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Measuring Electronic Service Quality (E-SQ) in Mobile E-Commerce Services Using Fuzzy AHP and TOPSIS*

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ABSTRACT

This paper proposes an approach to measuring E-Service Quality (E-SQ) in mobile commerce industry. Our approach is based on SERVQUAL instrument, which has been widely used in the context of web-based service quality measurement. Our model uses fuzzy method, specifically incorporating fuzzy analytical hierarchy process (AHP) and fuzzy TOPSIS to consider both quantitative and qualitative factors in order to measure electronic service quality (E-SQ) in mobile commerce application using SERVQUAL dimensions. Then, the model is utilized to rank four of the most competitive e-commerce related applications on mobile Android market using results from fuzzy AHP and TOPSIS.

Keywords: Mobile commerce, Fuzzy, AHP, TOPSIS, E-Service quality, Quality management

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INTRODUCTION

People's shopping habits around the world these days have shifted from visiting physical stores to shopping online using internet or mobile applications. As a result, in the USA, lots of bricks and mortar such as Sears, Toys-R-Us, Forever 21, and Blockbuster declared bankrupt. Due to emerging electronic commerce, many companies are shifting its gear towards building mobile application of its stores and concentrating on websites. In September 2018, according to the news report, total online shopping transactions in South Korea reached 10 billion dollars, which has increased 17.3% from last year's number. In past couple months, the most downloaded apps by users were 'shopping' related applications, and 73.8% of the apps remained in smartphones after installation. Reasons for preferring mobile shopping were accessibility, discounts, and payment convenience. According to Nielsen report, which is a worldwide audience measurement system operated by Nielsen Media, in September 2019, Coupang was ranked 1st among shopping related applications in Google Android market, followed by 11st, Wemaketheprice, and G-Market. As electronic commerce stands out, quality of the application is important for many companies in order to gain market share and attract consumers.

The purpose of this paper is to rank e-service quality (E-SQ) and in order to evaluate E-SQ, it is more effective to consider both quantitative and qualitative factors. Hence, this study will use the combination of fuzzy Analytic Hierarchy Process (AHP) and fuzzy TOPSIS to measure E-SQ in retail-related mobile application using SERVQUAL dimensions. On top of that, it will rank four of the most competitive retail-related applications on Android market using results from fuzzy AHP and TOPSIS.

LITERATURE REVIEW

Although research about service qualities of mobile applications is exceptionally rare, there was a literature on electronic service quality of healthcare industry and its websites using fuzzy AHP and TOPSIS by Büyüközkan (2012). This study combined fuzzy AHP and fuzzy TOPSIS to measure E-SQ performance. Based on its experiment, results showed that of the sub-criteria, hospital should focus more on specialization, interactivity, and accuracy of service. In addition, of six main criteria, reliability and responsiveness were thought to be important. There was a similar study conducted to measure service quality of airlines. Tsaur et al. (2002) measured service quality of airline using original SERVQUAL dimension, which are reliability, responsiveness, assurance, tangibles and empathy. Following study mentions that now, concept of service isn't just about technical aspect, but includes the customer's perception. It used AHP to obtain weight of criteria and used TOPSIS to evaluate those weights. It concludes that airlines need to focus on physical aspect of service rather than empathy aspect. As e-commerce emerged, Kang et al. (2016) utilized a Fuzzy TOPSIS to evaluate Business-2-Consumer websites using E-SQ dimensions. Kang et al. (2016) chose several retail websites as alternatives and identified E-S-QUAL dimensions as evaluation criteria. After that, the paper showed Closeness Coefficients (CCi) values for 6 alternatives. As a result, A3 website was shown to be the most effective website with CCi of 0.672, followed by A6 with CCi of 0.653. Tadic et al. (2013) focused on using fuzzy AHP and TOPSIS methodology to evaluate quality goals that are more important than others. The Fuzzy set theory was used to handle three problematic areas, which are imprecision, randomness, and ambiguity. After testing the industrial firms in Serbia, measures of process discrepancy, process effectiveness, and duration of production order realization were selected to be the most important quality goals. Although there was plethora of studies that used fuzzy methods, none of the studies measured E-SQ of mobile applications. Nowadays, people spend significant amount of time on mobile applications rather than on websites. In addition, since mobile applications have greater operational efficiency and offer exclusive features, it is essential to focus on mobile applications. This particular study combines Fuzzy AHP and Fuzzy TOPSIS as Ryu (2012) did on research about choosing suppliers. However, following study uses SERVQUAL dimensions to measure and rank top four retail mobile application in South Korea.

ELECTRONIC SERVICE QUALITY (E-SQ), SERVQUAL AND RESEARCH DESIGN

E-SQ / SERVQUAL

As mentioned above, with the development of internet commerce and mobile devices, many businesses are shifting gear to smartphone applications or websites. Many business organizations are investing their time and money to develop and maintain quality of applications and websites. However, measurement of service quality in mobile applications is in its early stages compared to measurement of quality of business. According to Ojasalo (2010), E-SQ can be defined as an extent to which a web site runs efficiently when purchasing, shopping, and delivering products and services. In order to deliver high quality service to customers, companies must understand what customers expect in using those websites or applications.

Websites and applications provide not only information, but also service. Since there are no instruments intended for mobile applications, this study uses E-SERVQUAL to assess quality of mobile applications. Zeithaml et al. (2002) summarized 11 dimensions about E-SQ as reliability, access, responsiveness, flexibility, efficiency, ease of navigation, security/privacy, price knowledge, assurance/trust, customization/personalization, and site aesthetics.

Research Design

Of numerous SERVQUAL dimension used in various studies, 5 categories used in this study are appearance, responsiveness, reliability, assurance, and information content/quality. First of all, appearance refers to physical attributes, animations or aesthetic of the applications. In mobile application context, it determines how easy it is for people to find what they need and use the application. Next dimension is responsiveness, which is how willingly application managers help customers consistently and accurately. This includes customer service and technical ability. Mobile applications can often crash when many people try to open them at the same time. Therefore, it is crucial for web developers of the application to fix the app when the help is needed. The third dimension is reliability.

It indicates how dependable the mobile application is. Nowadays, some retail applications offer 1-day delivery or same-day delivery, depending on the product and locations. People should be able to rely on the guaranteed delivery date and information on application, so that people can consistently trust and use same application. Next one is assurance. When people use the application, people input their personal information including credit card information and address. Therefore, companies have to make sure they protect customers' information. In addition, it is important for companies to compensate customers if they are dissatisfied with service or product. Lastly, information quality / content is the fifth dimension. It represents the information featured in mobile application. Customers look for everything they want on the applications such as accurate information regarding products, reviews and similar products that can be used along with certain products. Therefore, richness and accuracy of the content is vital for the mobile application.

RESEARCH METHODS

Fuzzy AHP

Fuzzy AHP is an effective method to use when solving MCDM (Multiple-Criteria Decision Making). Analytic Hierarchy Process (AHP) analyzes, structures and stratifies problems and shows people's opinions as relative weights and ratios. Nonetheless, using just AHP displayed multiple concerns because opinions from certain experts or subjects can be biased. Thus, particular study applies fuzzy set theory with AHP so that results from survey can be expressed as a fuzzy number rather than directly drawing conclusion from survey. Particularly, following study adopts method from Cheng (1997).

Fuzzy TOPSIS

Fuzzy TOPSIS is a method that was first proposed by Hwang and Yoon (1981), which allows decision maker to choose alternatives that are closest to Ideal Solution and farthest from Negative Ideal Solution. This particular method was further developed by Chen et al. (1992). In fuzzy TOPSIS, evaluations and criteria are first indicated as linguistic terms, which can be altered to triangular or trapezoid fuzzy numbers.

Combination of Fuzzy AHP and Fuzzy TOPSIS

Following are simple steps that integrates fuzzy AHP and TOPSIS to find fuzzy decision matrix value and crisp value. In these steps, alternatives refer to 4 mobile application choices and criterion refers to five electronic service quality dimensions described earlier.

Step 1. Build a hierarchical model by making a list of decision goals, evaluation criteria, and alternatives. Set the language variables to evaluate alternatives and language scale to evaluate prompt criteria. Both variables and scale are set to follow fuzzy triangular number.

Step 2. A fuzzy matrix is assembled for each triangular fuzzy number evaluated by evaluators for each service quality criteria and alternatives. For each alternative and criterion, the fuzzy decision matrix is calculated.

Step 3. Fuzzy decision matrix is normalized, and the normalized matrix is combined with alternatives to calculate the weight of service quality criteria.

Step 4. α-cut value is used to find the degree of fuzziness and the value obtained indicates the upper limit value and lower limit value. Lastly, weight of each alternative is shown to reveal rank of alternatives.

RESULTS

The main goal of this research is to find a retail related application that possesses the best quality based on 5 criteria. Under this goal, five evaluation criteria were used as figure 1: responsiveness (C1), assurance (C2), reliability (C3), information content/quality (C4) and appearance (C5).

After that, four mobile application platforms, Coupang, 11st, Wemaketheprice, G-Market were chosen as alternatives subjects. Although there are other retail mobile platforms used in South Korea, gap between those four applications and others was large that it seemed unnecessary to add others.

For the survey, some people were asked directly face-to-face,

Table 1. Evaluation of alternatives

Criterion	Alternatives	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1 (Responsiveness)	A1(Coupang)	F	F	F	F	G	VG	MG	F	G	F
	A2(11st)	F	F	MG	F	F	MG	VG	F	F	MG
	A3(Wemake)	MP	MP	F	F	F	G	F	F	F	F
	A4(GMarket)	MG	MG	F	F	G	G	VG	MP	MG	F
C2 (Assurance)	A1(Coupang)	MP	MP	F	MG	MG	MG	MG	G	G	F
	A2(11st)	F	F	MG	F	F	G	G	MG	MP	MG
	A3(Wemake)	MP	MP	MP	F	MP	MG	MG	F	MP	MP
	A4(GMarket)	MG	MG	G	F	F	MG	G	G	G	MG
C3 (Reliability)	A1(Coupang)	F	F	F	G	G	VG	G	G	G	MG
	A2(11st)	MG	MG	MG	F	F	G	VG	MG	MG	F
	A3(Wemake)	MP	MP	F	F	F	G	G	MP	MP	MP
	A4(GMarket)	F	F	F	F	MG	G	VG	G	MG	MG
C4 (Information content/quality)	A1(Coupang)	MP	MP	MG	MG	MG	MG	G	G	G	MG
	A2(11st)	F	F	MG	F	F	F	VG	MG	MG	MG
	A3(Wemake)	MP	MP	MG	F	MP	G	VG	F	MG	F
	A4(GMarket)	MG	MG	MG	MP	MP	F	VG	G	G	MG
C5 (Appearance)	A1(Coupang)	F	F	MG	F	F	G	MG	G	G	G
	A2(11st)	F	F	MG	F	F	F	F	G	MG	F
	A3(Wemake)	MP	MP	G	F	MP	G	G	G	F	MG
	A4(GMarket)	MG	MG	F	MP	MP	MG	G	G	G	G

Criterion	Alternatives	DM11	DM12	DM13	DM14	DM15	DM16	DM17	DM18	DM19	DM20
C1 (Responsiveness)	A1(Coupang)	MG	G	F	F	VG	F	F	F	G	F
	A2(11st)	VG	F	MG	F	MG	MG	F	F	F	F
	A3(Wemake)	F	F	F	F	G	F	MP	MP	F	F
	A4(GMarket)	VG	MG	F	MP	G	F	MG	MG	G	F
C2 (Assurance)	A1(Coupang)	MG	G	F	G	MG	F	MP	MP	MG	MG
	A2(11st)	G	MP	MG	MG	G	MG	F	F	F	F
	A3(Wemake)	MG	MP	MP	F	MG	MP	MP	MP	MP	F
	A4(GMarket)	G	G	G	G	MG	MG	MG	MG	F	F
C3 (Reliability)	A1(Coupang)	G	G	F	G	VG	MG	F	F	G	G
	A2(11st)	VG	MG	MG	MG	G	F	MG	MG	F	F
	A3(Wemake)	G	MP	F	MP	G	MP	MP	MP	F	F
	A4(GMarket)	VG	MG	F	G	G	MG	F	F	MG	F
C4 (Information content/quality)	A1(Coupang)	G	G	MG	G	MG	MG	MP	MP	MG	MG
	A2(11st)	VG	MG	MG	MG	F	MG	F	F	F	F
	A3(Wemake)	VG	MG	MG	F	G	F	MP	MP	MP	F
	A4(GMarket)	VG	G	MG	G	F	MG	MG	MG	MP	MP
C5 (Appearance)	A1(Coupang)	MG	G	MG	G	G	G	F	F	F	F
	A2(11st)	F	MG	MG	G	F	F	F	F	F	F
	A3(Wemake)	G	F	G	G	G	MG	MP	MP	MP	F
	A4(GMarket)	G	G	F	G	MG	G	MG	MG	MP	MP

and for some subjects, Google forms was used. In the Google forms, subjects were asked to do a pairwise comparison, answering questions such as: How good is the responsiveness when using Coupang (or G-Market..etc)? Subjects were 50 college students and employees from various fields such as finance and retail and all 50 people had four applications installed on their phone and had login credential on those four applications.

First, subjects evaluated each of the five service quality criteria and the linguistic variables considering alternatives. For example, when subjects were asked about the responsiveness of Coupang, subjects who answered “Fine” were marked as F, and “Moderately Good” was MG, as seen in table 1.

Next, all of the linguistic variables such as “Moderately Poor”, “Fine” were expressed as triangular fuzzy numbers. For example, based on those choices by each people, table 2 converted “Fine” to (4,5,6) and “Good” to (7,8,9) etc.

The following table 3 shows the result of questionnaire about how people think of five criteria (responsiveness, assurance, reliability, information content/quality, appearance) without considering four retail applications. Each answer is altered to triangular fuzzy numbers. For example, decision maker 1 has a standard of MH (Moderately High) for responsiveness and MH is modified to (0.5, 0.65, 0.8)

Table 4 shows the fuzzy weights for the four retail related applications and for service quality criteria. For example, for number such as (4, 6.25, 10), the first number presents minimum number from every first numbers in same row (from table 2). The second number adds up the second number of the same row and multiply it by (1/ total number of decision makers). Finally, the third number shows maximum number from the same row.

$$a = \min\{\underline{a}_k\}, b = \frac{1}{K}, \sum_{k=1}^{K} b_k c = \max\{c_k\}$$

The table 5 multiplies numbers from the table 4 below by 0.1 to normalize the decision matrices.

Table 6 was calculated by multiplying normalized decision matrix with evaluation criteria importance numbers from table 5. For example, for A1 of C1, numbers were calculated such as (0.4 * 0.4, 0.625 * 0.71, 0.9 * 1), which results (0.16, 0.44, 0.9).

Table 2. Evaluation of alternatives – Triangular fuzzy number

Criterion	Alternatives	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1 (Responsiveness)	A1(Coupang)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(8,10,10)	(5,6.5,8)	(4,5,6)	(7,8,9)	(4,5,6)
	A2(11st)	(4,5,6)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(5,6.5,8)	(8,10,10)	(4,5,6)	(4,5,6)	(5,6.5,8)
	A3(Wemake)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A4(GMarket)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(4,5,6)	(7,8,9)	(7,8,9)	(8,10,10)	(2,3.5,5)	(5,6.5,8)	(4,5,6)
C2 (Assurance)	A1(Coupang)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(7,8,9)	(4,5,6)
	A2(11st)	(4,5,6)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(7,8,9)	(7,8,9)	(5,6.5,8)	(2,3.5,5)	(5,6.5,8)
	A3(Wemake)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(2,3.5,5)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(2,3.5,5)	(2,3.5,5)
	A4(GMarket)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(4,5,6)	(4,5,6)	(5,6.5,8)	(7,8,9)	(7,8,9)	(7,8,9)	(5,6.5,8)
C3 (Reliability)	A1(Coupang)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(7,8,9)	(8,10,10)	(7,8,9)	(7,8,9)	(7,8,9)	(5,6.5,8)
	A2(11st)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(4,5,6)	(7,8,9)	(8,10,10)	(5,6.5,8)	(5,6.5,8)	(4,5,6)
	A3(Wemake)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(7,8,9)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)
	A4(GMarket)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(2,3.5,5)	(7,8,9)	(8,10,10)	(7,8,9)	(5,6.5,8)	(5,6.5,8)
C4 (Information content/quality)	A1(Coupang)	(2,3.5,5)	(2,3.5,5)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(7,8,9)	(7,8,9)	(5,6.5,8)
	A2(11st)	(4,5,6)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(4,5,6)	(8,10,10)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)
	A3(Wemake)	(2,3.5,5)	(2,3.5,5)	(5,6.5,8)	(4,5,6)	(2,3,5)	(7,8,9)	(8,10,10)	(4,5,6)	(5,6.5,8)	(4,5,6)
	A4(GMarket)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(8,10,10)	(7,8,9)	(7,8,9)	(5,6.5,8)
C5 (Appearance)	A1(Coupang)	(4,5,6)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(7,8,9)	(5,6.5,8)	(7,8,9)	(7,8,9)	(7,8,9)
	A2(11st)	(4,5,6)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(5,6.5,8)	(4,5,6)
	A3(Wemake)	(2,3.5,5)	(2,3.5,5)	(7,8,9)	(4,5,6)	(2,3.5,5)	(7,8,9)	(7,8,9)	(7,8,9)	(4,5,6)	(2,3.5,5)
	A4(GMarket)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(2,3.5,5)	(2,3.5,5)	(5,6.5,8)	(7,8,9)	(7,8,9)	(7,8,9)	(7,8,9)

Table 2. (continued)

Criterion	Alternatives	DM11	DM12	DM13	DM14	DM15	DM16	DM17	DM18	DM19	DM20
C1 (Responsiveness)	A1(Coupang)	(5,6.5,8)	(7,8,9)	(4,5,6)	(4,5,6)	(8,10,10)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(4,5,6)
	A2(11st)	(8,10,10)	(4,5,6)	(5,6.5,8)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A3(Wemake)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(7,8,9)	(4,5,6)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(4,5,6)
	A4(GMarket)	(8,10,10)	(5,6.5,8)	(4,5,6)	(2,3.5,5)	(7,8,9)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(4,5,6)
C2 (Assurance)	A1(Coupang)	(5,6.5,8)	(7,8,9)	(4,5,6)	(7,8,9)	(5,6.5,8)	(4,5,6)	(2,3.5,5)	(2,3.5,5)	(5,6.5,8)	(5,6.5,8)
	A2(11st)	(7,8,9)	(2,3.5,5)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(5,6.5,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A3(Wemake)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(4,5,6)
	A4(GMarket)	(7,8,9)	(7,8,9)	(7,8,9)	(7,8,9)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(4,5,6)
C3 (Reliability)	A1(Coupang)	(7,8,9)	(7,8,9)	(4,5,6)	(7,8,9)	(8,10,10)	(5,6.5,8)	(4,5,6)	(4,5,6)	(7,8,9)	(7,8,9)
	A2(11st)	(8,10,10)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(4,5,6)
	A3(Wemake)	(7,8,9)	(2,3.5,5)	(4,5,6)	(2,3.5,5)	(7,8,9)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(4,5,6)	(4,5,6)
	A4(GMarket)	(8,10,10)	(5,6.5,8)	(4,5,6)	(7,8,9)	(7,8,9)	(5,6.5,8)	(4,5,6)	(4,5,6)	(2,3.5,5)	(4,5,6)
C4 (Information content/quality)	A1(Coupang)	(7,8,9)	(7,8,9)	(5,6.5,8)	(7,8,9)	(5,6.5,8)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)	(5,6.5,8)	(5,6.5,8)
	A2(11st)	(8,10,10)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(5,6.5,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A3(Wemake)	(8,10,10)	(5,6.5,8)	(5,6.5,8)	(4,5,6)	(7,8,9)	(4,5,6)	(2,3.5,5)	(2,3.5,5)	(2,3,5)	(4,5,6)
	A4(GMarket)	(8,10,10)	(7,8,9)	(5,6.5,8)	(7,8,9)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)
C5 (Appearance)	A1(Coupang)	(5,6.5,8)	(7,8,9)	(5,6.5,8)	(7,8,9)	(7,8,9)	(7,8,9)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A2(11st)	(4,5,6)	(5,6.5,8)	(5,6.5,8)	(7,8,9)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
	A3(Wemake)	(7,8,9)	(4,5,6)	(7,8,9)	(7,8,9)	(7,8,9)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(2,3.5,5)	(4,5,6)
	A4(GMarket)	(7,8,9)	(7,8,9)	(4,5,6)	(7,8,9)	(5,6.5,8)	(7,8,9)	(5,6.5,8)	(5,6.5,8)	(2,3.5,5)	(2,3.5,5)

Table 3. Importance weight of decision makers on evaluation criteria

Criterion	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1 (Responsiveness)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C2 (Assurance)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C3 (Reliability)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)
C4 (Information content/quality)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)
C5 (Appearance)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)

Table 3. (continued)

Criterion	DM11	DM12	DM13	DM14	DM15	DM16	DM17	DM18	DM19	DM20
C1 (Responsiveness)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)
C2 (Assurance)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)
C3 (Reliability)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)
C4 (Information content/quality)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)
C5 (Appearance)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)

Table 4. Fuzzy weights for alternatives (applications) and five criteria

Alternatives	C1 (Responsiveness)	C2 (Assurance)	C3 (Reliability)	C4 (Information content/ quality)	C5 (Appearance)
A1(Coupang)	(1, 7.09, 10)	(1, 6.54, 10)	(1, 7.73, 10)	(2, 6.76, 10)	(2, 6.57, 10)
A2(11st)	(2, 6.15, 10)	(1, 6.02, 10)	(0, 6.81, 10)	(2, 6.46, 10)	(2, 6.08, 10)
A3(Wemake)	(0, 5.56, 10)	(0, 5.02, 9)	(0, 5.88, 9)	(1, 5.87, 9)	(1, 5.67, 10)
A4(GMarket)	(1, 5.93, 10)	(1, 6.2, 9)	(2, 6.47, 10)	(2, 6.35, 10)	(1, 6.05, 10)
Importance of evaluation criteria	(0.4, 0.715, 1)	(0.4, 0.69, 1)	(0.5, 0.852, 1)	(0.2, 0.734, 1)	(0.2, 0.673, 1)

Table 5. Normalized Decision Matrix

Alternatives	C1 (Responsiveness)	C2 (Assurance)	C3 (Reliability)	C4 (Information content/quality)	C5 (Appearance)
A1(Coupang)	(0.1, 0.709, 1)	(0.1, 0.654, 1)	(0.1, 0.773, 1)	(0.2, 0.676, 1)	(0.2, 0.657, 1)
A2(11st)	(0.2, 0615, 1)	(0.1, 0.602, 1)	(0, 0.681, 1)	(0.2, 0.646, 1)	(0.2, 0.608, 1)
A3(Wemake)	(0, 0.556, 1)	(0, 0.502, 0.9)	(0, 0.588, 0.9)	(0.1, 0.587, 0.9)	(0.1, 0.567, 1)
A4(GMarket)	(0.1, 0.593, 1)	(0.1, 0.62, 0.9)	(0.2, 0.647, 1)	(0.2, 0.635, 1)	(0.1, 0.606, 1)
Importance of evaluation criteria	(0.4, 0.715, 1)	(0.4, 0.69, 1)	(0.5, 0.852, 1)	(0.2, 0.734, 1)	(0.2, 0.673, 1)

Table 6. Weighted Normalized Decision Matrix

Alternatives	C1 (Responsiveness)	C2 (Assurance)	C3 (Reliability)	C4 (Information content/quality)	C5 (Appearance)
A1(Coupang)	(0.04, 0.507, 1)	(0.04, 0.451, 1)	(0.05, 0.659, 1)	(0.04, 0.496, 1)	(0.04, 0.442, 1)
A2(11st)	(0.08, 0.44, 1)	(0.04, 0.415, 1)	(0, 0.58, 1)	(0.04, 0.474, 1)	(0.04, 0.409, 1)
A3(Wemake)	(0, 0.398, 1)	(0, 0.346, 0.9)	(0, 0.5, 0.9)	(0.02, 0.431, 0.9)	(0.02, 0.382, 1)
A4(GMarket)	(0.04, 0.424, 1)	(0.04, 0.428, 0.9)	(0.1, 0.551, 1)	(0.04, 0.466, 1)	(0.02, 0.408, 1)

Table 7 now uses the α-cut to modify the degree of fuzziness. It is calculated by using numbers from table 6 and the following values of α = 0.8 and λ = 0.5. As a result, A1 of C1 would get value of 0.51. This calculation differs from the size of α value. For reliable results,

Table 7. Defuzzified value when α = 0.8 and λ = 0.5, and final weight of each evaluation

Alternatives	C1 (Responsiveness)	C2 (Assurance)	C3 (Reliability)	C4 (Information content/ quality)	C5 (Appearance)	Final Weight
A1(Coupang)	0.51	0.465	0.632	0.501	0.458	0.273
A2(11st)	0.46	0.436	0.564	0.483	0.431	0.253
A3(Wemake)	0.418	0.367	0.49	0.437	0.408	0.226
A4(GMarket)	0.443	0.436	0.551	0.477	0.429	0.249

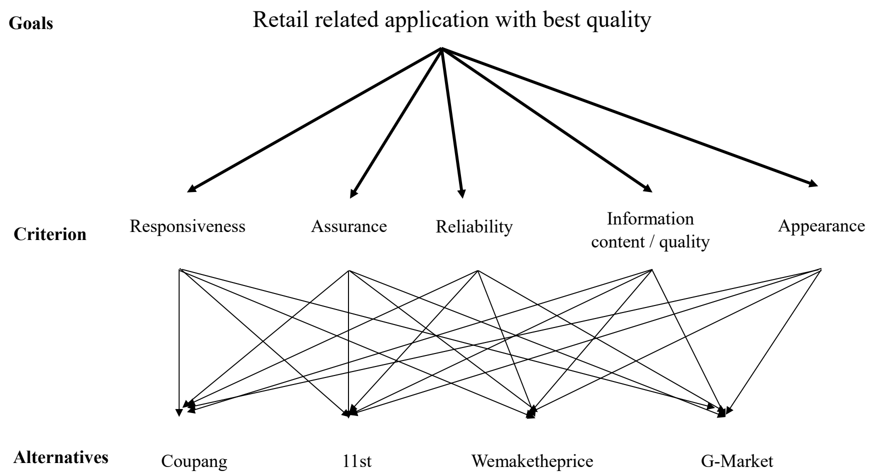

Figure 1. Division of criteria and survey

calculations with two distinct values of α were made: 0.5 and 0.2. Using two values showed that ranking of four retail applications did not change.

Next, final weights are calculated in table 7 by adding up the weight of all five service quality dimensions (responsiveness, assurance, reliability, information content/quality, appearance) and the number was divided by the weights of all four retail-related mobile applications. For Coupang, which is A1, five values of 0.51, 0.465, 0.632, 0.501, and 0.458 were added to 2.566. 2.566 divided by 9.363 resulted the highest weight of 0.273.

CONCLUSION & MANAGERIAL IMPLICATION

The objective of this research is to combine fuzzy AHP and fuzzy TOPSIS to evaluate what kind of quality dimensions retail companies should focus in order to satisfy needs and expectations of customers and to explore ranking of the mobile applications based on final weight. Interestingly, ranking shown from this research were similar to the ranking based on application's market share. As seen from the rank of the application based on market share, Coupang was ranked first with overall weight of 0.273 followed by 11st with 0.253. G-Market had a weight of 0.249 and Wemaketheprice had the lowest weight of 0.226 In addition, there were several interesting implications from table 7. Of the five evaluation criteria, Coupang ranked the highest on all of five service quality dimensions. In addition, 11st ranked second on all five dimensions. On assurance criteria, 11st and G-Market had same weight of 0.436, which showed that both applications have opportunity to top another for assuring customer when they use specific mobile applications. For responsiveness, difference between Coupang and Wemaketheprice was 0.1 and for reliability gap was 0.142. These results show that the overall customer perception, even before customers take quality into account, between Coupang and Wemaketheprice is quite big. From the weight of 4 mobile applications within five criteria, people think reliability is the most important criteria out of five dimensions. Coupang had the highest number of 0.632 and even Wemaketheprice, which has the lowest weight recorded 0.49. Depending on the location and the timing of the order, mobile applications offer same-day shipping or over-night shipping. Since those orders are usually something that people require instantly, the dependability and trustworthiness of the mobile applications seem crucial to the users. In addition, for appearance, Coupang had the highest number of 0.458 and Wemaketheprice's weight was 0.408. Following results imply that unless application is trustworthy and has good internal customer service, physical appearance of application does not matter that much. It would be much more beneficial for companies to rather focus on other aspects of quality dimensions. Moreover, final weight difference between 11st and G-Market, which ranked 2nd and 3rd, was only 0.004. Although weight of G-Market of all five service quality dimensions was lower than 11st, difference was minimal. This signifies that, in mobile e-commerce industry as of now, other than Coupang, there is potential for other competitors to catch up one another.

Nowadays, many stores are focusing on mobile application and developing exclusive membership/offers to customers who shop online. From this research, companies should be able to figure out which areas to target when they develop or update mobile applications. Since the outbreak of the Covid-19 from beginning of 2020, people prefer online shopping over offline shopping more than ever. Although South Korea is one of the countries that well-contained the virus, people still feel somewhat dangerous when going to the crowded place and numbers from numerous reports showed that profits of all four retail companies has gone up this year. Therefore, quality of these heavily used mobile applications will become crucial from now on. There were several limitations that occurred from this research. First of all, there was no specific service quality measure for mobile applications. SERVQUAL measurement is a measure initially developed for service and E-SQ is a measure intended for online website. Now that technology is developing faster than ever, new quality measurements for mobile applications seems necessary. Secondly, it wasn't easy to find people who had login credentials of all four applications, which means it is hard to change people's preferences once they start using certain application. For future research, it would be meaningful to develop a new service quality dimensions for mobile application that could be applied to various mobile application industries.

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