A QUALITY EVALUATION METHOD FOR SORTING EQUIPMENT BASED ON AHP AND QFD

Guoshu YUAN[1], Jian LYU[1,*], Zhen WANG[1], Huiliang ZHAO[2] and Zhenghong LIU[3]

[1]*Key Laboratory of Advanced Manufacturing Technology, Ministry of Education, Guizhou University, Guiyang 550025, China*

[2]*Guizhou Minzu University, Guiyang 550025, China*

[3]*School of Mechanical Engineering, Guiyang University, Guiyang 550025, China*

E-mail: jlv@gzu.edu.cn

ABSTRACT*: To further improve the user satisfaction of the customized automatic sorting equipment, this paper proposes a quality evaluation method for the automatic sorting equipment based on AHP (Analytic Hierarchy Process) and QFD (Quality Function Deployment). With the customization of the automatic sorting equipment in a company P as an example, AHP is adopted to determine the weight of each kind of user requirement, then combining with the quality features corresponding to the user requirements, the QFD tools are adopted to build a House of Quality (HOQ), then according to the data of HOQ, company P's and company K's automatic sorting equipment was compared and analyzed, and finally, the quality improvement direction of company P's automatic sorting equipment was obtained.*

KEYWORDS*: customization; automatic sorting equipment; analytic hierarchy process (AHP); quality function deployment (QFD); house of quality (HOQ).*

1 INTRODUCTION

In modern companies' manufacturing process, customer satisfaction has become the core objective of the quality strategy for the companies, and it's also an important foundation for the quality design (Jiang, et al., 2008). As the user requirements are becoming more diversified, the customization mode has gradually become the core competitiveness of manufacturing companies.

Different methods have been applied around the design quality issues of customized equipment. For the quantitative evaluation of the comprehensive competence of non-standard equipment manufacturers, by using the system analysis method, we can analyze the macro-coordination ability, technology and processing sequence, and processing ability of the companies by establishing prediction model, optimization model and coordination model, respectively (Zhuang and Burns, 1993; Minh et al., 2018). Modularization and adaptable design techniques were combined to achieve the development of new non-standard equipment products (Ma et al., 2013). Sahney et al. (2003) using QFD to obtain the correlation between quality features, and using SIT (Systemic Innovation Thinking) to solve the negative relationship is an effective solution for product innovative design (Xie et al., 2012). Design methods integrated QFD, TRIZ theory and Taguchi method can also achieve quality innovation design (Wang et al., 2005). Through user requirement analysis and quality feature weight calculation, Almannai et al. (2008) applied the QFD method to solve the problem of the aesthetic shape and disjointed product function of the friction welding machine to ensure the design effectiveness (Wang and Mao, 2018).

The QFD method can transform user requirements into design requirements. In order to avoid the influence of subjective experience on the evaluation of user requirements, by applying AHP (Saaty, 2000), we can establish a hierarchical model for the basic functions, auxiliary functions and each component element in product quality design, and calculate the weight distribution coefficient of each element (Jing et al., 2009), then combine the two methods to study the improvement of the quality of the customized sorting equipment.

2 AUTOMATIC SORTING EQUIPMENT USER REQUIREMENT SYSTEM ESTABLISHMENT AND IMPORTANCE DETERMINATION

2.1 Analytic hierarchy process (AHP)

AHP is a hierarchical weight decision analysis method that applies network system theories and multi-objective comprehensive evaluation method, and it combines qualitative and quantitative methods to solve multi-objective complex problems (Demirel et al., 2008; Xie and Yin, 2018). The specific analysis and evaluation process are as follows (Johannsen et al., 1994):

(1) Establish a user requirement hierarchical model for automatic sorting equipment, the model is divided into a first layer A, a second layer B and a third layer C;

(2) Layer by layer, compare the user requirements in pairs, judge the relative importance between the elements in each layer, and construct the judgment matrices for each layer $X = (x_{ij})_{n \times n}$.

(3) Use the square root method to calculate the eigenvector W and the largest eigenvalue $\lambda_{\max}$ of the judgment matrix X. The component corresponding to the eigenvector W is the weighted value of the single order of the corresponding element, and the largest eigenvalue $\lambda_{\max}$ is used to check the consistency of the judgment matrix. The main steps are as follows:

1) Calculate the continued product of the elements in each row of the judgment matrix X, that is:

$$M_i = \prod_{j=1}^{n} x_{ij}, \quad i = 1, 2, \cdots, n \tag{1}$$

2) Find the n-th root of M_i, namely:

$$\tilde{w}_i = \sqrt[n]{M_i}, \quad i = 1, 2, \cdots, n \tag{2}$$

3) Normalize vector $\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \cdots, \tilde{w}_n]^{T}$, that is:

$$w_i = \frac{\tilde{w}_i}{\sum_{i=1}^{n} \tilde{w}_i}, \quad i = 1, 2, \cdots, n \tag{3}$$

And the obtained vector $W = [w_1, w_2, \cdots, w_n]^{T}$ is the eigenvector to be solved.

4) Calculate the largest eigenvalue $\lambda_{\max}$, that is:

$$\lambda_{\max} = \sum_{i=1}^{n} \left[\frac{(X \bullet W)_i}{n w_i} \right] \tag{4}$$

where $(X \bullet W)_i$ is the i-th component of the product of the matrix *X* and the eigenvector *W*.

5) Calculate the consistency index $CI = \frac{\lambda_{\max} - n}{n - 1}$, look up to find the average random consistency index RI value, and calculate the random consistency ratio $CR = \frac{CI}{RI}$. When CR<0.1, it is considered that the constructed judgment matrix has satisfactory consistency.

2.2 Establishment of customized requirement system for the automatic sorting equipment

Taking company P's automatic sorting equipment as the research object, this study referred to the customized requirements of automatic sorting equipment obtained from the company's equipment R&D department and the user opinions, then it classified the various requirements, and constructed a customized user requirement hierarchical system for the automatic sorting equipment, as shown in Figure 1.

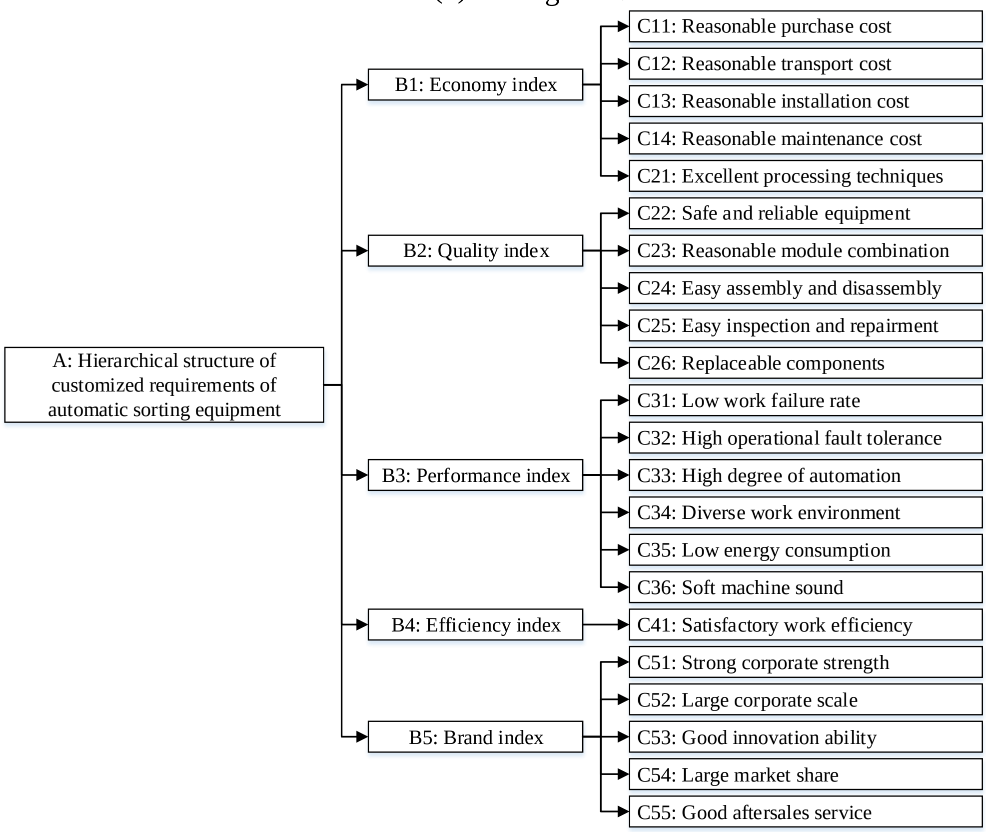


Fig. 1 Hierarchical structure of customized requirements of automatic sorting equipment

The A layer is the total customized requirement of the automatic sorting equipment; the B layer is the 5 categories of the customized requirements of the automatic sorting equipment, including economy, quality, performance, efficiency, and brand; C layer is the classified user requirements under the 5 categories of the total user requirement, including reasonable purchase cost, safe and reliable equipment, satisfactory work efficiency, and other specific requirements.

2.3 Determination of the importance of customized requirements of automatic sorting equipment

The importance of user requirements is an important basic quantity index in QFD, that is, each requirement is scored quantitatively to represent the importance degree of each requirement. The user requirements were classified and evaluated through expert scoring and questionnaire surveys of relevant operators and users. The actual users were carefully investigated and analyzed by professional designer to obtain the customized requirement matrix of the automatic sorting equipment. And then a 1-9 level importance scale method was adopted to assign the importance value of each user requirement in the judgment matrix, and the AHP method was used to calculate B and C, the weight coefficients of user requirements of the automatic sorting equipment. The importance degrees and their meanings are shown in Table 1.

Table 1. Judgment matrix importance degrees and their meanings

Degree of importance	Meanings
1	Requirement i and requirement j are equally important
3	Requirement i is slightly more important than requirement j
5	Requirement i is obviously more important than requirement j
7	Requirement i is strongly more important than requirement j
9	Requirement i is extremely more important than requirement j
2, 4, 6, 8	Intermediate value of two adjacent judgments
1/3, 1/5, 1/7, 1/9	Comparison results of the reciprocals of two comparative items

Through pairwise comparison of the B layer, a judgement matrix was constructed and the importance score of each user requirement was obtained, then according to the square root method, the weight coefficient of each element in the layer was obtained, the specific results are shown in Table 2.

Table 2. Judgment matrix of B1-B5 and the related calculation results (bi)

A-B	B_1	B_2	B_3	B_4	B_5	Weight coefficient
B_1	1	1/4	1/4	1/4	3	0.0882
B_2	4	1	1	6	4	0.2466
B_3	4	1	1	1	3	0.2674
B_4	4	1/6	1	1	5	0.3402
B_5	1/3	1/4	1/3	1/5	1	0.0576
λ_{max}=5.2217 RI=1.12 CI=0.0554 CR=0.0495<0.1 Satisfies the consistency check						

As can be seen from Table 2, the efficiency index B_4 has the largest weight, which is 0.3402, indicating that the work efficiency is the primary factor affecting the selection of automatic sorting equipment; the secondary factor is the performance index B_3, accounting for 0.2674; and the quality, economy and brand indices account for 0.2466, 0.0882, 0.0576, respectively.

The AHP method is used to establish the judgement matrix for the user requirements in the C layer corresponding to the economy index, and the weight coefficient of each requirement was calculated, as shown in Table 3.

Table 3. Judgment matrix of C11-C14 and the related calculation results (cij)

B_1-*C*	C_{11}	C_{12}	C_{13}	C_{14}	Weight coefficient
C_{11}	1	6	6	4	0.5872
C_{12}	1/6	1	1	1/5	0.0724
C_{13}	1/6	1	1	1/5	0.0724
C_{14}	1/4	5	5	1	0.2680
λ_{max}=4.1846 RI=0.9 CI=0.0615 CR=0.0684<0.1 Satisfies the consistency check					

In the same way, using AHP, the weight coefficients of the other user requirements in the C layer could be obtained as well.

Then the hierarchical total sorting was subject to the consistency check. The hierarchical total sorting refers to sort the weights of the relative importance of all elements in layer C to layer A, that is: $a_{ij}=b_i \times c_{ij}$ (i=1,2,…,5; j=1,2,…,6). The consistency index of the judgment matrix in the C layer corresponding to any element b_j of the B layer is set as CI_j, the average random consistency index is set as RI_j, then the random consistency ratio CR of the total soring of the C layer is:

$$CR=\frac{CI}{RI}=\frac{\sum_{j=1}^{m}\left(b_j CI_j\right)}{\sum_{j=1}^{m}\left(b_j RI_j\right)}, \quad j=1,2,\ldots,m \tag{6}$$

The random consistency ratio of the total sorting is obtained to be CR=0.0676<0.1, which satisfies the consistency check. Then the calculated weight of the total sorting was normalized to obtain the requirement importance of each element in the bottom layer, as shown in Table 4.

Table 4. User requirement importance

User requirements	Weight in the total sorting	Importance of the requirement
Reasonable purchase cost	0.0518	5
Reasonable transport cost	0.0064	1
Reasonable installation cost	0.0064	1
Reasonable maintenance cost	0.0236	2
Excellent processing techniques	0.0062	1
Safe and reliable equipment	0.1199	12
Reasonable module combination	0.0506	5
Easy assembly and disassembly	0.0271	3
Easy inspection and repairment	0.0294	3
Replaceable components	0.0133	1
Low work failure rate	0.1161	12
High operational fault tolerance	0.0411	4
High degree of automation	0.0638	6
Diverse work environment	0.0223	2
Low energy consumption	0.0152	2
Soft machine sound	0.0089	1
Satisfactory work efficiency	0.3402	34
Strong corporate strength	0.0120	1
Large corporate scale	0.0051	1
Good innovation ability	0.0254	3
Large market share	0.0055	1
Good aftersales service	0.0096	1

3 CONSTRUCTION OF HOQ FOR THE CUSTOMIZED REQUIREMENTS OF AUTOMATIC SORTING EQUIPMENT

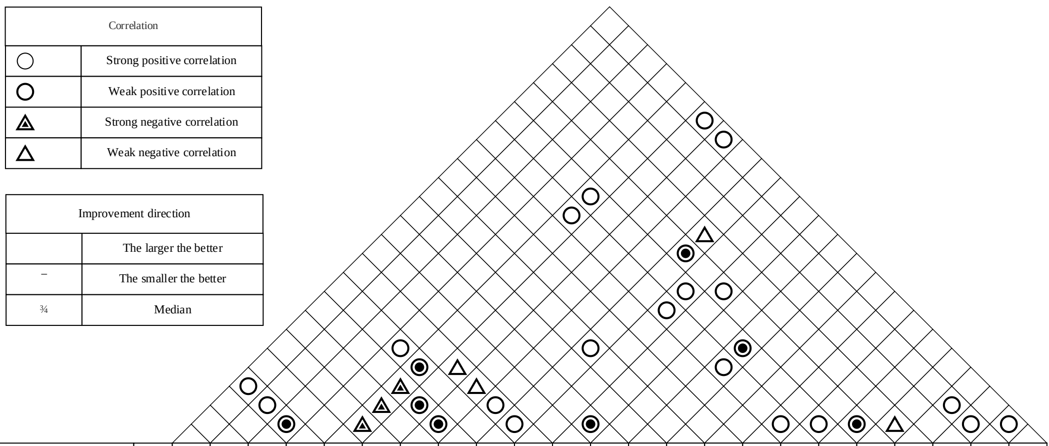
3.1 Quality function deployment (QFD) and house of quality (HOQ)

Quality Function Deployment (QFD) is a quality control management system method applied in the design stage (Akao and Mazur 2013), which expands user requirements into design, manufacture, assembly, after-sales, and other links to ensure the user requirements are reflected before the products are produced, it creatively transforms the quality management thought of the enterprise from the later-stage control to the earlier-stage control (Ho et al., 2009). The most direct advantage is to reduce the design time and design changes, reduce the manufacturing cost, and improve the product design quality and user satisfaction.

House of Quality (HOQ) is the core part that drives the entire QFD process. As a classic tool connecting user requirements and product quality features in the product development process, it reflects the correlation between the user requirements and the product engineering features. The structure is shown as Figure 2.

3.2 Quality feature extraction

The design and manufacture process of automatic sorting equipment involves many aspects, and the system structure is complex. There are many quality features associated with the user requirements of the automatic sorting equipment, in this study, we select quality features that are closely related to the user requirements, including 5 stages: design stage, manufacture stage, installation stage, debugging stage, and after-sales stage, the specific breakdown of each stage is shown in Figure 2.



Improvement direction					¾	–							¾				¾			¾		¾							
		Design stage					Manufacture stage					Installation stage					Competitiveness evaluation					After-sales stage			Competitiveness evaluation				
Relation matrix / Quality feature / User requirement	The importance of user requirements	Collection of user requirement information	Detail communication with user requirement	Equipment production detailed parameter determination	Determination of sketch plan and expected goals	Cost budget	Application of standard product structure	Application of universal components	Manufacture speed	Equipment safety, stability, reliability	Compression of manufacturing cost	Equipment basic inspection	Equipment fixation and in-position	Rationality of equipment combination	Simplification of the installation steps	Precision test and adjustment	Equipment lubrication	Smooth operation of equipment	Equipment operating efficiency	Project quality acceptance	Collection of user feedback information	Discussion of equipment failure	Solution of failure	Troubleshoot efficiency	Company P Company K				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	1	2	3	4	5
Reasonable purchase cost	5	1				9	3	3	3	3	9							3	9								K		P
Reasonable transport cost	1	1				9					3															K		P	
Reasonable installation cost	1	1				9	1	1			3	3	3	3	9	3	3	1	1								K	P	
Reasonable maintenance cost	2	1				9	3	3		1	3	1		1									3	3				K	P
Excellent processing techniques	1			1	3	3			1		3					9				1							P		K
Safe and reliable equipment	12			3	3		1	1		9		9	3	9	3	3	3			9	3		3	1				P	K
Reasonable module combination	5		3		1		1	1				1	9	9	1			3	3									K	P
Easy assembly and disassembly	3		1	1	1		9	9				1		1	3							3	3				P	K	
Easy inspection and repairment	3		1	1	1		1	1						3							3	3	3	3		K		P	
Replaceable components	1		1	1			9	9																			P		K
Low work failure rate	12		1							9		3				9	3	3	1	3	3	3	3	3			K		P
High operational fault tolerance	4		1		1									3					3								K		P
High degree of automation	6		3	1	3	3																					P		K
Diverse work environment	2	1	3		1																							P	K
Low energy consumption	2			3		3						3		1		3	3	3		3							K	P	
Soft machine sound	1		1									3	3	1		1	9										P	K	
Satisfactory work efficiency	34	1		3	1					1		3		3	3		1	9	9	9	9		3	3				P	K
Strong corporate strength	1				3				3	9	3					3		3	3				3	3			P		K
Large corporate scale	1									9	1																	P	K
Good innovation ability	3				9				3	9	9			3	9	3			3				9				P		K
Large market share	1								3	9	3									3				3				K	P
Good aftersales service	1					1	1	1													9	3	3	9				K	P
Target value		Communicate actively	Discuss the details carefully	Comply with relevant national standards	Display the effects with design drawings and 3D models	Satisfy user requirements and achieve a win-win situation	Repair and replace equipment effectively in a timely manner	Repair and replace equipment effectively in a timely manner	Guarantee both quality and quantity, deliver the products timely	Comply with relevant national standards	Satisfy user requirements, and achieve a win-win situation	Measurement and inspection meet safety design requirements	Equipment fixed firmly and operates stably without shaking	Operation runs smoothly without failure and satisfies the production requirement	Satisfy user production requirement	Achieve actual work requirement and satisfy the production	The equipment runs smoothly	The equipment runs smoothly	Satisfy user production requirement	Comply with relevant national standards, satisfy production requirements	Understand and collate feedback information comprehensively in detail	Organize professional technicians to conduct on-site investigation	Solve the problem at one time and carry out maintenance training at the same time	Cause no delay to the user company's production					
Technical evaluation	5	K		P	K	P					P		P	P	P			P	K		K		K						
	4	P	K	K			K	P	K	P		P		K		K	P	K		K		K		K					
	3		P		P		P	K	P	K	K	K	K			P			P	P	P		P	P					
	2					K									K		K					P							
	1																												
Absolute importance(t_x)		45	63	158	138	109	79	79	31	321	94	268	87	296	188	175	124	382	403	460	396	57	231	180					
Relative importance(v_x)		1.0	1.4	3.6	3.2	2.5	1.8	1.8	0.7	7.4	2.2	6.1	2.0	6.8	4.3	4.0	2.8	8.8	9.2	10.5	9.1	1.3	5.3	4.1					
Importance rating(1-10)		1	1	3	3	2	2	2	1	7	2	6	2	6	4	4	3	8	9	10	8	1	5	4					

Fig. 2 HOQ of automatic sorting equipment

3.3 Construction of HOQ

According to the above-mentioned user requirements, and their importance and quality features, with the help of the QFD theory, a HOQ was constructed, which mainly includes 6 steps:

Step 1: HOQ was filled with user requirements and quality features. According to user requirements and their importance, the left wall of the HOQ was built, namely the column matrix; then according to the main quality features and 3 improvement directions (↑: the larger the better; ↓: the smaller the better; — the median), the ceiling of the HOQ was built, namely the row matrix.

Step 2: Construct the relation matrix to determine the importance of quality features, analyze and evaluate the relationship between user requirements and corresponding quality features, and define s_{xy} (x=1,2,3,…,e; y=1,2,3,…,f) to represent the relation coefficient of the x-th quality feature and the y-th user requirement, the strong, medium and weak relations respectively took the values of 9, 3, 1 to construct the relation matrix, namely the HOQ room.

Step 3: Competitiveness evaluation. The statistical results of the actual operation data of company P's and company K's equipment in the recent 6 months were compared, referring to the user survey data, the 5-point scoring method (score within a range of 1-5 points, indicates from the worst to the best) was adopted to construct a competitiveness evaluation matrix, which was taken as the right wall of the HOQ.

Step 4: Determine the target values of the quality features. According to the user requirement survey data and combined with relevant standards, the target value of each quality feature was reasonably analyzed and taken as the floor of the HOQ.

Step 5: Technical competence evaluation. Experts evaluated the technical competence of two manufacturers of automatic sorting equipment, company P and company K, and the 5-point scoring method was adopted to construct the technical competence evaluation matrix.

According to the relation between the quality features and the corresponding user requirements, the importance of quality features was determined: define $t_x = \sum (s_{xy} \cdot u_y)$ as the absolute importance of the x-th quality feature; s_{xy} is the relation coefficient of the x-th quality feature and the y-th user requirement; u_y is the value of importance of the y-th user requirement. Define v_x as the relative importance of the x-th quality feature, then there is $v_x = t_x \Big/ \sum_{x=1}^{e} t_x \times 100$. The degree of importance was graded with the highest score of the relative importance (the highest score represents degree 10) as the standard, and the degree of importance = the score of relative importance /the highest relative importance score × 10. The four items (technical competence evaluation matrix, absolute importance, relative importance, degree of importance) together constitute the HOQ basement.

Step 6: Analyze and evaluate the correlation between quality features to establish the correlation matrix (positive correlation, negative correlation, no correlation) as the roof of the HOQ. ◉ represents strong positive correlation, ○ represents weak positive correlation, ▲ represents strong negative correlation, △ represents weak negative correlation.

A complete HOQ was constructed as shown in Figure 2.

4 HOQ ANALYSIS

4.1 Evaluation and comparison of competitiveness

From the results in Table 5 we can see that, the total score of K company's automatic sorting equipment is higher than that of P company's automatic sorting equipment, indicating that automatic sorting equipment of K company is more competitive than that of P company. In terms of the safety, reliability, automation degree and work efficiency of the equipment, the score of K company is obviously higher than that of P company. In addition, K company has a higher-level innovation ability, its equipment is easier to be disassembled or assembled, the processing technique of its equipment is better, and the components of the equipment are highly replaceable and can adapt to various working environments. However, in terms of economic costs such as purchase cost, transport cost, installation cost and maintenance cost, the cost of P company is higher than that of K company, and its combination is more reasonable, its equipment is easier to be inspected and repaired, the failure rate is significantly lower, and the fault tolerance is better, moreover, the P company's equipment saves more energy and its after-sales service is better. Therefore, its equipment has a certain market share. The existing automatic sorting equipment tends to gradually develop towards the direction of higher efficiency, better quality and better service. Therefore, under the premise of reasonable cost, reasonable equipment combination and low energy consumption, P company should enhance its innovation ability, thereby improving the equipment reliability and work efficiency.

Table 5. Evaluation and comparison results of market competitiveness

No.	User requirement	Importance of user requirements	Company P		Company K		Score difference
			5-point scoring	Score × Importance of user requirement	5-point scoring	Score × Importance of user requirement	
1	Reasonable purchase cost	5	5	25	3	15	10
2	Reasonable transport cost	1	4	4	2	2	2
3	Reasonable installation cost	1	4	4	3	3	1
4	Reasonable maintenance cost	2	5	10	4	8	2
5	Excellent processing techniques	1	3	3	5	5	-2
6	Safe and reliable equipment	12	4	48	5	60	-12
7	Reasonable module combination	5	5	25	4	20	5
8	Easy assembly and disassembly	3	3	9	4	12	-3
9	Easy inspection and repairment	3	4	12	2	6	6
10	Replaceable components	1	3	3	5	5	-2
11	Low work failure rate	12	5	60	3	36	24
12	High operational fault tolerance	4	5	20	3	12	8
13	High degree of automation	6	3	18	5	30	-12
14	Diverse work environment	2	4	8	5	10	-2
15	Low energy consumption	2	4	8	3	6	2
16	Soft machine sound	1	3	3	4	4	-1
17	Satisfactory work efficiency	34	4	136	5	170	-34
18	Strong corporate strength	1	3	3	5	5	-2
19	Large corporate scale	1	4	4	5	5	-1
20	Good innovation ability	3	3	9	5	15	-6
21	Large market share	1	5	5	4	4	1
22	Good aftersales service	1	5	5	4	4	1
	Total	—	—	**422**	—	**437**	**-15**

4.2 Evaluation and comparison of technical competence

From the results of Table 6 we can know that, the total score of K company is significantly higher than that of P company. From a corporate perspective, the K company has a better technical advantage than P company, especially in terms of the determination of sketch plans and expected goals, the application of standard parts, equipment operating efficiency, feedback information collection and fault resolution, etc., but in the aspect of cost budget, equipment safety and reliability, equipment combination and installation, there are still some deficiencies.

4.3 Comprehensive analysis of market competitiveness and technical evaluation

By comprehensively evaluating and analyzing the market competitiveness and technical competence we can see that, compared with the P company, K Company obtained a better market evaluation result with its higher technical index. In order to further improve the market competitiveness of company P's automatic sorting equipment, in the future planning and construction, the core is to enhance the innovation ability of the company, and guide it to continuously innovate its automatic sorting equipment services and technologies to meet diversified sorting needs. P Company can improve its market competitiveness through the following methods: 1) actively explore user requirements, deeply communicate with users, and thoroughly understand the most essential requirements of the users; 2) combine with related national standards to apply the standard components, thus improving production speed and equipment replaceability; 3) introduce technical talents, innovate equipment, improve work efficiency and user satisfaction; 4) collect feedback information, reduce failure occurrence, train maintenance personnel, and improve maintenance efficiency. P company can improve its operational management and technical competence by formulating long-term user requirement management objectives, establishing and improving standard equipment manufacturing systems, implementing equipment innovation and efficiency mechanisms, and training after-sales personnel.

Table 6. Technical competence evaluation and comparison results

Stages	Quality features	Quality features Absolute importance	Company P		Company K		Score difference
			5-points scoring	Score × Quality feature Absolute importance	5-points scoring	Score × Quality feature Absolute importance	
Design stage	Collection of user requirement information	45	4	180	5	225	-45
	Detail communication with user requirement	63	3	189	4	252	-63
	Equipment production detailed parameter determination	158	5	790	4	632	158
	Determination of sketch plan and expected goals	138	3	414	5	690	-276
	Cost budget	109	5	545	2	218	327
Manufacture stage	Application of standard product structure	79	3	237	4	316	-79
	Application of universal components	79	4	316	3	237	79
	Manufacturing speed	31	3	93	4	124	-31
	Equipment safety, stability, reliability	321	4	1284	3	963	321
	Compression of manufacture cost	94	5	470	3	282	188
Installation stage	Equipment basic inspection	268	4	1072	3	804	268
	Equipment fixation and in-position	87	5	435	3	261	174
	Rationality of equipment combination	296	5	1480	4	1184	296
	Simplification of the installation steps	188	5	940	2	376	564
	Precision test and adjustment	175	3	525	4	700	-175
Debugging stage	Equipment lubrication	124	4	496	2	248	248
	Smooth operation of equipment	382	5	1910	4	1528	382
	Equipment operating efficiency	403	3	1209	5	2015	-806
	Project quality acceptance	460	3	1380	4	1840	-460
After-sales stage	Collection of user feedback information	396	3	1188	5	1980	-792
	Discussion of equipment failure	57	2	114	4	228	-114
	Solution of failure	231	3	693	5	1155	-462
	Troubleshoot efficiency	180	3	540	4	720	-180
	Total	—	—	**16500**	—	**16978**	**-478**

4.4 Analysis of correlation between quality features

Analysis of the constructed HOQ roof in Figure 2 reveals a strong negative correlation between the application of the standard product structure and universal components and the cost budget. In addition, the security, stability and reliability of the equipment are negatively correlated with the collection of user feedback information. Therefore, it is possible to weaken the negative correlation between some quality features by improving the level of technical innovation, however, solely relying on the improvement of the level of technical innovation will inevitably increase the cost budget and it is not easy to achieve the purpose of improvement, therefore, under the premise of ensuring work efficiency, we should comprehensive consider the balance between cost and benefit to achieve a win-win outcome.

5 CONCLUSION

Combining the AHP and QFD methods, this paper evaluated and improved the automatic sorting equipment of Company P and Company K. When evaluating the market competitiveness, in order to avoid bias caused by subjective scores, the statistical data of the actual operation of the equipment was adopted to reflect the data indices such as performance index and efficiency index, etc. The final evaluation results showed that the market competitiveness of K company's automatic sorting equipment is slightly higher than that of P company, and its technical competence is significantly higher than that of P company. In the future design and planning, P company should enhance the its innovation ability, and guide the company to continuously innovate sorting equipment services and technologies to meet diversified sorting needs. Applying QFD to the evaluation and analysis of P company’s automatic equipment service system and to propose improvement methods is of certain limitations, especially it’s not conductive to the analysis when the index is too large, however, this method still has certain practical significance for the improvement of the problem.

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