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AN ONLINE REVIEWS INFORMATION FUSION METHOD AND ITS APPLICATION TO PUBLIC PROPERTY SERVICE QUALITY EVALUATION

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Abstract. With the rapid development of computer networking technology, people pay more and more attention to the role of online reviews in management decision making. The existing methods of online reviews fusion are limited to rational decision-making behavior, which does not accord with the characteristics of evaluators' behavior characteristics in the real environment. In order to solve the online reviews fusion problem based on bounded rational behavior which is closer to the reality of property service quality evaluation, the multi-index and multi-scale (MIMS) method is extended into the generalized form, the online reviews are quantified by using the adverb structure scaling method, and an online reviews fusion method based on the improved TODIM (an acronym in Portuguese of interactive and multi-criteria decision making) model is proposed. The feasibility and effectiveness of the proposed method are verified by an example analysis of property service quality evaluation. The research results are as follows: the adverb structure scaling method is suitable for a large number of online reviews processing, the proposed method improves the efficiency of online reviews information fusion, and it is feasible and effective to evaluate property service quality based on the bounded rationality of evaluator's behavior.

Keywords: generalized MIMS method, adverb structure scaling method, improved TODIM method, online reviews information fusion, public property service quality evaluation.

Introduction

Property management in the modern sense originated in Britain in the 1860s. Chicago Building Managers Organization (CBMO) was established in 1908, marking the birth of the world's first professional property management industry organization. In the 1930s, some property management research institutions in the United States studied the quantity, quality and management mode of housing, and advocated to solve the problem of insufficient quantity and low quality of housing by government intervention. In the 1980s, the research content of property management focused on how to improve the quality and comfort of housing, reduce government intervention, and expand the role of property management. Since the 1990s, some scholars frequently use the concept of property service, which integrating people, society and environment with the goal of improving the quality of people's production and life, property value and sustainable development. Subsequently, property service quality is becoming one of the core problems of property service theory.

In the early 1980s, property management was introduced into mainland China from Hong Kong. In 2003, the Chinese government promulgated "The Property Management Regulation", which established the basic system of property management in China. Since 2008, the operating cost of property service enterprises has risen rapidly, the profit space has been severely compressed, and the industry with low profit is facing unprecedented survival pressure. The traditional development mode is unsustainable, and it is urgent to accelerate the transformation and upgrading of the property service industry to the modern property service industry. The Chinese government put forward the concept of "high-quality development" in 2017, and promulgated National Standards for Basic Public Services in 2021. These internal and external factors put forward higher requirements for property service quality management. Improving property service quality is an important means to solve the dilemma faced by the property service industry. Therefore, the research of property service quality evaluation method is of great practical

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significance to the development of modern property service industry.

By the end of 2020, the number of Internet users in China has reached 989 million, accounting for 70.6% of the national population. More than 50% of Internet users are under the age of 40, and 21% of Internet users are students (China Internet Network Information Center, 2021). The online platforms provided by Internet companies such as Alibaba, Tencent and Baidu have become indispensable tools for most Chinese netizens in their work and life. With the popularity of Internet applications, online reviews have come into being. Online reviews refer to peer-generated product evaluations posted on company or third party websites (Mudambi & Schuff, 2010). Online reviews usually have no fixed format and are posted on online platforms related to the consumption of products or services (Robson et al., 2013). In the existing online reviews research results, the research on product trade is more than that on service trade, and there is no research specifically on property service quality evaluation. Furthermore, the existing information fusion methods cannot effectively solve the problem of property service quality evaluation under realistic conditions. This paper focuses on the innovation of online reviews information fusion method and its application to property perceived service quality evaluation.

1. Literature review

The service quality evaluation methods successively used in academia include SERVQUAL model (Parasuraman et al., 1985; Basfirinci & Mitra, 2015), BP neural network (Islam et al., 2016) and IVWMM (Liu & Zuo, 2019), etc. There are also reports on the application of quality function deployment (Chen & Chou, 2011), analytic hierarchy process (Li et al., 2017; Agrawal et al., 2020), entropy method (Atalay et al., 2019), structural equation model (Tiglao et al., 2020) and technique for order preference by similarity to an ideal solution (TOPSIS) (Yucesan & Gul, 2020). The application of service quality evaluation covers library service (Chen & Chou, 2011), medical treatment (Alimohammadzadeh et al., 2016), public transport service (Wang et al., 2021), and so on. As for property service evaluation method, Chiang and Perng (2018) proposed a refined KANO model based on SERVQUAL model. Huang and Lee (2020) comprehensively analyzed the role of property management in the service demand of elderly residents by factor analysis, cluster analysis and Chi-square test. Shen et al. (2021) used the fuzzy Delphi method and analytic hierarchy process to construct the quality evaluation scale and established the strategic framework of property customer service. For the perceived service quality evaluation of public building property, the large group decision making method (Zuo et al., 2019) and the linear programming technique for multidimensional analysis of preference (LINMAP) method (Zuo et al., 2020, 2021) were proposed successively. Although the existing research results of service quality evaluation methods are abundant, the property service quality evaluation methods based on a large amount of information are not enough.

As for the information fusion method of online reviews, Mi et al. (2014) proposed online reviews method for tour based on grey binary group language. Chen et al. (2015) used TOPSIS method to rank products based on product review information mining. Xi and Fan (2016) took the online reviews of Autohome Inc. as an example, processed the online reviews by using the cumulative distribution function decision matrix, determined the attribute weight by constructing the index weight optimization model, and realized the ranking order of all alternatives. Liang et al. (2017) used PROMETHEE method to rank products based on the combined analysis of consumer reviews' emotional information. Wang et al. (2018a) proposed a ranking order method based on time-aware review consistency. Bazeer Ahamed and Murugan (2020) proposed an online reviews system based on emotion scoring method. Zhang et al. (2020) proposed a novel heuristic method for finding an informative subset from online reviews. There are many methods of online evaluation information, but these methods are not suitable for scaling processing of basic evaluation information. The empirical analysis (Garoupa et al., 2012; Beim et al., 2016) is the most commonly used method in the existing research on online reviews. Although there are many research results of online reviews information fusion methods, the existing methods are based on the rational behavior which is far from the real human behavior. Modern management theory believes that the evaluator's behavior in the real evaluation environment is closer to bounded rationality, which is the logical starting point of this study. In a word, the existing information processing methods of online reviews cannot solve the problem of information fusion based on users' bounded rational behavior in the realistic evaluation environment.

TODIM (an acronym in Portuguese of interactive and multi-criteria decision making) was first proposed by Gomes and Lima (1991). The method processes the dominance degree of each alternative over other alternatives by constructing a value function, so as to realize the final ranking order of all alternatives. TODIM is a multi-attribute decision making method based on prospect theory, which can better process the behavior information of decision makers based on bounded rationality (Kahneman & Tversky, 1979). In recent years, scholars have successively applied TODIM method to process intuitionistic fuzzy number (Lourenzutti & Krohling, 2013), interval grey number (Wang & Dang, 2016), neutrosophic multiplicative set (Kseolu et al., 2020) and hybrid data (Fan et al., 2013). Lee and Shih (2016) proposed a generalized TODIM method to eliminate two types of scaling effects by incremental analysis. Qin et al. (2017) proposed an improved TODIM method based on triangular fuzzy numbers. Llamazares (2018) proposed a generalized version of the simplified TODIM method to overcome the inconsistencies between

the two paradoxes affecting model weights. Biswas and Sarkar (2018) proposed a TODIM method based on the interval Pythagorean fuzzy information. Xie et al. (2019) proposed an improved TODIM method based on 2-tuple linguistic information processing for the characteristics of multi-attribute group decision making problem. Leoneti and Gomes (2021) proposed the ExpTODIM method based on the exponential model of prospect theory, and compared and analyzed the above several TODIM methods by using several evaluation indexs. However, the existing group decision making methods are usually suitable for no more than a few dozen decision makers (Xu et al., 2017; Gou et al., 2018; Wang et al., 2018b), and there is no relevant research on TODIM method based on a lot of evaluation information and its application to online reviews fusion. The classical TODIM method can solve the evaluation problem based on the bounded rationality of evaluators, but it cannot meet the needs of a large number of online reviews information fusion.

The multi-index and multi-scale (MIMS) method is also called multi-attribute and multi- scale method. Zhang and Fan (2010) first proposed the large group decision making method based on stochastic dominance criteria by using the MIMS method. Subsequently, the LINMAP model based on the MIMS method can process large scale evaluation information (Zuo et al., 2019) and dynamic evaluation information (Zuo et al., 2020) respectively. These studies have effectively improved the efficiency of traditional decision making methods in processing basic data. However, existing MIMS methods require different evaluation indexes to use the same evaluation scale set, which limits the continuous improvement of the ability to process basic data and cannot meet the needs of evaluation practice (Zuo et al., 2020). However, the development and application of traditional MIMS methods is not enough, and there are not the combination method of MAMS and TODIM.

To sum up, the existing information processing methods of online reviews cannot solve the problem of information fusion based on users' bounded rational behavior in the realistic evaluation environment, and the classical TODIM method cannot meet the needs of a large number of online reviews information fusion. To solve the above problems, this paper introduces the classical MAMS method and extends into the generalized form. Based on the generalized MIMS method, the classic TODIM method is improved and used in public property quality evaluation based on online reviews.

2. Preprocessing of online reviews

2.1. MIMS method and its extension

In order to improve the processing ability of basic information by using MIMS method, this paper extends the MIMS method by the idea of existing study (Zuo et al., 2020). When different evaluation scale sets are allowed to evaluate different indexes in the classical MIMS method, which is called the generalized MIMS method. The decision information expressed by MIMS method is called MIMS information, the decision information expressed by generalized MIMS method is called generalized MIMS information. Obviously, the MIMS method is a special form of the generalized MIMS method. For the sake of description, the mathematical notation that will be used in this paper is described below.

Let $A=\{A_1,A_2,\ldots,A_m\}$ be the set with m evaluation objects $A_i \in A\ (i=1,2,\ldots,m)$, $I=\{I_1,I_2,\ldots,I_n\}$ be the set with n evaluation indexes $I_j \in I\ (j=1,2,\ldots,n)$, $\omega=\{\omega_1,\omega_2,\ldots,\omega_n\}$ be the weight set corresponding to the evaluation index set I, and ω_j be the weight of the evaluation index I_j, where $\sum_{j=1}^{n}\omega_j=1$ and $\omega_j \geq 0$. Let $S=\{s_1,s_2,\ldots,s_{n_j^l}\}$ be the set with l evaluation scales $s_k \in S\ (k=1,2,\ldots,n_j^l)$. The evaluation value u_{ijk} is the number who use the scale s_k evaluate the index A_j of the evaluation object F_i. Let e_{ijk} be the standardized value of u_{ijk} in MIMS information structure, and u_{ij} be the times by using the evaluation scale $s_{n_j^k}\ (k=1,2,\ldots,l)$ in the object A_i and the index I_j. Let E = (e_{ij}) be the multi-attribute decision evaluation matrix, where $e_{ij}=(u_{ij1},u_{ij2},\ldots,u_{ijn_j^l})$. Based on the above mathematical notations, the generalized MIMS information can be shown as Table 1.

The evaluation value based on online reviews by MIMS method is the basis of the standardization of basic evaluation data. Since online reviews are collected according to different evaluation objects and evaluation indexes, that is, the evaluation times of each evaluation object may be different under different evaluation indexes. Therefore,

Table 1. The generalized MIMS information

I	I_1				I_2				…	I_n			
s	s_1	s_2	…	$s_{n_1^l}$	s_1	s_2	…	$s_{n_2^l}$	…	s_1	s_2	…	$s_{n_n^l}$
A_1	u_{111}	u_{112}	…	$u_{11n_1^l}$	u_{121}	u_{122}	…	$u_{12n_2^l}$	…	u_{1n1}	u_{1n2}	…	$u_{1nn_n^l}$
A_2	u_{211}	u_{212}	…	$u_{21n_1^l}$	u_{221}	u_{222}	…	$u_{22n_2^l}$	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…
A_m	u_{m11}	u_{m12}	…	$u_{m1n_1^l}$	u_{m21}	u_{m22}	…	$u_{m2n_2^l}$	…	u_{mn1}	u_{mn2}	…	$u_{mnn_n^l}$

according to the requirement of comparability in data standardization, the evaluation value standardization is based on the sum of evaluation times of different evaluation indexes of each evaluation object. The standardized formulas are respectively expressed as follows:

$$u_{ij} = \sum_{k=1}^{n_j^l} u_{ijk}\ , \tag{1}$$

$$e_{ijk} = \frac{u_{ijk}}{u_{ij}}\ . \tag{2}$$

2.2. Adverb structure scaling method for online reviews

In order to standardize online reviews based on natural language, this paper proposes the adverb structure scaling method. The adverb structure scaling method refers to the method of converting the evaluation information expressed in the form of natural language, pictures, animations and sounds into scale values according to certain rules. The evaluation index, semantic information base, adverb structure and scale value should be determined successively in the adverb structure scaling method.

(1) Determine the evaluation indexes. The standardization of online reviews refers to the standardization of online reviews collected according to each evaluation index of the evaluation object. Therefore, evaluation index selection is the basis of online reviews collection. Because different products and services have greatly differences, it is necessary to select appropriate evaluation indexes according to the characteristics of the evaluation objects. The evaluation indexes selection is explained in detail in the following example analysis.

(2) Determine the semantic information base. The difficulty of evaluation information scaling is to construct semantic information base based on sentiment analysis. Online reviews are mainly natural language, and the semantic information base may be different in different evaluation environments. Therefore, it is necessary to build semantic information base according to specific evaluation information. A number of samples are randomly selected from the online reviews of evaluation objects, and the degree adverbs and emotion adverbs are extracted from the above samples by man-machine mix method. After consulting experts, the final semantic information base is determined. In order to improve the efficiency and quality of online reviews processing, some adverbs of the existing semantic information base can be appropriately added and deleted according to the characteristics of the evaluation environment. At the same time, complex statements and emotional information should be processed manually. After the semantic information base is determined, the man-machine mix method can be used to analyze the online reviews, and the number of repeated occurrence of all evaluation indexes of each object can be counted according to the preset scale value. When all online reviews are processed, the MIMS information is obtained.

(3) Determine the adverb structure and scale value. The adverb structure scaling method adopts individual adverbs and structural adverbs, where structural adverbs are determined by the structure of "degree adverb + emotion adverb". Refer to existing research results (Wang et al., 2018b; Bazeer Ahamed & Murugan, 2020), degree adverbs are divided into two levels: I and II, and emotion adverbs are divided into three categories: A, B and C according to emotional types. After structuring all adverbs, all adverb combinations are divided into several grades according to emotional characteristics, and different scale values are assigned to these adverb combinations of different grades.

Due to the differences in the research object and environment, each of the above steps may gain different results. The example analysis results of property service quality evaluation using the scale structuring method are shown in Section 4.1.

3. Basic principles of information fusion method

3.1. Determination of evaluation index weight based on LINMAP method

In the classical TODIM method, the index weight is usually preset value. The methods to determine the index weight can be divided into subjective weighting method and objective weighting method. In order to maximize the strengths and avoid the weaknesses of the two methods, this paper uses a combination weight method based on LINMAP model, which is used to solve the index weight based on subitem evaluation information and overall evaluation information. Since the LINMAP model is the key of the combination weight method, its basic principle is briefly introduced below.

The LINMAP method constructs consistency and inconsistency based on the distance between evaluation information of each object and its positive ideal point, and uses linear programming model to solve the weight of unknown evaluation indexes (Srinivasan & Shocker, 1973). Refer to the existing research methods (Li, 2008; Zuo et al., 2020, 2021), the LINMAP model based on the generalized MIMS information can be expressed as follows:

$$\min\left\{\sum_{(p,q)\in\Omega}\lambda_{pq}\right\}$$
$$\begin{cases}\sum\limits_{(p,q)\in\Omega}\sum\limits_{j=1}^{n}\sum\limits_{k=1}^{l}\omega_j[s_k{}^2(e_{pjk}{}^2-e_{qjk}{}^2)+2e_{jk}^{*}b_k{}^2(e_{qjk}-e_{pjk})]\geq h\\ \sum\limits_{j=1}^{n}\sum\limits_{k=1}^{l}\omega_j[s_k{}^2(e_{pjk}{}^2-e_{qjk}{}^2)+2e_{jk}^{*}s_k{}^2(e_{qjk}-e_{pjk})]+\lambda_{pq}\geq 0\ ((p,q)\in\Omega)\\ \sum\limits_{j=1}^{n}\omega_j=1,\omega_j>\varepsilon\ (j=1,2,\ldots,n)\\ \lambda_{pq}>0\ ((p,q)\in\Omega)\end{cases}, \tag{3}$$

where: λ_{pq} denotes the inconsistency of the evaluation object A_p and A_q; e_{jk}^{*} denotes the ideal point, $h > 0$ and $\varepsilon > 0$ be the threshold value in advance; h ensures that the

overall consistency of all evaluation objects is greater than their overall inconsistency; ε ensures that the weight of all evaluation indexes are greater than zero.

3.2. The improved TODIM model based on generalized MIMS information

Based on the requirement of online reviews information fusion, the generalized MIMS method is used to improve the TODIM model. Using the mathematical notation in Section 2.1, the basic steps to improve the TODIM method is as follows.

Step 1: Calculate the relative weight of each evaluation index. Based on the weight ω_j of any evaluation index and the weight ω_r of the reference evaluation index, the relative weight ω_{jr} of evaluation indexes is calculated as follows:

$$\omega_{jr} = \frac{\omega_j}{\omega_r}, \tag{4}$$

where the reference evaluation index is determined by the formula $\omega_r = \max_{1\le j\le n}\{\omega_j\}$.

The relative weight ω_{jr} of evaluation indexes reflects the interaction of TODIM method by comparing the weights of evaluation indexes.

Step 2: Calculate the dominance degree of each evaluation object. For any evaluation index I_j and evaluation scale s_k, the dominance degree $\Phi_j(A_p, A_q)$ of the evaluation object $A_p \in A$ $(p = 1,2,\ldots,m)$ over the evaluation object $A_q \in A$ $(q = 1,2,\ldots,m)$ is calculated as follows:

$$\Phi_{jk}(A_p, A_q) = \begin{cases} \sqrt{\omega_{jr}\left(s_{n_j^k} e_{pjk} - s_{n_j^k} e_{qjk}\right)} & (e_{pjk} \ge e_{qjk}) \\ -\frac{1}{\theta}\sqrt{\frac{\left(\sum_{j=1}^{n}\omega_{jr}\right)\left(s_{n_j^k} e_{qjk} - s_{n_j^k} e_{pjk}\right)}{\omega_{jr}}} & (e_{pjk} < e_{qjk}) \end{cases}, \tag{5}$$

where: $\theta > 0$ denotes the loss effect; $e_{pjk} \ge e_{qjk}$ denotes that the dominance degree is positive; $e_{pjk} < e_{qjk}$ denotes that the dominance degree is negative.

Calculating the dominance degree is the key step of the TODIM method. In order to improve the performance of the classical TODIM method, the influence of different evaluation scales in the generalized MIMS method is also introduced here. Therefore, the calculation results of Eq. (5) constitute four-dimensional data structure.

Step 3: Calculate the overall dominance degree of each evaluation object. For each evaluation index, the overall dominance degree $\Phi(A_p, A_q)$ of the evaluation object A_p over the evaluation object A_q can be expressed as follows:

$$\Phi(A_p, A_q) = \sum_{j=1}^{n}\sum_{k=1}^{l}\Phi_{jk}(A_p, A_q). \tag{6}$$

Based on the dominance degree of each evaluation object, the overall dominance degree can be calculated. Using the calculation results of Eq. (6), the overall dominance degree of different evaluation objects constitutes a decision matrix.

Step 4: Calculate the comprehensive value of each evaluation object. The comprehensive value of the evaluation object A_p can be expressed as follows:

$$\Phi(A_p) = \sum_{q=1}^{m}\Phi(A_p, A_q). \tag{7}$$

Step 5: Standardize the comprehensive value of each evaluation object. The standardized formula of the comprehensive value of each evaluation object A_p can be expressed as follows:

$$\xi(A_p) = \frac{\sum_{q=1}^{m}\Phi(A_p, A_q) - \min_{1\le p\le m}\left\{\sum_{q=1}^{m}\Phi(A_p, A_q)\right\}}{\max_{1\le p\le m}\left\{\sum_{q=1}^{m}\Phi(A_p, A_q)\right\} - \min_{1\le p\le m}\left\{\sum_{q=1}^{m}\Phi(A_p, A_q)\right\}}. \tag{8}$$

Step 6: Determine the final ranking order. According to the descending order of the comprehensive value of each evaluation object $\xi(A_p)$, the ranking order of the evaluation object A_p can be determined.

If the evaluation results are limited to ranking order, step 5 can be omitted. The function of Eq. (8) is to standardize the comprehensive evaluation value of each evaluation object. The evaluation results can be used for comprehensive ranking order, but also further used for numerical analysis.

4. Public property service quality evaluation based on online reviews

This paper uses the proposed method to evaluate property service quality of four adjacent public property service projects in Wenzhou. There are 1578 online reviews which mainly come from portal websites, WeChat, APP, QQ and other network platforms and related columns. These online reviews came from users' reviews of each property service project. The online reviews were collected by each evaluation object in 2020.

4.1. Identification of basic evaluation elements

The four public property services projects to be evaluated are museum (A_1), library (A_2), science & technology museum (A_3) and grand theater (A_4). Since the determination of evaluation indexes is an important and complex issue which is not the focus of this study, this paper does not conduct special research. By referring to the existing theoretical researches (Zuo et al., 2019, 2021) and the expert opinions of property management, five evaluation indexes including customer service (I_1), order (I_2), cleaning (I_3), equipment (I_4) and others (I_5) are selected. The weights of the corresponding five evaluation indexes are recorded as ω_1, ω_2, ω_3, ω_4 and ω_5 in turn.

Since online reviews usually do not directly state the evaluation indexes, this paper selects 50 online reviews as samples, which should be classified according to the property service personnel, specific functions and service process involved in the evaluation indexes. The first four evaluation indexes correspond to the four functional departments set up in most property service enterprises at present, and the fifth evaluation index corresponds to online reviews that cannot be grouped into the first four functional departments. According to the experience of evaluators and the advice of property service experts, the corresponding relationship between five evaluation indexes and online reviews is determined. To sum up, the evaluation indexes of online reviews on public property service quality in this example are classified as shown in Table 2.

Combined with the characteristics of online reviews of public property service quality in the example analysis, the semantic information base of online reviews is based on 50 online reviews. By using the adverb structure scaling method, the semantic information base of online reviews of public property service quality is obtained as summarized in Table 3.

This paper adopts the five-level scaling method commonly used in the theory and practice of property service quality evaluation. According to the above adverb structure scaling method and the semantic information base in Table 3, the scale structure and its assignment value are summarized in Table 4.

4.2. Processing of basic evaluation data

Based on the above analysis results from Table 3 and 4, the method combined web crawler with manual processing is used to preprocess online reviews information. Corresponding to the content in Table 1, Table 5 shows the total number of repeated online reviews on evaluation indexes and scales of each public property service project in 2020. For example, the last number 14 in the second column of Table 5 indicates that the number of online reviews for the customer service of the grand theater project using the scale value 1 is 14. Similarly, all the numbers in Table 5

Table 2. Evaluation index classification of online reviews of public property service quality

Evaluation indexes	Keywords of online reviews
Customer service	customer service, front desk, toll collector, dispute, complaint, property service center, gate post
Order	security guard, security officer, vehicle parking, entrance and exit management, order maintenance
Cleaning	cleaners (aunt), floor, wall, toilet (toilet), smell, ventilation, disinfection, sterilization
Equipment	maintenance, engineers, workers, elevators, air conditioning, entry and exit, lights, sound equipment, monitoring

Notes: The above lexicon is from the samples by Chinese. The contents of lexicon can be appropriately added, modified and deleted based on different research situations.

Table 3. Semantic information base of online reviews on public property service quality

Degree level	Semantic information base	Emotional categories	Semantic information base
I	absolutely, altogether, completely, entirely, extremely, fully, perfectly, quite, thoroughly, totally, utterly, wholly, badly, bitterly, deeply, enormously, far, greatly, heartily, highly, how, immensely, intensely, largely, particularly, profoundly, severely, so, strongly, terribly, tremendously, vastly, violently, well	A	good, like, give force, comfortable, gratified, neat, strong, friendly, ok, convenient, praise, clean
II	but, just, merely, mildly, moderately, only, partially, partly, quite, rather, simply, somewhat, slightly, a little, little, a bit, barely, hardly, scarcely, at all, in the least, in the slightest, almost, nearly, practically, virtually	B	poor, almost, average, ordinary, about, right, tolerable
		C	bad, slow, bad, waste, depressed, annoying, garbage, bad reviews

Notes: The above semantic information base is from the samples expressed by Chinese. The contents of semantic information base can be appropriately added, modified and deleted based on different research situations.

Table 4. Summary table of adverb structure and its assignment value

Scale value	1	2	3	4	5
Adverb structure	class C level I + class C	level I + class B level II + class C	class B level II + class B	class A level II + class A	level I + class A

Table 5. MIMS information for online reviews of public property service quality

	I_1					I_2					I_3					I_4					I_5				
S	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	1	2	3	4	5	1	2	3	4	5
A_1	6	76	98	24	4	15	105	135	54	3	15	99	126	66	6	21	114	138	36	3	6	93	174	33	6
A_2	12	51	32	7	2	8	75	57	12	5	11	74	57	14	2	15	72	54	14	2	6	72	65	14	0
A_3	60	120	111	18	3	23	75	47	11	2	8	19	21	4	1	7	25	18	3	1	6	23	17	6	1
A_4	14	50	118	24	2	3	19	20	10	1	11	29	84	30	3	9	42	69	33	3	14	33	74	29	8

can be interpreted in the same way. In addition, the connotations of all scale values are not literal. For example, the scale value 0 of the index I_1 has the same connotation as the scale value 1 of the index I_4.

For the generalized MIMS information, the existing method (Zuo et al., 2020) is used to standardize the scale values. The data in Table 5 are processed by using Eqs (1) and (2), the normalized evaluation information of online reviews is shown in Table 6.

According to the requirements of applying the LINMAP method, three property service experts are invited to evaluate comprehensive property service quality of four public property service projects. The evaluation information can be expressed as follows:

$$\Omega = \{(1,2),(2,3),(4,1),(4,3)\}, \tag{9}$$

where $(1,2)$ indicates that property service expert believed that the comprehensive property service quality of the project A_1 is generally better than that of the project A_2, and similar explanations can be made for other pairs.

Combined with the existing methods (Zuo et al., 2019, 2020) and property service expert opinions, the incomplete information for the indexes weight is determined as follows:

$$H = \{0.15 \le \omega_1 \le 0.45, 0.1 \le \omega_2 \le 0.2, 0.1 \le \omega_3 \le 0.25, \omega_4 \ge 0.12, \omega_5 \ge 0.15, \omega_1 \ge 1.3\omega_2, \omega_2 - \omega_3 \le 0.05, \omega_1 - \omega_2 \ge \omega_5 - \omega_4. \tag{10}$$

Table 6. Standardization of MIMS information for online reviews of public property service quality

	S	A_1	A_2	A_3	A_4
I_1	1	0.029	0.115	0.192	0.067
	2	0.365	0.490	0.385	0.240
	3	0.471	0.308	0.356	0.567
	4	0.115	0.067	0.058	0.115
	5	0.019	0.019	0.010	0.010
I_2	1	0.048	0.051	0.146	0.057
	2	0.337	0.478	0.475	0.358
	3	0.433	0.363	0.297	0.377
	4	0.173	0.076	0.070	0.189
	5	0.010	0.032	0.013	0.019
I_3	1	0.048	0.070	0.151	0.070
	2	0.317	0.468	0.358	0.185
	3	0.404	0.361	0.396	0.535
	4	0.212	0.089	0.075	0.191
	5	0.019	0.013	0.019	0.019
I_4	1	0.067	0.096	0.130	0.058
	2	0.365	0.459	0.463	0.269
	3	0.442	0.344	0.333	0.442
	4	0.115	0.089	0.056	0.212
	5	0.010	0.013	0.019	0.019
I_5	1	0.019	0.038	0.113	0.089
	2	0.298	0.459	0.434	0.209
	3	0.558	0.414	0.321	0.468
	4	0.106	0.089	0.113	0.184
	5	0.019	0.000	0.019	0.051

4.3. Calculation and analysis process

In this example, the LINMAP model is used to determine the index weight, and the specific analysis process is determined by referring to the existing methods (Li, 2008; Wan et al., 2020; Zuo et al., 2019, 2020). By substituting the data from Eqs (9), (10) and Table 5 into Eq. (3), the LINMAP model of four public projects based on online reviews is obtained as Eq. (11).

$$\begin{cases} \min\{\lambda_{12}+\lambda_{23}+\lambda_{41}+\lambda_{43}\} \\ 0.408\omega_1 + 0.391\omega_2 + 0.426\omega_3 + 0.519\omega_4 + 0.326\omega_5 \ge h \\ \lambda_{12} - 0.140\omega_1 - 0.041\omega_2 - 0.165\omega_3 - 0.118\omega_4 - 0.112\omega_5 \ge 0 \\ \lambda_{23} - 0.064\omega_1 - 0.155\omega_2 - 0.042\omega_3 - 0.089\omega_4 - 0.043\omega_5 \ge 0 \\ \lambda_{41} - 0.001\omega_1 - 0.000\omega_2 - 0.006\omega_3 - 0.053\omega_4 - 0.007\omega_5 \ge 0 \\ \lambda_{43} - 0.204\omega_1 - 0.196\omega_2 - 0.213\omega_3 - 0.260\omega_4 - 0.163\omega_5 \ge 0 \\ \lambda_{12} \ge 0, \lambda_{23} \ge 0, \lambda_{41} \ge 0, \lambda_{43} \ge 0 \\ \omega_1 \ge 0.15, \omega_2 \ge 0.1, \omega_3 \ge 0.1, \omega_4 \ge 0.12, \omega_5 \ge 0.15, \omega_1 \le 0.45, \omega_2 \le 0.2 \\ \omega_3 \le 0.25, \omega_1 \ge 1.3\omega_2, \omega_2 - \omega_3 \le 0.05, \omega_1 - \omega_2 \ge \omega_5 - \omega_4 \\ \omega_1+\omega_2+\omega_3+\omega_4+\omega_5=1 \end{cases} \tag{11}$$

Sensitivity analysis of Eq. (11) was performed according to different values of *h*. The analysis process based on different values of *h* is omitted here. The threshold value is determined by combining the existing research results (Li, 2008; Wan et al., 2020; Zuo et al., 2019, 2020) with the decision makers' experiences. Therefore, the indexes weights are $\omega_1 = 0.330$, $\omega_2 = 0.100$, $\omega_3 = 0.100$, $\omega_4 = 0.120$ and $\omega_5 = 0.350$ respectively.

Sensitivity analysis was performed considering the change of loss effect coefficient in Eq. (5). Refer to the

Table 7. Sensitivity analysis results by the improved TODIM method

θ	$\xi(A_1)$	$\xi(A_2)$	$\xi(A_3)$	$\xi(A_4)$	Ranking order
0.1	0.860	0.306	0.000	1.000	$A_4 \succ A_1 \succ A_2 \succ A_3$
1	0.832	0.288	0.000	1.000	$A_4 \succ A_1 \succ A_2 \succ A_3$
10	0.748	0.230	0.000	1.000	$A_4 \succ A_1 \succ A_2 \succ A_3$
100	0.706	0.201	0.000	1.000	$A_4 \succ A_1 \succ A_2 \succ A_3$

existing research results of TODIM method (Gomes & Lima, 1991; Lourenzutti & Krohling, 2013; Fan et al., 2013; Wang & Dang, 2016; Qin et al., 2017; Biswas & Sarkar, 2018; Xie et al., 2019; Kseolu et al., 2020), the loss effect coefficient is determined to be 0.1, 1, 10 and 100. According to the calculation process in Section 3.2, the above index weights and data in Table 5 are substituted into Eqs (4)～(8), and the comprehensive values are calculated and ranked order. The calculation results are summarized as shown in Table 7.

According to the above data analysis results and expert opinions, the loss effect coefficient is determined as $\theta = 1$. Then the comprehensive values of property service quality of the four public projects are as follows:

$$\xi(A_1) = 0.832; \tag{12}$$

$$\xi(A_2) = 0.288; \tag{13}$$

$$\xi(A_3) = 0.000; \tag{14}$$

$$\xi(A_4) = 1.000. \tag{15}$$

Therefore, the ranking order of property service quality of public projects based on online reviews is as follows:

$$A_4 \succ A_1 \succ A_2 \succ A_3 . \tag{16}$$

Although the amount of the basic data in the above example analysis is not large enough, the analysis results show that the proposed method in this paper is feasible and effective for a large number of online reviews. Compared with the existing research methods, the proposed method can better describe the behavior characteristics of evaluators in real environment, and can also be used to process a large number of online reviews.

Conclusions

To sum up, aiming at the problem that the existing online reviews information fusion methods cannot adapt to the behavioral characteristics of evaluators in the real environment, an information fusion method for a large number of online reviews based on TODIM model for generalized MIMS information is proposed, and the public property service quality evaluation based on bounded rational decision behavior of evaluators is taken as the real example analysis. The main contributions of this study are as follows:

(1) An adverb structure scaling method based on natural language for a lot of information processing is proposed. Quantitative analysis based on natural language evaluation information is a difficult and important problem. In this study, the method of collecting information by the scale values in econometric analysis is applied to quantitative processing of natural language. In order to process online reviews, this paper extends the MIMS method into the generalized form, innovates the quantitative method of natural language evaluation information, and proposes an adverb structure scaling method.

(2) An improved TODIM method based on generalized MIMS information for online reviews information fusion is proposed. The performance of existing TODIM methods is limited by both theory and practice, and there is a lack of research results on mass information processing. In this paper, the basic information is processed by the generalized MIMS method, which breaks through the dilemma of basic information processing and effectively improves the performance of TODIM method. With the increase in the amount of online reviews information, the superiority of the improved TODIM method will be further demonstrated.

(3) A property service quality evaluation method based on bounded rationality of the evaluator's behavior is proposed. The existing property service quality evaluation methods are based on the rational behavior, which does not accord with the behavior characteristics of evaluators in reality. TODIM method is a multi-attribute decision making method based on prospect theory, which is suitable for evaluating property service quality based on the behavior characteristics of evaluators in reality. Therefore, the example analysis shows a property service quality evaluation method which is based on the characteristics of bounded rational behavior.

The method proposed in this paper provides a new perspective for the innovation research of TODIM in theory, and helps to improve online information fusion and property service quality evaluation in application. However, the major limitation of this paper is that there is no special study of the index system, which is the basis of information collection and method innovation. In the follow-up research, it is necessary to study the universal index system based on online reviews and study targeted evaluation indexes according to the characteristics of different types of evaluation objects.

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Author contributions

LIN Shanshan was responsible for the method and the conclusion. ZUO Wenjin was the corresponding author and responsible for the research design and model development. LIN Hualin and HU Qiang developed the data analysis and the data collection.

Disclosure statement

Authors do not have any competing financial, professional, or personal interests from other parties.

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