Evaluation Research on the Quality of the Railway Passenger Service Based on the Linguistic Variables and the Improved PROMETHEE-II Method

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Abstract—**The evaluation of quality of the railway passenger service is an important way to know the quality of the railway passenger service. This paper firstly constructs an evaluation indicator system of the quality of the railway passenger service on the foundation of the related literatures, and constructs the multiple-attribute evaluation matrix and indicator weight vector based on the linguistic variables. Then the linguistic variables are transformed to triangular fuzzy numbers, and the priority relation based on the evaluation of the "common rule" is constructed using the improved PROMETHEE-II method. Then the fuzzy positive flux, fuzzy negative flux and fuzzy net flux are calculated. According to the triangular fuzzy number expected value of the net flux, the order of the projects is confirmed. Finally, the evaluation model is used to the evaluation of passenger service quality of three railway station of Ji'nan railway Administration. The application instance shows that this method is easy to use and can be used widely.**

Index Terms—**linguistic variable, triangular fuzzy number, PROMETHEE-II**

I. INTRODUCTION

Railway passenger transport which plays an extremely important role to meet people's demand for travel is an important component of the Passenger System. In recent years, the railway passenger transport markets are facing fierce competition from highway passenger and air passenger transport. In order to gain a competitive edge in the competition, Railway transport must improve their passenger service quality. The evaluation of quality of the railway passenger service is an important way to know the quality of the railway passenger service, through which we can identify shortcomings and improve service quality.

At present, scholars of domestic and foreign have had some researches on railway passenger service quality evaluation index system and evaluation methods already. In literature [1], Li-hua Liang, Bao-ming Han considered that the "Railway Passenger Transport service quality standards" always consider the service quality's improvement from the managers' view, and propose that we should refinement service flow from passenger's point, also they put forward the evaluation index system based on the views of the overwhelming majority of passengers. Yan Qi [2] sets up a station passenger service quality evaluation system with the theoretical methods of quality management and system analysis, and conducted a comprehensive evaluation and Empirical Analysis for Xi'an Railway Station's passenger service quality in 2000-2002. Jin Tao proposed to evaluate passenger service quality from the aspects of ticketing and waiting for services (ticketing service quality, and quality of service waiting), travel services (punctuality, comfort, safety) and get off at the service station, and so on with experts sort method, visitor survey evaluation method and the weighted average method in literature [3]. Xiao-jia Liu established an evaluation index system which comprehensive several transport passenger modes' quality, proposed a multi-objective decision-making Grey Relational projection method which can be sort and evaluate various modes of passenger transport model in literature [4]. In literature [1], Zhang qi establish a passenger satisfaction index system from railway passenger transport's own characteristics and passengers satisfaction, and set up a rail passenger satisfaction comprehensive evaluation model with fuzzy comprehensive evaluation methods. In overseas, mainly appraises the railway transportation service through the customer's satisfaction degree. Fielding [6] proposed 9 aspects to evaluate transportation project: three reflection efficiencies, four reflection benefits and two have both at the same time. Urban Mass Transportation Administration (UMTA) proposed some assessment method and the criterion in the transportation itemized appraisal aspect.

In the aspect of railway transportation quality service evaluating indicator system aspect, the research above proposed some good indicator systems. And in the evaluation method aspect, the research above mainly proposed the following methods: the AHP method, the fuzzy appraisal method, the weighted average computation method, the gray connection projection and so on. These methods are mainly suitable the situation where the policy-making data are accurately given. Since the railway passenger service quality evaluation indicators data are always uncertain, policy-makers often could not give accurate decision-making data (weight attributes and attribute values). As a result, many policy-makers prefer to use the words such as "very good" and "quite satisfied" to express his views. This paper proposes a railway passenger service quality evaluation method based on the linguistic variables and the improved PROMETHEE-II method. Firstly constructs an evaluation indicator system of the quality of the railway passenger service, and constructs the multiple-attribute evaluation matrix and indicator weight vector based on the linguistic variables. Then transforms the linguistic variables to triangular fuzzy numbers, and the priority relation based on the evaluation of the “common rule” is constructed using the improved PROMETHEE-II method. Then the fuzzy positive flux, fuzzy negative flux and fuzzy net flux are calculated. Finally, sorts the plans according to the fuzzy net current quantity triangle fuzzy number's expected value.

II. RAILWAY PASSENGER SERVICE QUALITY EVALUATION SYSTEMS

According to the researches above, with the indicator system's proposed in literature [3], and union our country railway transportation's actual situation at the present, we propose an indicator system like Table one showed.

TABLE 1 RAILWAY PASSENGER SERVICE QUALITY EVALUATION SYSTEMS

Contents	Indicators
A1 Ticketing service quality	B1 whether consignment outlets is convenient B2 the length of waiting time for ticketing B3 whether ticket information can be provided in time
A2 Waiting service quality	B4 whether waiting environment is comfortable B5 whether train raid of information forecasts promptly B6 whether organizes the passenger to train is in order
A3 Punctuality	B7 whether the train departure and arrival on time B8 whether the train movement is punctual
A4 Comfortable indicator	B9 Restroom toilet situation B10 Crowded conditions B11 Health situation B12 Chair comfortable degree B13 Train attendant’s service level B14 Satisfaction for providing meals, food and water, etc.
A5 Security indicators	B15 Train movement security B16 Carries goods’ security B17 Dining car’s health degree B18 Passenger’s security degree
A6 Exit service degree	B19 whether guidance information for exit is in time and accurate B20 speed of examines the ticket B21 provide interchanges information in time B22 takes the luggage fast and convenient

III. EVALUATION MODEL

A. Decision problem description

Suppose that there are m evaluation objectives $A=(a_1,a_2,\cdots,a_m)$, n evaluation indicators $C=(c_1,c_2,\cdots,c_n)$, the matrix composed of the evaluation index value of each evaluation objective is $X=[x_{ij}]_{m\times n}$, x_{ij} which is the element of predefined linguistic(or linguistic sign) evaluation set S indicates the jth indicator value of the ith evaluation objective. Here, linguistic evaluation set S is a sequence set composed of odd elements. For example: linguistic evaluation set $S=($ very poor, poor, medium, good, very good) composed of 5 elements. $W=(w_1,w_2,\cdots,w_n)$ is the relevant weight of n evaluation indicators. It is linguistic variable and linguistic evaluation set $Q=($very low, low, medium, high, very high). This decision problem is: Aims to linguistic decision matrix $X=[x_{ij}]_{m\times n}$ and indicator weight information W , finally get the rank result of projects through some decision analysis method.

B. Linguistic variable, triangular fuzzy number and their operation

(1) Transform linguistic variable to triangular fuzzy number

In practice, linguistic evaluation set element numbers often are adopted 5, 7, and 9. In the situation of subdivision further, 11 is adopted. When the element number is 7, the corresponding relation of evaluation linguistic variable, weighted linguistic variable and triangular fuzzy number is showed in Table-2[8]. When the element number are 5 and 9, the corresponding relation of evaluation linguistic variable, weighted linguistic variable and triangular fuzzy number is showed in literatures [9][10].

TABLE-2 TRIANGULAR FUZZY NUMBER（ELEMENT NUMBER =7）

number	evaluation linguistic variable S	weighted linguistic variable Q	triangular fuzzy number
1	very poor	very low	(0,0,0.1)
2	poor	low	(0,0.1,0.3)
3	medium poor	medium low	(0.1,0.3,0.5)
4	medium	medium	(0.3,0.5,0.7)
5	medium good	medium high	(0.5,0,7,0.9)
6	good	high	(0.7,0.9,1)
7	very good	very high	(0.9,1,1)

(2) The operation of triangular fuzzy number

The membership function of triangular fuzzy number can be expressed as follows:

$$\mu(x)=\begin{cases}(x-a_l)/(a_m-a_l) & a_l\le x\le a_m\\ (a_u-x)/(a_u-a_m) & a_m\le x\le a_u\\ 0 & x<a_l; x\ge a_u\end{cases} \quad (1)$$

The triangular fuzzy number can be marked $a=(a_l,a_m,a_u)$. For random two triangular fuzzy numbers $a=(a_l,a_m,a_u)$ and $b=(b_l,b_m,b_u)$, according the extension principle of fuzzy set, there are algorithms as follows:

1) $a\oplus b=(a_l+b_l,a_m+b_m,a_u+b_u)$ (2)

2） $-a=(-a_u,-a_m,-a_l)$ (3)

3） $a-b=(a_l-b_u,a_m-b_m,a_u-b_l)$ (4)

4) $\lambda a=(\lambda a_l,\lambda a_m,\lambda a_u)$ (5)

5) $a\otimes b=(a_lb_l,a_mb_m,a_ub_u)$ (6)

6) $\frac{1}{a}=(\frac{1}{a_u},\frac{1}{a_m},\frac{1}{a_l})$ (7)

C. Improved PROMETHEE-II evaluation method

PROMETHEE method, proposed by Brans in 1984, is a ranking method whose rank is higher than relation [11]. This method depicts the differences among each project according to the differences of satisfied degree of each project in each attribute. It includes two basic steps: one is constructing a priority relation based on the evaluation of “common rule” in project set to express the preference of decision-maker; the other is using priority relation to define the positive flux and negative flux of each project, and providing a group of part priority relation (PROMETHEEⅠ) or complete priority relation (PROMETHEEⅡ) of feasible project to decision-maker in order to decide. PROMETHEE method is only suitable to be applied in the situation that the attribute data is real number. This paper constructs the PROMETHEE-II evaluation method of fuzzy triangular number on the foundation of literature [12], the steps are as follows:

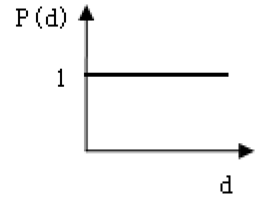
(1) Constructing the priority function

Priority function can be defined by decision-maker considering especially each rule C_k :

$$p_k[C_k(a_i)-C_k(a_j)]=p_k(d)\in[0,1] \quad (8)$$

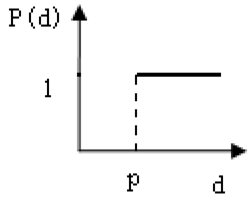
The priority degree of a_i to a_j can be changed from $p_k(d)=0$ (no difference) to $p_k(d)=1$ (strict priority), that is, this conception of priority is seeing the accurate degree of “project a_i is better than a_j” from the angle of rule C_j . $p_k(d)$ is a nondecreasing function . When $d<0$, use $p_k(d)=0$.

When constructing priority function in practice, there are 6 kinds of “common rule”: usual rule, “half” rule, linear priority rule, multiclass rule, indifference interval linear priority rule and Gaussian rule. Each rule has corresponding meaning, showed in Figure 1[13]. The 6 types basically covered most decision problems. Decision-makers can choose them according to their preference, and also construct rules themselves according to special situation.



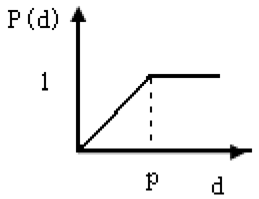
$$P(d)=\begin{cases}1 & d>0\\ 0 & d\le 0\end{cases}$$

①usual rule



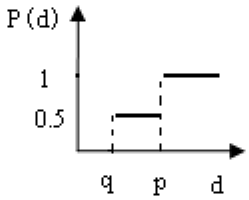
$$P(d)=\begin{cases}1 & d>p\\ 0 & d\le p\end{cases}$$

②“half” rule



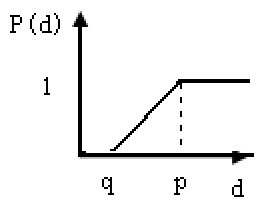
$$P(d)=\begin{cases}1 & d>p\\ d/p & d\le p\end{cases}$$

③linear priority rule



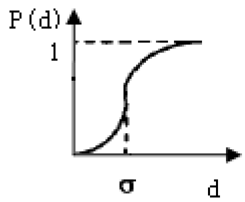
$$P(d)=\begin{cases}1 & d>p\\ 0.5 & q<d\le p\\ 0 & d\le q\end{cases}$$

④multiclass rule



$$P(d)=\begin{cases}1 & d>p\\ (d-q)/(p-q) & q<d\le p\\ 0 & d\le q\end{cases}$$

⑤indifference interval linear priority rule



$$P(d)=\begin{cases}1-e^{(-d^2/2\sigma^2)} & d>0\\ 0 & d\le 0\end{cases}$$

⑥ Gaussian rule

FIGURE 1. 6 KINDS OF COMMON RULES IN PROMETHEE METHOD

Finally, assign a special common rule aiming to each rule C_k . Calculate priority degree:

$$\begin{aligned}&p_k[C_k(a_i)-C_k(a_j)]=p_k[(a_{il},a_{im},a_{iu})-(a_{jl},a_{jm},a_{ju})]\\&=p_k(a_{il}-a_{ju},a_{im}-a_{jm},a_{iu}-a_{jl})\\&=(p_k(a_{il}-a_{ju}),p_k(a_{im}-a_{jm}),p_k(a_{iu}-a_{jl}))\\&=(b_l^k,b_m^k,b_u^k)\end{aligned} \tag{9}$$

(2) Define the fuzzy relation of all project $a_i, a_j \in A$:

$$\pi=\begin{cases}A\times A\to[0,1]\\ \pi(a_i,a_j)=\sum_{k=1}^{n}(p_k[C_k(a_i)-C_k(a_j)])\otimes w_k)\end{cases} \tag{10}$$

Thereinto，

$$\begin{aligned}&\pi(a_i,a_j)=\sum_{k=1}^{n}(p_k[C_k(a_i)-C_k(a_j)])\otimes w_k)\\&=\sum_{k=1}^{n}[(b_l^k,b_m^k,b_u^k)\otimes(w_{kl},w_{km},w_{ku})]\\&=\sum_{k=1}^{n}(b_l^k\times w_{kl},b_m^k\times w_{km},b_u^k\times w_{ku})\\&=(\sum_{k=1}^{n}(b_l^k\times w_{kl}),\sum_{k=1}^{n}(b_m^k\times w_{km}),\sum_{k=1}^{n}(b_u^k\times w_{ku}))\\&=(\alpha,\beta,\gamma)\end{aligned} \tag{11}$$

(3) Calculate fuzzy positive flux:

$$\Omega^+(a_i)=\frac{1}{m-1}\sum_{\substack{j=1\\ j\ne i}}^{m}\pi(a_i,a_j) \tag{12}$$

(4) Calculate fuzzy negative flux:

$$\Omega^-(a_i)=\frac{1}{m-1}\sum_{\substack{j=1\\ j\ne i}}^{m}\pi(a_j,a_i) \tag{13}$$

(5) Calculate net flux:

$$\Omega(a_i)=\Omega^+(a_i)-\Omega^-(a_i)=(r_l,r_m,r_u) \tag{14}$$

(6) Calculate the expected value of the net flux:

Because fuzzy positive flux, fuzzy negative flux and net flux are all fuzzy triangular numbers, we use the expected value of fuzzy triangular number in order to compare the fuzzy triangular numbers. The expected value of fuzzy triangular number can be calculated as follows:

$$E[\Omega(a_i)] = (r_l + 2r_m + r_u)/4 \quad (15)$$

(7) Rank the order.

According to the expected value of the net flux to rank the order of each project, we can get the order of each project finally, thus we can choose proper project.

IV. Application Instance

Consider to evaluate the passenger service quality of three railway station of Ji'nan railway Administration: Qing'dao station, Ji'nan station and Xu'zhou station. Evaluation indicators refer to the rank A indicators in Table-1.Through investigating the passengers and synthesizing all advice, it can form linguistic evaluation matrix (linguistic element number=7) and indicator weight linguistic vector below. Please evaluate the passenger service quality of the three stations.

$$X = \begin{bmatrix} G & MP & MG & G & MG & G \\ MG & M & G & MG & G & P \\ MP & MG & M & P & VG & M \end{bmatrix}$$

$$W = (M, M, H, MH, H, ML)$$

(1) Transform the linguistic variable to triangular fuzzy number:

$$X = \begin{bmatrix} (0.7,0.9,1) & (0.1,0.3,0.5) & (0.5,0,7,0.9) & (0.7,0.9,1) & (0.5,0.7,0.9) & (0.7,0.9,1) \\ (0.5,0,7,0.9) & (0.3,0.5,0.7) & (0.7,0.9,1) & (0.5,0,7,0.9) & (0.7,0.9,1) & (0,0.1,0.3) \\ (0.1,0.3,0.5) & (0.5,0,7,0.9) & (0.3,0.5,0.7) & (0,0.1,0.3) & (0.9,1,1) & (0.3,0.5,0.7) \end{bmatrix}$$

$$W = ((0.3,0.5,0.7),(0.3,0.5,0.7),(0.7,0.9,1),(0.5,0,7,0.9),(0.7,0.9,1),(0.1,0.3,0.5))$$

(2) Confirm the priority function and clique value of each rule:

	C_1	C_2	C_3	C_4	C_5	C_6
Common rule	linear prior	linear prior	linear prior	linear prior	linear prior	linear prior
p	0.6	0.4	0.4	0.7	0.4	0.7

(3) According to equation (9),(10),(11), we can get:

$$\pi(a_1,a_2) = (0.0571, 0.6667, 3.0762)$$
$$\pi(a_1,a_3) = (0.3857, 1.8214, 3.1000)$$
$$\pi(a_2,a_1) = (0, 1.1500, 3.1905)$$
$$\pi(a_2,a_3) = (0.1429, 1.8333, 3.2000)$$
$$\pi(a_3,a_1) = (0, 1.1750, 2.2000)$$
$$\pi(a_3,a_2) = (0, 0.6464, 1.9500)$$

(4) According to equation (12), calculate the fuzzy positive flux:

$$\Omega^+(a_1) = (0.2214, 1.2441, 3.0881)$$
$$\Omega^+(a_2) = (0.0715, 1.4917, 3.1953)$$
$$\Omega^+(a_3) = (0, 0.9107, 2.075)$$

(5) According to equation (13), calculate the fuzzy negative flux:

$$\Omega^-(a_1) = (0, 1.1625, 2.6953)$$
$$\Omega^-(a_2) = (0.0286, 0.6566, 2.5131)$$
$$\Omega^-(a_3) = (0.2643, 1.8274, 3.1500)$$

(6) According to equation (14), calculate the net flux:

$$\Omega(a_1) = (-2.4739, 0.0816, 3.0881)$$
$$\Omega(a_2) = (-2.4416, 0.8351, 3.1667)$$
$$\Omega(a_3) = (-3.1500, -0.9167, 1.8107)$$

(7) According to equation (15), calculate the expected value of the net flux:

$$E[\Omega(a_1)] = 0.1944$$
$$E[\Omega(a_2)] = 0.5988$$
$$E[\Omega(a_3)] = -0.7932$$

(8) Rank the order.

Above all, the order of the passenger service quality of Qing'dao station, Ji'nan station and Xu'zhou station is: Ji'nan station $\succ$ Qing'dao station $\succ$ Xu'zhou station.

V. CONCLUSIONS

Because of the complexity and uncertainty of railway passenger service quality evaluation, decision-makers sometimes can't give the accurate decision data (attribute weight and attribute value). So decision method based on linguistic variable is more suitable to evaluate railway passenger service quality. This paper proposes railway passenger service based on the linguistic variables and the improved PROMETHEE-II method. Firstly, it constructs evaluation indicator system of the railway passenger service quality. Then, it constructs the multiple-attribute evaluation matrix and indicator weight vector based on the linguistic variables. Meanwhile, the linguistic variables are transformed to triangular fuzzy numbers, and the priority relation based on the evaluation of the "common rule" is constructed using the improved PROMETHEE-II method. Furthermore, the fuzzy positive flux, fuzzy negative flux and fuzzy net flux are calculated. According to the triangular fuzzy number expected value of the net flux, the order of the projects is confirmed. Finally, the application instance shows that the whole evaluation steps are simple, the idea of the rank is easy to understand, the application is convenient and should be spread and applied. We should point out that this paper in the application instance only adopts linear priority rule to construct priority relation and not researches further other rule according to the character of the problem.

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