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Study on Dea-coordination Degree Evaluation Between the Public Service Facility and the Intake Population in Indemnificatory Community

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Abstract: Arising from the particularity of the intake population group of the indemnificatory communities, slow population intake process and low occupancy rate, there is a procedural imbalance existing between public service facility configuration and intake population which imposes an adverse effect on the life quality of the residents and an impediment on the realization of expected indemnificatory effect. This study adopts the modified DEA cross evaluation model and uses the MATLAB operational program to evaluate the coordination degree between the public service facility and the intake population in indemnificatory community in terms of the sequence, the scale and the structure. Some data in one indemnificatory community in Shanghai are adopted to test accuracy and objectivity of this model. The test results show DEA cross evaluation model has an excellent compatibility and more accuracy when it is used in the coordination degree evaluation between the public service facility and the intake population in indemnificatory community and provide the basis for the public service facilities reasonable configuration t in the sequence, the sale and the structure and is of certain practical guiding significance.

Key words: Indemnificatory community, public service facilities, intake population; DEA coordination degree evaluation, MATLAB program realization

INTRODUCTION

Against the backdrop of city renewal and implementation of government-subsidized housing system, a large number of indemnificatory communities are emerging across China. Arising from the particularity of the intake population group of the indemnificatory communities, slow population intake process and low occupancy rate, there is a procedural imbalance existing between public service facility configuration and intake population which imposes an adverse effect on the life quality of the residents and an impediment to the realization of expected indemnificatory effect. Under this circumstance, only with a study of the synergy configuration of subsidized community public service facilities with the intake population, especially an evaluation of the status quo of the synergy, is it possible to provide scientific synergy configuration plans and measures. The coordination degree evaluation is an important link of synergy configuration study from theory to practice.

Currently, the academia is striving to study the synergy development between different systems (such as social economy system, population system, resource system and biological system) and has made certain achievements. The first type of study applies the synergy development and coordination degree model into the relationship between economic development and the ecological environment. This includes macro study (Wang *et al*., 2007) and regional study (Kou and Xue, 2007). The second type is the study of the coordination degree of regional economy and social development, by segmenting the economic system and the social system and selecting among them the indicators to build up the coordination degree evaluation indicator system of regional economic development, list the efficacy function and calculate the coordination degree of the regional economic development (Zhou and Li, 2006). The third type studies the synergy development and coordination degree model in other areas, such as the coordination degree study of industrial water use system (Shen *et al*., 2012) and urban land use potential evaluation (Xiong *et al*., 2007). However, there has not been any literature of the study on the synergy configuration and coordination degree evaluation model between the public service facility and the intake population.

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This study has made the following innovations:

- It improves the DEA coordination degree evaluation model. This study builds the DEA coordination degree evaluation model between the public service facilities and the intake population in indemnificatory community to measure the coordination degree between the public service facility and the intake population at different times, thereby disclosing the conflicts and problems between the two
- It adopts the MATLAB method to solve the problem. The powerful matrix operation function and sufficient linear programming solution of MATLAB can be used to write convenient DEA programs
- It is the first to ever introduce the coordination degree evaluation into the study of the synergy configuration and coordination degree evaluation between the public service facility and the intake population in indemnificatory community and is of strong practical value and promotion capability

DETERMINATION OF THE INDICATORS FOR THE COORDINATIONDEGREEEVALUATIONBETWEEN THE PUBLIC SERVICE FACILITY AND THE INTAKE POPPULATION IN INDEMNIFICATORY COMMUNITY

The compound system theory considers the public service facility in indemnificatory community and the intake population as a compound system, with the public service facility and the intake population each being a sub-system; the synergy configuration between the two is a dynamic coordination relationship, including the synergy in three dimensions: sequence, scale and structure. Therefore, this study examines the development of the public service facility and the intake population in indemnificatory community from the perspectives of sequence, scale and structure.

Public service facility sub-system: The research on the coordination degree between the public service facility and the intake population is at a preliminary stage in China. There has been limited study of the evaluation indicator system for the public service facility. Typical examples are using the coverage rate, construction area and land area as indicators for the public service facility system (Zhang *et al*., 2006), using the provision scale, density and accessibility as indicators for the public service facility system (Gao and Su, 2010) and using the demand and satisfaction level of the public service facility as indicators for the public service facility system (Huang *et al*., 2009). This study chooses the following three indicators:

Variation rate of the demand for high-level public service facility: Based on the leveled demand theory of Abraham H. Maslow, this study divides the public service facility in indemnificatory community into fundamental life service facility and high-level demand facility, the later including cultural, sports, financial, administration and community service. This indicator is the variation rate of residents' demand for the high-level public service facility which represents the sequence indicator of the public service facility sub-system.

Total construction area of the public service facility: This indicator follows the classification of the public service facility by Shanghai 06 standards and summarizes the construction area of 11 different types of public service facility which represents the scale indicator of the public service facility sub-system.

Satisfaction level of the public service facility structure: The satisfaction level of the public service facility structure refers to the residents' feeling towards the actual service effects of the public service facility in the indemnificatory community compared to their expectation of the rationality of the structure configuration of the public service facility. This study adopts the five-rating evaluation, namely the scores "5, 4, 3, 2, 1", corresponding to "extremely important, very important, important, unimportant, extremely unimportant" for the expectation of the rationality of the structure configuration of the public service facility and corresponding to "very satisfied, satisfied, just so-so, dissatisfied, very dissatisfied" for the evaluation of the actual feeling towards the rationality of the structure configuration of the public service facility. This indicator of satisfaction level, through the ratings by residents and calculation, gets the rating of satisfaction level of public service facility structure equal to expectation rating divided by actual feeling rating which represents the structural indicator of the public service facility sub-system.

Intake population sub-system: The indicator system of intake population is mainly used to reflect the scale, structure, quality and variation of the intake population system. This study examines the development of intake population system from the three aspects of population scale, population structure and population demand and chooses the following three indicators.

Occupancy rate variation: This indicator is the variation of occupancy rate of the intake population in indemnificatory community which represents the sequence indicator of the intake population sub-system.

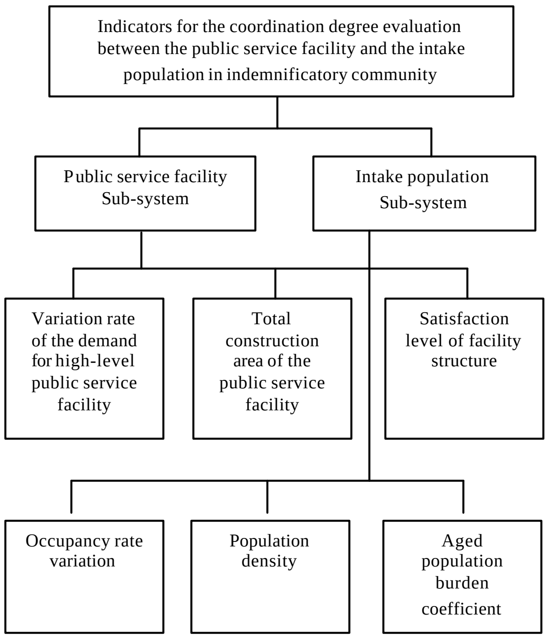

Fig. 1: Indicators for the coordination degree evaluation between the public service facility and the intake population in indemnificatory

Population density: This indicator is the density of the regular population in indemnificatory community which represents the scale indicator of the intake population sub-system.

Aged population burden coefficient: This indicator is the ratio of senior citizens above 65 years old in indemnificatory community which represents the structure indicator of the intake population sub-system.

In summary, the indicators for the coordination degree evaluation between the public service facility and the intake population in indemnificatory community are shown as Fig. 1.

DEA CROSS EVALUATION MODEL BETWEEN THE PUBLIC SERVICE FACILITY AND THE INTAKE POPULATION IN INDEMNIFICATORY COMMUNITY

Modified DEA cross-evaluation model

Theory of DEA model: Data Envelopment Analysis (DEA), a non-parameter programming technology first introduced by Charnes *et al.* (1978), provides a relatively effective measure to realize the multi-input and multi-output of Decision Making Units (DMUs). It has been proved to be an effective means for determining the optimal critical behavior and evaluating the performance of DMUs. Since the CCR model, the DEA model has had leapfrog development in both theory and application. W.Q. Lin *et al.* summarized the research achievement in DEA and pointed out that DEA has been extensively applied in the evaluation benchmarks for schools, hospitals, bank branches and industrial parks.

The C^2R model defines n DMUs: DMUi, i = 1, 2, …, n, DMUi input being $Xi = (x_{li}, x_{li}, \dots, x_{li})^T>0$, output being $Yi = (y_{1i}, y_{2i}, \dots, y_{ri})^T>0$ and introduces the variable weight input and output vectors $V = (v_1, v_2, \dots, v_m)^T$, $U = (u_1, u_2, \dots, u_r)^T$ for input and output "synthesis". We define the efficiency index of DMUi as the ratio between the output "synthesis" and the input "synthesis", the efficiency index of the DMU_0 under evaluation as the maximum objective and the efficiency index for all DMUs hi = 1 as constraint, this is the modified DEA model. Its fractional programming equation is as follows:

$$\begin{cases} \max h_0 = \dfrac{U^T Y_0}{V^T X_0} \\ \text{s.t. } hj = \dfrac{U^T Y_j}{V^T X_j} \le, j=1,\dots,n \\ U \ge 0;\ V \ge 0 \end{cases} \tag{1}$$

Using the Charnes-Cooper transformation, the fractional programming form (1) of the C^2R model is transformed into the following linear programming Eq. 2:

$$\begin{cases} \text{Max } \mu^T Y_0 \\ \text{s.t. } \omega^T X_j - \mu^T Y_j \ge, j=1,2,\dots,n \\ \omega^T X_0 = 1 \\ \omega \ge 0; U \ge 0 \end{cases} \tag{2}$$

Suppose "linear programming (2) has the optimal solutions ui* and vi* which is the optimal weight of DMUi:

$$w_i^* = \begin{bmatrix} v_i \\ u_i^* \end{bmatrix}$$

then the optimal solution $E_{ii} = y_i^T u_i^*$ is the efficiency score of DMUi. Since Eii is the calculation result using the optimal weight for DMUi, we call Eii the self-evaluation score of DMUi. In the DEA model, if Eii reaches the maximum value 1, then DMUi is efficient; if Eii<1, then DMUi is non-efficient. Model (2) is the self-evaluation model of DEA.

Modified DEA cross-evaluation model: Charnes found that the traditional DEA model is inapplicable for the ranking of DMUs due to its simple classification of DMUs into high-efficiency type and low-efficiency type. Some low-efficiency DMUs have better evaluation performance than the high-efficiency DMUs. For maximizing the DEA evaluation efficiency of the DMU under evaluation, it more often than not ignores other inputs and outputs, consequently starting from the most favorable perspective to weight the most advantageous evaluation measure. In practice, quite a few DMUs have the maximum efficiency score 1. Therefore, Eii alone does not suffice to distinguish the quality of these DMUs. In addition, model (2) allows each DMUi to get an Eii using the most favorable weight wi* which frequently has great disparity in the weighting of inputs and outputs. This over-emphasis on the few favorable input and output indicators and negligence of other indicators prevents the self-evaluation score Eii, calculated by using model (2), from faithfully reflecting the quality of DMUi.

To address this, we introduce the cross-evaluation mechanism. Sexton *et al*. (1986) are the first to introduce the cross-evaluation model which later is developed into a DEA extension tool, used for identifying the order and completeness of efficient DMUs. Cross-evaluation uses peer evaluation instead of the pure self-evaluation to sequence all DMUs and is extensively used in various fields (Qu, 2012). The evaluation results using the traditional DEA method, more often than not, fail to effectively distinguish the quality of various DMUs; and to achieve the maximum value of its efficiency evaluation index, it usually adopts extreme and unreasonable weight distribution for the input and output indicators.

The DEA cross-evaluation model, to a certain degree, makes up for these pitfalls of the traditional DEA method. The basic idea of the cross-evaluation is to use the optimal weight of each DMUi:

$$w_i^* = \begin{bmatrix} v_i \\ u_i^* \end{bmatrix}$$

to calculate the efficiency score of other DMUk. The cross-evaluation score is:

$$E_{ik} = \frac{y_k^T u_i^*}{x_k^T v_i^*} \tag{3}$$

The bigger the Eik is, the more favorable the DMUk and the more disadvantageous the DMUi are.

The cross-evaluation score Eik calculated using Eq. 3 has its uncertainty which can be remedied using the aggressive cross-evaluation (Tang *et al*., 2012). Steps for the aggressive cross-evaluation is as follows: (1) Get the self-evaluation score Eii of each DMUi using model (2); (2) Under the precondition of ensuring the maximum score Eii for DMUi, get the minimum possible cross-evaluation score Eik for other DMUk. The nature of the aggressive cross-evaluation is that each DMUi, while trying to maximize itself, tries to minimize other DMUk.

Accordingly, we set $\max y_i^T u$ as the primary goal and:

$$\min \frac{y_k^T u}{x_k^T v}$$

as the secondary goal and build the aggressive cross-evaluation model.

- **Step 1:** Use model (2) to get the self-evaluation score Eii (1 = i = n) for DMUi
- **Step 2:** Given i∈{1, 2, ..., n}, k∈{1, 2, ..., n}, solve the following linear programming:

$$\begin{cases} \min y_k^T u \\ \text{s.t.}\, y_k^T \le x_j^T v (1 \le j \le n),\ y_j^T u = E_{ii} x_i^T v = 1, u \ge 0, v \ge 0 \end{cases} \tag{4}$$

- **Step 3:** Use the optimal solutions uik* and vik* of model (4) to get the cross-evaluation score:

$$E_{ik} = \frac{y_k^T u_{ik}^*}{x_k^T v_{ik}^*} = y_k^T u_{ik}^*$$

- **Step 4:** Form the cross-evaluation matrix using the cross-evaluation scores:

$$E = \begin{bmatrix} E_{11} & E_{12} & \dots & E_{1n} \\ E_{21} & E_{22} & \dots & E_{2n} \\ \dots & \dots & \dots & \dots \\ E_{n1} & E_{n2} & \dots & E_{nn} \end{bmatrix}$$

In which, the element of principal diagonal Eii is self-evaluation score and the element of non-principal diagonal Eik (k≠i) is cross-evaluation score. Column i of E is the evaluation score by other DMUs on DMUi; the higher these scores are, the better the DMUi is. Row i of E (except for diagonal elements) is the evaluation score of DMUi on other DMUs; the lower these scores are, the more advantageous it is to the DMUi. Some literature uses DEA as the ranking tool for multi-attribute decisions and uses the average value of Column i of E:

$$e = \frac{1}{n}\sum_{k=1}^{n} E_{ki}$$

as an index for evaluating the quality of DMUi. The index ei can be regarded as the general evaluation of DMUi by other DMUs; the bigger it is, the better the DMUi is. Similarly, we can also use the average value of the elements of non-principal diagonal in Column i of E:

$$e_i' = \frac{1}{n-1}\sum_{k \neq l} E_{ki}$$

as an index for quality evaluation; the smaller it is, the better the DMUi is.

MATLAB programming for the DEA coordination Level evaluation model: To calculate the relative efficiency score of a DMUj and evaluate its (weak) efficiency, one linear programming is required; and to calculate the relative efficiency scores of all DMUj, n linear programming is required, with a vast amount of calculation. There are many different types of DEA software applications in the market which can be basically divided into two types: professional software, such as DEA Solver pro, DEAP, Efficiency Measurement System (EMS) and DEA excel solver which return the result with the input of DMU data selection model and the normal type, such as Matlab, Lingo, Lindo etc. (Han and Song, 2011) This study uses the mathematical software MATLAB to write the relevant programming code which is capable of convenient and rapid DEA coordination level evaluation analysis. The powerful matrix operation function and sufficient linear programming solution of MATLAB enable us to write convenient DEA programs. The standard form of MATLAB linear programming is a minimization problem:

$$\begin{cases} \min f^{*}{}_{w} \\ \text{s.t.}\, A^{*}w \le b, Aeq{*}w = beq, LB \le w \le UB \end{cases} \quad (5)$$

In which, w is a variable, f the coefficient vector of target function, A the coefficient matrix for the inequality constraint, Aeq the coefficient matrix for the equation constraint, LB and UB the lower and upper limit of the variable w.

The MATLAB statement for solving linear programming (5) is w = LINPROG(f, A, b, Aeq, beq, LB, UB). For solving the maximization problem maxf*w, we only have to transform it into the minimization problem min(-f)*w.

This study uses the model 4 based MATLAB programming to measure the coordination degree between the public service facility and the intake population in indemnificatory community.

EMPIRICAL ANALYSIS

Data collection and processing: Based on the indicators for the coordination degree evaluation between the public service facility and the intake population in indemnificatory community, this study uses data from Shanghai Statistical Yearbook, Shanghai Baoshan District Statistical Yearbook and Questionnaire for an Indemnificatory Community in Baoshan District, Shanghai from 2006 to 2010.

Status Coordination degree (μ1) of the public service facility with the intake population: Using the public service facility sub-system as input and the indicators of the intake population sub-system as output, entering the data into the MATLAB program of the DEA coordination degree evaluation model, we get the following evaluation matrix:

$$E = \begin{bmatrix} 0.8741 & 0.5418 & 1.0000 & 1.0000 & 0.7358 & 0.5468 & 0.6494 & 0.7337 & 0.7396 & 0.7325 \\ 0.7231 & 0.5952 & 0.9602 & 1.0000 & 0.8714 & 0.7543 & 0.8774 & 0.9691 & 0.9835 & 1.0000 \\ 0.6058 & 0.4698 & 1.0000 & 0.9010 & 0.6859 & 0.5048 & 0.6409 & 0.7337 & 0.7396 & 0.7325 \\ 0.1138 & 0.2251 & 0.4407 & 1.0000 & 0.6613 & 0.5000 & 0.4849 & 0.5036 & 0.4959 & 0.4742 \\ 0.3751 & 0.4817 & 0.6546 & 0.9771 & 1.0000 & 0.9798 & 0.9723 & 0.9619 & 0.9588 & 0.9515 \\ 0.0820 & 0.2106 & 0.4161 & 0.7813 & 0.8299 & 1.0000 & 0.7996 & 0.7391 & 0.7218 & 0.7076 \\ 0.1477 & 0.3884 & 0.4522 & 0.7783 & 0.9112 & 0.9961 & 1.0000 & 0.9844 & 0.9891 & 0.9971 \\ 0.3104 & 0.3400 & 0.6694 & 0.9918 & 0.9236 & 0.9963 & 0.9884 & 1.0000 & 0.9997 & 0.9977 \\ 0.2513 & 0.3030 & 0.6115 & 0.9200 & 0.8483 & 0.6734 & 0.8550 & 0.9748 & 1.0000 & 0.9950 \\ 0.0687 & 0.1845 & 0.3965 & 0.6153 & 0.7002 & 0.6399 & 0.8366 & 0.9526 & 0.9695 & 1.0000 \end{bmatrix}$$

In which, the diagonal elements are self-evaluation scores: $E_{11} = 1.0000$, $E_{22} = 1.0000$, $E_{33} = 0.7094$, $E_{44} = 0.5964$, $E_{55} = 0.7607$, $E_{66} = 1.0000$, $E_{77} = 0.8358$, $E_{88} = 0.8046$, $E_{99} = 0.8171$, $E_{1010} = 0.8545$.

The average cross-evaluation scores calculated by the programming for each year are: $e_1 = 0.7347$, $e_2 = 0.9317$, $e_3 = 0.5233$, $e_4 = 0.4135$, $e_5 = 0.5549$, $e_6 = 0.6886$, $e_7 = 0.6565$, $e_8 = 0.6177$, $e_9 = 0.6198$, $e_{10} = 0.6339$ which is the status coordination degree μ_2 of the intake population growth in each year with the public service facility system, as shown in Table 1 and 2.

Coordination degree (μ0) of coordinated development degree between the public service facility and the intake population: Based on formulas:

Table 1: Indicators of the public service facility sub-system in an indemnificatory community 2006-2010

Year	Configuration rate of high-level public service facility	Total construction area of the public service facility (m^2)	Satisfaction level of the public service facility structure
2006.6	0.0383	113303	0.5436
2006.12	0.0424	126688	0.5589
2007.6	0.0484	137552	0.5866
2007.12	0.0344	150421	0.6297
2008.6	0.0445	169051	0.6137
2008.12	0.0454	177195	0.6198
2009.6	0.0619	184516	0.6211
2009.12	0.0699	185276	0.6263
2010.6	0.0729	186847	0.6242
2010.12	0.0767	186847	0.6268

Table 2: Indicators of the population intake sub-system in an indemnificatory community 2006-2009

Year	Population occupancy rate (%)	Population density (persons km^{-2})	Aged population burden coefficient (%)
2006.6	3.60	698	6.80
2006.12	9.93	1928	4.70
2007.6	11.80	5969	9.55
2007.12	19.66	7243	9.41
2008.6	24.20	8033	8.05
2008.12	26.60	9802	6.21
2009.6	29.30	10686	8.21
2009.12	30.27	11154	9.63
2010.6	30.83	11361	9.89
2010.12	31.80	11718	9.95

Table 3: DEA coordination degree evaluation result

No.	DMU	μ_1	μ_2
1	2006.6	0.3552	0.7347
2	2006.12	0.3740	0.9317
3	2007.6	0.6601	0.5233
4	2007.12	0.8965	0.4135
5	2008.6	0.8170	0.5549
6	2008.12	0.7591	0.6886
7	2009.6	0.8105	0.6565
8	2009.12	0.8553	0.6177
9	2010.6	0.8598	0.6198
10	2010.12	0.8588	0.6339

$$\theta_0 = \frac{\min(\theta_1, \theta_2)}{\max(\theta_1, \theta_2)}$$

i.e., that is:

$$\mu_0 = \frac{\min(\mu_1, \mu_2)}{\max(\mu_1, \mu_2)}$$

we get the coordination degree μ_0 of coordinated development degree between the public service facility and the intake population in each year, as shown in Table 3.

The DEA coordination degree evaluation result of Table 3 suggests that the coordination degree changes over time between the public service facility and the intake population system in the community which will be discussed by dividing into several types:

The public service facility configuration in community has limited influence on the intake population: The evaluation result μ_1 suggests all relative efficiency below 1 throughout the years. From June 2006 to June 2007, the community was at a preliminary stage of construction, with incomplete configuration of public service facility which had little attraction to the intake population. Since December 2007, the public service facility has been increasing to adapt to the needs of population increase. This is mainly because the government has increased its investment in the public service facility and promoted the configuration of public service facility.

The intake population growth in community has relatively weak support effect on the public service facility: The evaluation result μ_2 suggests all relative efficiency below 1 throughout the years. Especially the low population occupancy rate from June 2007 to June 2008 could not effectively support the development of the public service facility. Since December 2008, the intake population has had a stable, supportive effect on the public service facility, but with limited effectiveness.

The overall coordination degree between the public service facility and the intake population varies drastically: The evaluation result μ_0 suggests drastic changes in the overall coordination degree between the public service facility and the intake population. According to the rating of the coordination degree μ_0, in June 2006, December 2006 and December 2007, the public service facility and the intake population were under critical coordinated development ($0.4<\mu_0<0.6$); in December 2008 and June 2009, the public service facility and the intake population were under coordinated development ($0.8<\mu_0<1.0$); in other years, they were under normal coordinated development ($0.6<\mu_0<0.8$). Therefore, the coordination degree between the public service facility and the intake population still has great room for improvement which can be made by making improvement based on an analysis of the configuration problems of the public service facility and the intake population in the sequence, the scale and the structure, so as to realize the coordinated configuration of the two and bring their coordination degree to a new level.

According to the coordination degree evaluation result and the empirical investigation data, the incoordination between the public service facility configuration and the intake population in indemnificatory community mainly lies in the following aspects:

Sequence configuration does not meet the needs: In terms of the sequence configuration, the fundamental public service facility for which residents have a strong demand, such as medical care, large supermarkets, convenience stores, postal office and banks, does not suffice. The status quo of the population age structure of the community and a trend forecast suggests that by December 2010, the aged population burden coefficient was 9.95%. There is a trend of accelerated growth of the aged population, but the corresponding service facility for the aged population lags behind, unable to meet the needs under the drastic growth of the aged population.

Scale configuration is inappropriate: In terms of the scale configuration, the cultural, sports and community service facility in the community do not meet Shanghai 06 standards. Yet in terms of the sub-item configuration area, there are an insufficient number of senior middle schools, a superfluous number of elementary schools, an excessive number of small restaurants and stores, scarcely any convenience stores or large supermarkets and no facility for aged population. The incomplete configuration network cannot meet different levels of needs of the residents.

Structure configuration is unreasonable: In terms of the structure configuration, the public service facility is of monotonous type and even lacking. Currently, the multimedia room, library, dancing room and information center are basically idle, business facilities have a high vacancy rate and transfer rate and the primary schools are not put into full use, while the senior citizen activity center and fitness square, for which the residents have a strong demand, are badly lagging behind and deficient.

CONCLUSION

The coordination degree model calculation analysis show DEA cross evaluation model has an excellent compatibility and more accuracy when it is used in the coordination degree evaluation between the public service facility and the intake population system in indemnificatory community. It excludes the subjective evaluation, reduces the subjectivity of project evaluation. Coordination degree evaluation result can be conducive to the mastering of coordinated development degree between public service facility and intake population in indemnificatory community and provides scientific basis for the public service facilities' reasonable configuration decision in the sequence, the sale and the structure, thereby helping to realize the coordinated development between the public service facility and the intake population, improving resource utilization rate and ensuring the indemnificatory effects.

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