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CUSTOMER-FOCUSED AIRCRAFT SEAT DESIGN: A CASE STUDY WITH AHP-QFD

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Abstract. Aviation is rapidly expanding and recovering from the pandemic impact driven by the experience economy. This is particularly subject to interfaces such as the aircraft seats, which are getting intense attention as a differentiator in the cabin. The focal point of this paper is to assess and convert customer requirements into what must be done for an optimum aircraft seat. To achieve this, a 2-step analytic hierarchy process and quality function deployment (AHP-QFD) methodology was successfully applied, consolidating product quality characteristics. Then, it leverages a novel scoring method of interdependencies to isolate dependable design variables. Consequently, safety, weight, and durability scored maximum, emphasizing backrest design and alternative composite materials, while test infrastructure was determined as a critical investment component. Furthermore, it is shown how AHP-QFD can be used for product strategy and strategic portfolio management of R&D projects.

Keywords: aircraft seat, aircraft cabin interior, customer-focused design, TCI, AHP-QFD.

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Introduction

Air travel is expected to increase by over 16,000 bn Revenue Passenger Kilometers by 2035 despite the 6% loss of the pandemic, which is almost doubling up the business volume when compared with the year 2019 (International Air Transport Association, 2022, p. 7). This means that the fleets must be expanded dramatically delivering a large market for the aviation supply chain. Today, experience drives economic value (Pine & Gilmore, 1998). Since air travelers choose airlines based on their travel experience, airlines are trying to maximize their market share by enhancing the perception of their services. One of the most pronounced interfaces immersing the air traveler is the aircraft seat, which attracts great attention in practice and research (Vink et al., 2012).

Aircraft seats surrounding the air traveler do deliver an immersive experience. So, the design of aircraft seats correlates positively with comfort (Vink et al., 2012), which can be used as a differentiator. This can be achieved by streamlining the voice of the customer (VOC) into the product.

Nevertheless, aircraft seats are constrained by strength and safety considerations. They must sustain structural integrity during dynamic loading in flight, landing, and impact situations, but the seats must be light to enable low fuel consumption. So, the aircraft seat certification process prerequisites proper homologation involving certification or (European) Technical Specification Order, (E)TSO, approval (Bhonge, 2008). This is made mainly according to European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA) standards. Consequently, seat structures are designed and validated for high static and dynamic forces (EASA, 2011).

Then, there are also specific requirements for seatbelts (EASA, 2003) to prevent potential harm to the passenger as described in the advisory circulars of FAA (2016). Moreover, evacuation capabilities must be assured in line with FAA and EASA regulations. This delivers a complex certification basis. Many calculations and tests are required, which are expensive and time-consuming. Most importantly, these detailed design constraints have the potential to yield a seat design, which negatively correlates with the passenger experience.

All in one, the requirements for aircraft seats are complex, and the high number of these requirements further complicates the complete transformation. There, some requirements can be contradictory or too expensive and trade-offs must be made. The optimum product must not be over-constrained but must satisfy the customer adequately. Consequently, prioritization is required. This requires extensive efforts at the front end of the development.

There are many attempts to transfer the customer needs into a final product by respecting technical constraints. Quality function deployment (QFD) is one of the most used structured techniques for the design stage (Revelle et al., 1998). It is a practical tool that also enables the visual representation of the problem (Ucler, 2017a). It can be leveraged easily to determine an optimum configuration in the solution space by streamlining needs into quality characteristics.

Optimization is about prioritization and selection of the most desirable items. In QFD, weighing is used to prioritize needs. This is not always straightforward, because the human brain is prone to make pairwise comparisons rather than ranking by a total view. The Analytic Hierarchy Process (AHP) of Saaty (1980) can be utilized there. It is a widely used analytical tool, which combination with QFD is called AHP-QFD (Bhattacharya et al., 2005). There are various examples in the literature for AHP-QFD, also within the aviation context (Ucler, 2017a).

The research question here is the determination of the requirements streamlining the VOC leading to what must be done to achieve an optimum aircraft seat using the AHP-QFD methodology. The paper is structured as follows: First, a literature review is made for passenger and aircraft seat design subject to QFD and AHP-QFD. Then, the details of the leveraged workshop and the AHP-QFD method are explained, and which results are discussed after that.

1. Literature review

The utilization of VOC can be misleading when data collection is not made adequately (Franceschini & Maisano, 2015) and can yield dissatisfaction and customer complaints (Lee et al., 2011). This can be avoided by QFD when used as a structured method to determine "must-be" (Kano, 1984) and "one dimensional" (Matzler & Hinterhuber, 1998) criteria building up targets and evaluations via customer feedback successfully. QFD is an analytical design tool widely used in industry and by scholars. It is a tool for product development but also embodies a planning process. Moreover, it enables the transformation of customer requirements into design quality (Govers, 2001).

QFD is a schema used during the development studies of manufactured products. It enables the assessment of breakthrough concepts by delivering a "conceptual map for the design process" called the house of quality (HoQ) involving the VOC (Dasuki & Romli, 2018). It is a matrix chart where product features, customer demands, and their relationships are shown with associated importance and the comparison with the benchmark (Ucler et al., 2006).

There are various applications of QFD and AHP-QFD including but not limited to automotive (Akao & Mazur, 2003) and its subsystem design (Cristiano et al., 2000), aircraft design (Ucler, 2017a; Bae et al., 2017; Dasuki et al., 2018), electronic component design (Chen et al., 2007), design of shop floor (Bhattacharya et al., 2005), design of education systems (Murgatroyd, 1993; Aytac & Deniz, 2005), and supplier selection (Rajesh & Malliga, 2013). QFD applies to almost any product, and there is a wide spectrum of application areas (Zarei et al., 2011).

Moreover, the QFD process involves people scoring and weighing various requirements, and there is always ambiguity in assessments due to the subjectivity of perceptions during evaluations. This is fuzzy content that can easily be incorporated into QFD by analytic hierarchical processes (AHP) (Ucler, 2017b). AHP supports multiple-criteria decisions of complex nature utilizing pairwise comparisons which are then integrated into the overall ranking and weighing (Saaty, 1990). It is widely used due to its flexibility and simplicity among other sectors also in aviation (Chen et al., 2014; Ucler, 2017b; Berawi et al., 2018). Consequently, both QFD as well as AHP-QFD are suitable tools for seat design across organizational boundaries.

Indeed, QFD has been used to improve the comfort and ergonomics of driver seats (Fahma et al., 2015), aircraft seats (Bekiaris, 1999), to reduce rearward space intrusion in aircraft seats (Koh, 1999), to compare different concepts in aircraft seats (Teo, 1999), for development of seat cushions with temperature control (Malkiewicz, 2011), to predict seat comfort (Amer, 2012), for development of vertical passenger seats (Dasuki & Romli, 2018), for designing car seats (Mat et al., 2020; Purba et al., 2020), in aircraft seat attachment systems (Kimball et al., 2020), and design of configurable seat track systems (Sun et al., 2021). Then, AHP-QFD was used to prioritize sensor performance characteristics of automotive seats (Haroglu et al., 2016), to design tractor seats (Hridoy et al., 2020), and to identify key passenger needs for seats (Yang et al., 2021). Then there are further attempts to develop car seats with AHP-QFD augmenting the methodology by additional techniques such as DEMATEL (Karasan et al. 2022). Nevertheless, DEMATEL is not used here, because there is no dependency among decision criteria that the AHP-QFD method is applied which is explained next.

2. Method

"The aircraft cabin interior environment is an integrated grey system of multiple subsystems and some information in subsystems cannot be known adequately and surely" (Jiang et al., 2013). Consequently, this work was necessitated by the need for the quantification of customer requirements for aircraft seats, which was initiated by survey results delivered by the main customer and in-house AHP-QFD workshops. The list of customer requirements was taken from a survey applied by an airline to the air travelers, the operation team, and the technical team. This airline is the major B2B customer of the seat manufacturing company, and it is an established international flag carrier. Respondents of the survey had a homogenous demographic and geographic distribution across a significantly large sample size. Since this survey is not the focal point of this research but is just leveraged as a starting point, further details are not included here. The marketing team first determined the weights of these assessments by averaging individual opinions, and intuitive assessments. Then, workshops were conducted. Hence, 12 experts from marketing, sales, R&D, production, and quality departments with a total of 148 man-years cumulative experience in aviation, seat design, seat production, and/ or new product development have gathered in 3 sessions to make the weighing by AHP and the 2 step QFD evaluation of a non-recline economy seat. In general, a full consensus was achieved within the group through discussions. Nevertheless, this was not possible for all cases where the row geometric mean method (RGMM) was utilized for the determination of the weights of the requirements as well as for the population of the QFD matrix. After finishing each QFD step, a comparison with the competition was also made. Nevertheless, due to confidentiality reasons, these are not part of this paper. The applied methods are explained below.

2.1. Quality function deployment (QFD)

QFD is a common NPD method with roots in total quality management (TQM) from Japan (Akao & Mazur, 2003). Hence, just an overview is given here. It can consider industry factors, needs, and interests (Terninko, 1997). QFD is a graphical technique (Bekiaris, 1999) mainly aiming to translate spoken as well as unspoken requirements into design characteristics (Alavi & Leidner 2001; Liang et al., 2012). Enabling customer-focused thinking, QFD can improve the design by reducing the required time and quality problems (Benner et al., 2003).

QFD is used to extract design targets from consumer requirements (Mizuno & Akao, 1994) by facilitating Concurrent Engineering principles (Cho et al., 2008). Hence, QFD leverages multidisciplinary teams across organizational boundaries (Ho & Lin, 2012) preventing repetitions and minimizing costs (Eggert, 2005; Zarei et al., 2011). It is a systematic (Adhaye, 2013) and structured new product development technique (Tidd et al., 2005) and can guide throughout the product realization process (Davis et al., 2004).

A complete QFD study is utilizing four matrices in the form of four distinct HoQ'ies (Franceschini, 2002). These are 4 phases, i.e. consecutive steps for product planning, product design, process planning, and production planning (Bouchereau & Rowlands, 2000). Each phase has its own HoQ matrix Q, where the lines are populated with n demanded qualities describing What's, and the columns are for m quality characteristics describing the How's (Ucler, 2017a). Each requirement line has a weight determined in advance (Bhattacharya et al., 2005) denoted here as α_i. The matrix $\boldsymbol{Q}$ is then populated with the relationships between the lines and columns as weak, moderate, and strong with the scoring of 1,3, and 9 respectively. Cumulative scores of columns are determined as $\vec{b}$ as follows (Ucler, 2017a).

$$\vec{b} = \begin{pmatrix} b_1 \\ \vdots \\ b_m \end{pmatrix} = Q^T \vec{a} = \begin{pmatrix} q_{11} & \cdots & q_{1m} \\ \vdots & \ddots & \vdots \\ q_{n1} & \cdots & q_{nm} \end{pmatrix}^T \times \begin{pmatrix} a_1 \\ \vdots \\ a_n \end{pmatrix}. \quad (1)$$

This vector is then normalized to determine the weights. Then, the interrelationships of the How's in the columns are defined within the roof of the HoQ as strong positive, positive, negative, or strong negative correlations. After that, competitive benchmarking is made on the right-hand side of the QFD matrix. The product under consideration and the competing products are scored for each line, i.e. What's, with a 5 points Likert scale. This delivers a comprehensive benchmark that the company where this research was made did insist on the exclusion of it for confidentiality reasons. Hence, this competitive benchmarking is not included here.

In the next step, the column (How's) of the previous HoQ becomes the input line (What's) with the associated computed weights so that new quality characteristics with their weights can be determined similarly. There, the interrelationships, as well as the competitive comparison, are made in a similar manner.

The initial definition of the weights as input for QFD is important. However, there is an ambiguity in the understanding and comparison of the weights of distinct characteristics based on personal perceptions spanning an uncertain environment. To enable a straightforward comparison, the weights of the first step can be computed by AHP, which is then used as an enhancement for the QFD application.

2.2. Analytic Hierarchy Process (AHP)

AHP is a decision-making method widely used and available in various tools and software. Consequently, just a short overview is given here. AHP first starts with the decomposition of the problem into a hierarchy. This is breaking down the problem at the upper level into associated subproblems, i.e. criteria in the lower level, which can be further detailed into sub-criteria at lower levels. Each criterion can contribute to decision-making by its weight, and the partial contributions add up to the overall score (Ucler, 2017b). Since the human brain is not capable to respect all criteria simultaneously to assign correct weights intrinsically, weighing within a single layer leverages pairwise comparisons of hierarchically set criteria with verbal expressions, and the associated numeric value is assigned to each expression (see Table 1) populating the positive reciprocal ($n \times n$) comparison matrix $\boldsymbol{C}$ (Saaty, 1980, 1990; Cho et al., 2003).

Lines, as well as columns of the matrix $\boldsymbol{C}$, are for these n criteria, which are then compared against each other so that the diagonal of the comparison matrix $\boldsymbol{C}$ is populated with factor 1. The normalized eigenvector $\vec{\ }$ of C yields

Table 1. Comparison Scale of Saaty (1990)

Verbal Expression	Comparison Factor	Inverse Factor
Equal	1	1
Moderate	3	1/3
Strong	5	1/5
Very Strong	7	1/7
Extreme	9	1/9

associated weights of the criteria respecting $A\vec{w} = \lambda\vec{w}$ with λ as the maximum eigenvalue (Ucler, 2017b). Nevertheless, there can be errors in the judgment that the consistency ratio (*CR*) must be better than 10%, which is computed as

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \text{ and } CR = \frac{CI}{RI} < 0.1. \quad (2)$$

There, the Consistency Index (*CI*) is a function of λ and *n*, while the Random *CI*(*RI*) can be taken from Alonso and Lamata (2006). In the case of multiple evaluators either full consensus is to be sought after or RGMM prioritization procedure can be utilized given there is an acceptable inconsistency in each evaluation (Escobar et al., 2004).

2.3. Analytic hierarchy hrocess and quality function deployment (AHP-QFD)

The combination of AHP with QFD is a common method used to incorporate the weights of the customer requirements determined by AHP into the first step of QFD (Bhattacharya et al., 2005; Chen et al., 2007; Dai & Blackhurst, 2012; Chadawada et al., 2015; Ucler, 2017a). Since this does not include a hierarchical problem definition, a simple pairwise comparison can be utilized to yield the weighing. Here, fuzzy AHP was not used due to practical reasons; AHP was used simply as a real-time assessment tool, without data post-processing but just weighing. Then, since fuzzy extend analysis can deliver incorrect weights (Yan et al., 2012) and mislead wrong decisions (Wang et al., 2008) it was also not applied. Moreover, the aim is to consolidate product design and associated requirements here that only the first 2 steps of QFD were utilized, where the output of AHP is the input of the 1st HoQ (see Figure 1).

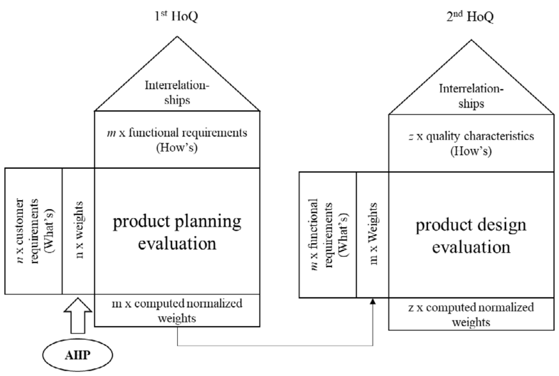

Figure 1. Combination of AHP with the 2-step QFD applied

3. Results and discussion

The customer requirements were based on a survey by a major airline as described in the method section. There were no weights associated with the criteria, which made it impractical to judge for trade-offs. Hence, an initial expert assessment of the importance of these criteria was done in the marketing department, which is subject to intuitive-logical analysis (Boiko, 2018). The first intention was to

Matrix		Low weight 1	Low price 2	Esthetic & Modern design 3	Comfort & Ergonomics 4	Durability & Robustness 5	Certification 6	Aircraft OEM approval 7	Technology integration 8	Passenger experience & Privacy 9	Lowest operational cost & Easy 10
Low weight	1	-	1	1 3/8	1 1/4	1 1/6	1	1 1/6	1 1/4	1 1/3	1 1/3
Low price	2	1	-	1 1/3	1 1/4	1 1/4	1	1 1/6	1 1/6	1 1/3	1 1/3
Esthetic & Modern design	3	3/4	3/4	-	6/7	4/5	3/4	6/7	6/7	6/7	6/7
Comfort & Ergonomics	4	4/5	4/5	1 1/6	-	1	3/4	6/7	1	1	1
Durability & Robustness	5	6/7	4/5	1 1/4	1	-	4/5	1	1	1 1/6	1 1/6
Certification	6	1	1	1 3/8	1 1/3	1 1/4	-	1 1/3	1 1/3	1 1/4	1 1/4
Aircraft OEM approval	7	6/7	6/7	1 1/6	1 1/6	1	3/4	-	1 1/6	1 1/6	1 1/6
Technology integration	8	4/5	6/7	1 1/6	1	1	3/4	6/7	-	1 1/9	1 1/9
Passenger experience & Privacy	9	3/4	3/4	1 1/6	1	6/7	4/5	6/7	1	-	1
Lowest operational cost & Easy maintenance	10	3/4	3/4	1 1/6	1	6/7	4/5	6/7	1	1	-

Figure 2. Comparison matrix for AHP

leverage those weights in the QFD work, but during the weighing process, the consensus was not achieved that the AHP methodology was used involving pairwise comparisons (see Figure 2). This delivered the partial importance of each requirement, which was slightly adjusting the initial values (see Table 2). Moreover, being an analytical tool, AHP did stop argumentation and the results were better accepted and internalized by the team members.

Yang et al. (2021) made a Gemba walk and extracted the main needs of railway seats as body-friendly seat structure and reasonable layout from the perspective of the end user, i.e., the traveler. Here, the criterion for comfort and ergonomics covers these items, but there are other important customer requirements because the assessment here is about the preferences of the airline during the airborne operation as well. Hence, the scope in aviation is wider including life-cycle aspects, certification, weight, and other airline-related perspectives. Thus, an analogy to seat development in other transportation vertices is given but further insight is required for aircraft seats.

There, certification requirements, low weight, and low price were dominating with a cumulative significance of 68% as expected. These items were highlighted together with the passenger experience in the internal development procedures of the company as priorities. However, the passenger experience was cut lower than expected with just 3% participation. This seemed to be contradicting the new trend of experience economy in transportation. Experience is a phenomenon related to the service interaction between the airline and the air traveler.

It wouldn't be wrong to say that subsystem suppliers such as seat manufacturers have not finished the transformation of their mindset towards immersive experience yet. Similarly, lower operational costs and easy maintenance were also ranked lower than initially expected. It is recommended to have a review and update of the weighing together with the customer and preferably also with some end-users, i.e. air travelers. Hence, inter-organizational concurrent engineering involving airlines and Maintenance, Repair and Overhaul Organizations (MROs) can be practiced in suppliers to enhance the level of insight further.

Table 2. Weighing customer requirements

n	Criteria	Initial Expert Assessment, %	Assessment with AHP, %
1	Low weight	20	22
2	Low price	20	21
3	Aesthetics & Modern Design	3	2
4	Comfort & Ergonomics	5	4
5	Durability & Robustness	6	7
6	Certification	20	25
7	Aircraft OEM approval	8	8
8	Technology integration	6	5
9	Passenger Experience & Privacy	7	3
10	Lowest operational cost & Easy maintenance	5	3

Note: RGMM; α = 0.1; CR = 3%.

Then, the 1st HoQ (see Figure 3) was created by using the customer requirements and brainstorming the associated functional requirements. These requirements and their associated relative weights were quantified as main structure design (15.8%), backrest design (15.5%), usage of new generation & lightweight materials (11.4%), seat density (0.7%), number of parts (5.8%), seat width (2.6%), armrest design (2.3%), ergonomic & comfort cushion (8.5%), seat pan design (3.8%), modernization & 4K monitor (6.3%), Bring Your Own Device (BYOD) solutions (7.4%), optimized living space (1.3%), test & HIC compliance (6.4%), official suppliers of aircraft OEM (6.4%), and modularity & adaptation (5.7%).

As expected, the structural design requirements did participate with a cumulative weight of 49.1%. Consequently, the associated R&D projects involving computer-aided engineering (CAE) resources were justified. Aviation involves high certification costs. Once a design is certified and goes into production further optimization is usually not preferred. Nevertheless, this contradicts the outcome of this QFD work. Optimization projects for leg and backrest design are proven to be of high importance and alternative materials and design elements must be leveraged to enhance customer satisfaction.

Then, the part reduction did arise as a further development project. Similarly, ergonomics research as suggested by Bekiaris (1999) and BYOD projects have to be looked at to enhance the experience in the cabin. Moreover, the low AHP rating of experience implies that it is not perceived well as a single argument. Its constructs must be further broken down. QFD was used in the past for strategic justification (Singh et al., 2015) and AHP was utilized for many selection problematics (Ucler, 2017b), but the usage of AHP-QFD for product strategy and the strategic portfolio management of R&D projects in aviation as made here is worth to note as a unique application.

The interrelationships of the quality characteristics were defined as strong positive/negative correlation and positive/negative correlation in the roof of the HoQ, in which absolute values were used as 3 and 1 respectively to determine the interrelationship scores (IS) by summing up their products with associated frequencies. Consequently, it was seen that the backrest design, main structure design, seat width, and test & HIC compliance were cut as

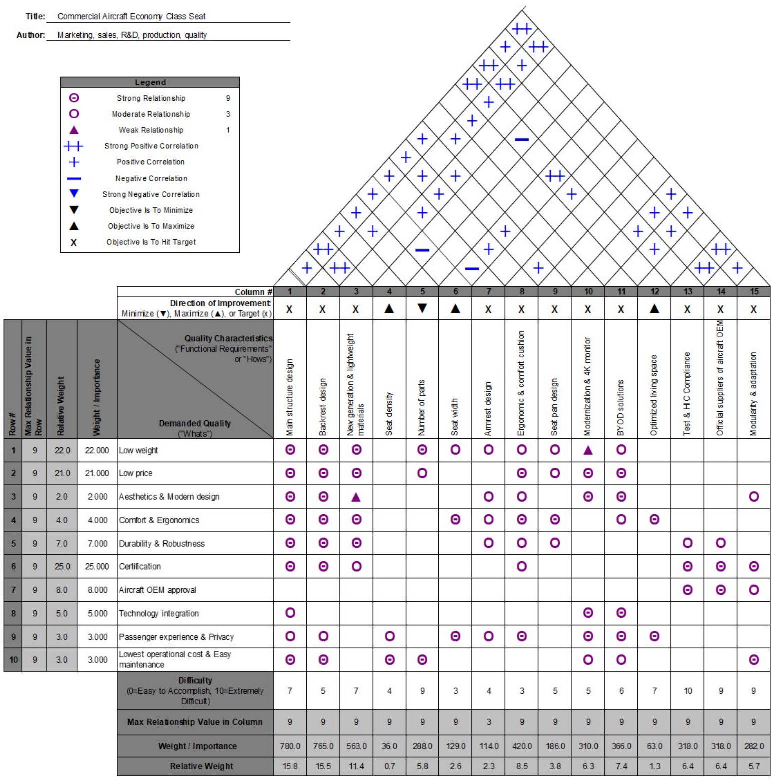

Figure 3. The 1st HoQ for product planning

Table 3. Interrelationship Scores of the 1st HoQ

Rank	Quality Characteristics (How's) of the 1st HoQ	IS
1	Backrest design	27
2	Main structure design	20
3	Seat width	6
3	Test & HIC Compliance	6
4	New generation & lightweight materials	3
4	Modernization & 4K monitor	3
4	BYOD solutions	3
5	Seat density	2
6	Armrest design	1
6	Ergonomic & comfort cushion	1
6	Official suppliers of aircraft OEM	1
7	Number of parts	0
7	Seat pan design	0
7	Optimized living space	0
7	Modularity & adaptation	0

Note: IS = sum (a x b), with a = frequency, b = 0 for no correlation, b = 1 for correlation & b = 3 for strong correlation.

Table 4. Interrelationship Scores of the 2nd HoQ

Rank	Quality Characteristics (How's) of the 2nd HoQ	IS
1	Material selection	25
2	Manufacturing method	16
3	Number of validation tests	15
4	Strength & stiffness	11
5	Abuse load case	7
6	Dynamic load case	6
6	Cost of part production	6
7	Cost of engineering	4
7	Ease of installation	4
8	Flammability	3
8	Weight of parts	3
8	Safety	3
9	Accessibility of spare parts	2
10	Easy to use	0
10	Durability	0

Note: IS = sum (a x b), with a = frequency, b = 0 for no correlation, b = 1 for correlation & b = 3 for strong correlation.

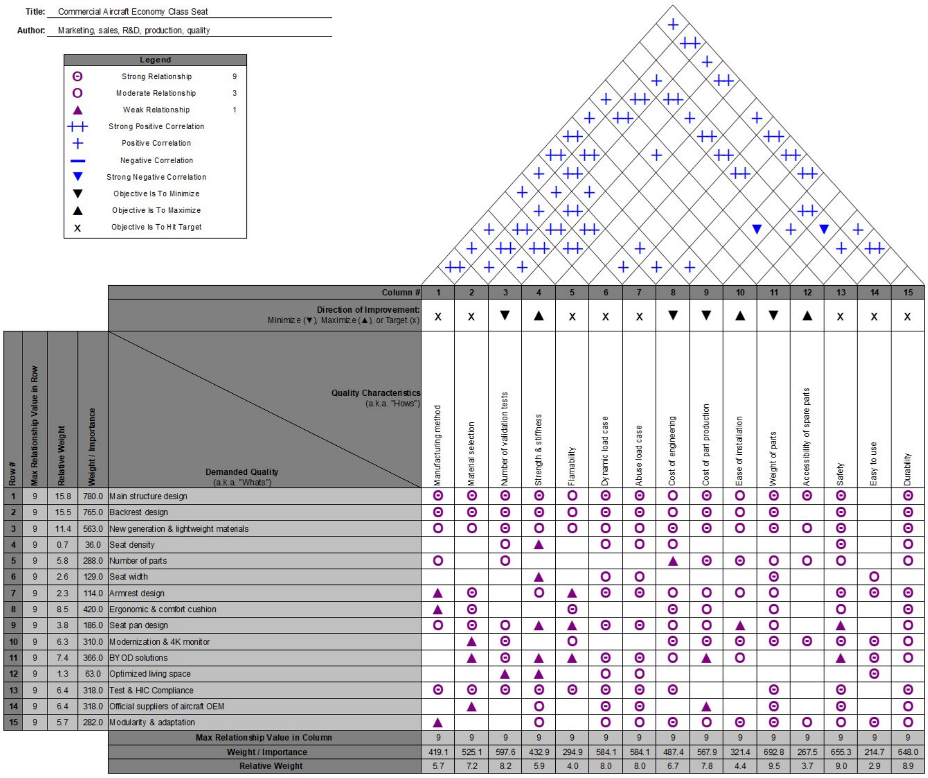

Figure 4. The 2nd HoQ for product design

the top three with the highest IS (see Table 3). These characteristics are indeed related to most of the other parameters subject to trade-offs. Any iteration for these quality characteristics is subject to be checked with respect to its impact on its dependent variables as defined in the QFD workshop. Hence a formal step for this check was added to the design routines.

These results of the 1st HoQ were then used to create the 2nd HoQ (see Figure 4). There, the How's and their associated weights were determined within the group as manufacturing method (5.7%), material selection (7.2%), number of validation tests (8.2%), strength & stiffness (5.9%), flammability (4%), dynamic load case (8%), abuse load case (8%), cost of engineering (6.7), cost of part production (7.8%), ease of installation (4.4%), weight of parts (9.5%), accessibility of spare parts (3.7%), safety (9%), ease of use (2.9%), and durability (8.9%).

64.7% of these quality characteristics, i.e. material selection, number of validation tests, strength & stiffness, dynamic load case, abuse load case, the weight of parts, safety, and durability, are related to structural design and its validation. This implies that product development mainly involves simulations and tests to assure durability by keeping the weight down, which was expected as well. Nevertheless, the number of tests and the amount of engineering work are driving the costs up, which must also be kept low.

Consequently, new manufacturing methods and new materials must be explored to yield light and durable seat designs. This corresponds to 12.9% weight, which justifies composite materials R&D programs for this purpose. Considering the high number of tests related to various load cases with 24.2%, it is obvious that the test infrastructure deserves new investments, particularly tools such as strain gauges for safety and durability assessments (17.9%). This is also a strategic decision, which requires investment. It is also worth mentioning that the flammability must be looked at individually despite its low participation of 4% because it acts as a must-have boundary condition rather than an objective. The remaining items, i.e., accessibility of spare parts and ease of use, are of lower weight and deserve attention but no extra measures were planned since these are assessed as already covered adequately.

The IS computation of the 2nd HoQ resulted in the top three interrelationships being related to material selection, manufacturing method, and the number of validation tests (see Table 4).

Conclusions

Aviation is recovering from the pandemic outbreak rapidly. New aircraft orders are driving the supply chain to enhance cabin experience, which is particularly influenced by seat design. There, the perception of the experience is not the same for everyone. Moreover, the main customer is the airline while the end-user is the air traveler, and preferences can become easily contradicting. Distinct constructs are contributing to the fact that customer requirements must be explored adequately with respect to their importance. Hence the AHP-QFD methodology is used here to understand and weigh customer requirements to conclude what must be done to yield optimum products.

AHP-QFD is an established method to convert the VOC into a product, but the literature given for seats is usually focused either on single-step QFD or seats are not exemplified. Moreover, there are neither any AHP-QFD applications related to aircraft seats nor any examples for the strategic usage of AHP-QFD subject to R&D project portfolio planning. However, aircraft seats are unique and have special requirements compared to those for other means of transportation. Hence, to the best of the knowledge of the authors, the application here is unique concerning its scope.

Survey results from a major airline were leveraged as a starting point, which delivers insight into aviation and operator-side requirements for aircraft seats. This is a novelty as well. The comparison of intuitive weights of requirements with AHP results indicated that the perception forming expert opinion did prove to be consistent despite the need for small adjustments. However, the analytical approach of AHP was superior with respect to its support of the internalization of the results: The team simply accepted the outcome, and the process was much smoother without debates.

Certification, low weight, and low price were determined by AHP as the top three requirements with a weight of 25, 22, and 21% respectively. Moreover, AHP results indicated that particularly the passenger experience is not well perceived. Hence, the development work inside aircraft sub-systems suppliers must include further inter-organizational collaboration to transform the mindset of suppliers into a similar constitution at airlines.

The 1st HoQ indicated that the main structure design, backrest design, and the usage of new generation & lightweight materials are the top three quality characteristics with weights of 15.8, 15.5, and 11.4% respectively. Then, the 2nd HoQ indicated a homogenous distribution across various quality characteristics with a cluster of 64.7% coverage particularly related to structural design and its validation. A novel scoring method of interdependencies is used to isolate design variables subject to trade-offs. Then, the structural design requirements were leveraged to justify new R&D projects focusing on composite materials, part reduction, and ergonomics by also enhancing the CAE and testing infrastructure. This involves new development projects in the backrest and leg design and justifies investments.

The most important managerial implication is that the AHP-QFD framework is shown to be easily applicable enabling cross-organizational collaboration, and it can be used for product strategy and strategic portfolio management of R&D projects. Another practical application is the divergence of perception of the experience by suppliers versus the airlines. Suppliers are highly encouraged to explore product variations by including airlines and air travelers as well.

Considering that the initial sample is taken from a major airline and the research is carried out in an aircraft seat manufacturer working on a global scale, the generality is assumed to be given. Nevertheless, there are still some limitations: the case study leveraged the incorporation of bidirectional requirements flow from a single airline and did utilize experts from a single company without an inter-organizational context. Although comparisons were made against the international benchmark, they cannot be given here due to confidentiality reasons. Consequently, future research is planned first to incorporate airline members and MROs during the QFD workshops and then to collaborate with various airlines to underline the generality. Then, the scope was to focus on civil aviation seats, but any other seat for transportation purposes, i.e., cars, trains, ships, can be looked at in analogy as well. Finally, further research into passenger experience subject to its constructs and the consolidation of end-user requirements in relation is planned.

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The authors declare herewith that there are no competing financial, professional, or personal interests from other parties with respect to this research work.

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