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Discussion on table tennis size reform advantages and disadvantages based on fuzzy comprehensive analysis and game theory

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ABSTRACT

For table tennis reforming from small to big influence, the paper will make quantitative analysis from athletes' experience qualities and audience appreciation qualities two aspects so as to ensure its comprehensiveness. For athletes' experience qualities, the paper establishes fuzzy comprehensive analysis algorithm's evaluation model, it gets before table tennis reforming (that is small ball era) athletes' experience qualities fuzzy comprehensive value as 70.586, and after reforming one is 63.812, so that get athlete experience qualities have some reductions. The next is establishing competition hosting manufacturers and professional technicians two parties game model, it gets organizers' pure economic efficiency increases, which mapping audiences appreciation interests have been improved. Finally with the help of fuzzy mathematical thought, it establishes proportional distribution model, and makes reasonable suggestions for table tennis size.

KEYWORDS

Fuzzy algorithm;
Game theory;
Analytic hierarchy process;
Table tennis reform;
Economic efficiency;
Distribution model.

INTRODUCTION

In 2000, international table tennis federation increased international table tennis professional competition official ball diameter from 38mm to 40mm. The aim is to further increase ball's air resistance during air running, slow down competition's ball running speed, so that achieve the purpose of further increasing and enriching table tennis professional athletes hitting techniques and skills, and finally increase table tennis competitions' overall appreciation. However, since incoming of table tennis "big ball era" up to now, dispute about ball diameter has never ceased. Chinese and foreign coaches and athletes from all walks of life have mixed. It is worth noting that due to professional athletes' height, playing habit, gripping habit differences, their sensitivities to ball diameter changes are also different.

Then the paper establishes models so that make quantitative research on the problem. At first, for athletes' experience qualities, it takes hierarchical processing with athletes' psychological quality, hand regulation, in-situ level of play, offensive and defensive awareness conversion and physical fitness such five basic indicators affected by table tennis reforming, and based on analytic hierarchy process method, it gets each level indicator weight vector, meanwhile quantize the grades. After that, establish hierarchical membership function, and on the basis of the function, it gets evaluation indicators and grades fuzzy relation matrix. And then carry out fuzzy operator processing with each layer evalua-

tion indicator weight and fuzzy relation matrix, it gets comprehensive evaluation matrix, finally it gets before table tennis reforming (that is small ball era) athletes' experience qualities fuzzy comprehensive evaluation value is 70.5860, after reforming is 63.8120, so that further get athlete experience quality has reduced. According to game theory model, assume model includes competition organizers and professional technicians' two main interest subjects, thereupon it establishes competition organizers and professional technicians two parties game model. In the following, it carries out pure strategy Nash equilibrium analysis and mixed strategy Nash equilibrium analysis, finally competition game two parties' result in competition organizers wins. Therefore, after ball diameter changing, comparing to "small ball era", organizers pure economic efficiency increases, it maps audiences appreciation interests improve that their appreciation qualities promote.

According to proportional distribution model, with the help of fuzzy mathematical thought, according to international table tennis professional league official website before and after reforming post competition random investigation achieved data listed audiences appreciation qualities fuzzy relation matrix, apply MATLAB software, it gets comprehensive evaluation matrix. And then, establish proportional distribution model, carry out proportional distribution on considered factors and table tennis diameters, finally it gets best table tennis diameters best scheme.

FUZZY COMPREHENSIVE ANALYTICAL ALGORITHM EVALUATION MODELS

Fuzzy comprehensive evaluation is a method on the basis of fuzzy mathematics, applying fuzzy relation compound principle to quantify some unclear boundary, not easily quantifying factors and making comprehensive evaluation, its feature is that evaluation result is not absolutely positive or negative but expressed by a fuzzy set. Fuzzy mathematics is just a kind of mathematical method that uses precise mathematical language or algorithm to describe and process fuzzy concept. In order to carry out analysis and research on after table tennis reforming athletes experience quality influences in the paper, it firstly introduces two concepts based on fuzzy mathematics here.

Set there are two finite sets $U=\{u_1,u_2,u_3,\cdots,u_n\}, V=\{v_1,v_2,v_3,\cdots,v_n\}$, if R is u and v one fuzzy relation, that:

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}$$

Among them, $A=\{a_1,a_2,a_3,\cdots,a_n\}$ and V fuzzy set $B=\{b_1,b_2,b_3,\cdots,b_m\}$ meet $B=A\cdot R$, and then call R is U to V one fuzzy relation.

Set it is given a fuzzy matrix $R=(r_{ij})_{n\times m}$, from which $0<r_{ij}<1$, two fuzzy vectors:

$X=(x_1,x_2,\cdots x_i,\cdots x_n)$, from which $0<x_i<1$, $(i=1,2,\cdots,n)$

$Y=(y_1,y_2,\cdots y_i,\cdots y_n)$, from which $0<y_i<1$, $(i=1,2,\cdots,m)$

If $Y=X\cdot R$ is true then formula $X\cdot R=Y$ becomes fuzzy transformation.

Set factors set is, evaluation set is, set the factor single factor evaluation matrix is,, it can be regarded as one fuzzy subset. Among them, represents the factor evaluation to the grade membership, pieces of factors total evaluation matrix is:

Set factors set is $U=\{u_1,u_2,u_3,\cdots,u_n\}$, evaluation set is $V=\{v_1,v_2,v_3,\cdots,v_n\}$, set the i factor single factor evaluation matrix is $R_i=(r_{i1},r_{i2},\cdots,r_{ij},\cdots,r_{im}),(i=1,2,\cdots,n)$, it can be regarded as v one fuzzy subset. Among them, r_{ij} represents the i factor evaluation to the j grade membership, n pieces of factors total evaluation matrix is:

$$R=\begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{pmatrix}=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}$$

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Use minimum and maximum operators' method to calculate, it gets comprehensive evaluation vector $B = A \cdot R$.

Apply fuzzy comprehensive evaluation method to establish mathematical model to athletes' experience qualities, it calculates before table tennis reforming fuzzy comprehensive evaluation value: $U = \{u_1, u_2, u_3, u_4, u_5\}$ is athletes' experience qualities affected factors set, from which u_1 is psychological quality, u_2 is hand regulation, u_3 is level of play, u_4 is physical fitness and u_5 is awareness conversion. $A = \{a_1, a_2, a_3, a_4, a_5\}$ represents each evaluation indicator weight.

Establish hierarchical structure

By analyzing, it can get ball diameter changes to athletes' influences mainly reflect on psychological qualities, hand regulation, in-situ level of play, offensive and defensive awareness conversion and physical fitness such five aspects. Establish their and table tennis diameter changes hierarchical structure as Figure 1 show:

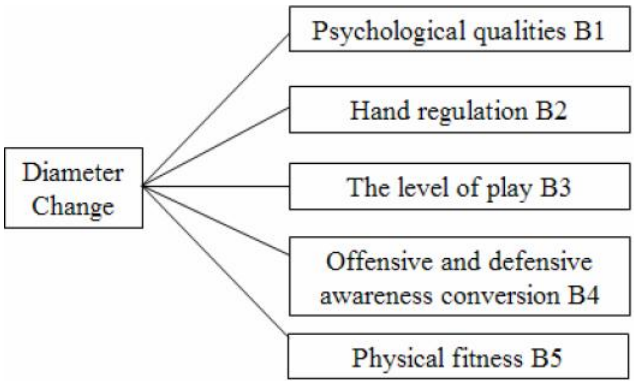

Figure 1: Hierarchical structure

Construct judgment matrix

Hierarchical structure reflects relations among elements, but a criterion hierarchy's every criteria weight in target measuring is not always the same. The paper adopts paired comparison establishing paired comparison matrix method on factor B. That is extracting two factors B_i and B_j every time, use a_{ij} representing B_i and B_j to A influences sizes ratio, whole comparison result uses matrix $C = (a_{ij})_{n\times n}$ to express, call C is $A-B$ paired comparison judgment matrix, it is called judgment matrix for short. To B_1, B_2, B_3, B_4, B_5 such two, respectively make comparison, and it can get judgment matrix C:

$$C = \begin{bmatrix} 1 & 5 & \frac{1}{3} & 6 & 7 \\ \frac{1}{5} & 1 & \frac{1}{4} & 3 & 2 \\ 3 & 4 & 1 & 5 & 5 \\ \frac{1}{6} & \frac{1}{3} & \frac{1}{5} & 1 & 2 \\ \frac{1}{7} & \frac{1}{2} & \frac{1}{5} & \frac{1}{2} & 1 \end{bmatrix},$$

With the help of MATLAB calculating, it can get $A = (0.3257, 0.1076, 0.4517, 0.0643, 0.0508)^T$

Hierarchical single arrangement and consistency test

Judgment matrix A corresponding maximum feature value $\lambda_{\max}$ vector weight W, after normalization it is same layer corresponding factors to previous layer one factors relative important arrangement weight, the process is called hierarchical single arrangement. Consistency indicator:

$$\mathbf{CI} = \frac{\boldsymbol{\lambda} - \mathbf{n}}{\mathbf{n} - \mathbf{1}} \quad \mathbf{(1)}$$

When $CI = 0$, C is consistency matrix CI gets bigger and then C inconsistency degree gets more serious. Random consistency indicator RI value is as TABLE 1 show.

To $n \geq 3$ paired comparison matrix C, call its consistency indicator and same order (refers n is the same) random consistency indicator RI ratio is consistency ratio CR, when:

$$\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RI}} < \mathbf{0.1} \quad \mathbf{(2)}$$

It is thought that C inconsistency degree is within tolerance range, it can use its feature vector as weight vector.

Use MATLAB software calculating comparison matrix C maximum feature value is $\lambda_{\max} = 5.3892$, input into formula (1), it gets $CI = \frac{5.3892 - 5}{5 - 1} = 0.0973$,

TABLE 1: Random consistency indicator RI

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

and because $n = 5$, consult table and can get RI is 1.12, input CI, RI into (2) to calculate and can get $CR = \frac{0.0973}{1.12} = 0.0869 < 0.1$, therefore comparison matrix C meets consistency test. So w can be used as weight vector.

w Each component is table tennis diameter changes to technical level, hand regulation, psychological qualities, offensive and defensive awareness conversion, physical fitness influence weight, from which, table tennis diameter changes to technical level, hand regulation and psychological qualities influence weights are largest.

Define evaluation grades set

$V = \{v_1, v_2, v_3, v_4, v_5\} = (\text{very well}, \text{good}, \text{normal}, \text{poor}, \text{bad}) = (A, B, C, D, E)$

Corresponding grades scores column vector $C = \{c_1, c_2, c_3, c_4, c_5\}^{\mathrm{T}} = (100, 80, 60, 40, 20)^T$, correspondingly define athletes' experience qualities grades.

Each evaluation matrix distribution

According to table tennis before reforming competition periods' self experience quality five main influence factors' post competition investigation data, it gets its fuzzy matrix.

By TABLE 2 data, obtained fuzzy matrix is:

$$R = \begin{pmatrix} 0.32 & 0.25 & 0.24 & 0.18 & 0.01 \\ 0.38 & 0.35 & 0.10 & 0.14 & 0.03 \\ 0.25 & 0.23 & 0.17 & 0.21 & 0.14 \\ 0.40 & 0.21 & 0.23 & 0.05 & 0.11 \\ 0.42 & 0.22 & 0.29 & 0.07 & 0 \end{pmatrix}$$

Fuzzy transformation

$$B = A \cdot R$$

$$= (0.3257, 0.1076, 0.4517, 0.0643, 0.0508)$$

$$\begin{pmatrix} 0.32 & 0.25 & 0.24 & 0.18 & 0.01 \\ 0.38 & 0.35 & 0.10 & 0.14 & 0.03 \\ 0.25 & 0.23 & 0.17 & 0.21 & 0.14 \\ 0.40 & 0.21 & 0.23 & 0.05 & 0.11 \\ 0.42 & 0.22 & 0.29 & 0.07 & 0 \end{pmatrix}$$

$$= (0.3051, 0.2477, 0.1952, 0.1753, 0.0768)$$

Calculate fuzzy comprehensive evaluation value

$$H = B \cdot C$$

$$= (0.3051, 0.2477, 0.1952, 0.1753, 0.0768)(100, 80, 60, 40, 20)^T$$

$$= 70.5860$$

Therefore, it is clear that before table tennis reforming (that is small ball era) athlete experience qualities fuzzy comprehensive evaluation value is 70.5860. Similarly it can get table tennis after reforming (that is big ball era) athlete experience qualities fuzzy comprehensive evaluation value is 63.8120. Exact used data is as following TABLE 3.

By TABLE 3, obtained fuzzy matrix is:

$$R' = \begin{pmatrix} 0.20 & 0.22 & 0.32 & 0.19 & 0.07 \\ 0.31 & 0.29 & 0.26 & 0.09 & 0.05 \\ 0.20 & 0.20 & 0.17 & 0.18 & 0.25 \\ 0.35 & 0.21 & 0.27 & 0.07 & 0.10 \\ 0.27 & 0.14 & 0.30 & 0.16 & 0.13 \end{pmatrix}$$

Fuzzy transformation is:

TABLE 2 : Before reforming athletes' five main factors influences evaluation investigation percentage

	Grade				
	A	B	C	D	E
Psychological qualities	32	25	24	18	1
Hand regulation	38	35	10	14	3
Level of play	25	23	17	21	14
Physical fitness	40	21	23	5	11
Offensive and defensive awareness conversion	42	22	29	7	0

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TABLE 3 : After reforming athletes' five main factors influences evaluation investigation percentage

	Grade				
	A	B	C	D	E
Psychological qualities	20	22	32	19	7
Hand regulation	31	29	26	9	5
Level of play	20	20	17	18	25
Physical fitness	35	21	27	7	10
Offensive and defensive awareness conversion	27	14	30	16	13

$$B' = A \cdot R'$$

$$= (0.3257, 0.1076, 0.4517, 0.0643, 0.0508)$$

$$\begin{pmatrix} 0.20 & 0.22 & 0.32 & 0.19 & 0.07 \\ 0.31 & 0.29 & 0.26 & 0.09 & 0.05 \\ 0.20 & 0.20 & 0.17 & 0.18 & 0.25 \\ 0.35 & 0.21 & 0.27 & 0.07 & 0.10 \\ 0.27 & 0.14 & 0.30 & 0.16 & 0.13 \end{pmatrix}$$

$$= (0.2251, 0.2138, 0.2416, 0.1655, 0.1541)$$

Fuzzy comprehensive evaluation value is :

$$H' = B' \cdot C$$

$$= (0.2251, 0.2138, 0.2416, 0.1655, 0.1541)(100, 80, 60, 40, 20)^T$$

$$= 63.8120$$

To sum up, after reforming athletes' experience qualities fuzzy comprehensive evaluation value 63.8120 is obviously smaller than before reforming athletes' experience qualities fuzzy comprehensive evaluation value 70.5860, therefore athletes' experience qualities has been reduced after table tennis changing from 38mm to 40mm.

GAME THEORY MODEL

Competition organizers and professional technicians two parties game model

Assume that in model it includes competition organizers and professional technicians' two main interest subjects. Competition organizers are competition hosting revenue subject, professional technicians include professional coaches, professional athletes. Due to small ball playing and service most changeful, speed is fast, rotation is diversity, it is dazzling. But just due to ball speed is too fast, many exciting and wonderful parts cannot be understood by audiences. So that weakens table tennis enthusiasts' interests, which directly threatens organizers' profits. And on the other hand, most of professional athletes take it as lifelong career, due to sphere enlarge, ball speed slows down, rotations weakens, these changes all generate great influences on table tennis. Athlete should also master big ball speed, rotation, strength as well as big ball sphericity changes again, which is also the issue that is worth coaches researching. Therefore, both the two are locked in a stalemate for their own profits.

Because table tennis reforming from small to big affects athletes' competition period experience quality P, now specially set it as kP, so as to express experience quality value measurement, and then it can further more easily make numerical comparison with organizers' revenue.

To organizer and athlete's revenue and cost under different strategic conditions, it makes following assumption : one competition total number of athletes X, athletes reject changing ball, experience quality is kP_1; When athlete select to change table tennis, experience quality is kP_1'. To organizer, ball game ticket unit price is S_A, when ball not changing, it needs to pay off organizing charge C_F (payoff organizing unit charge and sit fees), after ball changing organizing charge is C_F'. Person-time of audience that selects no changing ball is X_A, advertisement revenue is G_A; When athlete selects ball changing, person-time of audience is X_A' advertisement revenue G_A'. In the following, two parties' game revenue matrix is as TABLE 4 show.

Two parties' game model equilibrium analysis

Pure strategy Nash equilibrium analysis

(1) If $-C_F' + S_A X_A' + G_A' < -C_F + S_A X_A + G_A$ that organizer after reforming revenue is smaller than before reforming revenue. The condition can be transformed as: $(S_A X_A + G_A) - (S_A X_A' + G') > C_F - C_F'$, it

TABLE 4 : Organizer and athlete revenue matrix

		Organizer	
		Select to change ball	**Reject changing ball**
Athlete	Select to change ball	$kP_1', -C_F' + S_A X_A' + G_A'$	$kP_1', -C_F + S_A X_A + G_A$
	Reject changing ball	$kP_1, -C_F' + S_A X_A' + G_A'$	$kP_1, -C_F + S_A X_A + G_A$

represents organizer after ball changing revenue growth is smaller than organizing charge added value, then:

If $kP_1' > kP_1$, that $P_1' > P_1$, it represents athlete has high experience qualities in case ball not change, athlete will select "not change" strategy, now it will have unique Nash equilibrium stable solution, strategy profile is (not change, not change).

If $kP_1' < kP_1$, that $P_1' < P_1$, it represents athlete has high experience qualities in case ball changes, athlete will select "change" strategy.

If $-C_F' + S_A X_A' + G_A' > -C_F + S_A X_A + G_A$, it represents organizer after ball changing revenue is larger than not changing revenue, organizer is willing to change ball, now, game has unique Nash equilibrium stable solution, and strategy is (change ball, change ball).

If $-C_F' + S_A X_A' + G_A' < -C_F + S_A X_A + G_A$, it represents organizers not changing ball revenue is larger than after changing ball revenue, then now it doesn't exist unique Nash equilibrium stable solution.

(2) If $-C_F' + S_A X_A' + G_A' >$, it represents organizer after changing ball revenue is larger than not changing ball revenue. The condition can be transformed as: $(S_A X_A + G_A) - (S_A X_A' + G') < C_F - C_F'$, it represents after changing ball organizer revenue growth can make up organizing charge growth. Then:

If $kP_1' > kP_1$, that $P_1' > P_1$, it represents athlete has high experience qualities in case ball not changes, athlete will select "not change" strategy, it doesn't exist unique Nash equilibrium stable solution.

If $kP_1' < kP_1$, that $P_1' < P_1$, it represents athlete has high experience qualities in case ball changes, athlete will select "change" strategy, now game has unique Nash equilibrium stable solution, and strategy is (change ball, change ball).

Above discussion result possible pure strategy profile result table is as TABLE 5 show.

Mixed strategy nash equilibrium analysis

In case it doesn't exist pure strategy Nash equilibrium, athlete and organizer will adopt mixed strategy that respectively adopt its pure strategy with certain probabilities, assume that athlete takes p_1 probability to adopt strategy B_1 (change ball), takes $1 - p_1$ probability to adopt strategy B_2 (not change), organizer takes p_2 probability to adopt strategy B_1 (change ball), takes $1 - p_2$ probability to adopt strategy B_2 (not change), here $0 < p_2 < 1$ and $0 < p_2 < 1$. Then athlete and organizer expected revenue is as following

$$\mathbf{E_1(q_1,q_2) = p_1[p_2 kP_1' + (1-p_2)kP_1'] + (1-p_1)[kP_1 + (1-p_2)kP_1]} \quad (3)$$

$$\mathbf{E_2(p_1,p_2) = p_2\begin{bmatrix} p_1(-C_F' + S_A X_A' + G_A') + \\ (1-p_1)(-C_F' + S_A X_A' + G_A') \end{bmatrix} + (1-p_2)\begin{bmatrix} p_1(-C_F + S_A X_A + G_A) \\ + (1-p_1)(-C_F + S_A X_A + G_A) \end{bmatrix}} \quad (4)$$

$$\mathbf{Let\ \frac{\partial E_1}{p_1} = 0\ .\ then:\ p_2 = \frac{2P_1' - P_1}{P_1'}} \quad (5)$$

$$\mathbf{Let\ \frac{\partial E_2}{p_2} = 0\ ,\ then:\ p_1 = \frac{(S_A X_A' + G_A') - (S_A X_A + G_A)}{C_F' - C_F}} \quad (6)$$

In order to easier to analyze, it presents p_2 another kind of expression, it can refer to formula (6).

$$\mathbf{p_2 = \frac{2P_1' - P_1}{P_1'} = 2 - \frac{P_1}{P_1'}} \quad (7)$$

Regarding p_2 influence factors analysis, by formula (5)and formula (7), it can see:

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TABLE 5 : Organizer and athlete game pure strategy Nash equilibrium

Condition	Pure strategy profile
$-C_F' + S_A X_A' + G_A' < -C_F + S_A X_A + G_A \quad kP_1' > kP_1$	(not change, not change)
$-C_F' + S_A X_A' + G_A' > -C_F + S_A X_A + G_A \quad kP_1' < kP_1$	(change ball, change ball)

p_2 is increasing function of P_1'. When P_1' increases, athletes ball changing experience qualities will improve, similarly, p_2 is decreasing function of P_1, P_1 gets smaller, athletes' ball unchanged experience qualities will get smaller, organizer's ball unchanged experience qualities will get larger, so p_2 will increase, that organizer changing ball probability is larger.

(2) Regarding p_1 influence factors analysis, by formula (6) it can see:

p_1 is decreasing function of $C_F' - C_F$, when $C_F' - C_F$ increases, p_1 reduces, that athlete changing ball probability increases, and now, organizer before and after ball changing organizing charge increment is far less than economic efficiency increment, two parties achieve win-win.

To sum up, after competition ball diameter changing, comparing to "small ball era", organizer pure economic efficiency increases, it indicates person-time of audience increases, indirectly maps audience appreciation interests improves that their appreciation qualities improve.

PROPORTIONAL DISTRIBUTION MODELS

Apply fuzzy comprehensive evaluation method to establish mathematical model regarding audience appreciation quality, calculate table tennis before reforming fuzzy comprehensive evaluation value: $U = \{u_1, u_2, u_3, u_4\}$ is audience appreciation quality influence factors set, from which u_1 is competition round number, u_2 is competition positivity, u_3 is competition density, u_4 is cost performance. $A = \{a_1, a_2, a_3, a_4, a_5\}$ is each evaluation indicator weight.

Establish hierarchical structure

By analyzing, it can get ball diameter changes to audience appreciation qualities influences mainly reflect in competition round number, competition positivity, competition density and cost performance so on four aspects.

Construct judgment matrix

Judgment matrix C:

$$C = \begin{pmatrix} 1 & \frac{7}{3} & \frac{4}{3} & \frac{2}{3} \\ \frac{3}{7} & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{3}{4} & 2 & 1 & \frac{1}{2} \\ \frac{3}{2} & 3 & 2 & 1 \end{pmatrix}$$

With the help of MATLAB calculating, it can get $A = (0.2736, 0.1182\ 0.2126, 0.3957)^T$

Use MATLAB software to calculate, it gets comparison matrix C maximum feature value is $\lambda_{\max} = 4.0078$, input into formula (1) and get $CI = \frac{4.0078 - 4}{4-1} = 0.0026$, and because $n = 4$, by consulting table, it can get RI is 0.90, input CI, RI into (2), calculate and get $CR = \frac{0.0026}{0.90} = 0.0003 < 0.1$, therefore comparison matrix C meets consistency test. So A can be used as weight vector.

Define evaluation grades set $V = \{v_1, v_2, v_3, v_4, v_5\} = (A, B, C, D, E)$

A: very satisfied;B: satisfied;C:normal;D: dissatisfied;E: very dissatisfied;

Corresponding grades scores column vec-

tor $C = \{c_1, c_2, c_3, c_4, c_5\}^T = (100, 80, 60, 40, 20)^T$,

Correspondingly define audiences' experience qualities grades.

Each evaluation matrix distribution

According to table tennis before reforming athletes during competition periods' affect audience appreciation qualities four main influence factors' post competition investigation data; it gets its fuzzy matrix.

By Figure 2 data, obtained fuzzy matrix is:

$$R = \begin{pmatrix} 0.07 & 0.24 & 0.44 & 0.11 & 0.14 \\ 0.27 & 0.21 & 0.39 & 0.07 & 0.08 \\ 0.14 & 0.11 & 0.52 & 0.20 & 0.03 \\ 0.20 & 0.17 & 0.24 & 0.22 & 0.17 \end{pmatrix}$$

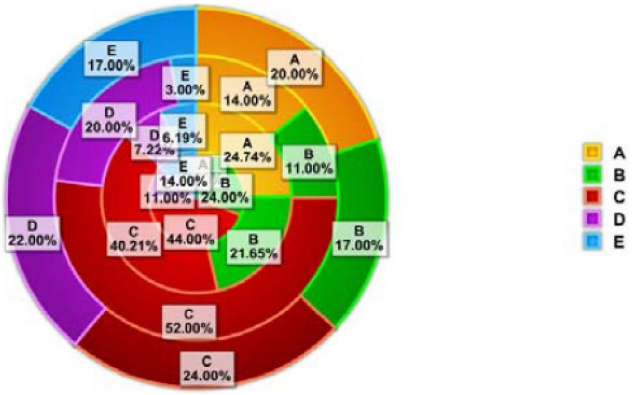

Figure 2 : Before reforming audience appreciation qualities influence factors

Fuzzy transformation

$$B = A \cdot R$$

$$= (0.2736, 0.1182\ 0.2126, 0.3957) \begin{pmatrix} 0.07 & 0.24 & 0.44 & 0.11 & 0.14 \\ 0.27 & 0.21 & 0.39 & 0.07 & 0.08 \\ 0.14 & 0.11 & 0.52 & 0.20 & 0.03 \\ 0.20 & 0.17 & 0.24 & 0.22 & 0.17 \end{pmatrix}$$

$$= (0.1600\ 0.1811\ 0.3720\ 0.1679\ 0.1190)$$

(6)Calculate fuzzy comprehensive evaluation value

$$H = B \cdot C$$

$$= (0.1600\ 0.1811\ 0.3720\ 0.1679\ 0.1190)(100,80,60,40,20)^T$$

$$= 61.9040$$

Therefore, it is clear that before table tennis reforming (that is small ball era) audience appreciation quality fuzzy comprehensive evaluation value is 61.9040.

Similarly it can get table tennis after reforming (that is big ball era) audience appreciation quality fuzzy comprehensive evaluation value is 75.2220. Exact used data is as following Figure 3.

By Figure 3, obtained fuzzy matrix is:

$$R' = \begin{pmatrix} 0.27 & 0.34 & 0.30 & 0.05 & 0.04 \\ 0.25 & 0.19 & 0.41 & 0.10 & 0.05 \\ 0.22 & 0.22 & 0.52 & 0.03 & 0.01 \\ 0.37 & 0.27 & 0.30 & 0.04 & 0.02 \end{pmatrix}$$

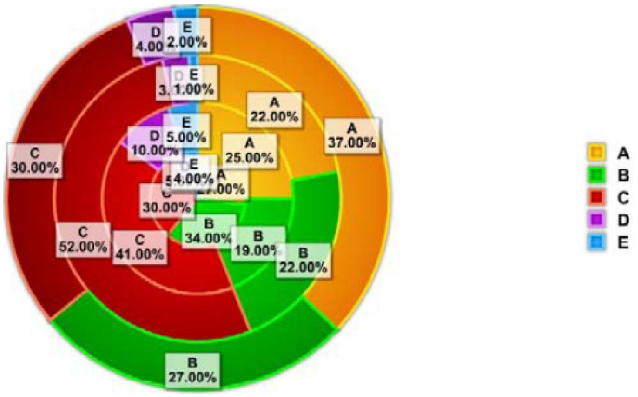

Figure 3 : After reforming audience appreciation quality influence factors

Fuzzy transformation is:

$$B' = A \cdot R'$$

$$= (0.2736, 0.1182\ 0.2126, 0.3957) \begin{pmatrix} 0.27 & 0.34 & 0.30 & 0.05 & 0.04 \\ 0.25 & 0.19 & 0.41 & 0.10 & 0.05 \\ 0.22 & 0.22 & 0.52 & 0.03 & 0.01 \\ 0.37 & 0.27 & 0.30 & 0.04 & 0.02 \end{pmatrix}$$

$$= (0.2966, 0.2691, 0.3598, 0.0477, 0.0269)$$

Fuzzy comprehensive evaluation value is:

$$H' = B' \cdot C$$

$$= (0.2966, 0.2691, 0.3598, 0.0477, 0.0269)(100,80,60,40,20)^T$$

$$= 75.2220$$

To sum up, after reforming audience appreciation quality fuzzy comprehensive evaluation value 75.2220 is obviously larger than before reforming audience appreciation quality fuzzy comprehensive evaluation value 61.9040, therefore audience appreciation quality has been raised after table tennis changing from 38mm to 40mm.

Establish proportional distribution model

Athlete experience quality change rate

$$w_1 = \frac{63.8120 - 70.5860}{70.5860} \times 100\% = -9.60\%$$

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Audience appreciation quality change rate

$$w_2 = \frac{75.2220 - 61.9040}{61.9040} \times 100\% = 21.5\%$$

Assume that table tennis best diameter is x

Then it should meet $\frac{x-38}{x-40} = \frac{21.5\%}{-9.60\%}$

It gets $x = 39.38mm$

By above model establishing and solution, we finally get table tennis best diameter is $39.38mm$.

CONCLUSIONS

To Model one, the model is different from traditional fuzzy comprehensive evaluation model, in order to make up for traditional analysis weight definition artificial is judged by human and so causes weight endowing so subjective such shortcoming, it combines fuzzy comprehensive analysis basic model with analytic hierarchy process to proceed with impacts solution. Though analytic hierarchy process has also certain subjectivities to judgment matrix definition, it is on the basis of higher theoretical foundation mathematical knowledge and logic is careful, use the method can objectively calculate each indicator weight. Besides, in final evaluation, the model doesn't dwell on simple maximum membership principle, and on this basis it additionally adopts scoring grades method, and solves comprehensive evaluation exact scores. Finally make comparison on before and after reforming fuzzy comprehensive evaluation values, and further get that athlete experience quality has slightly reduction.

To Model two, the model skillfully set organizer and professional technician two main interest subjects as game two parties, relying on pure strategy Nash equilibrium analysis and mixed strategy Nash equilibrium analysis, it deepens two parties benefits discussion again. Finally successfully apply operational research game theory into sports fields, and make optimization, it better show audience appreciation quality changes.

To Model three, the model well draws support from Model one thought and carries out further calculation, and by skillfully combining with proportional distribution model, its calculation steps are simple, easily understood, and is another improvement on solving optimization problems.

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