In this formula, I is the measured values of evaluation indictor, P_n is the grade value of grade n, including 9,7,5,3,1. ω_{in} is the probability that the i-th evaluation in grade n. Put Values in Table 2 into formula (6), calculated the measured values of evaluation indictor ,the result is shown in Table 3.

Table 3 The measured values of evaluation indictor

Evaluation indictor	Measured values	Evaluation indictor	Measured values
I_1	5.23	I_9	8.52

I_2	6.94	I_{10}	7.82
I_3	7.26	I_{11}	6.84
I_4	4.48	I_{12}	7.03
I_5	7.38	I_{13}	5.20
I_6	6.04	I_{14}	5.92
I_7	7.16	I_{15}	5.00
I_8	8.00	I_{16}	5.46

Measure Passenger Satisfaction Degree of Wuhan-Guangzhou High-speed Rail

Measure the connection degree of evaluation indictor. Put the indicator values in Table 3 according to formula (2) - formula (6), calculate the connection degree of the evaluation indictor, the results are shown in Table 4.

Table 4 The connection degree of each evaluation indictor

Indictor	very satisfied	satisfied	satisfied in general	dissatisfied	very dissatisfied
I_1	0.115	1	0.88	0	0
I_2	0.97	1	0.03	0	0
I_3	1	0.87	0	0	0
I_4	0	0.74	1	0.26	0
I_5	1	0.81	0	0	0
I_6	0.52	1	0.48	0	0
I_7	1	0.97	0	0	0
I_8	1	0.5	0	0	0
I_9	1	0.24	0	0	0
I_{10}	1	0.59	0	0	0
I_{11}	0.92	1	0.08	0	0
I_{12}	1	0.986	0	0	0
I_{13}	0.1	1	0.9	0	0
I_{14}	0.46	1	0.54	0	0
I_{15}	0	1	1	0	0
I_{16}	0.23	1	0.77	0	0

Measure the total connection degree. The connection degree of evaluation indictor about the high-speed rail's stations and train are U_1, U_2, and the total connection degree U are shown in Table 5.

Table 5 Total connection degree of evaluation indictor

Indictor	very satisfied	satisfied	satisfied in general	dissatisfied	very dissatisfied
U	10.315	13.706	5.68	0.26	0
U_1	5.605	6.89	2.39	0.26	0
U_2	4.71	6.816	3.29	0	0

We can find that maxμ= 13.706. Based on criteria of the maximum contact degree, through the research and data , the passenger satisfaction of Wuhan-Guangzhou high-speed rail is in grade (Ⅳ), in other words, perception and evaluation of passenger on the Wuhan-Guangzhou high-speed rail is at a satisfactory level.

Conclusions

It's more simple and easier to evaluate the passenger satisfaction degree of Wuhan-Guangzhou high-speed rail by the method SPA. SPA can tell us the evaluation indictor of rail system in which grade

systematically, and the difference of different evaluation indictor. Moreover, it provides a new way for the comprehensive evaluation of high-speed rail system.

However, there are some defects. For example, building the evaluation indictor system of passenger satisfaction, only some direct factors are taken in consider. To make a further research, some indirect factors can be taken into consider, such as the affordability of consumers, the region's economic development status and so on. Besides, it also can be studied in depth about how to select grade's limits objectively and reasonably.

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