Frontiers in Economics and Management Volume 6 Issue 1, 2025
ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

DEMATEL-ANP Method for Evaluating the Importance Rating of Customer Requirements in Smart TV Industry

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Abstract

This research is conducted in order to scientifically judge the various types of customer requirements and their priorities in smart TV industry, to provide references to the design process of smart TVs, and to improve the customer satisfaction and competitiveness of related companies. The KJ method is utilized to establish a customer requirements factor system consisting of two levels of factors – the target level (the higher level) factors and the goal level (the lower level) factors. The DEMATEL method is then used to gain the interrelation among different factors. After which, considering the interrelation of factors and clusters, using ANP method to evaluate the importance rating of customer requirements. This process forms a kind of method for investigating customer requirements and ranking their importance. A case study focusing on a mid-to-high-end smart TV product of Company A is conducted as an example, verified the applicability of this method.

Keywords

DEMATEL; ANP; Customer Requirements; Smart TV.

1. Introduction

With the development of science, technology and the economy, the trend of mobile Internet is becoming increasingly widespread. Cell phones, tablets and other smart gadgets have been widely used. In China, televisions have gradually been marginalized from being an indispensable piece of furniture in ordinary households. Meanwhile, the real estate purchase restriction policies in China, along with the transformation of younger generation's consumption concept have further reduced the demand for television products. According to the data from AVC (All View Cloud) [1, 2] the scale of China's color TV market has been declining continuously in the past five years. In the first half of 2024, the sales volume of China's color TV market was 13.51 million units, a year-on-year decrease of 7.9%. The competition in TV industry has become increasingly fierce. In addition, after many years of development, the panel technology – the most important key technology of TV industry has entered a plateau period, which makes it rather difficult to make innovations in technology and services. At present, the price, quality, functions and services of TV products are becoming more and more homogeneous. How to win the favor of consumers and form differentiated competitiveness is the utmost important points for major TV companies to solve. [3]

With the rise of AI technology, tremendous changes have taken place in television industry. Smart TV, which means TV products equipped with high-performance chips and open operating systems, integrating functions such as audio-visual, entertainment and games through Internet technologies, are gradually replacing traditional TVs. By the end of 2022, the popularizing rate of global smart TV shipments had approached 95%, and it was as high as 99% in China. [4] Customers' requirements for TV products are also gradually changing, from merely meeting basic functions in the past to the current state of being highly personalized, intelligent

ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

and diversified. Whether it can meet customers' needs is the key to win the market. At present, the existing researches on the design of smart TV products mainly focused on the system design and environment design of intelligent household electrical appliance. There are little studies related to the design of smart TV products based on customer requirements. [5] However, for smart TV which has rich functions and few differences in key technologies, one that should be regarded as a more crucial starting point for its design is to identify the potential customer requirements and to satisfy them. Therefore, it is necessary to conduct a comprehensive investigation and analysis of customer requirements before designing smart TVs for making the products better meet customers' needs.

This research presents a method of customer demand acquisition and importance calculation in smart TV industry using DEMATEL – ANP method, which makes up for the deficiencies in the existing design process of smart TVs. Moreover, by taking a certain mid-to-high-end smart TV product of Company A - a traditional home appliance enterprise in China - as an example, the feasibility of the method is verified.

2. Literature Review

All factor prioritization evaluation studies in every fields have these following three processes: determining factors, estimating the interrelations between factors and ranking the importance of factors. How to exactly select factors to form a system and how to determine the weights of the factors varies according to the attributes of the industry.

Li et al. [6,7,8] proposed a method by using Lagrange function and rough sets theory in order to determine the initial importance rating of customer requirements. Haber et al. [9] used AHP method and fuzzy logic combined with QFD method to deal with the subjectivity, uncertainty and ambiguity of customer requirements, extended the traditional method of customer requirements collection and importance rating calculation. Lin [10] et al. used AHP combined with TOPSIS method to identify and calculate the importance rating of customer requirements to help in the evaluation of final design solutions. Ye et al. [11] considered both relative and absolute performances in the competitive analysis of customer requirements, extracted customer requirements using feature selection techniques, and determined the final importance of customer requirements using the maximum deviation approach, the power factors method and the weighted arithmetic mean method. Yang et al. [12] analyzed the competitive priority and sensitivity of customer requirements using intuitionistic fuzzy sets combined with improved Kano model. Xu et al. [13] transformed customer and expert evaluations of customer requirements importance into cloud model, reflecting both the fuzziness and randomness of evaluation information through cloud diagrams. Qiu et al. [14] proposed a combination of hesitant fuzzy DEMATEL and improved A-Kano model in QFD method to synthesize the objective importance rating of customer requirements, Kano importance and competitive importance to get the final importance of customer requirements. Lee et al. [15] used customer value as the evaluation system, utilizing ANP and niche theory to make program evaluation by introducing competitive factors among different products into customer preference.

As can be seen from the former academic research results, the focus and difficulty of academic research in the determination of customer requirements mainly lied in how to deal with the uncertainty, ambiguity and redundancy of the information expressed in customer requirements. In the determination of customer requirements importance, the traditional methods such as AHP and TOPSIS were often used in the calculation of customer requirements importance. When it comes to considering the interrelation of factors, DEMATEL and ANP methods were often introduced into the evaluating process.

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3. Research Methodology

Customer requirements is the needs, goals and expectations of customers for the products provided by enterprise, which is highly related to customer satisfaction. Whether the requirements can be accurately and sufficiently obtained is the key to successfully doing the subsequent steps of product and service system design. This research starts from the acquisition, screening and determination of the original information of customer requirements. After which, determining the interrelation of customer requirements, and then calculating the final importance rating of customer requirements. By these steps, establishing a set of systematic methods for acquiring and analyzing the customer requirements of product and service systems.

First, set up a research team. In terms of acquiring, screening and determining customer requirements, appropriate ways of collecting customer requirements is needed. In view of the characteristics of the original customer requirements, which are often repetitive, redundant and semantically ambiguous, the team adopt KJ method to classify and organize the original customer requirements, transforming the colloquial ambiguous expressions into relatively more rigorous terminological expressions, so as to determine the final customer requirements for the next step.

After determining customer requirements, it is necessary to carry out an importance rating evaluation of them to determine the order of different customer requirements' importance in the design of product and service systems. Traditional analysis methods, such as hierarchical analysis, are based on the assumption that the correlation between customer requirements is symmetric. However, in reality, the factors are often asymmetric to each other. Considering that customer requirements are often in large quantities, which are mutually inclusive, synergistic or contradictory and have contain complicated subjective and objective thoughts, this research utilizes the multi - criteria decision making (MCDM) method combining DEMATEL and ANP to deal with the customer requirements which have asymmetric correlation relationships. This method reveals the causal relationship among the customer requirements and carry out the objective order of importance rating, then combines the subjective experts' scoring to obtain the importance rating of the customer requirements.

3.1. Screening of Customer Requirements Factors and Construction of Factor System

According to the design requirements of smart TV and characteristics of TV industry, to start with, a relevant research team must be established. After which the team need to obtain customer requirements by method combined with questionnaire survey, desktop research and offline interviews. Then, the KJ method is used to organize and classify the customer requirements, eliminating ambiguities and redundancies in the original information. Finally, the customer requirements factor system with two levels: the low-level customer requirements and the high-level customer requirements is obtained.

3.2. The Detailed Procedures of DEMATEL Method

The customer requirements is expressed as C_i $(i = 1, 2, \ldots, n)$, and the importance rating degree given by the expert E_k $(k = 1, 2, \ldots, q)$ in the research team based on subjective experience is W_i $(i = 1, 2, \ldots, n)$. The 0~4 grading scale method is adopted to represent the degree of impact among customer requirements, where 0~4 respectively represent no direct impact, low impact, medium impact, strong impact, and very strong impact. After calculating the arithmetic mean results of the grades given by experts, the direct impact matrices among low-level customer requirements and high-level customer requirements respectively established. Since there is no impact when a factor is compared with itself, all the elements on

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the diagonal of the direct impact matrices are constantly 0. The form of the direct impact matrix W of customer requirements is established as follows:

$$W = \begin{bmatrix} 0 & w_{12} & \cdots & w_{1n} \\ w_{21} & 0 & \cdots & w_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & 0 \end{bmatrix} \tag{1}$$

Among which, w_{ij} indicates the extent to which customer requirements i impact customer requirements j.

Normalizing W yields the normalized direct relation matrix A:

$$W_{max} = max\{\sum_{j=1}^{n} w_{ij}\} \tag{2}$$

$$a_{ij} = \frac{w_{ij}}{W_{max}} \tag{3}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{m2} & \cdots & a_{nn} \end{bmatrix} \tag{4}$$

Calculate the total impact matrix T , where I is the unit matrix:

$$T = A(I - A)^{-1} \tag{5}$$

Among which, $T = \{t_{ij}\}_{n\times n}$.

This research proposes to choose an appropriate threshold value γ for the total impact matrix T in order to rationally ignore the less influential relationships in the total impact matrix T and to simplify the composite impact matrix and to further clarify the relationships.

The value of γ is obtained after discussions among experts. It is stipulated that the element smaller than γ can be ignored, and only the element in T larger than γ will be retained. According to the given threshold value γ, the final impact matrix T_A is like:

$$T_A = \begin{cases} 0, & t_{ij} < \gamma \\ t_{ij}, & t_{ij} \geq \gamma \end{cases} \tag{6}$$

The significance indicator M_i and the relation indicator N_i were calculated for the first i indicator:

$$D_i = \sum_{j=1}^{n} T_{ij} (i = 1,2,\ldots,n) \tag{7}$$

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$$E_i = \sum_{j=1}^{n} T_{ji} (i = 1,2,\ldots,n) \tag{8}$$

$$M_i = D_i + E_i \tag{9}$$

$$N_i = D_i - E_i \tag{10}$$

Where D_i is the total (direct and indirect) influence from indicator i to indicator j and E_i is the total influence from indicator j to i.

The significance indicator M_i represents the importance of the element, the relation indicator N_i represents the degree to which the element impacts other elements (which is positive number) or the degree to which the element is influenced by other factors (which is negative number).

3.3. The Detailed Procedures of ANP Method

In the process of determining factors' weights by using ANP method, the various factors are not isolated from each other but have mutual impact. Based on the final impact matrix T_A of two levels of customer requirements calculated by DEMATEL method in the previous text, this research will estimate and obtain the correlation relationships among low-level factors and high-level factors. According to the interrelations among these factors, a judgment matrix is established. After that, use SuperDecisions software to establish a ANP network interrelation structure diagram, with high-level customer requirements (judgment layer) as the main criterion and the low-level customer requirements (network layer) as the secondary criterion.

To fully consider the mutual impact among various factors, the 1~9 grading scale method is adopted. Through experts' scoring, scores are made on whether there are influence relationships for one factor among others. The factors are compared pairwise, and the judgment matrices of the first-level and second-level factors are established respectively.

SuperDecisions software will be utilized afterwards to calculate the unweighted super matrix, the weighted super matrix and the limit matrix. The column of the limit matrix will be the global priority vector ω'. The global weights of the customer requirements corresponding to ω' will be the final result of the importance rating of the factors, which is the final importance rating of the customer requirements, symbolled as k_i. Expressed in vector form with ω, it is shown in Equation 11 as follows:

$$\omega = [k_1, k_2, \ldots, k_n]^T \tag{11}$$

4. Case Study

4.1. Screening of Customer Requirements and Construction of Indicator System

This research choose a mid-to-high-end smart TV product of Company A as a case. A research team consisting of four engineers from the R&D and design departments, three marketing personnel and three customer representatives is set up to collect customer requirements and to construct a customer requirements factor system. The result is shown in Table 1.

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Table 1. The customer requirements factor system

High-level customer requirements	Low-level customer requirements
Great graphics (C_1)	Large screen (C_{11})
	High resolution (C_{12})
	Color reproduction (C_{13})
	Smooth motion (C_{14})
Excellent sound (C_2)	Surround sound (C_{21})
	Good sound quality (C_{22})
Reliable and durable (C_3)	Long life span (C_{31})
	Screen retains its color for a long time (C_{32})
	Retains good sound quality for a long time (C_{33})
Smooth running (C_4)	Lag-free system operation (C_{41})
	Smooth linkage with other devices, no delay in casting, maneuvering, etc. (C_{42})
Excellent interactive experience (C_5)	Clear and convenient interactive interface (C_{51})
	Supports connection to a wide range of devices in an intuitive and simple way (C_{52})
	Support voice, gesture, cell phone and other intelligent control (C_{53})
Rich functions and contents (C_6)	Wealthy in TV programs and game resources (C_{61})
	Software compatibility and scalability (C_{62})
Good after-sales experience (C_7)	Quick and easy repair and Q&A process (C_{71})

4.2. Determining Customer Requirements' Interrelation by DEMATEL Method

Table 2. Direct impact matrix of high-level customer requirements

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	1.2	0	3.2	1	0.5
C_2	0	0	1	0	2.4	1.2	0
C_3	1.8	1.6	0	2.2	2	0	1
C_4	0.6	0.8	2	0	3.8	2	1.8
C_5	1.8	0.8	0.4	1.8	0	2.2	1
C_6	1.2	1	1	2	2.5	0	1.5
C_7	0	0	1	1	0	1.2	0

Table 3. Direct impact matrix of low-level customer requirements

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{31}	...	C_{53}	C_{61}	C_{62}	C_{71}
C_{11}	0	1.2	1.4	2.8	0	0	0	...	0	0	0	0
C_{12}	3	0	0	2.8	0	0	0	...	0	0	0	0
C_{13}	1	1	0	0	0	0	1	...	0	0	0	0
C_{14}	1	2.2	1.8	0	0	0	0.8	...	1	0	0	0.6
C_{21}	0	0	0	0	0	1.2	0.6	...	0	0	0	0
C_{22}	0	0	0	0	2	0	0	...	0	0	0	0
C_{31}	0.8	2.4	2	1.8	1.4	2.8	0	...	0	1	2.2	2.2
...	...	...	...	...	...	...	...	0	...	...	...	...
C_{53}	2	1.4	0	1	0	0	0	...	0	0	0	1.2
C_{61}	0	0	0	0	0	0	0	...	3.2	0	3	0
C_{62}	0	0	0	0	0	0	0	...	0.6	1.2	0	1
C_{71}	0	0	0	0	0	0	1	...	1	0	1.2	0

ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

Through experts' scoring and by aggregating the scores of different experts, the direct impact matrices W of high-level customer requirements and low-level customer requirements are gained and are shown respectively in Table 2 and Table 3. Only part of the content of the direct impact matrices of the low-level customer requirements is listed due to space limitations.

The direct impact matrix is normalized and calculated through equation (2) to equation (4) to get the total impact matrix T by using matlab software. Then, according to equation (6) to equation (10), D_i and E_i of the high-level customer requirements are gained. After discussion among experts, the threshold value γ of the impact among the first-level factors is determined as 0.13. The total impact matrix T_A of the high-level is shown in Table 4:

Table 4. Total impact matrix for high-level Customer requirements

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0.003	0	0.2727	0	0
C_2	0	0	0	0	0.1548	0	0
C_3	0.0591	0.0499	0	0.2081	0.3096	0.0372	0.094
C_4	0.028	0.0836	0.1765	0.1573	0.5459	0.2656	0.2348
C_5	0.1264	0.039	0	0.2145	0.1766	0.1964	0.0981
C_6	0	0	0	0.1889	0.2489	0.0215	0.0814
C_7	0	0	0.0159	0.054	0.0131	0.0331	0

Following the previous method, the low-level customer requirements impact is then calculated. After discussion, the threshold value of the impact among the low-level factors γ is determined to be 0.046, and the final impact matrix T_A is shown in Table 5. Due to space limitation, the total impact matrix of low-level customer requirements is only listed partially.

Table 5. Total impact matrix for low-level Customer Requirements

	C_{11}	C_{12}	C_{13}	C_{14}	...	C_{53}	C_{61}	C_{62}	C_{71}
C_{11}	0	0.0623	0.0611	0.1124	...	0	0	0	0
C_{12}	0.1213	0	0	0.1186	...	0	0	0	0
C_{13}	0.0484	0.0506	0	0	...	0	0	0	0
C_{14}	0.0568	0.0954	0.0745	0	...	0	0	0	0
...	...	...	...	...	...	...	...	...	...
C_{53}	0.1105	0.0839	0	0.0601	...	0	0	0	0.0653
C_{61}	0	0	0	0	...	0.1523	0	0.1237	0
C_{62}	0	0	0	0	...	0.0494	0.0491	0	0.0519
C_{71}	0	0	0	0	...	0.0524	0	0.0532	0

4.3. Calculating Customer Requirements' Importance Rating Through ANP Method

According to the interrelation among factors in the Total impact matrices by DEMATEL method, the ANP network impact relationship model of the evaluation system is constructed through SuperDecisions software, as shown in Fig. 1:

ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

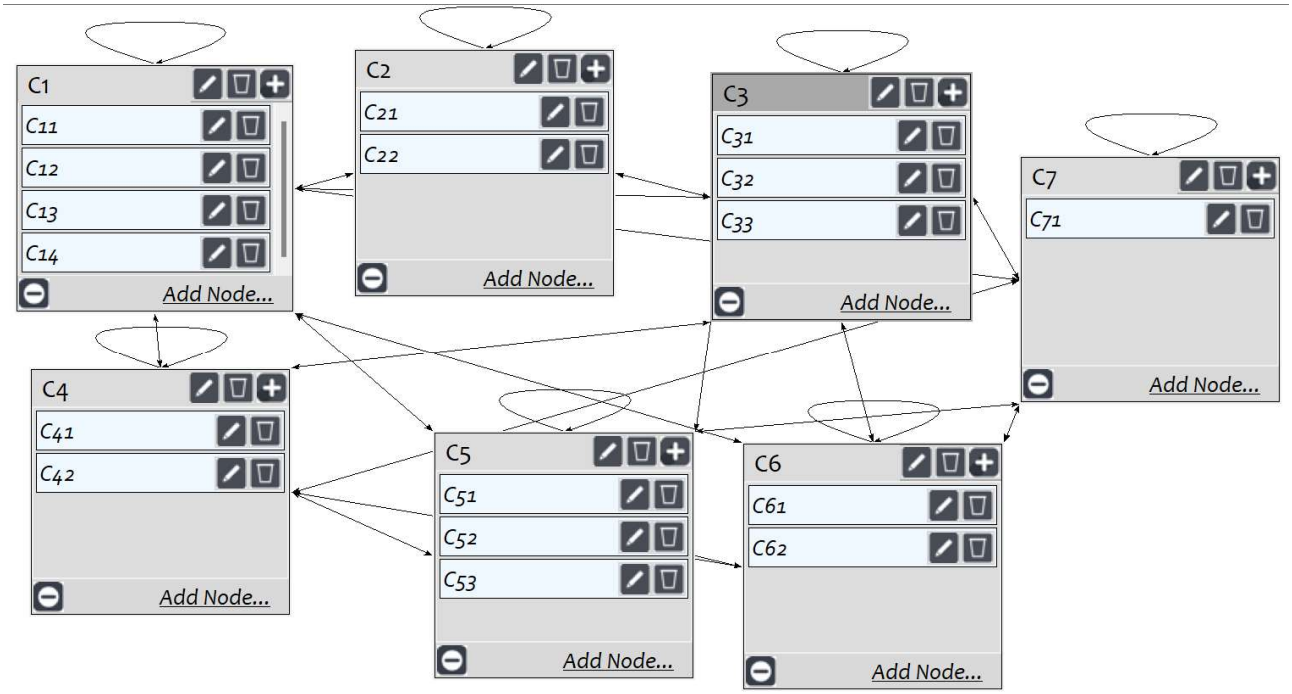

Fig. 1 Customer requirements impact relationship model

Three engineers from the R&D and design department, one marketer and one customer representative, totaling five experts are selected from the research team to score the interrelation among the first-level customer requirements and the second-level customer requirements respectively. The scores are aggregated by the arithmetic mean method and then rounded up. The data were then put into SuperDecisions software. After completing all the judgment matrices of the high-level and low-level customer requirements, the unweighted super matrices, the weighted super matrices and the limit matrices are obtained in turn. The result of the weighted super matrices and the limit matrices of the low-level customer requirements are shown in Table 6 and Table 7 as an example. Due to space limitations, only part of the data is listed.

Table 6. Weighted super matrix of the low-level customer requirements

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	...	C_{53}	C_{61}	C_{62}	C_{71}
C_{11}	0.000	0.307	0.490	0.145	0.122	0.000	...	0.000	0.000	0.000	0.000
C_{12}	0.264	0.000	0.000	0.436	0.000	0.000	...	0.000	0.000	0.000	0.000
C_{13}	0.146	0.081	0.000	0.000	0.000	0.000	...	0.000	0.000	0.000	0.000
C_{14}	0.080	0.193	0.163	0.000	0.000	0.000	...	0.207	0.214	0.000	0.000
C_{21}	0.157	0.000	0.000	0.000	0.000	0.636	...	0.000	0.000	0.000	0.000
C_{22}	0.000	0.000	0.000	0.000	0.558	0.000	...	0.000	0.000	0.000	0.000
...		...	...		...	...	...	...	...		...
C_{53}	0.028	0.033	0.000	0.111	0.000	0.000	...	0.217	0.000	0.000	0.029
C_{61}	0.000	0.000	0.000	0.000	0.000	0.000	...	0.040	0.000	0.143	0.035
C_{62}	0.000	0.000	0.000	0.000	0.000	0.000	...	0.079	0.143	0.000	0.141
C_{71}	0.000	0.000	0.000	0.000	0.000	0.000	...	0.050	0.000	0.214	0.176

ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

Table 7. Limit matrix of the low-level customer requirements

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	...	C_{53}	C_{61}	C_{62}	C_{71}
C_{11}	0.051	0.051	0.051	0.051	0.051	0.051	...	0.051	0.051	0.051	0.051
C_{12}	0.035	0.035	0.035	0.035	0.035	0.035	...	0.035	0.035	0.035	0.035
C_{13}	0.063	0.063	0.063	0.063	0.063	0.063	...	0.063	0.063	0.063	0.063
C_{14}	0.046	0.046	0.046	0.046	0.046	0.046	...	0.046	0.046	0.046	0.046
C_{21}	0.020	0.020	0.020	0.020	0.020	0.020	...	0.020	0.020	0.020	0.020
C_{22}	0.017	0.017	0.017	0.017	0.017	0.017	...	0.017	0.017	0.017	0.017
...	...	...	...	...	...	...	...	...	...	...	...
C_{53}	0.013	0.013	0.013	0.013	0.013	0.013		0.013	0.013	0.013	0.013
C_{61}	0.014	0.014	0.014	0.014	0.014	0.014		0.014	0.014	0.014	0.014
C_{62}	0.035	0.035	0.035	0.035	0.035	0.035		0.035	0.035	0.035	0.035
C_{71}	0.011	0.011	0.011	0.011	0.011	0.011		0.011	0.011	0.011	0.011

The weights and rankings of the factors evaluated by ANP method are shown in Table 8 The global weights are taken as the final importance rating of each customer requirements.

Table 8. Results of customer requirements' importance rating

High-level customer requirements	Arrange in order	Low-level customer requirements	global weight	Arrange in order
Great graphics (C_1)	6	Large screen (C_{11})	0.0511	6
		High resolution (C_{12})	0.0346	10
		Color reproduction (C_{13})	0.0627	4
		Smooth motion (C_{14})	0.0462	8
Excellent sound (C_2)	7	Surround sound (C_{21})	0.0201	11
		Good sound quality (C_{22})	0.0168	12
Reliable and durable (C_3)	4	Long life span (C_{31})	0.3571	1
		Screen retains its color for a long time (C_{32})	0.0537	5
		Retains good sound quality for a long time (C_{33})	0.0498	7
Smooth running (C_4)	2	Lag-free system operation (C_{41})	0.1528	2
		Smooth linkage with other devices, no delay in casting, maneuvering, etc. (C_{42})	0.0684	3
Excellent interactive experience (C_5)	1	Clear and convenient interactive interface (C_{51})	0.0059	17
		Supports connection to a wide range of devices in an intuitive and simple way (C_{52})	0.0087	16
		Support voice, gesture, cell phone and other intelligent control (C_{53})	0.0128	14
Functional and content-rich (C_6)	3	Wealthy in TV programs and game resources (C_{61})	0.0137	13
		Software compatibility and scalability (C_{62})	0.0351	9
Good after-sales experience (C_7)	6	Quick and easy repair and Q&A process (C_{71})	0.0106	15

ISSN: 2692-7608 DOI: 10.6981/FEM.202501_6(1).0018

Based on the results of global weights, the importance rating vector of customer requirements is shown as follows:

$$\omega = [0.0511, 0.0346, 0.0627, 0.0462, 0.0201, 0.0168, \ldots, 0.0137, 0.0351, 0.0106]^T$$

5. Summaries and Discussions

Firstly, the results of the case study in this research show that for a mid-to-high-end smart TV product of Company A, long life span, lag-free system operation, smooth linkage with other devices, no delay in casting, maneuvering, etc. and color reproduction are the most important factors that customers value when purchasing this type of smart TV product. Customers attach the most importance to the quality and smooth operation of the TV, and also have high requirements for panel quality. In order to improve the competitiveness of enterprises, the design process would better further enhance the technical and service features related to these factors.

What's more, this research adopts KJ method to screen and organize customer requirements, find customer requirements interrelation by using DEMATEL method, and afterwards evaluate customer requirements importance rating by the ANP method. The research comes up with a feasible method of analyzing customer requirements and acquiring their importance rating in smart TV industry, whose feasibility is also verified through the case study. This research not only solves the practical problems for the design process of one kind of smart TV product of company A but also provides ideas and methodology for managers in TV industry in terms of collecting and analyzing customer requirements.

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