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Improving Service Quality With the Fuzzy TOPSIS Method: A Case Study of the Beijing Rail Transit System

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ABSTRACT Rail transit (RT) has been favored by passengers because it effectively alleviates the problems of dense population, housing shortages, small natural areas, and serious air pollution in urban centers. In this paper, we propose a framework that combines statistical analysis, fuzzy theory, and the technique for order preference by similarity to an ideal solution (TOPSIS) to evaluate the service quality of RT. First, the passenger perception of service quality is modeled as trapezoidal fuzzy numbers from the fuzzy theory, which solves the uncertainty problem of passenger perception that how factors affect service quality. Next, a case study that evaluates the service quality of the Beijing metro system is proposed using the fuzzy TOPSIS method. During the evaluation process, 8011 surveys are collected from 16 metro lines operated by Beijing Metro Operating Company Ltd. The evaluation results show that transfers, in-vehicle experience, and ticket purchases or recharges are the three factors that passengers find most unsatisfactory about metro travel and that need to be greatly improved in the future construction and management of metros. Furthermore, we analyze the stableness of the fuzzy TOPSIS method by the ranking change of service quality for a line from different comparison sets of metro lines. Finally, we provide suggestions and guidance for the optimization of RT infrastructure and investment.

INDEX TERMS Rail transit, fuzzy theory, TOPSIS, service quality.

I. INTRODUCTION

Along with increasingly crowded metros, how to improve the service quality (SQ) has received more and more attention. To improve the SQ, operation optimization has got increasingly attention to by China Metros [1] and other countries [2]. In these optimization studies, SQ evaluation has been applied to address bottlenecks efficiently. The construction of new lines has also been proposed to ease traffic congestion and improve the SQ of the entire metro system. Herein, the SQ evaluation is employed to guide metro construction, promote infrastructure optimization, and improve passenger satisfaction [3], [4]. Therefore, it is critical to conduct the SQ evaluation and identify the main factors affecting the SQ to improve the SQ of rail transit (RT) systems.

There are many factors that affect the SQ of RT systems. For example, Aydin *et al.* [5] developed the criteria including train comfort, ticketing, information systems, accessibility, safety, station comfort, fare, and time to analyze the SQ of Istanbul RT systems. Eboli *et al.* [6] considered seven indicators (i.e., safety, cleanliness, comfort, service, information, crew, and other) to evaluate the SQ of railways. Shen *et al.* [7] proposed fifty service attributes from nine service dimensions (e.g., direction, guidance, cleanliness, comfort, and convenience) to evaluate the satisfaction with RT systems. Kim *et al.* [8] evaluated the SQ of transfer facilities in urban RT from the following five categories: information, mobility, comfort, convenience, and security. Miranda *et al.* [9] proposed a SERVQUAL extension with a specific dimension

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(e.g., comfort, connectivity, and convenience) to examine the customer satisfaction with the railway system. It is concluded that service characteristics, such as punctuality, regularity, frequency, and cleanliness, has the highest positive impact on the SQ. Based on the above studies and the intrinsic congested characteristics of Beijing metro [10], the following eight factors are considered in the SQ evaluation: access (egress), security check, ticket purchases or recharges, card swiping, waiting for boarding, in-vehicle experience, and other extended services.

Measuring the passengers' perceptions of influencing factors is also a critical task in SQ evaluations, and previous studies have made many contributions. Eboli and Mazzulla [11] established a structural equation model to explore the relationship between global satisfaction and passenger perception attributes. de Oña *et al.* [12] proposed the structural equation method to mine the latent factors that describe bus SQ hidden under 12 attributes. Díez-Mesa *et al.* [13] developed a hybrid method that combines Bayesian network with structural equation model to measure the SQ of the Seville Metro Light Rail Service. However, the aforementioned methods have some limitations. For example, structural equation models require that the initial structure be known, and that each variable in the hypothetical model be concretized and quantified [14]. Moreover, structural equation models may produce some unexplained results and require a large sample size [15].

Multi criteria decision making (MCDM) methods have been an alternative way to address the above limitations. MCDM has been one of the best methods to solve the decision-making problem with multiple attributes [16]–[19]. MCDM methods have been also successfully applied to model passenger perception by considering different factors to evaluate the SQ of RT [20]–[24]. Further, there are many tools to implement MCDM: data envelopment analysis (DEA), the analytic hierarchy process (AHP), and the technique for order preference by similarity to an ideal solution (TOPSIS) [25]. Lee and Kim [20] developed an DEA-based overall SQ measure method, with benchmarking carried out by using SERVQUAL to measure the SQ. Based on the type-2 fuzzy set, [21] improved the passenger satisfaction in public transit service by combining GRA with TOPSIS. Nassereddine and Eskandari [22] proposed a hybrid MCDM method (i.e., DELPHI, GAHP, and PROMETHEE) to evaluate Tehran's public transit system and improve the customer satisfaction. Balci *et al.* [23] proposed seven main criteria to select dry bulk terminal, where six criteria are determined by the fuzzy AHP. However, evaluation SQ by a single MCDM will inevitably lead to incomplete and inaccurate evaluations [24]. The above studies should combine with other methods to achieve more reliable and realistic results. Hence, an integrated MCDM model that combines statistical analysis, fuzzy theory, and TOPSIS is proposed to evaluate the SQ of RT systems.

The primary goal of this paper is to evaluate SQ, identify weak service factors, and offer suggestions for RT managers. First, we collect a large amount of data about passenger satisfaction with eight factors affecting SQ from a satisfaction survey. The survey is conducted at stations that cover 40% of the Beijing metro stations by online and offline. Second, the passenger perception of SQ are modeled as trapezoidal fuzzy numbers from the fuzzy theory, which solves the uncertainty problem of passenger perception on factors affecting SQ. Next, a case study that evaluates the SQ of RT systems is illustrated by the proposed method. Then, the stableness of the proposed method is discussed, and it can be applied to the SQ evaluation of RT systems in any scenario in which RT lines increase or decrease in the future. Finally, suggestions for the optimization RT infrastructure and future investment are given.

This paper is structured as follows: In Section II, the methodology applied in this research are introduced. The study area and survey data analysis are described in Section III. In Section IV, a case study of the SQ evaluation of a rail transit system is developed, and the stableness analysis of the method is discussed. The conclusions are presented at the end.

II. METHODOLOGY

A. TRAPEZOIDAL FUZZY NUMBERS

Because fuzziness can describe uncertain and unclear concepts, fuzzy theory has been applied to solve various transportation problems along with other methods. For example, Tsai and Lu [26] combined the fuzzy algorithm with the generalized Choquet integral to evaluate service quality. The definition of ambiguity is as follows:

The fuzzy set on a given universe U means that for any $x \in U$, there is a corresponding number of $u(x) \in [0, 1]$. Herein, $u(x)$ is called the membership degree of x to U, and u is called the membership function of x.

If $A = (a, b, c, d)$, then A is called a trapezoidal fuzzy number. The membership function is:

$$u_A(x) = \begin{cases} \dfrac{x-a}{b-a}, & x \in [a, b] \\ 1, & x \in [b, c] \\ \dfrac{x-c}{d-c}, & x \in [c, d] \\ 0, & other \end{cases} \tag{1}$$

Given any two sets of fuzzy numbers $M = (m_1, m_2, m_3, m_4)$ and $N = (n_1, n_2, n_3, n_4)$, and the operation rules are as follows [27], [28]:

$$M + N = (m_1 + n_1, m_2 + n_2, m_3 + n_3, m_4 + n_4) \tag{2}$$

$$M - N = (m_1 - n_4, m_2 - n_3, m_3 - n_2, m_4 - n_1) \tag{3}$$

$$M \times N = (m_1 \times n_1, m_2 \times n_2, m_3 \times n_3, m_4 \times n_4) \tag{4}$$

$$k \times M = (k \times n_1, k \times n_2, k \times n_3, k \times n_4) \tag{5}$$

B. SERVICE QUALITY EVALUATION METHOD

TOPSIS method is one of the comprehensive evaluation methods for multiobjective decision-making problem [29]. The TOPSIS method eliminates the influence of different index dimensions and processes the original data with the

TABLE 1. Information of SQ factors.

Sym.	Factor	Primary Coverage
SQ1	Access (egress)	Staff Attitudes; Equipment; Environment
SQ2	Security check	Staff Attitudes; Equipment; Environment
SQ3	Ticket purchases or recharge	Staff Attitudes; Equipment; Environment
SQ4	Card Swiping	Staff Attitudes; Equipment; Environment
SQ5	Waiting for boarding	Staff Attitudes; Equipment; Environment; Guide sign
SQ6	in-vehicle experience	Train operation; Attitude of crew; Equipment; Environment
SQ7	Transfer	Staff Attitudes; Equipment; Environment; Guide sign
SQ8	Extended service	Advertisement/TV; Convenient service; Network Hotline

same trend and normalization. Herein, we focus on how to combine TOPSIS with the above Trapezoidal fuzzy numbers (i.e., Fuzzy TOPSIS method). More details about the TOPSIS method can refer to [30].

The main idea of the Fuzzy TOPSIS method is that the evaluation values and weights are expressed by linguistic variables. Main steps of the Fuzzy TOPSIS method applied to evaluate the service quality are as follows:

Step 1: Calculate the importance weight of the evaluation factors and the trapezoidal fuzzy performance values for each RT line with respect to each factor.

Assume F be set of factors, $F = \{f_1, f_2, \ldots, f_m\}$. The average weighting matrix is calculated as follows:

$$w_c = (w_j)_{1\times m} = [w_j^1, \ldots, w_j^m] \quad (6)$$
$$w_c = (w_i^c)_{1\times m} = f_1 f_2 \ldots f_m/[w_1^c, w_2^c, \ldots, w_m^c] \quad (7)$$

where w_j is a trapezoidal fuzzy number calculated by $w_j = (\frac{w_j^1+w_j^2+..+w_j^k}{k})$, and m and k are the number of SQ factors and the number of passengers for each RT line, respectively.

Also, the trapezoidal fuzzy performance values for each RT line with respect to each factor are obtained by using Eq. (7).

Step 2: Calculate the normalized decision matrix.

Let R be the normalized fuzzy decision matrix with m rows and n columns:

$$R = [r_{ij}]_{m\times n}, \quad i = 1, \ldots, m,\ j = 1, \ldots, n \quad (8)$$

Let B and C be the sets of benefit criteria and cost criteria, respectively, and $(a_{ij}, b_{ij}, c_{ij}, d_{ij})$ be a set of trapezoidal fuzzy numbers,

$$r_{ij} = (\frac{a_{ij}}{d_j^+}, \frac{b_{ij}}{d_j^+}, \frac{c_{ij}}{d_j^+}, \frac{d_{ij}}{d_j^+}), \quad j \in B \quad (9)$$
$$r_{ij} = (\frac{a_j^-}{d_{ij}}, \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}), \quad j \in C \quad (10)$$
$$d_j^+ = \max d_{ij}, \quad j \in B \quad (11)$$
$$a_j^- = \max a_{ij}, \quad j \in C \quad (12)$$

Note that the above criteria can be divided into two categories: larger-the-better (benefit) and smaller-the-better (cost).

Step 3: Calculate the weighted normalized decision matrix.

The weighted normalized value v_{ij} is equal to the importance weight of the evaluation factors w_j times the values in the normalized decision matrix r_{ij}. That is, $v_{ij} = r_{ij}w_j$. Thus, the weighed normalized decision matrix is defined as

$$V = [v_{ij}]_{m\times n}, \quad i = 1, \ldots, m,\ j = 1, \ldots, n \quad (13)$$

Step 4: Obtain the fuzzy positive ideal solution (A^+) and the fuzzy negative ideal solution (A^-).

$$A^+ = (v_1^+, v_2^+ \ldots, v_n^+) \quad (14)$$
$$A^- = (v_1^-, v_2^- \ldots, v_n^-) \quad (15)$$

Step 5: Calculate the distance of each line from the positive and ideal solutions.

$$d_i^+ = \sqrt{\sum\nolimits_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (16)$$
$$d_i^- = \sqrt{\sum\nolimits_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (17)$$

Step 6: Calculate the closeness coefficient (CC_i) for each line.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}, \quad i = 1, \ldots, n \quad (18)$$

Step 7: Rank SQ for lines.

The larger the value of CC_i is, the higher the preference of the line is.

III. STUDY AREA AND DATA

A. SURVEY DESIGN AND DATA COLLECTION

Beijing Metro Operations Company Ltd. operates approximately 80% of the lines of Beijing RT system (i.e., 16 RT lines), with a total of 261 stations. There are 1, 2, 5, 6, 7, 8, 9, 10, 13, 15, Fangshan (F), Batong (B), Changping (C), Yizhuang (Y), Airport (A), and S1 Lines. Based on the 16 lines, a survey is investigated to evaluate the SQ of the Beijing RT system.

The data collected from the survey can be divided into three parts: 1) the passenger satisfaction of eight influential factors, including access (egress), security check, ticket

TABLE 2. Questionnaire of satisfaction with card swiping link.

Q1. What are the unsatisfactory situations when you enter the station by card swiping? 【Multiple selection】		
Staff	You need help when card swiping access or egress, but you cannot find anybody.	☐
	The staff are unfriendly and impatient.	☐
Card swiping machine	Insufficient number of card swiping machines affects access or egress.	☐
	Card swiping machine often breaks down and is not repaired in time.	☐
	Mobile phone is insensitive when swiping cards and has many faults.	☐
Environment	The hygienic appearance of the card swipe machine is poor.	☐
	The sanitation of the area around the card swipe machine is poor.	☐
Not known/refusing to answer		☐
Q2. Please rate the satisfaction of the access and egress links of card swiping. 【Single election】		
Access and egress links of card swiping	Evaluation (Note: The higher the score is, the higher your evaluation. 99 is not clear) 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 99 ☐	

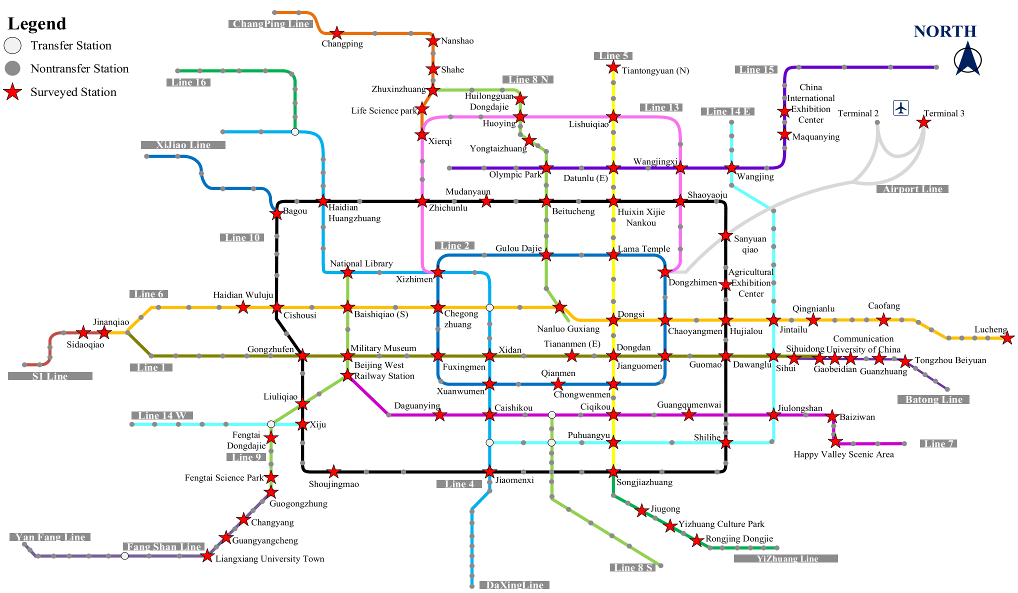


FIGURE 1. The distribution of surveyed stations in the Beijing metro system.

purchases or recharges, card swiping, waiting for boarding, in-vehicle experience, and other extended services as shown in Table 1; 2) the overall passenger satisfaction of the 16 RT lines; and 3) personal characteristics, including: gender, age, driving frequency, education, and income level. Note that there are several questions to measure the satisfaction in regard to the eight factors from different perspectives, including those of staff, facilities, environment, and management, in the first part. Subsequently, note that respondents are requested to rate the overall satisfaction level of each factor with a 5-point Likert scale. The wording of the scale labels vary with the content of the measurement [31]:1) For determining the importance weights of the SQ factors, each scale point is labeled according to its importance level: 1 = not important, 2 = less important, 3 = medium important, 4 = important, and 5 = very important; 2) For calculating the performance values of the RT lines, each scale point is labeled according to its satisfaction level: 1 = absolutely unsatisfied, 2 = unsatisfied, 3 = moderately satisfied, 4 = satisfied, and 5 = absolutely satisfied. Finally, the managers from the Beijing Metro Operations Company Ltd. worked with us to optimize the survey and ensure its efficiency. Some questionnaires are shown in Table 2.

The passenger satisfaction survey was conducted from October to December 2018. The respondents were randomly selected from waiting passengers at the platforms. To obtain passenger satisfaction with multiple routes, we selected the survey stations based on the following rules: 1) transfer stations were the main consideration. 2) some no transfer stations with large passenger flow are also considered, such as stations near universities, near parks, near commercial, office and tourist attractions, and suburban stations with large passenger flows [32]. Finally, the number of surveyed stations was approximately 40% of the total number of all stations based on the suggestion from managers of the Mass Transit Railway Operation Corporation LTD. The distribution of surveyed stations is shown in Fig. 1.

A total of 8011 surveys were collected through online and offline questionnaires, and at least 80% of the questionnaires were obtained face-to-face. Note that the percentage

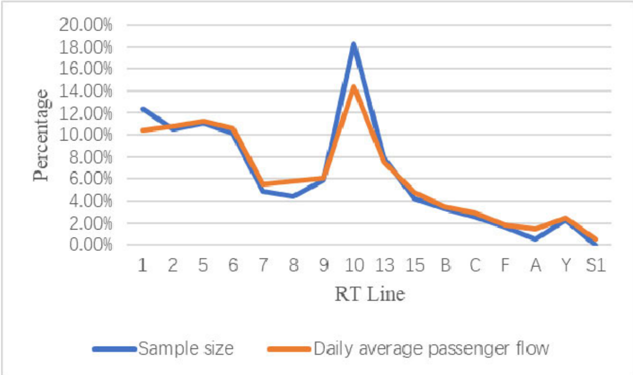


FIGURE 2. The percentage of sample size and daily average passenger flow per RT line.

TABLE 3. Reliability statistics.

Cronbach's alpha	N of items
0.934	8

of sample size per RT line is according to the percentage of daily average passenger flow per RT, as shown in Fig. 2.

B. SURVEY DATA AND STATISTICAL ANALYSES

The Cronbach's alpha coefficient test for the reliability of the survey data is shown in Table 3, and the significant value of 0.934 proves the reliability of the survey data [33]. Further, 4328 males and 3683 females participated in the survey as shown in Table 4, which was statistically representative compared to the number of males and females (i.e., 11.134 million males and 10.571 million females) in Beijing in 2015 [34].

Next, the socioeconomic characteristics of metro passengers is studied in details as shown in Table 4. First, the age attribute is investigated. People aged 18-30 years travel by metro, accounting for 50.967% of all travel groups, followed by people aged 31-44 years; the percentage of people over 45 who choose to travel by metro is less than 15%. It is worth noting that young and middle-aged people are the main group that participates in work and entertainment activities, and young adults travel much more frequently by metro and other means of transportation than the elderly [35]. The survey also takes into account the educational level, which is also related to occupation and income level [36]. More than 80% of people with higher education choose to travel by metro, which may be related to the higher education level of Beijing as a whole. Meanwhile, the survey finds that people with a monthly income of 5001-15,000￥ are the main component of metro passengers, while low-income groups choose Metro travel only a small proportion of the time. This result is in line with the findings of [37], who showed that lower income groups seem to be more enthusiastic about bus travel to reduce travel costs.

Trip characteristics of metro passengers is also investigated as shown in Table 5. Table 5 shows that the number of people

TABLE 4. Socioeconomic characteristics of metro passengers.

Socioeconomic characteristics	No. of observations	Percentage
Gender		
Male	4328	54.026%
Female	3683	45.974%
Age Group		
18-30 years	4083	50.967%
31-44 years	2770	34.577%
45-60 years	953	11.896%
>60 years	205	2.559%
Monthly Income (in CNY*)		
Up to CNY 2000￥	565	7.1%
CNY 2001￥to 5000￥	1261	15.7%
CNY 5001￥to 8000￥	2331	29.1%
CNY 8001￥to 15000￥	1826	22.8%
More than CNY 15001￥	674	8.4%
Refuse to answer	1354	16.9%
Education Level		
Compulsory education level and below	122	1.5%
High school	1253	15.6%
Undergraduate	5208	65%
Master and above	1428	17.8%

TABLE 5. Trip characteristics of metro users.

Trip characteristics	No. of observations	Percentage
Trip rate (trip by metro/week)		
1 trip/week	1131	14.1%
2-3 trips/week	2252	28.1%
4-5 trips/week	1307	16.3%
More than 5 trips/week	3321	41.5%
The most frequent departure time		
Weekday peak hours (7:00-9:00, 17:00-19:00)	4977	62.1%
Off-peak weekday	1642	20.5%
Weekends/holidays	1392	17.4%

who take the metro for more than five trips weekly is the highest, and the percentage of people who take the subway for more than two trips weekly accounts for approximately 80% of the total. Indeed, RT is a preferred way for people to travel, and it is the main transfer mode for a combination of travel plans [27]. Additionally, we find that 62.1% of people travel during peak hours. The best explanation is that people travel for work and are time-bound [38].

IV. CASE STUDY

In this section, we first explain the calculation process of the proposed fuzzy TOPSIS method to evaluate the SQ of the Beijing Rail Transit System. Later, the results are given, and

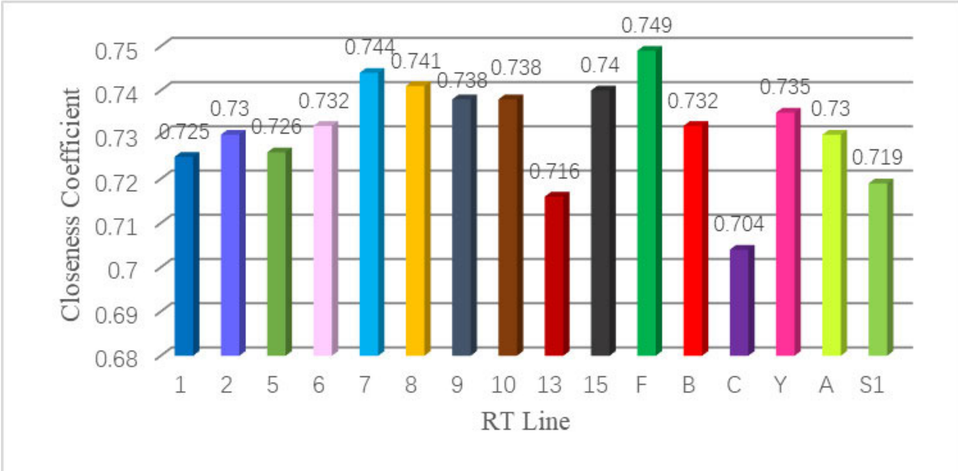


FIGURE 3. RT line performance changes with respect to each factor.

TABLE 6. Language terms of importance of SQ factor and performance value of RT lines.

Linguistic terms of importance of SQ factors		Linguistic terms of performance values of RT lines	
Linguistic Variables	**Trapezoidal Fuzzy Numbers**	**Linguistic Variables**	**Trapezoidal Fuzzy Numbers**
Very Important	(0.93, 0.98, 0.98, 1.00)	**Absolutely Satisfied**	(0.93, 0.98, 0.98, 1.00)
Important	(0.58, 0.63, 0.80, 0.86)	**Satisfied**	(0.72, 0.78, 0.92, 0.97)
Medium Important	(0.32, 0.41, 0.58, 0.65)	**Moderately Satisfied**	(0.32, 0.41, 0.58, 0.65)
Less Important	(0.17, 0.22, 0.36, 0.42)	**Unsatisfied**	(0.17, 0.22, 0.36, 0.42)
Not Important	(0.04, 0.10, 0.18, 0.23)	**Absolutely Unsatisfied**	(0.04, 0.10, 0.18, 0.23)

TABLE 7. Rating of users for SQ factors.

Linguistic Variables	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8
Very Important	4163	3985	3600	4984	4294	3923	4165	4146
Important	2967	2740	1915	2425	2908	3054	2818	2926
Medium Important	642	878	408	406	630	798	793	673
Less Important	144	188	71	79	95	139	152	143
Not Important	95	139	36	30	40	57	44	48

the proposed suggestions are made. Last, the stableness of the fuzzy TOPSIS method is discussed.

A. APPLICATION OF FUZZY TOPSIS

The two sets of ambiguities involved in this study are shown in Table 6. The data obtained from the above survey are shown in Table 7. Each set of ambiguities has five linguistic variables, but the fuzzy trapezoidal numbers are different ([27], [26]). The largest set of fuzzy numbers and the smallest set of fuzzy numbers are regarded as the positive and negative ideal solutions, respectively, and are $v_j^+ = (1, 1, 1, 1)$ and $v_j^- = (0, 0, 0, 0), j = 1, 2, \ldots, n$.

First, the fuzzy weight of each SQ factor is obtained from Eq. (7) as shown in Table 8, where the top three service quality factors are SQ4-card swiping, SQ3-Ticket purchases or recharges, and SQ5-waiting for boarding. In fact, the differences of the fuzzy values between each factor are small, but the passengers pay more attention to the above three factors than the other factors. Furthermore, the trapezoidal fuzzy performance values for each RT line with respect to each factor are calculated using Eq. (7). The results are shown in Appendix A.

Next, the normalized decision matrix is obtained based on Eq. (8) shown in Appendix B. The weighted normalized fuzzy decision matrix for evaluating SQ level is obtained shown in Appendix C. Then, the Euclidean distance between the objective value and the ideal solution is calculated by Eq. (16) and Eq. (17), as shown in Table 9. Finally, the SQ ranking for the lines is given base on the closeness coefficient of each RT line calculated by Eq. (18) as shown in Table 10.

B. RESULTS AND DISCUSSION

Based on the above fuzzy TOPSIS method, the results are calculated shown in Fig. 3. We can intuitively see the ranking

TABLE 8. Fuzzy weights of SQ factors.

Factor	Fuzzy weights	Factor	Fuzzy weights
SQ1	(0.727, 0.781, 0.861, 0.901)	SQ5	(0.740, 0.794, 0.871, 0.910)
SQ2	(0.708, 0.763, 0.845, 0.886)	SQ6	(0.715, 0.769, 0.854, 0.896)
SQ3	(0.763, 0.816, 0.884, 0.920)	SQ7	(0.726, 0.780, 0.860, 0.900)
SQ4	(0.781, 0.833, 0.895, 0.931)	SQ8	(0.730, 0.784, 0.864, 0.904)

TABLE 9. Positive and negative ideal solutions for each RT line.

	1	2	5	6	7	8	9	10
d_{RT}^{+}	1.609	1.579	1.6	1.567	1.495	1.511	1.533	1.533
d_{RT}^{-}	4.237	4.268	4.244	4.28	4.345	4.334	4.309	4.316
	13	**15**	**F**	**B**	**C**	**Y**	**A**	**S1**
d_{RT}^{+}	1.662	1.519	1.469	1.571	1.732	1.548	1.572	1.636
d_{RT}^{-}	4.193	4.317	4.373	4.284	4.122	4.295	4.256	4.195

TABLE 10. Closeness coefficients for each RT line.

	1	2	5	6	7	8	9	10
CC_i	0.725	0.73	0.726	0.732	0.744	0.741	0.738	0.738
	13	**15**	**F**	**B**	**C**	**Y**	**A**	**S1**
CC_i	0.716	0.74	0.749	0.732	0.704	0.735	0.73	0.719

of each RT line: 1) Fangshan Line (i.e., green pillars) is considered to be the best RT line, with a CC value of 0.749, and Lines 7 (i.e., light blue pillars) and 8 (i.e., orange pillars) are the other two top RT lines; 2) Changping Line (i.e., purple pillars) and Line 13 (i.e., dark red pillars) are the two lowest ranked lines, with CC values of 0.704 and 0.716; and 3) S1 Line (i.e., light green pillars) and Line 1 (i.e., blue pillars) are ranked the third and fourth worst RT lines, with CC values of 0.719 and 0.725, respectively.

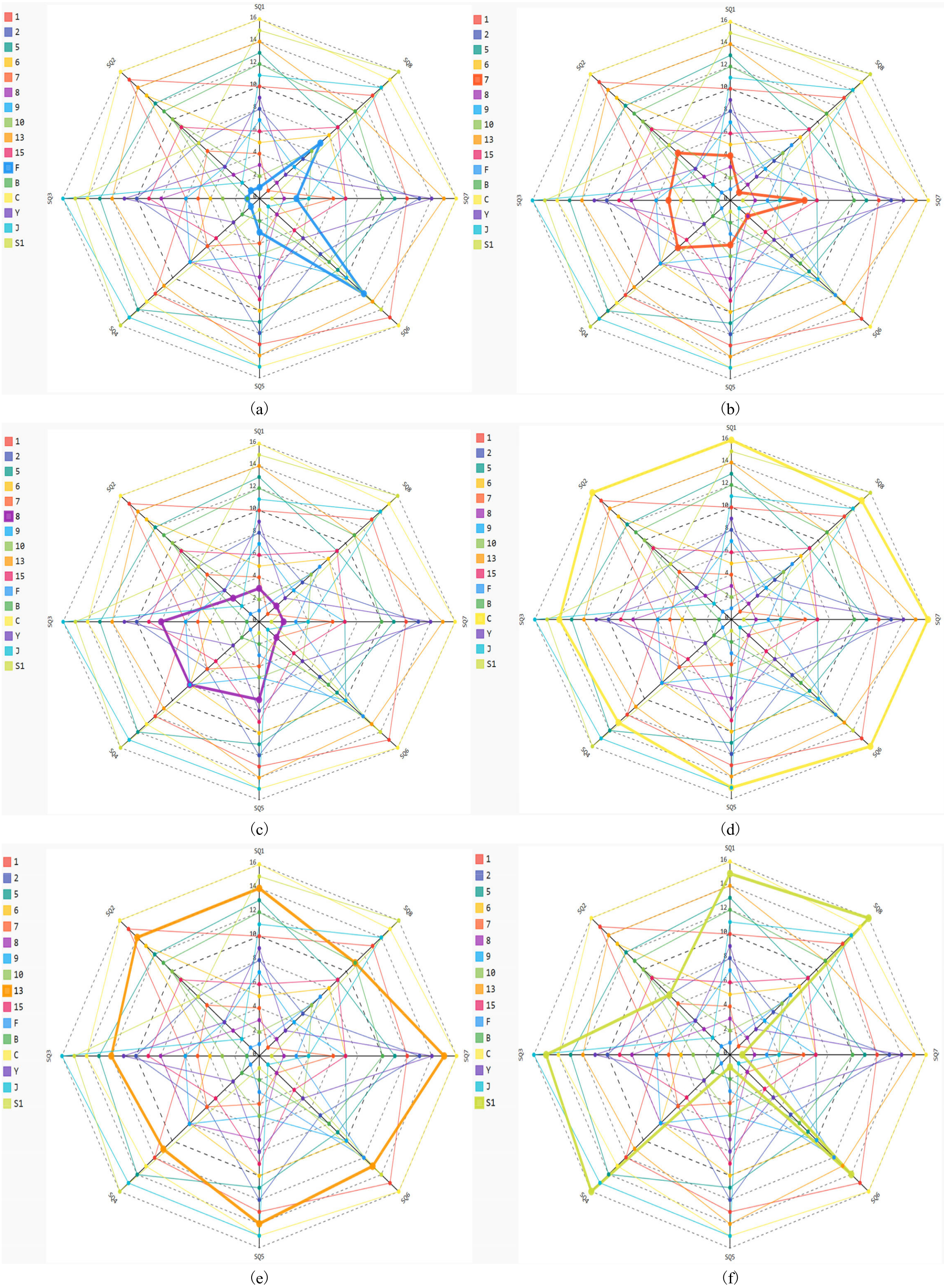
Specifically, the ranking of Fangshan Line, Line 7, Line 8, Changping Line, Line 13, and S1 Line in the RT network is shown in Fig. 4 (a), (b), (c), (d), (e), and (f), respectively. Note that the nearer the ranking of trapezoidal fuzzy performance values of each RT line respect to each factor is to the origin of coordinates in Fig. 4, indicating that the RT line is a better line; otherwise the opposite is true. For example, Fangshan line is a better RT line because its ranking of trapezoidal fuzzy performance values respect to each factor is all close to the origin of coordinates, while Changping line is opposite. The discussion of the ranking of the RT lines is given as follow:

1) RT lines with better CC values. The Fangshan Line is the best RT Line, which can be attributed to the fact that the extension line of the Fangshan Line was opened at the end of 2019 and transferred to Line 10. At the same time, it responds to the voice of the public and meets their expectations [39]. Second, the Fangshan Line is the first metro train with a speed of 100 km/h in China. It is also the first metro line with air conditioning and a refrigeration group control system.

For Line 7, the opening and diversion of Line 7 alleviates the passenger flow of Line 1 and the Batong Line and improves the evacuation capacity and efficiency of the Beijing West Railway Station. Additionally, Line 8 is known as the Olympic Line, which is popular with passengers because of its unique humanistic construction concept.

2) RT lines with worse CC values. The Changping Line and Line 13 are the two lowest ranked lines for the following reasons. First, the Changping Line is a suburban line that merges into Metro Line 13 at the Xierqi Station. During the morning rush hours of the working day, a large number of passengers enter the city from the suburbs to work, while in the evening rush hours, people return to their suburban homes. This tide phenomenon causes serious congestion in subway trains and stations during rush hours, and the line is in supersaturated operation [1]. Second, there are only two transfer stations on the Changping Line and other lines - the Zhuxinzhuang and Xierqi Stations - which provide a single mode of transfer for passengers. In addition, Line 13 is on the ground, and it very difficult to transfer to the underground Line 2 in the Xizhimen Station. A follow-up survey of 128 passengers revealed that the average walk time for passengers to transfer between Line 13 and Line 2 was 9 minutes and 47 seconds, which is too long to complain about the transfer.

For Line 1, the reason for the poor ranking is that it is limited by the old construction age and poor facility conditions,



(a) (b) (c) (d) (e) (f)

FIGURE 4. **Ranking of the RT lines in the urban rail network.**

such as small platform areas, which leads to an imbalance between supply and demand and results in crowd congestion. Second, Line 1 carries a large number of passengers every day, and the capacity of the facilities (e.g., security checks, stairs and automatic escalators) cannot meet the needs of passengers [40].

Additionally, the S1 Line is a newly opened medium - and low - speed maglev line, and its performance value is

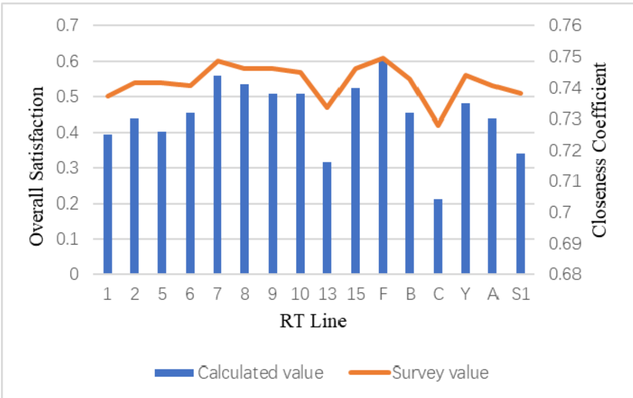


FIGURE 5. Overall passenger satisfaction and CC values of 16 RT lines.

only 0.719, which is mainly attributed to the inconvenience of transfers.

Next, we find that the CC values of the 16 RT lines and the change trends of the overall passenger satisfaction obtained from the survey are similar as shown in Fig. 5. The comparison results show that the fuzzy TOPSIS method can effectively evaluate the SQ.

C. RALATED SUGGESTIONS

The ranking of RT lines with respect to the SQ factors is shown in Fig. 6, and the corresponding suggestions are proposed to improve the unsatisfactory SQ factors.

It is found that transfers, in-vehicle experience, and ticket purchases or recharges are the most unsatisfactory factors for passengers. Indeed, many researchers have also found that these factors are the main factors restricting capacity and affecting user satisfaction [40], [41]. Main suggestions about transfers, in-vehicle experience, and ticket purchases or recharges are as follows:

First, unclear signs and long transfer times in the transfer process receives the most complains from passengers according to the survey results. Specifically, Changping Line, Yizhuang Line, Line 13, Line 2, and Line 1 show very poor performance in transfers shown in Fig. 6. One possible improvement strategy is that station staff can isolate transfer passengers with obvious directional flow through removable impediments (guardrails), and use guardrails properly expand the travel corridor according to the tidal characteristics of transfer passenger flow [42]. Another strategy is that apply the real-time release of information and build a station with a specific cultural culture. For example, people-oriented transfer station has been successfully applied in the Guangzhou metro to contribute the development of an optimized design [43]. Moreover, managers should improve the visualization and readability of markings at stations. For example, the font design of signs should fully consider the characteristics of visual impairment of the elderly.

Second, the in-vehicle experience is an urgent factor that needs to be improved for Changping Line, S1 Line, and Line 1 shown in Fig. 6. Especially, carriage comfort and crowdedness are two aspects of user feedback that need to be improved. The first proposal is to achieve free WIFI coverage in the carriages and platforms to supply more entertainment, which is already applied in the Shenzhen Metro and Wuhan Metro of China and it works very well [44], [45]. The second suggestion is to install a device at the waiting area on the platform to show the actual number of passengers in each carriage. In this way, passengers waiting outside the safety door can choose a waiting area with a small number of passengers, so that the passenger distribution on each carriage is even and the congestion is reduced [46].

Finally, ticket purchases or recharges have become the primary factors for improvement of the S1 Line and Changping Line, because of the inconvenience and slow speed of self-service ticketing and manual ticketing. Therefore, we propose to increase the promotion of some passengers' mobile devices applications to make up for the function deficiencies of ticket

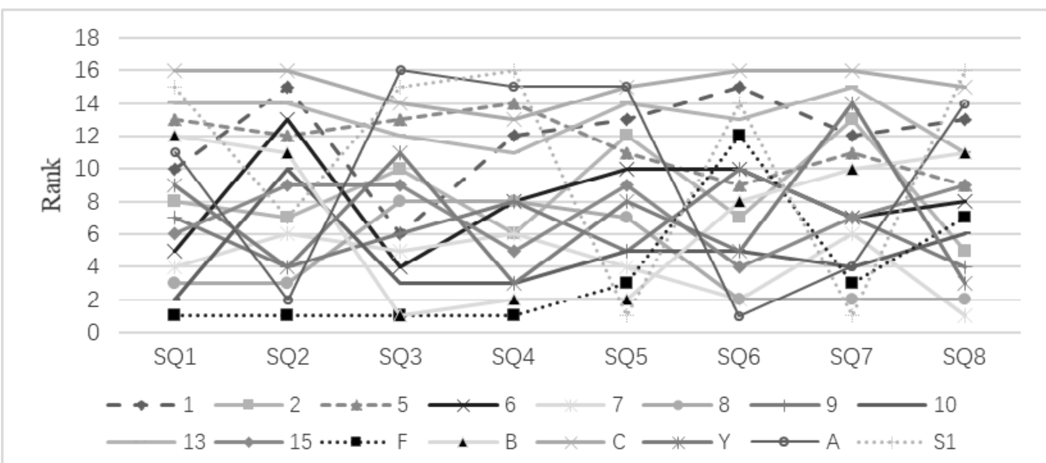


FIGURE 6. Ranking of RT lines with respect to SQ factors.

TABLE 11. Rating of users for SQ factors of imaginary line.

Linguistic Variables	SQ1	SQ2	SQ3	SQ4	SQ5	SQ6	SQ7	SQ8
Very Important	332	215	456	299	369	321	412	338
Important	145	99	208	201	255	289	77	243
Medium Important	52	72	32	98	88	108	58	67
Less Important	11	1	11	6	10	14	3	12
Not Important	3	2	5	2	1	7	5	5

storage services by utilizing Ruuby Pay, Apple Pay, Alipay, and Tencent Ride Codes [47]. Furthermore, we find that the demand for electronic periodic tickets is becoming more and more prominent for some passengers. Therefore, there is also a good way to sell electronic periodic tickets in a tourist city, and this suggestion has been accepted and put into trial operation in Beijing metro [48].

D. STABLENESS ANALYSIS

The ranking of metro lines can still maintain its consistency under different scenarios with a changing number of lines, which is very important for the SQ evaluation. It is called the stability of the method in this paper. Next, the stability of the fuzzy TOPSIS method is analyzed under two scenarios [49]: one imaginary line is added to the evaluation process, and one line is excluded. For the inclusion scenario, the data of an imaginary line are shown in Table 11.

For the exclusion scenario, Line 15 is excluded from the evaluation process. In these two scenarios, the line rankings based on the fuzzy TOPSIS method are as follows:

Reality: $L_F > L_7 > L_8 > L_{15} > L_{10} > L_9 > L_Y > L_6 > L_B > L_2 > L_J > L_5 > L_1 > L_{S1} > L_{13} > L_C$

Imaginary: $L_F > L_7 > L_8 > L_{15} > L_{10} > L_9 > L_Y > L_6 > L_B > L_2 > L_J > L_5 > L_{imaginary} > L_1 > L_{S1} > L_{13} > L_C$

Excluded: $L_F > L_7 > L_8 > L_{15(excluded)} > L_{10} > L_9 > L_Y > L_6 > L_B > L_J > L_2 > L_5 > L_1 > L_{S1} > L_{13} > L_C$

Based on the analysis of the above results, the following conclusions can be reached:

1) For the inclusion scenario, when the number of metro lines increases, the ranking order of the metro lines does not change, which is consistent with the results obtained from the foregoing result analysis in Section IV B.

2) For the exclusion scenario, the ranking order of other lines is consistent with the results of the above case study, except that the ranking order of Line 2 and the Airport Line is reversed. However, the above situation can be explained by the fact that when the initial data change, the calculation results can be rounded slightly, and the closeness coefficient of Line 2 and the Airport Line are very close; reversal may even occur.

In short, we can safely draw the conclusion that the fuzzy TOPSIS method can generate a stable result in the evaluation of the SQ under the condition of a change in the number of subway lines.

V. CONCLUSIONS

This study first conducted a face-to-face and on-line questionnaire survey regarding the 16 metro lines operated by the Beijing Metro Operations Company Ltd. A total of 8011 surveys were collected. These surveys included eight passenger perceptions of service quality: access (egress), security check, ticket purchases or recharges, card swiping, transfers, waiting for boarding, in-vehicle experience and other extended services. Second, the survey data are analyzed, and the SQ is evaluated by combining the fuzzy theory and the TOPSIS method. Herein, the fuzzy theory expresses human perception with a set of trapezoidal fuzzy numbers; the TOPSIS method normalizes the fuzzy matrix and generates the ranking of each RT line. In addition, we discuss the stableness of the fuzzy TOPSIS method and find that the method is suitable for evaluating SQ under different metro lines.

Some important results can be summarized as follows: First, compared with other RT lines, the Fangshan Line, Line 7 and Line 8 show better SQ performance shown in Fig.6. In particular, half of the SQ factors of Fangshan Line are ranked first, and the remaining factors are ranked relatively highly. Second, Changping Line, Line 13, the S1 Line, and Line 1 are the lower ranked RT lines. Based on the feedback from passengers, transfers, in-vehicle experience, and ticket purchases or recharges are identified as the factors that need improvement, and we put forward some suggestions for improvement as follows:

1) Station staff can isolate transfer passengers with obvious directional flow through removable impediments (guardrails), and use guardrails properly expand the travel corridor according to the tidal characteristics of transfer passenger flow [42].

2) Install a display device in the waiting area of the platform to show the dynamic number of passengers in the carriage. In this way, the passengers waiting outside the safety door can choose a waiting area with a small number of passengers, so that the passenger distribution on each carriage is even and the comfort of passengers is improved in the in-vehicle experience [50].

3) Through the Ruuby Pay, Apple Pay, Alipay, Tencent riding code, and other passengers' mobile devices applications, more vigorous function of ticket services can be developed to improve the process of ticket purchases or recharges [47].

APPENDIX A
THE TRAPEZOIDAL FUZZY PERFORMANCE VALUES FOR EACH RT LINE WITH RESPECT TO EACH FACTOR

	1	2	5	6
SQ1	[0.775,0.832,0.902,0.938]	[0.779,0.837,0.907,0.944]	[0.755,0.813,0.888,0.925]	[0.786,0.843,0.913,0.949]
SQ2	[0.737,0.795,0.871,0.909]	[0.759,0.818,0.890,0.928]	[0.752,0.810,0.882,0.920]	[0.749,0.807,0.877,0.915]
SQ3	[0.807,0.863,0.922,0.956]	[0.799,0.856,0.919,0.954]	[0.801,0.857,0.912,0.945]	[0.813,0.868,0.926,0.960]
SQ4	[0.818,0.873,0.928,0.960]	[0.822,0.877,0.932,0.965]	[0.812,0.868,0.922,0.955]	[0.819,0.875,0.931,0.964]
SQ5	[0.772,0.829,0.900,0.937]	[0.779,0.837,0.908,0.945]	[0.778,0.835,0.911,0.948]	[0.795,0.852,0.917,0.952]
SQ6	[0.746,0.805,0.883,0.922]	[0.772,0.830,0.904,0.941]	[0.769,0.827,0.902,0.939]	[0.767,0.825,0.899,0.936]
SQ7	[0.774,0.831,0.901,0.937]	[0.760,0.818,0.892,0.929]	[0.772,0.830,0.901,0.938]	[0.779,0.836,0.906,0.943]
SQ8	[0.772,0.831,0.902,0.939]	[0.785,0.842,0.910,0.946]	[0.778,0.835,0.905,0.941]	[0.778,0.835,0.906,0.942]
	7	**8**	**9**	**10**
SQ1	[0.807,0.863,0.921,0.955]	[0.797,0.854,0.921,0.957]	[0.789,0.846,0.910,0.945]	[0.804,0.860,0.924,0.958]
SQ2	[0.782,0.838,0.902,0.937]	[0.780,0.837,0.907,0.944]	[0.772,0.830,0.901,0.938]	[0.755,0.813,0.884,0.922]
SQ3	[0.814,0.869,0.924,0.957]	[0.809,0.865,0.921,0.955]	[0.816,0.871,0.923,0.956]	[0.818,0.873,0.929,0.962]
SQ4	[0.828,0.883,0.934,0.965]	[0.820,0.875,0.931,0.964]	[0.827,0.882,0.933,0.964]	[0.835,0.889,0.939,0.970]
SQ5	[0.814,0.870,0.929,0.962]	[0.804,0.860,0.924,0.959]	[0.807,0.863,0.925,0.960]	[0.804,0.860,0.925,0.960]
SQ6	[0.797,0.853,0.916,0.950]	[0.787,0.844,0.914,0.950]	[0.771,0.829,0.899,0.936]	[0.777,0.835,0.907,0.944]
SQ7	[0.789,0.846,0.910,0.945]	[0.804,0.860,0.924,0.959]	[0.785,0.843,0.908,0.943]	[0.786,0.843,0.911,0.947]
SQ8	[0.815,0.870,0.930,0.963]	[0.794,0.851,0.920,0.956]	[0.794,0.850,0.914,0.949]	[0.782,0.839,0.909,0.945]
	13	**15**	**F**	**B**
SQ1	[0.724,0.784,0.870,0.911]	[0.799,0.855,0.913,0.947]	[0.823,0.877,0.933,0.965]	[0.757,0.816,0.894,0.932]
SQ2	[0.727,0.787,0.873,0.914]	[0.765,0.822,0.887,0.923]	[0.828,0.883,0.937,0.969]	[0.749,0.808,0.883,0.921]
SQ3	[0.788,0.845,0.913,0.949]	[0.819,0.874,0.923,0.954]	[0.832,0.887,0.939,0.971]	[0.822,0.877,0.937,0.971]
SQ4	[0.809,0.865,0.928,0.963]	[0.840 0.894,0.938,0.968]	[0.850,0.904,0.947,0.977]	[0.835,0.889,0.940,0.971]
SQ5	[0.764,0.823,0.900,0.938]	[0.808,0.864,0.921,0.955]	[0.820,0.875,0.931,0.963]	[0.808,0.864,0.929,0.964]
SQ6	[0.751,0.810,0.892,0.932]	[0.797,0.853,0.912,0.946]	[0.763,0.821,0.896,0.934]	[0.762,0.820,0.901,0.940]
SQ7	[0.741,0.801,0.881,0.920]	[0.792,0.849,0.909,0.943]	[0.800,0.856,0.915,0.949]	[0.771,0.829,0.902,0.939]
SQ8	[0.769,0.827,0.902,0.940]	[0.792,0.848,0.907,0.941]	[0.790,0.847,0.910,0.944]	[0.774,0.832,0.903,0.940]
	C	**Y**	**J**	**S1**
SQ1	[0.688,0.749,0.836,0.877]	[0.783,0.839,0.906,0.942]	[0.810,0.863,0.905,0.935]	[0.756,0.813,0.873,0.909]
SQ2	[0.720,0.780,0.865,0.905]	[0.776,0.833,0.901,0.938]	[0.828,0.882,0.922,0.952]	[0.769,0.825,0.892,0.928]
SQ3	[0.775,0.832,0.901,0.937]	[0.796,0.853,0.915,0.950]	[0.723,0.779,0.848,0.884]	[0.772,0.827,0.872,0.904]
SQ4	[0.808,0.864,0.924,0.958]	[0.826,0.881,0.936,0.969]	[0.836,0.889,0.924,0.953]	[0.783,0.838,0.896,0.930]
SQ5	[0.754,0.812,0.891,0.930]	[0.801,0.857,0.922,0.957]	[0.763,0.819,0.892,0.929]	[0.819,0.875,0.933,0.967]
SQ6	[0.729,0.789,0.876,0.917]	[0.781,0.838,0.908,0.944]	[0.786,0.842,0.916,0.952]	[0.769,0.825,0.892,0.928]
SQ7	[0.734,0.793,0.876,0.916]	[0.766,0.823,0.888,0.924]	[0.804,0.857,0.914,0.947]	[0.805,0.862,0.929,0.965]
SQ8	[0.730,0.790,0.876,0.917]	[0.800,0.856,0.920,0.955]	[0.766,0.821,0.895,0.932]	[0.709,0.765,0.833,0.870]

APPENDIX B
THE NORMALIZED FUZZY DECISION MATRIX FOR EVALUATING SQ LEVEL OF RT LINES

	1	2	5	6
SQ1	[0.803,0.862,0.935,0.972]	[0.807,0.867,0.940,0.978]	[0.782,0.842,0.920,0.959]	[0.815,0.874,0.946,0.983]
SQ2	[0.761,0.820,0.899,0.938]	[0.783,0.844,0.918,0.958]	[0.776,0.836,0.910,0.949]	[0.773,0.833,0.905,0.944]
SQ3	[0.831,0.889,0.950,0.985]	[0.823,0.882,0.946,0.982]	[0.825,0.883,0.939,0.973]	[0.837,0.894,0.954,0.989]
SQ4	[0.837,0.894,0.950,0.983]	[0.841,0.898,0.954,0.988]	[0.831,0.888,0.944,0.977]	[0.838,0.896,0.953,0.987]
SQ5	[0.798,0.857,0.931,0.969]	[0.806,0.866,0.939,0.977]	[0.805,0.863,0.942,0.980]	[0.822,0.881,0.948,0.984]
SQ6	[0.784,0.846,0.928,0.968]	[0.811,0.872,0.950,0.988]	[0.808,0.869,0.947,0.986]	[0.806,0.867,0.944,0.983]
SQ7	[0.802,0.861,0.934,0.971]	[0.788,0.848,0.924,0.963]	[0.800,0.860,0.934,0.972]	[0.807,0.866,0.939,0.977]
SQ8	[0.802,0.863,0.937,0.975]	[0.815,0.874,0.945,0.982]	[0.808,0.867,0.940,0.977]	[0.808,0.867,0.941,0.978]
	7	**8**	**9**	**10**
SQ1	[0.836,0.894,0.954,0.990]	[0.826,0.885,0.954,0.992]	[0.818,0.877,0.943,0.979]	[0.833,0.891,0.958,0.993]
SQ2	[0.807,0.865,0.931,0.967]	[0.805,0.864,0.936,0.974]	[0.797,0.857,0.930,0.968]	[0.779,0.839,0.912,0.951]
SQ3	[0.838,0.895,0.952,0.986]	[0.833,0.891,0.949,0.984]	[0.840,0.897,0.951,0.985]	[0.842,0.899,0.957,0.991]
SQ4	[0.847,0.904,0.956,0.988]	[0.839,0.896,0.953,0.987]	[0.846,0.903,0.955,0.987]	[0.855,0.910,0.961,0.993]
SQ5	[0.842,0.900,0.961,0.995]	[0.831,0.889,0.956,0.992]	[0.835,0.892,0.957,0.993]	[0.831,0.889,0.957,0.993]
SQ6	[0.837,0.896,0.962,0.998]	[0.827,0.887,0.960,0.998]	[0.810,0.871,0.944,0.983]	[0.816,0.877,0.953,0.992]
SQ7	[0.818,0.877,0.943,0.979]	[0.833,0.891,0.958,0.994]	[0.813,0.874,0.941,0.977]	[0.815,0.874,0.944,0.981]
SQ8	[0.846,0.903,0.966,1.000]	[0.825,0.884,0.955,0.993]	[0.825,0.883,0.949,0.985]	[0.812,0.871,0.944,0.981]
	13	**15**	**F**	**B**
SQ1	[0.750,0.812,0.902,0.944]	[0.828,0.886,0.946,0.981]	[0.853,0.909,0.967,1.000]	[0.784,0.846,0.926,0.966]
SQ2	[0.750,0.812,0.901,0.943]	[0.789,0.848,0.915,0.953]	[0.854,0.911,0.967,1.000]	[0.773,0.834,0.911,0.950]
SQ3	[0.812,0.870,0.940,0.977]	[0.843,0.900,0.951,0.982]	[0.857,0.913,0.967 1.000]	[0.847,0.903,0.965,1.000]
SQ4	[0.828,0.885,0.950,0.986]	[0.860,0.915,0.960,0.991]	[0.870,0.925,0.969,1.000]	[0.855,0.910,0.962,0.994]
SQ5	[0.790,0.851,0.931,0.970]	[0.836,0.893,0.952,0.988]	[0.848,0.905,0.963,0.996]	[0.836,0.893,0.961,0.997]
SQ6	[0.789,0.851,0.937,0.979]	[0.837,0.896,0.958,0.994]	[0.801,0.862,0.941,0.981]	[0.800,0.861,0.946,0.987]
SQ7	[0.768,0.830,0.913,0.953]	[0.821,0.880,0.942,0.977]	[0.829,0.887,0.948,0.983]	[0.799,0.859,0.935,0.973]
SQ8	[0.799,0.859,0.937,0.976]	[0.822,0.881,0.942,0.977]	[0.820,0.880,0.945,0.980]	[0.804,0.864,0.938,0.976]

	C	Y	J	S1
SQ1	[0.713,0.776,0.866,0.909]	[0.811,0.869,0.939,0.976]	[0.839,0.894,0.938,0.969]	[0.783,0.842,0.905,0.942]
SQ2	[0.743,0.805,0.893,0.934]	[0.801,0.860,0.930,0.968]	[0.854,0.910,0.951,0.982]	[0.794,0.851,0.921,0.958]
SQ3	[0.798,0.857,0.928,0.965]	[0.820,0.878,0.942,0.978]	[0.745,0.802,0.873,0.910]	[0.795,0.852,0.898,0.931]
SQ4	[0.827,0.884,0.946,0.981]	[0.845,0.902,0.958,0.992]	[0.856,0.910,0.946,0.975]	[0.801,0.858,0.917,0.952]
SQ5	[0.780,0.840,0.921,0.962]	[0.828,0.886,0.953,0.990]	[0.789,0.847,0.922,0.961]	[0.847,0.905,0.965,1.000]
SQ6	[0.766,0.829,0.920,0.963]	[0.820,0.880,0.954,0.992]	[0.826,0.884,0.962,1.000]	[0.808,0.867,0.937,0.975]
SQ7	[0.761,0.822,0.908,0.949]	[0.794,0.853,0.920,0.958]	[0.833,0.888,0.947,0.981]	[0.834,0.893,0.963,1.000]
SQ8	[0.758,0.820,0.910,0.952]	[0.831,0.889,0.955,0.992]	[0.795,0.853,0.929,0.968]	[0.736,0.794,0.865,0.903]

APPENDIX C
THE WEIGHTED NORMALIZED FUZZY DECISION MATRIX FOR EVALUATING SQ LEVEL

	1	2	5	6
SQ1	[0.584,0.673,0.805,0.876]	[0.587,0.677,0.809,0.881]	[0.569,0.658,0.792,0.864]	[0.593,0.683,0.815,0.886]
SQ2	[0.539,0.626,0.760,0.831]	[0.554,0.644,0.776,0.849]	[0.549,0.638,0.769,0.841]	[0.547,0.636,0.765,0.836]
SQ3	[0.634,0.725,0.840,0.906]	[0.628,0.720,0.836,0.903]	[0.629,0.721,0.830,0.895]	[0.639,0.730,0.843,0.910]
SQ4	[0.654,0.745,0.850,0.915]	[0.657,0.748,0.854,0.920]	[0.649,0.740,0.845,0.910]	[0.654,0.746,0.853,0.919]
SQ5	[0.591,0.680,0.811,0.882]	[0.596,0.688,0.818,0.889]	[0.596,0.685,0.820,0.892]	[0.608,0.700,0.826,0.895]
SQ6	[0.561,0.651,0.793,0.867]	[0.580,0.671,0.811,0.885]	[0.578,0.668,0.809,0.883]	[0.576,0.667,0.806,0.881]
SQ7	[0.582,0.672,0.803,0.874]	[0.572,0.661,0.795,0.867]	[0.581,0.671,0.803,0.875]	[0.586,0.675,0.808,0.879]
SQ8	[0.585,0.677,0.810,0.881]	[0.595,0.685,0.816,0.888]	[0.590,0.680,0.812,0.883]	[0.590,0.680,0.813,0.884]
	7	**8**	**9**	**10**
SQ1	[0.608,0.698,0.821,0.892]	[0.601,0.691,0.821,0.894]	[0.595,0.685,0.812,0.882]	[0.606,0.696,0.825,0.895]
SQ2	[0.571,0.660,0.787,0.857]	[0.570,0.659,0.791,0.863]	[0.564,0.654,0.786,0.858]	[0.552,0.640,0.771,0.843]
SQ3	[0.639,0.730,0.842,0.907]	[0.636,0.727,0.839,0.905]	[0.641,0.732,0.841,0.906]	[0.642,0.734,0.846,0.912]
SQ4	[0.662,0.753,0.856,0.920]	[0.655,0.746,0.853,0.919]	[0.661,0.752,0.855,0.919]	[0.668,0.758,0.860,0.924]
SQ5	[0.623,0.715,0.837,0.905]	[0.615,0.706,0.833,0.903]	[0.618,0.708,0.834,0.904]	[0.615,0.706,0.834,0.904]
SQ6	[0.598,0.689,0.822,0.894]	[0.591,0.682,0.820,0.894]	[0.579,0.670,0.806,0.881]	[0.583,0.674,0.814,0.889]
SQ7	[0.594,0.684,0.811,0.881]	[0.605,0.695,0.824,0.895]	[0.590,0.682,0.809,0.879]	[0.592,0.682,0.812,0.883]
SQ8	[0.618,0.708,0.835,0.904]	[0.602,0.693,0.825,0.898]	[0.602,0.692,0.820,0.890]	[0.593,0.683,0.816,0.887]
	13	**15**	**F**	**B**
SQ1	[0.545,0.634,0.777,0.851]	[0.602,0.692,0.815,0.884]	[0.620,0.710,0.833,0.901]	[0.570,0.661,0.797,0.870]
SQ2	[0.531,0.620,0.761,0.835]	[0.559,0.647,0.773,0.844]	[0.605,0.695,0.817,0.886]	[0.547,0.636,0.770,0.842]
SQ3	[0.620,0.710,0.831,0.899]	[0.643,0.734,0.841,0.903]	[0.654,0.745,0.855,0.920]	[0.646,0.737,0.853,0.920]
SQ4	[0.647,0.737,0.850,0.918]	[0.672,0.762,0.859,0.923]	[0.679,0.771,0.867,0.931]	[0.668,0.758,0.861,0.925]
SQ5	[0.585,0.676,0.811,0.883]	[0.619,0.709,0.829,0.899]	[0.628,0.719,0.839,0.906]	[0.619,0.709,0.837,0.907]
SQ6	[0.564,0.654,0.800,0.877]	[0.598,0.689,0.818,0.891]	[0.573,0.663,0.804,0.879]	[0.572,0.662,0.808,0.884]
SQ7	[0.558,0.647,0.785,0.858]	[0.596,0.686,0.810,0.879]	[0.602,0.692,0.815,0.885]	[0.580,0.670,0.804,0.876]
SQ8	[0.583,0.673,0.810,0.882]	[0.600,0.691,0.814,0.883]	[0.599,0.690,0.816,0.886]	[0.587,0.677,0.810,0.882]
	C	**Y**	**J**	**S1**
SQ1	[0.518,0.606,0.746,0.819]	[0.590,0.679,0.808,0.879]	[0.610,0.698,0.808,0.873]	[0.569,0.658,0.779,0.849]
SQ2	[0.526,0.614,0.755,0.828]	[0.567,0.656,0.786,0.858]	[0.605,0.694,0.804,0.870]	[0.562,0.649,0.778,0.849]
SQ3	[0.609,0.699,0.820,0.888]	[0.626,0.716,0.833,0.900]	[0.568,0.654,0.772,0.837]	[0.607,0.695,0.794,0.857]
SQ4	[0.646,0.736,0.847,0.913]	[0.660,0.751,0.857,0.924]	[0.669,0.758,0.847,0.908]	[0.626,0.715,0.821,0.886]
SQ5	[0.577,0.667,0.802,0.875]	[0.613,0.703,0.830,0.901]	[0.584,0.673,0.803,0.875]	[0.627,0.719,0.841,0.910]
SQ6	[0.548,0.638,0.786,0.863]	[0.586,0.677,0.815,0.889]	[0.591,0.680,0.822,0.896]	[0.578,0.667,0.800,0.874]
SQ7	[0.552,0.641,0.781,0.854]	[0.576,0.665,0.791,0.862]	[0.605,0.693,0.814,0.883]	[0.605,0.697,0.828,0.900]
SQ8	[0.553,0.643,0.786,0.861]	[0.607,0.697,0.825,0.897]	[0.580,0.669,0.803,0.875]	[0.537,0.622,0.747,0.816]

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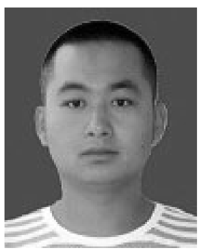

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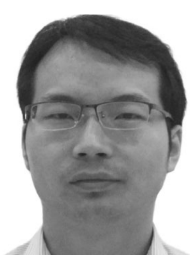

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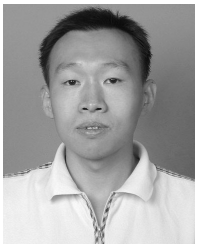

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