Stakeholder's Needs Analysis Methodology For Civil Aircraft Projects

He Yuwei¹, Li Haomin², Zhang Xinai³, Shi Yaming⁴ and Chen Fudong⁵

¹Shanghai Aircraft Design and Research Institute, Shanghai, 201210, China
²Shanghai Aircraft Design and Research Institute, Shanghai, 201210, China
³Shanghai Aircraft Design and Research Institute, Shanghai, 201210, China
⁴Shanghai Aircraft Design and Research Institute, Shanghai, 201210, China
⁵Shanghai Aircraft Design and Research Institute, Shanghai, 201210, China

*Corresponding author’s e-mail: heyuwei@comac.cc

Abstract. Aircraft product development process is quite complex, involving many stakeholders. Therefore, aircraft owner manufacturers need to fully capture the needs of stakeholders at the beginning of design, establish analysis methods of stakeholder’s needs, and transform "customer voice" into aircraft development requirements, so as to ensure that the aircraft products can meet the needs of stakeholders. This paper introduces stakeholder’s needs analysis methods such as quality function deployment (QFD), analytic hierarchy process (AHP), and analytic network process (ANP). This paper establishes a Stakeholder's needs analysis model, which can be used to carry out stakeholder’s needs analysis of civil aircraft.

1. Introduction

Air transport has entered the age of popularization. The pressure of cost has made airlines turn the pursuit of technological advancement to the pursuit of market economy. For civil aircraft projects, the stakeholders include not only the traditional customers, namely airlines and leasing companies, but also their suppliers, subcontractors, airworthiness, etc. To achieve commercial success in the development of civil aircraft projects, all the stakeholder’s needs must be fully considered at the beginning of the project design, so as to ensure the final market competitiveness of civil aircraft.

Aircraft product development process is quite complex and involves extensive stakeholders. Various stakeholders will put forward different "requirements and expectations" for aircraft products based on their own usage perspectives. In the field of design development, the "requirements and expectations" of stakeholders are collectively referred to as their "needs" for aircraft products. Most of these "needs" of stakeholders are reasonable, but not all of them are. The notion that "Stakeholder's needs are design requirements" is wrong and harmful to aircraft development. If the needs of all stakeholders were taken into account, the aircraft would become "bloated" and uneconomical. Successful products have common focus: focusing on the needs of most stakeholders rather than the needs of all stakeholders. Therefore, it is necessary to establish the tradeoff analysis methods of stakeholder’s needs, transform "customer voice" into development requirements, and finally implement the needs of stakeholders in aircraft products.
2. Stakeholders’ needs capture and classify
Stakeholder’s needs are the requirements or expectations for the aircraft product. The needs of stakeholders are generally vague, general, but can be classified and sorted.

Stakeholder's needs capture methods include brainstorming, questionnaires and interviews, prototypes and simulations etc. First, according to the stakeholder identification model, identify the various stakeholders, and define their types and importance; Secondly, there are many traditional methods to capture the needs of stakeholders, including questionnaires, interview, analyzing historical data and collecting industry information.

After capturing the needs of stakeholders, all the original information is recorded. These needs can be classified and sorted by KJ method. These needs can also be combined with product quality according to the following attributes: a) expected needs, or the "Must be" category; B) Performance needs, or "Satisfiers" categories; C) Excited needs, or "Delighter" category; D) "unimportant" categories in which the customer is not interested in the existence of product features or services; E) "Reverse" category, where the product features or services will cause customer dissatisfaction. Among the above five categories, the first three are the positive aspects of product quality, which will affect customer demand satisfaction to different degrees. Stakeholders' needs can be classified by stakeholders' needs satisfaction model, as shown in Figure 1.

![Figure 1. Stakeholders' needs satisfaction model.](image)

3. Stakeholders' needs analysis methods
Considering the characteristics of the aircraft product, as well as the marketing and commercial success of the project, not all the stakeholders' needs need to be met. Therefore, these requirements need to be trade off during the conceptual design stage of aircraft development.

Several methods were found to address Stakeholder's needs analysis, including: quality function deployment (QFD), analytic hierarchy process (AHP), and network analysis (ANP).

3.1. Quality function Expansion (QFD method)
QFD is a structured approach[1], and can be used to transform the needs of stakeholders into aircraft development requirements, usually including operators, end users of products, airworthiness, manufacturers and regulatory authorities. Stakeholders’ needs can be linked to aircraft development needs through QFD analysis method, be confirmed through QFD matrix. The analysis model of QFD is a series of matrix unfolding diagrams that quantify the relationship between Stakeholder's needs and design characteristics[2]. The structure of this analysis model is described as "House type", which is called "House of Quality ", as shown in Figure 2.
Figure 2. QFD analysis of Stakeholder's needs

A) Room 1 - Stakeholder's needs

Room 1 is stakeholder's needs, it is also known as "customer voice" that should be captured in the early stages of aircraft development. The stakeholder's needs of Room 1 are the basis of stakeholder's needs analysis, and can be classification and prioritization before analysis.

B) Room 2 - Competitive comparison

According to the existing data and experience of aircraft development, stakeholder's needs can be compared with competitive models, including the comparison of market, schedule, cost, manufacturing and other aspects. Through competitive comparison, the relative importance of stakeholder's needs can be determined. The result of this comparison can be entered into room 2 of QFD.

C) Room 3 - Technical requirements

This step is mainly based on technical features to realize stakeholder's needs, transforming "customer voice" into "design requirements", and establishing quantifiable design requirements. To ensure that the correct requirements are included in the list, they should be properly classified. It is an important step to establish the relationship between stakeholder needs and aircraft product characteristics. For example, the minimum design service objectives required by the customer are related to aircraft taxiing time, flight mission profile, wheel stop time, etc.

D) Room 4 - Competitive benchmark for technology assessment

This step adopts quantitative analysis technology for technical evaluation through competitive products or services, so as to analyze the importance of technical requirements.

E) Room 5 - Relationship matrix between stakeholder's needs and technical requirements

Each technical requirement must be determined to have a close, moderate or weak impact on the stakeholder's needs. Through the application of QFD process, we can determine which requirements are the most important to meet the needs of customers. The degree of the relationship between customer requirements and various technical requirements or standards can be analyzed and listed. If necessary, the relational matrix can be confirmed by review.

According to the importance of the relationship between stakeholder's needs and technical requirements, evaluate and rank the importance of stakeholder's needs. The weighted coefficient is the importance of the corresponding customer demand, which can be expressed as a numerical value between 1 and 10.

The importance of the relationship between stakeholder's needs and technical requirements generally includes the following:

1) Weak relationships: For relatively large changes in technical requirements, predict slight improvements in customer satisfaction. The value of weak correlation is generally 1;

2) Moderate relationships: significant changes in customer satisfaction are predicted for relatively large changes in technical requirements. The value of moderate correlation is generally 3;

3) Close relationship: For minor changes in technical requirements, predict significant changes in customer satisfaction. Strongly correlated values are usually 9.
F) Roof 6 - Technical characteristics correlation matrix
The correlation between reaction corresponding technical characteristics. The degree of correlation is divided into: positive correlation, that is, mutual support between technical characteristics; Strong positive correlation; Negative correlation refers to the conflict between technical characteristics. Strong negative correlation. Correlation can be represented by different coincidence, for example: +: positive correlation; --: Negative correlation. If there is no correlation, this area should be left blank.

G) Room 7 - Objectives and restrictions
According to the technical requirements needed to meet customer requirements, determine the numerical index.
Using the QFD method, the first step is to investigate the needs of stakeholders, convert the needs of stakeholders into requirements, and determine the relative importance of the requirements. The second step is to analyze the market competitiveness. The third step is to identify the design characteristics. The fourth step is to complete the relational matrix to determine the impact of design characteristics on requirements. The fifth step is to determine the technical indicators of design characteristics. The sixth step is to complete the correlation matrix. The core step of using the QFD method is to create a relational matrix and a correlation matrix.
The QFD method should be carried out at all stages of product development. The house of quality outputs the relative importance of the design features. The design team determines how to design new aircraft products or improve existing products based on the relative importance of the design features, ultimately satisfying all the needs of stakeholders.

3.2. Analytic Hierarchy Process (AHP)
The Analytic Hierarchy Process (AHP) uses a multi-layered structure to represent a complex decision. It is assumed that the higher-level elements can be decomposed into lower-level elements[3]. Through subjective judgment and mathematical calculation, the pros and cons of different schemes can be obtained. The basic idea of AHP is to decompose first and then synthesize. The problems to be analyzed are decomposed into models of different levels, and a multi-layer structural model is formed according to the relationship between superior and subordinate levels and the advantages and disadvantages of elements of the same level. Finally, the weight or relative importance order of the importance of the bottom level (scheme, measure and technical index) relative to the top level (overall goal) is obtained. Its workflow and structural models are shown in Figures 3.

Figure 3. AHP workflow
The specific workflow of AHP is as follows:
- Managers and decision makers hold seminars to understand decision-making ideas, principles and programs;
- To collect information related to the system extensively, have an in-depth understanding of the system, determine the overall objectives, and develop guidelines and strategies;
- Establish an index system for evaluating decision-making schemes. According to different objectives and functions, a multi-level structure model is established.
- To test the rationality of the indicator system and structural model and obtain the approval of managers and decision-makers;
- Determine the importance distribution of each indicator through discussion according to the decision goal;
- Construct paired comparison judgment matrix and calculation process, use each element to evaluate the pros and cons of each element in the next layer, and calculate its relative importance;
- Conduct consistency test on the judgment matrix formed in the previous step;
Carry out the hierarchy general ranking, calculate the total importance degree of each layer element to the system target, and get the importance degree of the lowest layer element to the total target;

Check the design process and analyze the decision results to provide basis for decision makers.

To sum up the above process, AHP can be divided into three main steps for multi-criteria decision making of complex system: (1) establishing hierarchical structure model; (2) Conduct preference analysis and establish the relative importance ranking of each layer; (3) Comprehensive, establish the total ranking. The first step is to analyze the structure and then build a hierarchical model. That is, for a decision problem, according to the content of the problem and the overall goal of the decision, the problem is decomposed into different elements, and the elements are divided into different levels according to the relationship between the elements, finally forming the order of the relative importance of the lowest level relative to the highest level.

AHP provides an efficient method of assessment decision makers, and is a flexible approach, suitable for all kinds of decision problem, particularly applicable to the stakeholders’ needs trade-off. The advantages and disadvantages of AHP are as follows:

- Treat the object handled as a system and a system analysis tool;
- Ability to combine qualitative and quantitative analysis;
- The input information comes from the decision maker's judgment and choice, which reflects the decision maker's cognition of the decision problem;
- Enable communication between decision makers and decision analysts;
- Not much quantitative information is required for analysis;
- Simple and clear thinking;
- Suitable for decision analysis of complex problems with multiple criteria and objectives.

Prior to the use of the QFD method, the AHP method can be used to prioritize the needs of stakeholders. When using the quality QFD method, the AHP method can be used to compare the competitive evaluation index.

3.3. Analytic Network Process (ANP)

Analytic Network Process (ANP) is developed on the basis of Analytic hierarchy Process[4]. The key of ANP is to divide the system into different levels, considering the influence of upper elements on lower elements, and the elements of the same layer are independent of each other.

ANP considers the interdependence of different levels and elements at the same level, so that the relationships between elements actually form a network structure, which can better make decisions for practical problems. ANP divides system elements into two parts: control layer and network layer[5]. The control layer consists of problem objectives and decision criteria, which are independent of each other and can form a hierarchical structure. The control layer can also have no decision criteria and only goals, in which case goals are the only decision criteria. The network layer is composed of elements dominated by the control layer. Similar elements constitute the element set, and the elements interact with each other, forming the network structure as shown in Figure 4.
ANP is mostly used in feedback systems where there is an interdependency between the index and the scheme. In the QFD method, there is an interdependent relationship between Stakeholder’s needs and design characteristics in the HOUSE of Quality. QFD and ANP method can be used in combination in the analysis process of stakeholder's needs tradeoff. ANP method is more suitable for the decomposition process of quality function expansion, and can provide better hierarchical structure and traceability than AHP.

4. Summary
Based on the research on above three typical analysis methods for stakeholders’s needs of civil aircraft, the following indicators are proposed to compare the advantages and disadvantages of these methods, as shown in Table 1:
- Applicability of complex systems (e.g., civil aircraft systems);
- Traceability from Stakeholder's needs to requirements;
- Ability to extract qualitative and quantitative information;
- The ability to provide a framework for requirements.

Table 1 Evaluation comparison of the three methods

| Evaluation                          | QFD | AHP | ANP |
|------------------------------------|-----|-----|-----|
| Applicability of complex systems   | 5   | 6   | 8   |
| traceability                       | 6   | 6   | 8   |
| Information extraction capability  | 5   | 6   | 6   |
| Requirements framework             | 6   | 6   | 8   |

Note: The value represents the degree of applicability. The higher the value, the better.

The QFD method, which can be used as a benchmark to transform stakeholder's needs into design requirements, has been widely used and is very mature. The structure of AHP and ANP is similar to the complex structure of civil aircraft system, and it is very flexible, which can guarantee the traceability of information. During the transformation, the three methods can be combined to obtain the best solution and finally form the analysis method for typical civil aircraft stakeholders.

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