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Fuzzy analysis of PZB service quality on optimization customer evaluations : An empirical study

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Abstract

This study used the five service quality dimensions under the PZB model, including 1. Tangibility, 2. Reliability, 3. responsiveness, 4. Assurance and 5. empathy, to develop a questionnaire and collect customer feedback from four different retail stores. The PZB framework, a well-established tool for assessing service quality, guided our survey design. Employing methods from fuzzy theory—specifically fuzzy numbers, membership functions, fuzzy weighting, and defuzzification—we quantified how consumers rated each retailer

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across these dimensions. Our analysis highlights both strengths and weaknesses in service delivery, provides insights that are of practical help in improving the quality of retail services. The results indicate that retailers A and B enjoy similarly high levels of customer satisfaction, placing them in a more favorable category. In contrast, retailers C and D fall into a lower satisfaction group, with customers rating their service quality noticeably lower. These differences are evident both in overall evaluations and when considering each individual dimension. Nonetheless, even the higher-rated retailers, A and B, have considerable room for improvement, suggesting positive prospects for future enhancements.

Subject Classification: *93E03, 93A14, 93C15.*

Keywords: *Retailing business, PZB model, Service quality, Fuzzy theory.*

1. Introduction

In today's customer-oriented market, service quality is a crucial factor. In addition, a review of the existing literature on the PZB model shows that the research can be divided into three categories:1. Model Validation and Adaptation: These studies either confirm the five dimensions as captured by the SERVQUAL scale or propose modifications to the original [1]. They assess the model's suitability in various service contexts, offer comprehensive reviews of SERVQUAL-related research, or compare the PZB model with alternative service quality models [2], [3], [4]. 2. Exploration of Causes and Effects: This line of research investigates the factors that influence PZB service quality and examines how these factors impact business outcomes—such as satisfaction, loyalty, financial performance, and market competitiveness—both directly and indirectly [5], [6], [4]. 3. Cross-Cultural Comparative Studies: Research in this category employs the PZB model to conduct empirical studies that compare service quality expectations and perceptions across different cultures. These studies analyze how cultural differences shape customer evaluations and corporate performance, facilitating market segmentation and elucidating the role of culture in service assessment [7], [8].

This study specifically examines four large retail companies with varying revenue levels. The aim is to analyze how consumers perceive and evaluate service quality within the competitive retail sector, assess overall customer satisfaction, and indirectly explore how satisfaction with service quality relates to business performance.

2. Literature review

2.1 *Service quality*

Since the 1980s, researchers have increasingly used cognitive theories to examine service quality. Gronroos [9] underscored that both the outcome and the delivery process are crucial, arguing that service quality is a perception formed by customers who compare their expectations with their actual experiences rather than a metric firms should self-assess. In a similar vein, Parasuraman, Zeithaml, and Berry [1] proposed that the perceived quality of a service depends on the gap between what customers expect and what they actually experience. When the actual service exceeds expectations, it signals that customer needs have been met at an ideal level; conversely, if the service falls short, it reflects poor quality

More recent studies have expanded the application of the PZB model into various sectors. For instance, Chen [10] categorizes the PZB framework into three areas—commercial, service industry, and tourism—to evaluate international tourists' satisfaction with tour guide services in Taiwan, offering useful insights for national tour guide training programs. Similarly, Li [11] Evaluating airline service quality from customer intuition by combining the five service quality dimensions with the PZB gap model [12], thereby developing an evaluation index that can guide improvements in the aviation industry. In addition, Deng, Liu, and Liu [13] applied the PZB model in vocational education and found that its use not only enhances teaching and learning quality but also fosters collaboration between schools and educators to elevate overall management and instructional standards. Lastly, Prabhu [14] reviewed service marketing literature from 1938 to 2018, organizing it into six categories. This systematic classification deepens our understanding of how service quality is measured and operationalized, especially in terms of the development and application of measurement scales.

2.2 Fuzzy Sets、Membership Function、Fuzzy Number

Zadeh [15] introduced fuzzy logic as a solution for controlling steam turbine engines, challenging the traditional notion of crisp sets. In classical mathematics, a crisp (or clear) set defines membership in a binary manner—each element is either a member (1) or not (0). This binary approach, however, falls short when applied to the ambiguous scenarios often encountered in real-world situations. Instead of a strict yes/no classification, it is more practical to use a membership (or affiliation)

function that assigns any value between 0 and 1 indicates the element is the size of the set t. Values close to 1 indicate a strong connection, while values close to 0 indicate a weak connection. A common representation of a fuzzy set is expressed as:

$$\tilde{A} = \{x,\ \mu_{\tilde{A}}(x) \mid x \in X\} \tag{2.1}$$

This formulation defines the fuzzy set A in terms of a membership function $\mu_a(x)$, which quantifies the level of membership of an element x. As Klir and Yuan [16] pointed out, fuzzy sets differ fundamentally from crisp sets because they allow for partial membership. That is, an element can belong to several sets simultaneously, each with a different degree of association. When the membership function only yields 0 or 1, the fuzzy set effectively becomes a crisp set.

Chen and Hwang [17] developed a method to convert qualitative descriptors such as "extremely important," "important," "ordinary," "unimportant," and "very unimportant" into fuzzy numbers for use in multi-criteria decision analysis (MCDA). In these analyses, the weight of each attribute—whether determined subjectively, objectively, or through a blend of both methods—significantly influences the final decision [18]. Once fuzzy numbers have been computed, they must be defuzzified to transform the results into comprehensible values. Common defuzzification techniques include the maximum membership method, the value with the highest membership is selected; the area center (or centroid) method, which calculates the centroid of the area under the membership curve; and the average of the maximum values, which averages the values at the peak of the membership function. Over time, fuzzy logic has evolved from initial skepticism to becoming a broadly accepted tool across many domains—including consumer electronics, transportation analysis, finance, speech recognition, image retrieval, pattern recognition, and biotechnology. Its advantages in handling uncertainty, offering flexible data representation, improving system stability, and simplifying complex designs make fuzzy logic particularly valuable for solving a wide range of practical problems.

3. Methodology

This study integrates fuzzy theory with the PZB service quality model to better capture the nuanced feelings of customers. Fuzzy theory excels at addressing the inherent uncertainty and ambiguity in customer

perceptions and expectations, making it particularly useful for evaluating service quality.

3.1 *Questionnaire Design*

The questionnaire was structured in two distinct parts. The first section gathered demographic information, including details such as gender, age, education level, occupation, and the shopping centers that respondents visit most often. The second section was based on a revised version of the SERVQUAL scale from Parasuraman et al. [1] and included 27 items distributed across five important dimensions: tangibility, reliability, responsiveness, assurance, and empathy.

Respondents were asked to rate their level of satisfaction using a 5-point Liker scale., where 1 indicates "extremely dissatisfied" and 5 indicates "extremely satisfied." They evaluated the retailer they frequented most among four options based on their personal experiences [19]. The tangibility items focused on factors like the availability of modern equipment, a clean shopping environment, a broad range of products, well-qualified staff, and sufficient information channels. Reliability items examined whether the retailer consistently met promises, provided timely help, and maintained accurate service records [20]. The responsiveness section assessed the retailer's effectiveness in communicating service details and promotions, offering prompt assistance, and addressing issues swiftly. Assurance items looked at the presence of complaint channels, the professionalism of service, and proactive customer engagement, while empathy items measured how well the retailer addressed diverse customer needs, prioritized customer interests, and handled emergencies.

3.2 *Questionnaire distribution objects*

In this study, we distributed 145 questionnaires using a random sampling approach, both online and on-site. After excluding incomplete or invalid submissions, we obtained 120 valid responses for analysis. Among these, 56.7% were male and 43.3% were female. The age breakdown was as follows: 19.18% were under 20 years old; 31.67% were between 21 and 29; 25.57% were between 30 and 39; 13.33% were between 40 and 49; 6.67% were between 50 and 59; and 3.58% were over 60. Regarding education, 26% had a high school education or less, 13.67% attended college, 50.33% were university graduates, and 10% had pursued graduate studies or higher. In terms of occupation, the majority of respondents were students (46.7%), followed by service workers (26.4%).

3.3 *Reliability Analysis*

To verify the revised questionnaire's validity and reliability, we first employed an expert review process. Scholars and industry specialists provided feedback and recommended adjustments to the questionnaire items. In the initial phase, we conducted a reliability analysis using SPSS, which confirmed that the Cronbach's α for the five dimensions (covering all 27 items) exceeded 0.6. Following these adjustments, the finalized questionnaire was administered to consumers from four sales companies, yielding 120 valid responses. The subsequent reliability analysis produced an overall Cronbach's α of 0.921, demonstrating strong internal consistency. Furthermore, the individual Cronbach's α values were 0.891 for tangibility, 0.714 for reliability, 0.713 for responsiveness, 0.862 for assurance, and 0.675 for empathy—all above the 0.6 threshold—indicating that the items and dimensions used in the study are reliably measured.

3.4 *Transformation of fuzzy semantics and performance value calculation*

In our study, we adopted the subjective ratings "very dissatisfied," "dissatisfied," "average," "satisfied," and "extremely satisfied" to evaluate performance across the five service quality dimensions. Following the method of Chen and Hwang [17], these qualitative ratings were converted into fuzzy numbers on a scale from 0 to 1. For example, "extremely dissatisfied" corresponds to the fuzzy number (0.0, 0.0, 0.3), "dissatisfied" to (0.0, 0.25, 0.5), "average" to (0.3, 0.5, 0.7), "satisfied" to (0.5, 0.75, 1.0), and "extremely satisfied" to (0.7, 1.0, 1.0).

Based on our theoretical framework, we assume that all five service quality dimensions carry equal importance. Therefore, each respondent's judgment is equally weighted, and the overall fuzzy weight is calculated as the average of these individual evaluations. The endpoints of each item's triangular fuzzy number are determined using Buckley's [21] approach. By performing a series of fuzzy arithmetic operations, we derive the fuzzy performance value that represents consumers' overall assessment of the five service quality dimensions for the four retail companies. Specifically, let x represent the fuzzy performance value provided by the kth consumer for the jth criterion of the ith retailer. All rated items are collected in the set S (Equation 3-1). The fuzzy weight from m consumers is then averaged as shown in Equation (3-2), where the symbol $\odot$ denotes the fuzzy addition operation. The resulting average, expressed as a triangular fuzzy number, is defined in Equation (3-3). Finally, Buckley's

[21] method is used to compute the endpoint values of this triangular fuzzy number, as outlined in Equations (3-4), (3-5), and (3-6).

$$\mathrm{E}_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}),\ j \in S \tag{3-1}$$

$$E_{ij} = (1/m) \odot (E_{ij}^{1} \oplus E_{ij}^{2} \oplus .... \oplus E_{ij}^{m}). \tag{3-2}$$

$$\mathrm{E}_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}). \tag{3-3}$$

$$LE_{ij} = (1/m) \odot \left[\sum_{k=1}^{m} LE_{ij}^{k} \right] \tag{3-4}$$

$$ME_{ij} = (1/m) \odot \left[\sum_{k=1}^{m} ME_{ij}^{k} \right] \tag{3-5}$$

$$UE_{ij} = (1/m) \odot \left[\sum_{k=1}^{m} UE_{ij}^{k} \right] \tag{3-6}$$

4. Research results and analysis

To extract precise data from the fuzzy evaluations, we processed the results using fuzzy number calculations followed by defuzzification. This conversion turns the subjective assessments of service quality into clear numerical ratings, making comparative analysis possible.

4.1 *Calculating fuzzy performance values*

Initially, we converted the qualitative fuzzy ratings into quantitative fuzzy numbers. Following the procedure outlined in steps 3-1 to 3-6, Then,

Table 1

Overall average fuzzy performance values of the original five service quality dimensions of the four sales firms.

Dimension	A	B	C	D
Tangibility	(0.61,0.73,0.83)	(0.52,0.71,0.87)	(0.44,0.63,0.83)	(0.43,0.61,0.81)
Reliability	(0.56,0.77,0.91)	(0.57,0.73,0.92)	(0.46,0.68,0.84)	(0.41,0.58,0.78)
Reactivity	(0.55,0.75,0.88)	(0.55,0.72,0.92)	(0.45,0.67,0.86)	(0.42,0.62,0.82)
Assurance	(0.53,0.74,0.89)	(0.55,0.72,0.91)	(0.48,0.65,0.84)	(0.43,0.61,0.83)
Empathy	(0.55,0.76,0.90)	(0.54,0.73,0.90)	(0.47,0.66,0.81)	(0.35,0.55,0.74)

we calculated the overall mean fuzzy performance scores for the five service quality dimensions across the four sales companies. These scores are summarized in Table 1.

4.2 *Defuzzification*

To better interpret the fuzzy performance scores presented in Table 1, we defuzzified these values to convert them into precise numerical ratings. This conversion enables us to more accurately evaluate and compare the service quality satisfaction levels of the four sales companies. Although there are several defuzzification methods, we chose the centroid method proposed by Teng and Tzeng [22]. This research approach considers the overall shape of the membership function and then uses the relevant information within the fuzzy set to obtain more accurate results (see Formula 4-1).

$$\tilde{A}_{ij} = (L_{ij}, M_{ij}, U_{ij})$$

$$DF_{ij} = \frac{[(U_{ij} - L_{ij}) + (M_{ij} - L_{ij})]}{3} + \mathrm{L_{ij}}\ ,\ \ \forall i, j = 1...n. \qquad (4\text{-}1)$$

After applying this research method, we got the overall satisfaction scores of the four sales companies on the five service quality dimensions. The overall satisfaction scores of the four sales companies on five service quality dimensions were obtained. The defuzzified values are listed in Table 2 below.

According to Table 2, the average scores for the five dimensions range from 0.67 to 0.69, with little variation among them. Notably, companies A and B consistently achieved higher scores in all dimensions compared to

Table 2

Performance Values of Four Sales Companies after Defuzzification of Their Top Five Service Quality Satisfaction Levels.

Dimension	A	B	C	D	Facet average
Tangibility	0.72	0.70	0.63	0.62	0.67
Reliability	0.75	0.74	0.66	0.59	0.69
Reactivity	0.73	0.73	0.66	0.62	0.68
Assurance	0.72	0.73	0.66	0.62	0.68
Empathy	0.74	0.72	0.65	0.55	0.67
overall performance value	0.73	0.72	0.65	0.60	0.68

companies C and D, with D registering the lowest performance. Overall, the aggregated service quality ratings are 0.73 for Company A, 0.72 for Company B, 0.65 for Company C, and 0.60 for Company D, resulting in an overall average of 0.68.

5. Conclusion and recommendations

This study adopts the service quality gap model proposed by Parasuraman et al. (1988) et al. The performance of four sales companies in southern Taiwan was evaluated using fuzzy evaluation method. The study focused on five important dimensions of service quality: Tangibility pertains to the visible aspects of service, such as the condition and upkeep of facilities, the appearance of equipment, the attire of service staff, and the accessibility of information. Our findings reveal that Retailers A and B scored higher in tangibility than Retailers C and D. Similarly, the reliability dimension—which measures whether retailers and their staff consistently meet their promises and foster customer trust—also favors A and B over C and D. When evaluating responsiveness, which reflects the promptness and courtesy with which customer needs are addressed, the same pattern emerged with A and B outperforming their competitors. In terms of assurance, which involves the professional competence and confidence conveyed by the service team, and empathy, which assesses the degree of personalized care provided to customers, Retailers A and B again led in performance. Overall, the aggregated service quality scores further underscore that A and B deliver superior service relative to C and D.

Despite these higher ratings, the overall scores for A and B—0.73 and 0.72 out of 1, respectively—suggest that there remains considerable scope for improvement. Additionally, the study indicates a correlation between service quality and business performance: Retailers A and B are not only rated higher in service quality but also demonstrate stronger financial performance and market presence, whereas C and D lag in both respects. It is important to note that due to limited resources, this study focused on a subset of the sales industry, and the results may not be directly applicable to other sectors. Some respondents also found the questionnaire lengthy when administered on-site, which may have affected participation and introduced potential biases. Future research should consider refining the survey design and employing more efficient data collection methods. Furthermore, as this study is cross-sectional, it does not capture temporal changes; incorporating longitudinal analyses in future studies could offer the deeper insights to the evolution of service quality over time.

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