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Measuring service quality of video communication tools using specific service quality dimensions and multiple-criteria decision-making (MCDM) method

서비스 품질 척도와 다기준 의사결정방법을
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Abstract

This paper proposes to examine service quality of video communication tools. In the midst of Covid-19, one of the worst pandemics in history, companies and schools are shifting their attention towards actively adopting technologies related to digital transformation. Specifically, video communication tools are widely used across the world. First, this study aims to determine specific service quality dimensions for video communication tools and identify which video communication tools offer the best service quality. The model uses Multi-Criteria Decision-Making (MCDM) method, specifically incorporating fuzzy Analytical Hierarchy Process (AHP) and fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to consider both quantitative and qualitative factors in order to measure the service quality of video communication tools. Next, it will rank four of the most competitive video communication tools using results from fuzzy AHP and TOPSIS. Five service quality dimensions were selected by survey and literature review and those dimensions were applied to four video communication tools. The ranking within those tools showed different results than actual market share.

Keyword : Video communication tools, Service Quality, fuzzy AHP, fuzzy TOPSIS, MCDM, SERVQUAL

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1. Introduction

Covid−19 brought enormous changes to our lives in 2020. Masks became part of our daily lives, and countries are scrambling to get their hands on vaccines. In particular, workplaces and schools had to adapt to a new trend of work called “Smart Work” (Hu, 2020). Many companies in Korea began to implement telecommuting and make work shifts more flexible. Big conglomerates such as LG, Naver and Kakao started telecommuting, and universities around the world decided to use video communication tools in class instead of making students commute to school. In addition, working using video communication tools was introduced to meetings, seminars, training at work, and sales and business meetings.

Smart work specifically refers to a flexible work behavior without any restrictions in time and place, and more than 50% of companies in the US and Europe are using it. It was possible in majority of developed countries because IT−based technologies such as cloud, VPN, and video communication tool were widely used. This new shift in trend in the workplace was already happening but the rate of change increased. Millennials and Generation Z that value efficiency and rationality favored different type of communication methods from baby boomers and Generation X. Generation X preferred email communication, instant messenger, and voice online conference, whereas the newer generation preferred video conference, business SNS, and messenger that recorded history (Hangsterfer, 2020).

Video communication tools are tools that enable chat, video conference, file sharing, and collaboration. Some of the biggest video communications tools include Zoom, Skype, Google Meet and Microsoft Teams. Giant tech companies such as Google, Microsoft, and Facebook are entering the steadily growing video communication tool market. In 2020, Zoom added 2.22 million active users and using these tools reportedly cut travel costs by 30%. According to Fortune Business Insights, global video communication tool market is expected to grow from $11 billion in 2018 to $13.6 billion (Fortune, 2020).

Usage of video communication tools will not be reduced even with the end of Covid-19 pandemic. With intensifying competition in the market, it looked significant to apply service quality measures to these tools and see how these tools are doing in terms of quality and which aspects they can improve. There are no studies on video communication tools, and studies regarding service quality of technologies are also rare. This study could be used as a reference to managements of these tools to signify overall performance. In the future, these service quality measures may be applicable to other 4th industrial revolution tools in addition to video communication tools.

The remainder of the paper is organized as follows. Section 2 discusses previous literatures that use SERVQUAL with MCDM methods. Section 3 presents the research design and shows how five service quality dimensions were chosen. Section 4 discusses basic concept of fuzzy AHP and TOPSIS and how this study intends to use it. Section 5 presents the result of this study and finally, section 6 concludes the paper and explains how this paper can be improved in the future.

2. Literature Review

Since the concept of service quality was first established by Parasuraman et al. (1988), many scholars measured service quality in various industries using MCDM methods such as AHP, TOPSIS, Fuzzy AHP and Fuzzy TOPSIS.

Airline industry was one of the industries that most commonly used the aforementioned concepts. Li (2017) measured and compared differences in passengers' expectations in terms of reliability, assurance, facilities, employees, flight patterns, customization and responsiveness. The result showed that flight schedule and information, employees, and facilities are some of the more important criteria. Büyüközkan et al. (2012) used fuzzy AHP and fuzzy TOPSIS to measure the service quality in healthcare industry, which proved that hospitals should focus on reliability and responsiveness to provide satisfying service quality. A study of Ocampo et al. (2019) also applied AHP and TOPSIS to evaluate service quality in the context of Philippines government agencies and showed that a lot of dimensions needed improvement while promptness was the most important sub-division. Chen et al. (2014) presented an evaluation system using fuzzy AHP and evaluated teaching performance to determine factors and its weights. Chen et al. (2014) mentioned that, since fuzzy AHP can capture the vagueness of human judgements, using fuzzy method makes the index system less vague and reliable.

There weren't many studies that evaluated service quality of technology-related industry. However, Kumar (2017) developed own service quality dimension called "Mappsql" to assess service quality of a mobile application. Mappsql was a modified version of electronic service quality (E-S-Qual) developed by Zeithaml (2005). E-S-Qual dimension by Zeithaml (2005) included efficiency, fulfillment, system availability and privacy. Kumar (2017) added dimensions such as mobile app design and customization to become helpful for a service provider that uses mobile based application to reach its customer. In addition, Lai (2007) used original SERVQUAL dimension to assess China's mobile communications industry. Using survey, Lai (2007) measured if five SERVQUAL dimensions are fit to the study and further added convenience as additional dimension. Parasuraman et al. (1988) admitted in his study that items in their 22-item SERVQUAL scale might have deleted some of the measures that is qualified for another industry. In addition, Yi et al. (2016) looked at mobile shopping behavior of KakaoTalk, the most used messenger app in South Korea. Yi et al. (2016) examined effects of information sources and concluded that, among electronic service quality dimensions, efficiency was an important factor. There was one study that analyzed service quality of new emerging technology, Internet of Things (IoT). Minh Ly et al. (2018) conducted fuzzy AHP with five service quality dimensions, which were connectivity, telepresence, intelligence, security, and value. Using MCDM method, the study identified specific service quality dimensions that should be improved to reach a good performance in the future, which were IoT effectiveness, internet connectivity and telepresence.

From the literature review, although there were numerous studies that assessed service quality in various industries, very few studies concentrated on new technology such as video communication tools. Since the popularity of video communication tools are recently rising with the ongoing pandemic, a following study can be a start of a new research paradigm. This study integrates Fuzzy AHP and Fuzzy TOPSIS as Ryu (2012) did and uses it to examine four video communication tools.

3. Research Design

3.1 SERVQUAL

SERVQUAL instrument was first developed by Parasuraman et al. (1988), and it is a well-known model of service quality which has been used by several authors to assess service quality. Initial dimensions of service quality included tangibles, reliability, responsiveness, communication, credibility, security, competence, courtesy, understanding / knowing the customer and access. Later, through several studies, it was reduced to tangible, reliability, responsiveness, empathy, and assurance. SERVQUAL has been successfully applied in various industries such as hospitals, airline, travel, tourism, banking, and business. Several authors such as Tsaur (2002), Samen (2013), Ocampo et al. (2019), and Gilbert (2003) either used Parasuram et al. (1988)'s original SERVQUAL dimension or added extra dimensions that fits certain industries. However, several authors tried to completely create new service quality measures based on the industries they studied such as E-S-Qual and others introduced by Ojasalo (2010). Yoo (2001) studied people's online shopping habit and created own service quality dimension called "Sitequal". Madu (2002) also made its own dimensions for quality for virtual operations by adding factors such as performance features, structure, and aesthetics. With the development of new technologies, measuring service quality of video communication tools with previously used dimensions didn't seem suitable. Recent technologies and other areas involving electronic service quality does not have direct interaction with customers as other industries such as airline and healthcare. Therefore, the following study will first gather service quality measures from various studies that fit the category of video communication tools. Then, based on the literature review and survey, we will decide service quality dimensions that users consider the most important when using video communication tools.

3.2 Service Quality dimensions in video communication tools

Based on the literature review, nine service quality dimensions will be evaluated by users of video communication tools as dimensions that need to be considered. These measures were derived from literature review of SERVQUAL and Electronic SERVQUAL used by authors mentioned beforehand and Parasuraman (1988), Zeithaml (2005), Kang (2016), Pham (2018), and Yoo (2001).

First of all, reliability refers to the ability to perform the promised service reliably and accurately. People should consider whether video communication tools are capable of delivering service by updating some of its new features and making sure users can effectively communicate with others. As one of the original service quality dimensions that Parasuraman et al. (1988) developed, Lai (2007), Büyüközkan et al. (2012) and many more scholars used reliability as dimensions. Next dimension is responsiveness, which is willingness to help customers and provide prompt service. There may be some errors when using the tools, and if it happens, it is important for the tool to promptly fix the problem. The third dimension is assurance, which, in this context, measures knowledge and courtesy of employees and their ability to inspire trust and confidence. For this specific industry, video communication tools need to ensure that their employees are knowledgeable about their action, courteous in their responses, and able to give confidence and trust to users. Assurance was used in various studies related to E-SQ and service quality such as Lai (2007) and Samen (2013). The fourth dimension is tangibles, which refer to video communication tool icon and display appearance. Every tool has different interface, so users can think of how physical attributes, animations and appearance of tools are shown. The fifth dimension is empathy, which means caring and individualized attention tools provide to its customers. Even though there is no direct human interaction in video communication tools, certain human contacts exist such as through e-mail communications. Therefore, users can determine whether video communication tools provide individualized attention to customer's concerns and requests. The next one is efficiency, which indicates ease and speed of access and use of communication tool. Since video communication tools are widely used in businesses, many use it to save time and handle urgent matters. Therefore, it would be important for tools to offer efficient service to users. Kang (2016) and Yi (2016) also used efficiency as one of the dimensions in electronic service quality context. The seventh dimension is functionality. Since video communication tools these days offer various extra features such as voting polls, chat service, screen sharing, and additional background options, it is important for video communication tools to offer technically sound and convenient functions. Functionality was recently used as service quality dimensions in Kumar (2017). The next one is security, which refers to safety when using video communication tools that protects privacy of personal information and content of communication. It would be important for companies to have video communication tools that are safe from cyber-attacks since personal information and content of communications could be confidential. As security is a crucial factor when using mobile devices, it was emphasized in Pham (2018) and Yoo (2001). The last service quality dimension is connectivity. Video communications tools have a server system to keep the communication smooth, which plays an essential role in making tools successful. Connectivity here means that users can have continuous communication among people by using video communications tools, which consists of compatibility, standardization and smooth networks. Connectivity was one of the first electronic service quality dimensions in Parasuraman et al. (1988), and Pham (2018) also utilized it.

Through Google Forms, question about service quality dimension of video communication tools were asked to college students and company employees in age range of 20~30s. People were asked to choose five dimensions among nine of them that they think are important. Total of 107 responses were collected. Among nine dimensions, connectivity (83 votes), efficiency (82 votes), security (70 votes), reliability (61 votes), and functionality (57 votes) were chosen as five important service quality dimensions when using video communication tools.

4. Research Method

4.1 Fuzzy AHP

Analytic Hierarchy Process (AHP) was first developed by Saaty (1980), and it is widely used to tackle MCDM problems in real life application. AHP analyses a MCDM problem by setting up a hierarchy of criteria and sub-criteria. AHP takes advantage of analyzing, structuring, and stratifying problems, as well as calculating relative weights and preferences in a systematic ratio. However, AHP itself has underlying limitations since experts believe that making decisions based on criteria can have subjective bias, so they started to integrate fuzzy set theory with AHP. Fuzzy theory extends the existing set theory to reflect the ambiguity and inaccuracy caused by the lack of complete information. It compensates MCDM problems to deal with intrinsic inaccuracies and ambiguities that occur in the decision-making process of evaluators. Fuzzy number can be expressed as triangular and trapezoidal fuzzy numbers, but this research focused on triangular fuzzy numbers. Fuzzy set $\tilde{A}$ can be described by a triplet (l,m,u), where u is greater than m and m is greater than l.

Fuzzy AHP is a useful method when evaluating certain factors because decision makers' views on various criteria play a key role in solving a problem. In addition, fuzzy AHP solves ambiguity and uncertainty problems and decision makers' judgments are expressed as intervals rather than single numbers. Each paper determines its number scale for triangular or trapezoidal fuzzy numbers slightly differently, but usually, a questionnaire is received, and people's answer can be written as linguistic variable. After that, the weight is calculated by changing the answers to fuzzy triangle number scale, and the criteria are ranked based on the weight. There were several studies that compared results coming from both AHP and fuzzy AHP. Mo (2012) used AHP and fuzzy AHP to figure out the importance of the industrial sector according to country-specific FTA. When using both techniques, results were more structured when using fuzzy AHP than when using AHP. In addition, Ozdagoglu (2007) stated that with complex economic condition these days, decision making process takes place in fuzzy environment, which makes fuzzy AHP more preferred.

Therefore, in this study, we apply fuzzy AHP to derive and express people's opinion as fuzzy numbers and rank people's views about video communication tools. This study follows fuzzy AHP method used by Cheng (1997) and utilizes relative importance of the unfuzzy composite decision matrix.

4.2 Fuzzy TOPSIS

The Technique for Order of Preference by Similar to Ideal Solution (TOPSIS) was first proposed by Hwang and Yoon (1981). However, identical to AHP, TOPSIS could not reflect human style thinking with expressing preferences in crisp number. Therefore, fuzzy logic was combined with TOPSIS to express human judgements and assign the importance of factors using fuzzy numbers.

Fuzzy TOPSIS is a method in which a decision maker chooses the best alternatives that are closest to IS (Ideal Solution) and farthest from NIS (Negative Ideal Solution) for the alternatives that they think are the most ideal and the worst. The method was further developed by Chen and Hwang (1992). In fuzzy TOPSIS, similar to fuzzy AHP, evaluations are first expressed by linguistic terms, which can later be indicated as fuzzy numbers.

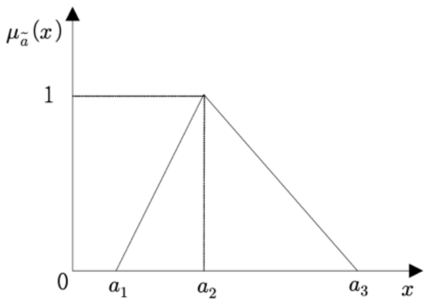
Kabir (2012) used both TOPSIS and fuzzy TOPSIS to evaluate travel website service quality and argued that, when it is tough to assign a precise performance rating, it is better to show the importance using fuzzy numbers. According to the study, fuzzy TOPSIS is a better choice to solve the imprecise performance ratings. Ataei (2013) and Jahanshashloo et al. (2006) also used both methods and suggested fuzzy TOPSIS as a more dependable method when compared with TOPSIS.

4.3 Combination of Fuzzy AHP and Fuzzy TOPSIS

The following are nine steps that combine fuzzy AHP and TOPSIS to find fuzzy decision matrix value and crisp value. In these steps, alternative refers to four video communication tools choices and criteria refers to five service quality dimensions chosen earlier.

Step 1. Build a hierarchical model/table within the criteria by making a list of decision goals, evaluation criteria, and alternatives.

Step 2. Set the language scale for evaluating criteria and the language variables for evaluating alternatives. Language scales and language variables are assumed to follow the triangular fuzzy number as shown below. Subjects will evaluate the evaluation criteria and alternatives based on language scale and language variables.



<Figure 1: Triangular Fuzzy Number>

Step 3. A fuzzy matrix is obtained for each triangular fuzzy number evaluated by subjects for each alternative and evaluation criteria. We can define the fuzzy performance measures evaluated by decision maker as following:

$$\tilde{R}_k = (a_k,\ b_k,\ c_k),\ k = 1,\ 2,\ \dots,\ K$$

Therefore, aggregated fuzzy performance measures can be defined as following: b_k

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

Step 4. For each alternative ($\tilde{D}$) and criteria ($\tilde{W}$), fuzzy decision matrix can be calculated as following:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots\cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots\cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots\cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots\cdots & \tilde{x}_{mn} \end{bmatrix} \end{array},$$

$$i = 1,\ 2,\ \dots,\ m;\ j = 1,\ 2,\ \dots,\ \mathrm{n}$$

$$\tilde{W} = [\tilde{w}_1,\ \tilde{w}_2,\ \dots,\ \tilde{w}_n]^T$$

Step 5. The next step is to normalize the fuzzy decision matrix. The normalized fuzzy decision matrix ($\tilde{R}$) is computed as

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n},\ i = 1,\ 2,\ \dots,\ m;\ j = 1,\ 2,\ \dots,\ n$$

Step 6. The normalized decision matrix is multiplied by the alternative to find the decision matrix with weights. By multiplying the normalized decision matrix ($\tilde{R}$) by the weight vector ($\widetilde{W}$) for the alternative, the fuzzy decision matrix given weight $\tilde{A}$ can be obtained as follows.

$$\widetilde{A} = \widetilde{R} \otimes \widetilde{W} = \begin{bmatrix} \tilde{r}_{11} \times \tilde{w}_1 & \tilde{r}_{12} \times \tilde{w}_2 & \cdots\cdots & \tilde{r}_{1n} \times \tilde{w}_n \\ \tilde{r}_{21} \times \tilde{w}_1 & \tilde{r}_{22} \times \tilde{w}_2 & \cdots\cdots & \tilde{r}_{2n} \times \tilde{w}_n \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{m1} \times \tilde{w}_1 & \tilde{r}_{m2} \times \tilde{w}_2 & \cdots\cdots & \tilde{r}_{mn} \times \tilde{w}_n \end{bmatrix}$$

Step 7. Assuming that the above elements a_{ij} of the decision matrix $\tilde{A}$ are triangular fuzzy numbers, (a_1, a_2, a_3), following α−cut $(0 \leq \alpha \leq 1)$ can be used to find the degree of fuzziness.

$$\tilde{A}_{\alpha} = [\alpha_1^{\alpha}, \ \alpha_3^{\alpha}] =$$

$$[(\alpha_2 - \alpha_1)\alpha + \alpha_1, -(\alpha_3 - \alpha_2)\ \alpha + \alpha_3]$$

Step 8. The element $(\breve{\alpha}_{ij})\alpha$ of $\tilde{A}\alpha$ obtained by α−cut can be expressed as an upper limit value and a lower limit value. If we can say, $(\breve{\alpha}_{ij})\alpha = [lij, u_{ij}]$, defuzzied comprehensive decision matrix's $\tilde{A}$ elements are as follows:

$$\breve{\alpha}_{ij} = (1-\lambda)\, l_{ij} + \lambda u_{ij} \quad \text{if and only if} \quad 0 \leq \lambda \leq 1$$

Step 9. A sum of each column of matrix, Ã, which is $\check{s}_k = \sum_{j=1}^{n} \breve{\alpha}_{kj}$ ($k = 1,2,\ldots,m$), can be calculated as following to calculate weight φ_i of alternatives.

$$\varphi_i = \frac{\check{s}_i}{\sum_{k=1}^{m} \check{s}_k}$$

5. Results

5.1 Users survey

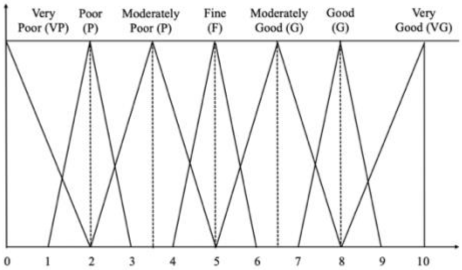
After discerning five service quality dimensions for the following research, there were two main questions left to answer. The first one was to figure out how people perceive and think which five service quality dimensions are important, and the next one was to assess how four alternatives (video communication tools) are doing in terms of those five service quality dimensions. Four video communication tools used for this study and the survey were chosen based on market share and rankings from the iOS and Android market. Survey about measuring service quality of four video communication tools was conducted using Amazon Mechanical Turk. Amazon MTurk is a paid crowdsourcing service that connects requesters and workers. People around the world are registered as workers, who voluntarily access and perform tasks. Target number of samples for this study was 100 participants. There were several qualification requirements designated for those who participated in the survey. First of all, those who had “Masters” title could only participate. Amazon MTurk monitors and analyzes worker’s performance, and workers who demonstrated excellent performance across various tasks are awarded the Masters status. Masters are constantly monitored by the system to maintain their status. Secondly, only those that were located in the US could participate. Main reason for applying this qualification was that North America has the biggest market due to early adoption and success of many video communication tool companies. Third, participants must possess US Bachelor’s Degree. These were the qualifications that were chosen from various options that Amazon MTurk provided. Most importantly, participants must have experience with all four communication tools. The survey that was uploaded to Amazon MTurk was prepared by Google Docs with six questions to answer. The examples of questions were as follows: when using video communication tools, how important are five service quality dimensions respectively? In addition, workers were asked to compare four video communication tools such as: how good is the Reliability when using A/B/C/D video communication tools? For the participants of the survey, A/B/C/D were displayed as actual name of the video communication tools. The questionnaire was shown in Appendix A table 1.

Initial survey was intended for 200 participants at a cost of \$1.50 per each survey and only ten surveys were collected. Second survey was for 100 participants at a cost of \$2.50 per each survey and nine of them were collected. Third one was planned for 50 participants at a cost of \$4.50 per each survey and all 50 were collected. Last survey was designed for 31 participants at a cost of \$4.50 per each survey and all of them were collected. There was no difference in qualification requirements, content, and questions of the survey. Difference between the first two surveys and the last two were the time the survey was uploaded and the amount of reward money for the survey. The upload time of the first two surveys was 3:03 am EST and 3:22 am EST, and the upload time of the last two surveys was 10:58am EST and 10:27 am EST. It is speculated that since the first two surveys were uploaded early in the morning, by the time people woke up and tried to participate in the surveys, the survey for this study may have been pushed to the back pages, which made it harder to get people’s attention. The last two surveys were planned to be uploaded for five days, but both took less than five hours to complete. In addition, on the Google Forms survey, Amazon MTurk workers’ individual IDs were collected ensure that same people did not participate in the survey multiple times.

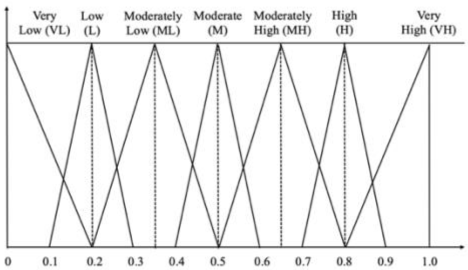
5.2 Fuzzy AHP and fuzzy TOPSIS results

The main goal of this research is to find a video communication tool that possesses the best quality based on the five criteria. Under this goal, five evaluation criteria were used: reliability (C1), efficiency (C2), functionality (C3), security (C4) and connectivity (C5). After that, four video communication tools, shown as A, B, C, and D were chosen as alternative subjects. The hierarchical model for this study is displayed in Appendix A figure 2.

First, subjects evaluated each of the five criteria (C1 ~ C5) and the linguistic variables considering alternatives using the figure 2 below.



<Figure 2: Language variable for evaluating alternatives>



<Figure 3: Language variable for importance of criteria>

For example, when subjects were asked about the reliability of A video communication tool, subjects who answered "Fine" were marked as F, and "Moderately Good" as MG, as seen in table 1. In this table, linguistic variables were also expressed. For example, linguistic variables such as "Good" and "Fine" were shown as triangular fuzzy numbers. Based on figure 2 above, table 1 also shows triangular fuzzy numbers such as (7,8,9) and (4,5,6). For display purpose, results for only ten decision makers will be shown, and rest of the results is shown in Appendix B. The following table 2 shows the results of Google Forms survey about how people think of five criteria (reliability, efficiency, functionality, security, connectivity) without considering specific video communication tools. Each answer is converted into triangular fuzzy numbers according to figure 3 above. For example, decision maker 1 has a standard of H (High) for efficiency. Therefore, according to the figure 3, H is converted to (0.7, 0.8, 0.9).

Table 1 Evaluation of alternatives - Triangular fuzzy number

*Criteria	Alternatives	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1 (Reliability)	A1(A)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A2(B)	F(4,5,6)	MG(5,6.5,8)	VG(8,10,10)	P(1,2,3)	F(4,5,6)	VG(8,10,10)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)
	A4(D)	F(4,5,6)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
C2 (Efficiency)	A1(A)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A2(B)	F(4,5,6)	VG(8,10,10)	VG(8,10,10)	P(1,2,3)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A3(C)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)
	A4(D)	MP(2,3.5,5)	VG(8,10,10)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
C3 (Functionality)	A1(A)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A2(B)	F(4,5,6)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)
	A3(C)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)
	A4(D)	MP(2,3.5,5)	G(7,8,9)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)
C4 (Security)	A1(A)	F(4,5,6)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MP(2,3.5,5)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A2(B)	MP(2,3.5,5)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	VG(8,10,10)	MP(2,3.5,5)	G(7,8,9)	G(7,8,9)	G(7,8,9)
	A3(C)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	F(4,5,6)	MP(2,3.5,5)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)
	A4(D)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MP(2,3.5,5)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
C5 (Connectivity)	A1(A)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)
	A2(B)	F(4,5,6)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)
	A4(D)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	F(4,5,6)	G(7,8,9)

Table 2 Importance weight of decision makers on evaluation criteria

*Criteria	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1 (Reliability)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)
C2 (Efficiency)	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)	ML (0.2, 0.35, 0.5)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)
C3 (Functionality)	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)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C4 (Security)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	ML (0.2, 0.35, 0.5)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	ML (0.2, 0.35, 0.5)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)
C5 (Connectivity)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)

Table 3 Fuzzy weights for alternatives (tools) and five criteria

Alternatives	C1 (Reliability)	C2 (Efficiency)	C3 (Functionality)	C4 (Security)	C5 (Connectivity)
A1(A)	(2, 7.79, 10)	(1, 7.7, 10)	(2, 7.54, 10)	(0, 6.01, 10)	(2, 7.43, 10)
A2(B)	(0, 7.31, 10)	(1, 7.16, 10)	(2, 7.37, 10)	(1, 7.32, 10)	(2, 7.42, 10)
A3(C)	(2, 7.66, 10)	(2, 7.45, 10)	(2, 7.31, 10)	(1, 7.1, 10)	(4, 7.49, 10)
A4(D)	(0, 6.59, 10)	(1, 6.68, 10)	(1, 6.68, 10)	(1, 7.29, 10)	(2, 6.51, 10)
Importance of evaluation criteria	(0.4, 0.9, 1)	(0.2, 0.87, 1)	(0.2, 0.78, 1)	(0.1, 0.77, 1)	(0.2, 0.86, 1)

Table 3 above shows the fuzzy weights for the alternatives and for evaluation criteria, which is service quality dimensions. Using the equation below, there are three triangular fuzzy numbers for each alternative: for example, in (2, 7.79, 10), the first number is the minimum number of all the first numbers in the same row (from table 1: Evaluation of alternatives – Triangular fuzzy number). The second number sums up all the second number from the same row and multiplies it by $\frac{1}{100}$, in which 100 comes from the total number of decision makers. The third number is the maximum number of all the third numbers in same row. From table 3, the row named importance of evaluation criteria is calculated in the same way as explained above using the equation below. However, the following row is calculated by numbers from table 2.

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

Table 4 multiplies fuzzy triangle numbers from the table 3 above by 0.1 to normalize the numbers. The following step is necessary to unify the numbers to the same form.

Table 5 is a weighted normalized decision matrix, which was calculated by multiplying table 4, normalized decision matrix, with the importance of evaluation criteria row from the same table. For example, when people think of functionality while using video communication tools A (A1 of C3), it would be calculated as (0.2 * 0.2, 0.754 * 0.78, 1 * 1), which results in (0.04, 0.588, 1).

Table 6 uses the alpha−cut to adjust the fuzzy degree and is calculated by plugging in the numbers from table 5 and α=0.8 and λ=0.5 to the equation below knowing that triangle fuzzy number has a form of (a_1, a_2, a_3). Thus, A1 of C1 would end up with a value of 0.669 as shown in the calculation below. The following calculation may depend on the size of the α value. The fuzzy logic is the study of ambiguity, and there may be some degree of error. Therefore, alpha−cut is used to define the limit of an acceptable degree of error. For crisp results, calculations with α values of 0.5 and 0.2 were also done. Although there was a difference in gap of the ranking between alternatives, the final ranking within four alternatives did not change.

$$\tilde{A}_\alpha = [a_{1\alpha}, a_{3\alpha}] = [(a_2 - a_1)\alpha + a_1, -(a_3 - a_2)\alpha + a_3]$$
$$\breve{a}_{ij} = (1-\lambda)l_{ij} + \lambda_{\text{uij}}$$

Lastly, to calculate the final weight, weights of all five criteria (reliability, efficiency, functionality, security, connectivity) were added up, and the number was divided by the added-up weights of four video communication tools. In the case of video communication tool A from table 6, five values of 0.669, 0.638, 0.574, 0.47, and 0.615 for each service quality dimensions were added to give 2.966. This was divided by 11.261, which is the added-up weight of four video communication tools with each dimension, yielding the final weight of 0.263.

The result showed that company C had the highest final weight of 0.267 followed by company A, which had 0.263 and by a slight margin, company B had 0.262. The gap between the first three video communication tools and company D was quite large with D's weight of 0.207. As of mid-December 2020, A is currently the number one mobile application in entire iOS App Store ranking, but according to the result, users felt C was the most satisfactory video communication tool. In business category of the iOS app store, B ranked the second, followed by C. Of the five categories, in reliability, A had the highest weight of 0.669 followed by C with 0.659. The difference between A and D, which ranked the last, was 0.095. In efficiency, A also ranked the first with 0.638 followed by C with 0.622. In functionality, A had the highest weight of 0.574, followed by B with 0.564 and C with just 0.004 short. Interestingly, the concern of security issue in A stood out from the result. A had the lowest weight in security with 0.47, and B had the highest weight with 0.552 followed by D with 0.55. This showed that users that participated in the survey and used all four communication tools were already aware of the security problem. Although B had the highest weight with 0.552 in security, compared to other categories, 0.552 is a fairly low number, which indicates all four tools need to focus more on security. In connectivity category, C had the highest weight of 0.623 followed by A with 0.615 and B with 0.614. Of the five criteria, most video communication tools seemed to do well on reliability and connectivity, since three out of four tools had weights over 0.6. The tools seemed to be not doing well in terms of their functionality and security. For those two service quality dimensions, none of the tools had a weight over 0.6.

Table 4 Normalized Decision Matrix

Alternatives	C1 (Reliability)	C2 (Efficiency)	C3 (Functionality)	C4 (Security)	C5 (Connectivity)
A1(A)	(0.2, 0.779, 1)	(0.1, 0.77, 1)	(0.2, 0.754, 1)	(0, 0.601, 1)	(0.2, 0.743, 1)
A2(B)	(0, 0.731, 1)	(0.1, 0.716, 1)	(0.2, 0.737, 1)	(0.1, 0.732, 1)	(0.2, 0.742, 1)
A3(C)	(0.2, 0.766, 1)	(0.2, 0.745, 1)	(0.2, 0.731, 1)	(0.1, 0.71, 1)	(0.4, 0.749, 1)
A4(D)	(0, 0.659, 1)	(0.1, 0.668, 1)	(0.1, 0.668, 1)	(0.1, 0.729, 1)	(0.2, 0.651, 1)
Importance of evaluation criteria	(0.4, 0.9, 1)	(0.2, 0.87, 1)	(0.2, 0.78, 1)	(0.1, 0.77, 1)	(0.2, 0.86, 1)

Table 5 Weighted normalized decision matrix

Alternatives	C1 (Reliability)	C2 (Efficiency)	C3 (Functionality)	C4 (Security)	C5 (Connectivity)
A1(A)	(0.08, 0.701, 1)	(0.02, 0.67, 1)	(0.04, 0.588, 1)	(0, 0.463, 1)	(0.04, 0.639, 1)
A2(B)	(0, 0.658, 1)	(0.02, 0.623, 1)	(0.04, 0.575, 1)	(0.01, 0.564, 1)	(0.04, 0.638, 1)
A3(C)	(0.08, 0.689, 1)	(0.04, 0.648, 1)	(0.04, 0.57, 1)	(0.01, 0.547, 1)	(0.08, 0.644, 1)
A4(D)	(0, 0.593, 1)	(0.02, 0.581, 1)	(0.02, 0.521, 1)	(0.01, 0.561, 1)	(0.04, 0.56, 1)

Table 6 Defuzzified value when α=0.8 and λ=0.5, and final weight of each evaluation

Alternatives	C1 (Reliability)	C2 (Efficiency)	C3 (Functionality)	C4 (Security)	C5 (Connectivity)	Final Weight
A1(A)	0.669	0.638	0.574	0.47	0.615	0.263
A2(B)	0.626	0.6	0.564	0.552	0.614	0.262
A3(C)	0.659	0.622	0.56	0.539	0.623	0.267
A4(D)	0.574	0.567	0.519	0.55	0.552	0.207

6. Discussion

6.1 Conclusion

This study was the first study to analyze the capability of the MCDM methods, specifically combining fuzzy AHP and TOPSIS, to assess service quality of new rising technology such as video communication tools. Although fuzzy AHP and TOPSIS were widely used to assess service quality of various industries, none of them considered such 4th industry technology. Five quality dimensions used in the study were established for the usage of video communication tools. From the literature review, there were no service quality dimensions that could be applied to this particular study. Through surveys from the users and literature review, five quality dimensions were chosen from nine possible choices, which were reliability, functionality, efficiency, security and connectivity. The four most used video communication tools were chosen as alternatives. In order to reflect the subjective opinions from survey participants, fuzzy AHP and TOPSIS were combined to calculate the weight and rank the alternatives. For the survey required to perform fuzzy method, Amazon MTurk was used to collect 100 surveys. The result showed that video communication tool C had the best service quality, which proved differently than actual market share of four video communication tools.

6.2 Managerial Implication

As Covid-19 is expected to continue for a long time or stay with us just like flu, market for video communication tools is expected to grow in even faster rate. Recent surge of growth in global video communication market and usage of these tools around the world adds to how much this study can contribute to real world.

Managers of these video communication tools may use these results to improve its features and functions to users according to the results and users' perception of quality. These results indicate that the actual gap between four video communication tools is slimmer than the market share presented, which shows that any improvement in the weaknesses can be a huge opportunity for the company. Most of the companies are benefitting from using video communication tools because it increases productivity of work, saves time and accelerates decision-making process. Another important reason is that video communication tools are directly related to saving cost for the company, which is crucial for every business. These aspects reinforce the importance of improving service quality of video communication tools, and from current ongoing situation, all four companies grew immensely in sales and number of people using the tools.

Of the five service quality dimensions, security and functionality were two categories with the lowest weight, which will require extra managerial efforts from the companies. Investing more resources into these areas will be crucial for companies to grow. The three companies in this study had the lowest weight in security out of five service quality dimensions, showing that it is the biggest concern among the users. Company A suffered several security issues that blocked companies from attracting more customers, and big conglomerates such as Tesla and Bank of America avoid using tools serviced by A (Wu, 2020). To further strengthen the security of video communication tools, confidential call policies or revision in settings might be some options for managers. Security will be an ongoing interest for all four companies as hackers will try to find ways to break through these programs. However, security is not the area that could be easily fixed, so it will take time and some regulation changes within the companies.

In terms of functionality, features that A, company with the biggest market share, offers and what others offer are similar. All tools provide video conferences that are easy to join and connects well. Therefore, from now on, competition between these companies will differentiate in what new features and products they offer. For example, some companies have noise cancelling software to block outside noise. Many companies that use A are spending less on it or moving onto B because every company use paid version of universal document system of B company. Since B includes access to video communication tool on its cost, it is much more cost-efficient to use B. Efficiency is also closely knitted with functionality because those features should be easy to use and access. The results of efficiency and functionality were very similar with only C ranking higher than B on efficiency and other way around for functionality. Considering that all four companies that service video communication tools are specified in IT, efficiency of many features will be expected to naturally follow.

For reliability, efficiency and connectivity, three of the applications out of four had a weight over 0.6, which proves that users are quite satisfied with how applications are operating. Since difference in weights within tools in those three dimensions are not big, slight edge in these areas can really boost usage of company's tool. In addition, there are more video communication tools alternatives that users can choose other than four mentioned in this study. Therefore, quality of video communication tools will become more and more prominent.

This unusual pandemic crisis hinted that velocity of innovation is increasing since technologies are more strategic than ever nowadays. In the future, it will be very important for companies to be the first to combine video communication tools with new technologies such as Augmented Reality or Virtual Reality. In addition, performance of these tools is related to quality, thus ranking and result have significant impacts to efficiency and success of these tools in future.

6.3 Limitations and Future Research

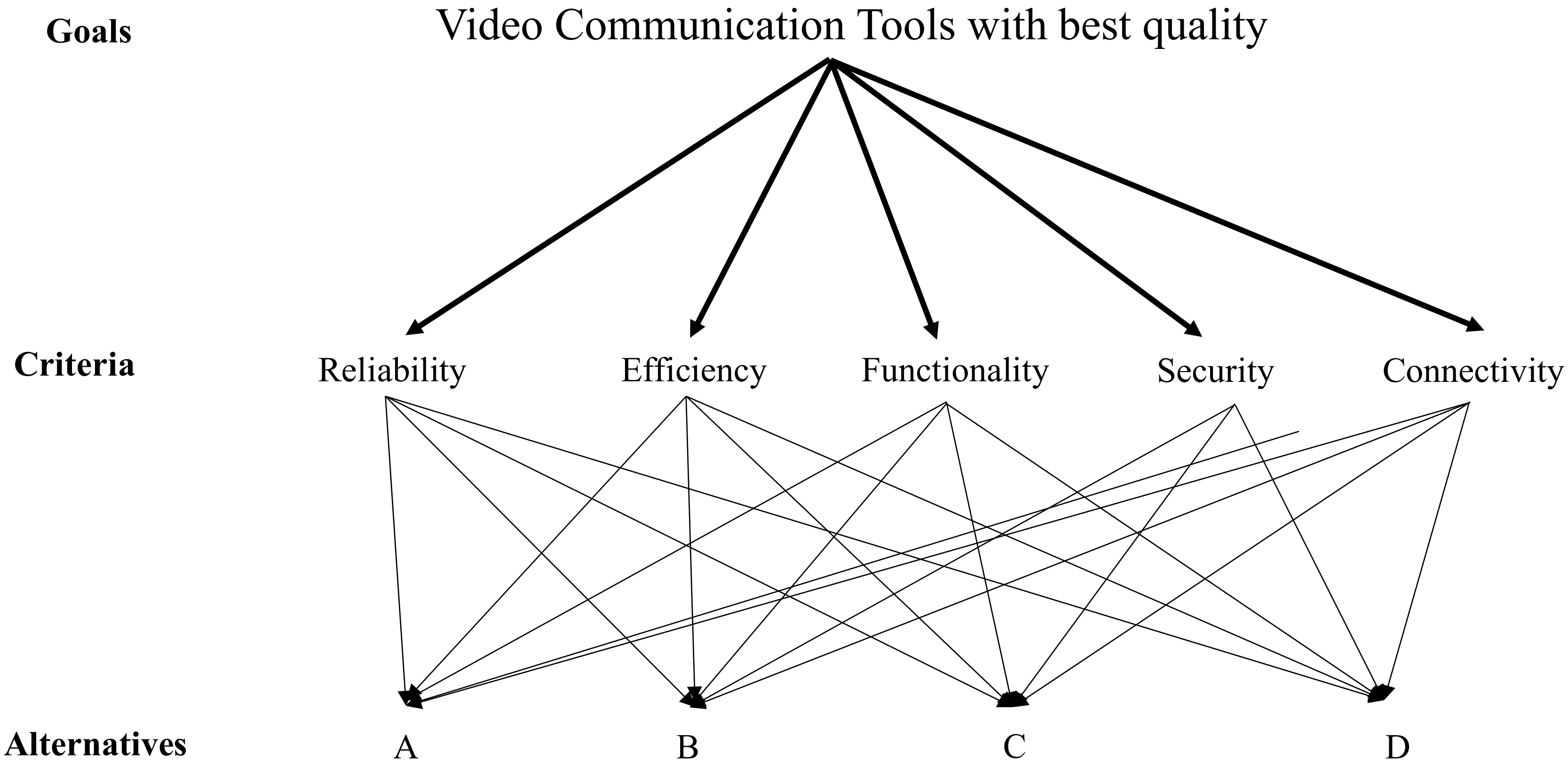
As with many studies, the following study has limitations. First, despite five service quality dimensions that took users' opinions into account, it does not cover all the factors when using the service. Other than survey and literature review, future studies may use different methods to select the factors that influence quality of service. There may be additional service quality measure that could be applied and considered for this study. It would also be meaningful to further dissect criteria to sub−criteria. Second, figuring out appropriate samples can be important factor. To specify the research, the survey was intended for those who possessed master's degree and resided in the United States. However, depending on the location of participants, background, age and status, the results might differ. In addition, future research may increase the number of samples. Larger samples may have allowed more worldly evaluation analysis. Since market share of video communication tools and results ended differently, it might be better to include more video communication tools to the study. Next, different statistical approach or MCDM methods may be used. This study used fuzzy AHP and TOPSIS for various purposes, but different techniques or approaches may bring different results. In addition, it might be meaningful to use conventional AHP and TOPSIS and compare the results with this study to see if different MCDM methods bring different results. Since there aren't any studies conducted based on video communication tools and its service quality, this study can be used as a cornerstone to further research. Last but not least, these service quality measures can be applied to other 4th industry revolution technologies such as AR/VR devices or those that involve Big Data and IoT.

Appendix A

Table A.1

NO.	QUESTION	SCALE
1	When using video communication tools, how important are five service quality dimensions respectively?	Very Low Low Moderately Low Moderate Moderately High High Very High
2	How good is the Reliability when using A/B/C/D video application tools?	Very Poor Poor Moderately Poor Fair Moderately Good Good Very Good
3	How good is the Efficiency when using A/B/C/D video application tools?	Very Poor Poor Moderately Poor Fair Moderately Good Good Very Good
4	How good is the Functionality when using A/B/C/D video application tools?	Very Poor Poor Moderately Poor Fair Moderately Good Good Very Good
5	How good is the Security when using A/B/C/D video application tools?	Very Poor Poor Moderately Poor Fair Moderately Good Good Very Good
6	How good is the Connectivity when using A/B/C/D video application tools?	Very Poor Poor Moderately Poor Fair Moderately Good Good Very Good

Figure A.2


Goals
Video Communication Tools with best quality
Criteria
Reliability
Efficiency
Functionality
Security
Connectivity
Alternatives
A
B
C
D

Appendix B

Table B.1 Evaluation of Alternatives – Triangular Fuzzy Number

*Criteria	Alternatives	DM11	DM12	DM13	DM14	DM15	DM16	DM17	DM18	DM19	DM20
C1 (Reliability)	A1(A)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)
	A2(B)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	VG(8,10,10)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A4(D)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)
C2 (Efficiency)	A1(A)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)
	A3(C)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	VG(8,10,10)
	A4(D)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)
C3 (Functionality)	A1(A)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)
	A2(B)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	VG(8,10,10)
	A3(C)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A4(D)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
C4 (Security)	A1(A)	F(4,5,6)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	MP(2,3.5,5)	G(7,8,9)	F(4,5,6)	F(4,5,6)	F(4,5,6)	F(4,5,6)
	A2(B)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	VG(8,10,10)
	A3(C)	VG(8,10,10)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	MG(5,6.5,8)	F(4,5,6)	MG(5,6.5,8)	G(7,8,9)
	A4(D)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	F(4,5,6)	G(7,8,9)	G(7,8,9)
C5 (Connectivity)	A1(A)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	F(4,5,6)	MG(5,6.5,8)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	F(4,5,6)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)
	A3(C)	VG(8,10,10)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	F(4,5,6)	F(4,5,6)	MG(5,6.5,8)	G(7,8,9)
	A4(D)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	G(7,8,9)

*Criteria	Alternatives	DM21	DM22	DM23	DM24	DM25	DM26	DM27	DM28	DM29	DM30
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	VP(0,0,2) VG(8,10,10) VG(8,10,10) P(1,2,3)	VG(8,10,10) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	MG(5,6.5,8) VG(8,10,10) G(7,8,9) G(7,8,9)	G(7,8,9) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) F(4,5,6) VG(8,10,10) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) VG(8,10,10)	G(7,8,9) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	F(4,5,6) G(7,8,9) G(7,8,9) MG(5,6.5,8)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	VP(0,0,2) F(4,5,6) VG(8,10,10) P(1,2,3)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	MG(5,6.5,8) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) VG(8,10,10) VG(8,10,10) VG(8,10,10)	G(7,8,9) VG(8,10,10) G(7,8,9) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	F(4,5,6) G(7,8,9) G(7,8,9) MG(5,6.5,8)
C3 (Functional ity)	A1(A) A2(B) A3(C) A4(D)	VP(0,0,2) VG(8,10,10) VG(8,10,10) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	MG(5,6.5,8) G(7,8,9) G(7,8,9) G(7,8,9)	F(4,5,6) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	MG(5,6.5,8) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) G(7,8,9) VG(8,10,10)	MG(5,6.5,8) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	F(4,5,6) VG(8,10,10) VG(8,10,10) MG(5,6.5,8)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	VP(0,0,2) VG(8,10,10) VG(8,10,10) VG(8,10,10)	MG(5,6.5,8) MG(5,6.5,8) G(7,8,9) G(7,8,9)	MP(2,3.5,5) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	MG(5,6.5,8) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) VG(8,10,10) VG(8,10,10) VG(8,10,10)	MG(5,6.5,8) VG(8,10,10) VG(8,10,10) VG(8,10,10)	G(7,8,9) G(7,8,9) G(7,8,9) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VP(0,0,2) VG(8,10,10) G(7,8,9) G(7,8,9)
C5 (Connectivi ty)	A1(A) A2(B) A3(C) A4(D)	VP(0,0,2) G(7,8,9) VG(8,10,10) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) VG(8,10,10) G(7,8,9) G(7,8,9)	MG(5,6.5,8) G(7,8,9) G(7,8,9) F(4,5,6)	VG(8,10,10) VG(8,10,10) VG(8,10,10) MG(5,6.5,8)	VG(8,10,10) VG(8,10,10) G(7,8,9) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	MP(2,3.5,5) VG(8,10,10) VG(8,10,10) MG(5,6.5,8)

*Criteria	Alternatives	DM31	DM32	DM33	DM34	DM35	DM36	DM37	DM38	DM39	DM40
C1 (Reliability)	A1(A)	F(4,5,6)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	VG(8,10,10)	G(7,8,9)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	F(4,5,6)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A4(D)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	VG(8,10,10)	VP(0,0,2)	F(4,5,6)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)
C2 (Efficiency)	A1(A)	F(4,5,6)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	G(7,8,9)
	A4(D)	G(7,8,9)	G(7,8,9)	G(7,8,9)	F(4,5,6)	F(4,5,6)	F(4,5,6)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
C3 (Functional ity)	A1(A)	MP(2,3.5,5)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MP(2,3.5,5)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A2(B)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	G(7,8,9)	F(4,5,6)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	G(7,8,9)
	A4(D)	G(7,8,9)	G(7,8,9)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)	P(1,2,3)	F(4,5,6)	MG(5,6.5,8)	MP(2,3.5,5)	G(7,8,9)
C4 (Security)	A1(A)	VP(0,0,2)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MP(2,3.5,5)	P(1,2,3)	G(7,8,9)	F(4,5,6)	F(4,5,6)	G(7,8,9)
	A2(B)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	F(4,5,6)	P(1,2,3)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	F(4,5,6)	P(1,2,3)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)
	A4(D)	MG(5,6.5,8)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	F(4,5,6)	P(1,2,3)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
C5 (Connectivi ty)	A1(A)	F(4,5,6)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	VG(8,10,10)	VG(8,10,10)	VG(8,10,10)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A3(C)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)
	A4(D)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)

*Criteria	Alternatives	DM41	DM42	DM43	DM44	DM45	DM46	DM47	DM48	DM49	DM50
C1 (Reliability)	A1(A)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MP(2,3.5,5)	G(7,8,9)	MP(2,3.5,5)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	MP(2,3.5,5)	F(4,5,6)
	A4(D)	G(7,8,9)	G(7,8,9)	F(4,5,6)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	F(4,5,6)
C2 (Efficiency)	A1(A)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	G(7,8,9)	G(7,8,9)	P(1,2,3)	VG(8,10,10)	G(7,8,9)	G(7,8,9)
	A2(B)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	P(1,2,3)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)
	A3(C)	MG(5,6.5,8)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
	A4(D)	MG(5,6.5,8)	F(4,5,6)	F(4,5,6)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
C3 (Functionality)	A1(A)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	VG(8,10,10)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	MG(5,6.5,8)	MP(2,3.5,5)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
	A3(C)	G(7,8,9)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	MP(2,3.5,5)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)
	A4(D)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	P(1,2,3)	MG(5,6.5,8)	F(4,5,6)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)
C4 (Security)	A1(A)	MG(5,6.5,8)	G(7,8,9)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	P(1,2,3)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MP(2,3.5,5)	MG(5,6.5,8)	MG(5,6.5,8)	G(7,8,9)
	A3(C)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)	F(4,5,6)	VG(8,10,10)	G(7,8,9)	MG(5,6.5,8)	G(7,8,9)
	A4(D)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	MG(5,6.5,8)	F(4,5,6)	F(4,5,6)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)
C5 (Connectivity)	A1(A)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	F(4,5,6)	MG(5,6.5,8)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)	MG(5,6.5,8)	MG(5,6.5,8)
	A2(B)	G(7,8,9)	VG(8,10,10)	G(7,8,9)	F(4,5,6)	MP(2,3.5,5)	F(4,5,6)	P(1,2,3)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
	A3(C)	G(7,8,9)	G(7,8,9)	VG(8,10,10)	F(4,5,6)	MP(2,3.5,5)	VG(8,10,10)	G(7,8,9)	G(7,8,9)	F(4,5,6)	MG(5,6.5,8)
	A4(D)	G(7,8,9)	G(7,8,9)	MG(5,6.5,8)	F(4,5,6)	MP(2,3.5,5)	F(4,5,6)	G(7,8,9)	VG(8,10,10)	MG(5,6.5,8)	MG(5,6.5,8)

*Criteria	Alternatives	DM51	DM52	DM53	DM54	DM55	DM56	DM57	DM58	DM59	DM60
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) MG(5,6.5,8) VG(8,10,10) G(7,8,9)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) F(4,5,6) MG(5,6.5,8)	VG(8,10,10) VG(8,10,10) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) VG(8,10,10) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) VG(8,10,10) F(4,5,6) F(4,5,6)	G(7,8,9) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	F(4,5,6) G(7,8,9) MG(5,6.5,8) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) F(4,5,6) VG(8,10,10) G(7,8,9)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) G(7,8,9) G(7,8,9) VG(8,10,10)	VG(8,10,10) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) VG(8,10,10) MG(5,6.5,8) F(4,5,6)	G(7,8,9) F(4,5,6) G(7,8,9) F(4,5,6)	F(4,5,6) G(7,8,9) F(4,5,6) G(7,8,9)	MG(5,6.5,8) F(4,5,6) G(7,8,9) G(7,8,9)
C3 (Functional ity)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) G(7,8,9) F(4,5,6) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) MG(5,6.5,8) F(4,5,6) F(4,5,6)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) VG(8,10,10)	G(7,8,9) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	F(4,5,6) G(7,8,9) F(4,5,6) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	MP(2,3.5,5) MG(5,6.5,8) F(4,5,6) G(7,8,9)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) MG(5,6.5,8) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) VG(8,10,10)	F(4,5,6) VG(8,10,10) VG(8,10,10) VG(8,10,10)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	MP(2,3.5,5) G(7,8,9) MG(5,6.5,8) G(7,8,9)	MP(2,3.5,5) MG(5,6.5,8) G(7,8,9) G(7,8,9)
C5 (Connectivi ty)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) G(7,8,9) VG(8,10,10) VG(8,10,10)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) F(4,5,6) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) G(7,8,9) VG(8,10,10) VG(8,10,10)	VG(8,10,10) VG(8,10,10) VG(8,10,10) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) VG(8,10,10)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	MG(5,6.5,8) VG(8,10,10) G(7,8,9) G(7,8,9)	MP(2,3.5,5) G(7,8,9) G(7,8,9) G(7,8,9)

*Criteria	Alternatives	DM61	DM62	DM63	DM64	DM65	DM66	DM67	DM68	DM69	DM70
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) MG(5,6.5,8) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) VP(0,0,2) MG(5,6.5,8) P(1,2,3)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	F(4,5,6) MG(5,6.5,8) MP(2,3.5,5) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) G(7,8,9) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) G(7,8,9) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) MG(5,6.5,8) G(7,8,9) MP(2,3.5,5)
C3 (Functionality)	A1(A) A2(B) A3(C) A4(D)	VG(8,10,10) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) F(4,5,6)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) G(7,8,9) G(7,8,9) MG(5,6.5,8)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) G(7,8,9) MP(2,3.5,5)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) G(7,8,9) G(7,8,9) MG(5,6.5,8)	F(4,5,6) MG(5,6.5,8) G(7,8,9) G(7,8,9)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) VG(8,10,10)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	MG(5,6.5,8) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) F(4,5,6) G(7,8,9) MP(2,3.5,5)
C5 (Connectivity)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	G(7,8,9) VG(8,10,10) VG(8,10,10) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) VG(8,10,10) VG(8,10,10) VG(8,10,10)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) F(4,5,6)	VG(8,10,10) F(4,5,6) G(7,8,9) F(4,5,6)

*Criteria	Alternatives	DM71	DM72	DM73	DM74	DM75	DM76	DM77	DM78	DM79	DM80
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	MP(2,3.5,5) MG(5,6.5,8) F(4,5,6) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)	MG(5,6.5,8) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) MP(2,3.5,5)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) G(7,8,9) F(4,5,6)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	MP(2,3.5,5) MP(2,3.5,5) MP(2,3.5,5) MP(2,3.5,5)	VG(8,10,10) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	MG(5,6.5,8) F(4,5,6) MG(5,6.5,8) MP(2,3.5,5)	F(4,5,6) MG(5,6.5,8) F(4,5,6) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) MG(5,6.5,8) G(7,8,9)	F(4,5,6) MG(5,6.5,8) G(7,8,9) F(4,5,6)	G(7,8,9) F(4,5,6) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) F(4,5,6)
C3 (Functional ity)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) F(4,5,6) MP(2,3.5,5) F(4,5,6)	MG(5,6.5,8) G(7,8,9) G(7,8,9) MG(5,6.5,8)	F(4,5,6) F(4,5,6) MG(5,6.5,8) MP(2,3.5,5)	F(4,5,6) G(7,8,9) MG(5,6.5,8) G(7,8,9)	VG(8,10,10) VG(8,10,10) VG(8,10,10) G(7,8,9)	MG(5,6.5,8) G(7,8,9) MG(5,6.5,8) G(7,8,9)	MP(2,3.5,5) F(4,5,6) MG(5,6.5,8) MG(5,6.5,8)	MG(5,6.5,8) VG(8,10,10) MG(5,6.5,8) F(4,5,6)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) VG(8,10,10) VG(8,10,10) F(4,5,6)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	MG(5,6.5,8) MP(2,3.5,5) MP(2,3.5,5) F(4,5,6)	MP(2,3.5,5) MG(5,6.5,8) F(4,5,6) G(7,8,9)	VP(0,0,2) MG(5,6.5,8) F(4,5,6) MG(5,6.5,8)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) G(7,8,9) MG(5,6.5,8) VG(8,10,10)	MP(2,3.5,5) F(4,5,6) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) G(7,8,9) F(4,5,6) G(7,8,9)	MP(2,3.5,5) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) F(4,5,6)
C5 (Connectivi ty)	A1(A) A2(B) A3(C) A4(D)	P(1,2,3) MP(2,3.5,5) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) MG(5,6.5,8) MG(5,6.5,8)	MP(2,3.5,5) MG(5,6.5,8) F(4,5,6) MG(5,6.5,8)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)	F(4,5,6) G(7,8,9) G(7,8,9) MG(5,6.5,8)	MG(5,6.5,8) G(7,8,9) G(7,8,9) F(4,5,6)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) F(4,5,6)

*Criteria	Alternatives	DM81	DM82	DM83	DM84	DM85	DM86	DM87	DM88	DM89	DM90
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) F(4,5,6) G(7,8,9) MG(5,6.5,8)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	G(7,8,9) VG(8,10,10) F(4,5,6) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) G(7,8,9) VG(8,10,10) G(7,8,9)	F(4,5,6) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) F(4,5,6)	G(7,8,9) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) VG(8,10,10)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	MG(5,6.5,8) G(7,8,9) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) G(7,8,9) VG(8,10,10) G(7,8,9)	P(1,2,3) F(4,5,6) MG(5,6.5,8) F(4,5,6)	F(4,5,6) MG(5,6.5,8) G(7,8,9) G(7,8,9)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)	G(7,8,9) G(7,8,9) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)
C3 (Functionality)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) G(7,8,9) G(7,8,9) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) VG(8,10,10) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	VG(8,10,10) G(7,8,9) G(7,8,9) VG(8,10,10)	F(4,5,6) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	F(4,5,6) MG(5,6.5,8) F(4,5,6) G(7,8,9)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) F(4,5,6)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) G(7,8,9) G(7,8,9) F(4,5,6)	F(4,5,6) F(4,5,6) F(4,5,6) MG(5,6.5,8)	MP(2,3.5,5) G(7,8,9) F(4,5,6) MG(5,6.5,8)	MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8) MG(5,6.5,8)	F(4,5,6) G(7,8,9) VG(8,10,10) G(7,8,9)	F(4,5,6) F(4,5,6) F(4,5,6) F(4,5,6)	MG(5,6.5,8) G(7,8,9) MG(5,6.5,8) VG(8,10,10)	MG(5,6.5,8) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) MG(5,6.5,8) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)
C5 (Connectivity)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) VG(8,10,10)	F(4,5,6) F(4,5,6) F(4,5,6) G(7,8,9)	G(7,8,9) VG(8,10,10) G(7,8,9) MG(5,6.5,8)	G(7,8,9) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) VG(8,10,10) VG(8,10,10)	MP(2,3.5,5) F(4,5,6) F(4,5,6) F(4,5,6)	MG(5,6.5,8) F(4,5,6) MG(5,6.5,8) G(7,8,9)	MG(5,6.5,8) F(4,5,6) F(4,5,6) MP(2,3.5,5)	MG(5,6.5,8) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)

*Criteria	Alternatives	DM91	DM92	DM93	DM94	DM95	DM96	DM97	DM98	DM99	DM100
C1 (Reliability)	A1(A) A2(B) A3(C) A4(D)	MG(5,6.5,8) MG(5,6.5,8) G(7,8,9) F(4,5,6)	G(7,8,9) F(4,5,6) G(7,8,9) P(1,2,3)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) F(4,5,6) MG(5,6.5,8) F(4,5,6)	G(7,8,9) G(7,8,9) VG(8,10,10) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)	G(7,8,9) MG(5,6.5,8) MG(5,6.5,8) G(7,8,9)
C2 (Efficiency)	A1(A) A2(B) A3(C) A4(D)	F(4,5,6) F(4,5,6) G(7,8,9) MP(2,3.5,5)	G(7,8,9) F(4,5,6) G(7,8,9) P(1,2,3)	VG(8,10,10) G(7,8,9) G(7,8,9) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) F(4,5,6) MG(5,6.5,8) F(4,5,6)	MG(5,6.5,8) F(4,5,6) G(7,8,9) F(4,5,6)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)
C3 (Functional ity)	A1(A) A2(B) A3(C) A4(D)	G(7,8,9) MG(5,6.5,8) G(7,8,9) F(4,5,6)	G(7,8,9) F(4,5,6) G(7,8,9) F(4,5,6)	G(7,8,9) G(7,8,9) MG(5,6.5,8) G(7,8,9)	G(7,8,9) G(7,8,9) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) F(4,5,6) MG(5,6.5,8) F(4,5,6)	F(4,5,6) MG(5,6.5,8) F(4,5,6) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) G(7,8,9) VG(8,10,10) VG(8,10,10)
C4 (Security)	A1(A) A2(B) A3(C) A4(D)	MP(2,3.5,5) F(4,5,6) F(4,5,6) G(7,8,9)	P(1,2,3) F(4,5,6) F(4,5,6) MG(5,6.5,8)	P(1,2,3) G(7,8,9) F(4,5,6) MG(5,6.5,8)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) F(4,5,6) MG(5,6.5,8) F(4,5,6)	G(7,8,9) VG(8,10,10) VG(8,10,10) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	MP(2,3.5,5) MG(5,6.5,8) G(7,8,9) MG(5,6.5,8)
C5 (Connectivi ty)	A1(A) A2(B) A3(C) A4(D)	F(4,5,6) F(4,5,6) MG(5,6.5,8) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	F(4,5,6) MG(5,6.5,8) MG(5,6.5,8) F(4,5,6)	G(7,8,9) G(7,8,9) G(7,8,9) G(7,8,9)	VG(8,10,10) VG(8,10,10) G(7,8,9) G(7,8,9)	VG(8,10,10) F(4,5,6) MG(5,6.5,8) F(4,5,6)	VG(8,10,10) G(7,8,9) G(7,8,9) MG(5,6.5,8)	VG(8,10,10) F(4,5,6) F(4,5,6) F(4,5,6)	VG(8,10,10) G(7,8,9) MG(5,6.5,8) G(7,8,9)	VG(8,10,10) G(7,8,9) G(7,8,9) VG(8,10,10)

Table B.2 Importance weight of decision makers on evaluation Criteria

*Criteria	DM11	DM12	DM13	DM14	DM15	DM16	DM17	DM18	DM19	DM20
C1 (Reliability)	VH (0.8, 1,1)	VH (0.8, 1,1)	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)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C2 (Efficiency)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	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)	MH (0.5, 0.65, 0.8)
C3 (Functionality)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	VH (0.8, 1,1)	ML (0.2, 0.35, 0.5)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)
C4 (Security)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)
C5 (Connectivity)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)

*Criteria	DM21	DM22	DM23	DM24	DM25	DM26	DM27	DM28	DM29	DM30
C1 (Reliability)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C2 (Efficiency)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C3 (Functionality)	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)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C4 (Security)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)
C5 (Connectivity)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)

*Criteria	DM31	DM32	DM33	DM34	DM35	DM36	DM37	DM38	DM39	DM40
C1 (Reliability)	H (0.7, 0.8, 0.9)	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)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)
C2 (Efficiency)	MH (0.5, 0.65, 0.8)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	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)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C3 (Functionality)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)
C4 (Security)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	ML (0.2, 0.35, 0.5)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)
C5 (Connectivity)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	ML (0.2, 0.35, 0.5)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)

*Criteria	DM41	DM42	DM43	DM44	DM45	DM46	DM47	DM48	DM49	DM50
C1 (Reliability)	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)	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)
C2 (Efficiency)	H (0.7, 0.8, 0.9)	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)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C3 (Functionality)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C4 (Security)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)
C5 (Connectivity)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)

*Criteria	DM51	DM52	DM53	DM54	DM55	DM56	DM57	DM58	DM59	DM60
C1 (Reliability)	VH (0.8, 1,1)	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)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)
C2 (Efficiency)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	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)
C3 (Functionality)	ML (0.2, 0.35, 0.5)	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)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C4 (Security)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	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)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)
C5 (Connectivity)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	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)	VH (0.8, 1,1)	VH (0.8, 1,1)

*Criteria	DM61	DM62	DM63	DM64	DM65	DM66	DM67	DM68	DM69	DM70
C1 (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)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C2 (Efficiency)	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)	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)	VH (0.8, 1,1)
C3 (Functionality)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C4 (Security)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	L (0.1, 0.2, 0.3)	MH (0.5, 0.65, 0.8)
C5 (Connectivity)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)

*Criteria	DM71	DM72	DM73	DM74	DM75	DM76	DM77	DM78	DM79	DM80
C1 (Reliability)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	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)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)
C2 (Efficiency)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)
C3 (Functionality)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	ML (0.2, 0.35, 0.5)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)
C4 (Security)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	ML (0.2, 0.35, 0.5)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)
C5 (Connectivity)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)

*Criteria	DM81	DM82	DM83	DM84	DM85	DM86	DM87	DM88	DM89	DM90
C1 (Reliability)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	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)
C2 (Efficiency)	ML (0.2, 0.35, 0.5)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	MH (0.5, 0.65, 0.8)
C3 (Functionality)	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)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	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)
C4 (Security)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)
C5 (Connectivity)	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)	VH (0.8, 1,1)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	M (0.4, 0.5, 0.6)	MH (0.5, 0.65, 0.8)	H (0.7, 0.8, 0.9)

*Criteria	DM91	DM92	DM93	DM94	DM95	DM96	DM97	DM98	DM99	DM100
C1 (Reliability)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	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)
C2 (Efficiency)	H (0.7, 0.8, 0.9)	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)	MH (0.5, 0.65, 0.8)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C3 (Functionality)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	H (0.7, 0.8, 0.9)	VH (0.8, 1,1)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C4 (Security)	H (0.7, 0.8, 0.9)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	MH (0.5, 0.65, 0.8)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)	H (0.7, 0.8, 0.9)
C5 (Connectivity)	VH (0.8, 1,1)	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)	VH (0.8, 1,1)	M (0.4, 0.5, 0.6)	VH (0.8, 1,1)	VH (0.8, 1,1)	H (0.7, 0.8, 0.9)

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국문초록

서비스 품질 척도와 다기준 의사결정방법을 이용한 비디오 협업툴의 품질 측정

김현창

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4차산업혁명 기술들의 발전과 코로나-19로 인한 사태가 장기화됨에 따라서 학교와 직장에서는 비디오 협업툴이 새로운 트렌드로 떠올랐고 현재는 전세계적으로 비디오 협업툴의 활용이 증가하고 있다. 따라서 본 연구는 서비스 품질 측정 도구들을 이용해서 비디오 협업툴의 품질을 측정한다. 본 연구의 적합한 서비스 품질 측정 척도가 없었기 때문에 문헌 연구와 1차적인 설문을 통해서 아홉개의 품질 측정 척도에서 비디오 협업툴에 가장 적합한 서비스 품질 척도 다섯 가지를 식별했다. 다섯가지로는 연결성, 효율성, 보안, 신뢰성, 기능성이 선정되었다.

이후 Amazon MTurk를 이용해서 다섯 가지 품질 척도가 현재 세계적으로 가장 많이 쓰이는 비디오 협업툴 4개를 대상으로 품질적으로 어떻게 평가되는지 2차 설문을 실시하였다. 그리고 퍼지AHP와 퍼지 TOPSIS 두가지 MCDM 툴을 활용해서 4개의 비디오 협업툴에 대한 가중치를 구해서 어느 협업툴이 어느 품질척도에서 가장 뛰어나고 협업툴끼리도 어느 협업툴이 가장 나은지 알아볼 수 있었다.

비디오 협업툴 4가지 중에서 C 협업툴이 종합적으로 가장 뛰어

나다는 평가를 받았고 그 뒤를 A,B,D 순으로 이어졌다. 신뢰성, 효율성, 기능성에서는 A사가 가장 뛰어난 품질을 가지고 있었고 연결성에서는 C사가 가장 뛰어났다. 보안에서는 D 협업툴이 가장 높은 가중치를 기록했고 A 협업툴이 가장 낮았다. 4개의 비디오 협업툴이 모두 기능성과 보안에서 가장 낮은 가중치를 기록했기 때문에 이 두가지 척도에 특별한 개선 사항이 필요하다는 것을 알 수 있었다. 비디오 협업툴과 같은 4차 산업혁명 기술에 대한 서비스 품질 연구는 거의 없었고 이 분야는 앞으로 더 많은 각광을 받을 분야이기 때문에 시사점과 개선 목표를 제시함과 동시에 향후 이 분야에서 경쟁력을 강화할 수 있는 참고자료로 활용되기를 목적으로 한다.

주요어 : 비디오 협업툴, 서비스 품질, 퍼지AHP, 퍼지TOPSIS, 다기준 의사결정방법

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