Exploratory Study on Sub-supplier Management for Commercial Aircraft

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Abstract. With the development of commercial airplanes, the entire aircraft supply chain is becoming more and more complex and involves more and more suppliers, which puts higher requirements on the supply chain management capability of the main manufacturer. The management of supply chain and related suppliers by international mainstream aircraft manufacturers has been relatively mature, and a set of relatively mature models and mechanisms have been formed from the direct control of the first-tier suppliers to the control of the first-tier suppliers over the sub-suppliers. On the contrary, due to the late development of domestic large aircraft, production delivery is just starting, the main manufacturer for the supply chain and even sub-supplier management is still at the stage of figuring out. This paper combines the supply chain management concept and the main manufacturer's actual supplier management experience, based on the idea of forward design, identifies the concerns of commercial airplanes in sub-supplier management, and establishes an evaluation model of sub-supplier management for commercial airplanes. The research results provide new ideas for managing sub-suppliers for the main manufacturer.

Keywords: Commercial Aircraft; Supply Chain; Supplier Management; Sub-Tier Suppliers

1 INTRODUCTION

With the extreme prosperity of the commodity economy in modern society, the closer between goods and commodities, the concept of supply chain has slowly come into people's view, and supply chain management is more and more important for the development of modern enterprises[1]. The concept of supply chain was first introduced by an American, Harrison, around the 1980s. A supply chain is generally considered to be a network of business sectors such as suppliers (suppliers of raw materials and parts), manufacturers (producers of products), and vendors (sellers of products) that are organized to acquire materials, process products, and ultimately deliver products to users [2]. The air transport is an important pillar of international transportation and is one of the most important economic activities for development and economic progress[3]. In recent years, significant progress has been made in the development, certi

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fication, delivery and operation of domestic large airplanes [4]. For commercial airplanes, from systems, subsystems, equipment to materials and components as many as several million parts, it is a project of huge scale, involving a wide variety of technologies, taking a long time, and involving a large number of people, and commercial airplanes with a long supply chain, many control nodes, and overlapping suppliers and sub-suppliers, with intricate and complex relationships [5]. Thomas Bilczo et al. analyzed the dynamic evolution, design, and optimization of the aircraft supply chain using Boeing as an example, thus illustrating the dynamic process between Boeing and its suppliers [6]. The control of commercial aircraft supply chain is more demanding. Doing a good job in the control of commercial aircraft supply chain can help the main manufacturer to integrate the resources and strengths of all parties, and lead to the enhancement of the capability of the whole aircraft supply chain. The civil aircraft supply chain structure is shown in Fig 1.

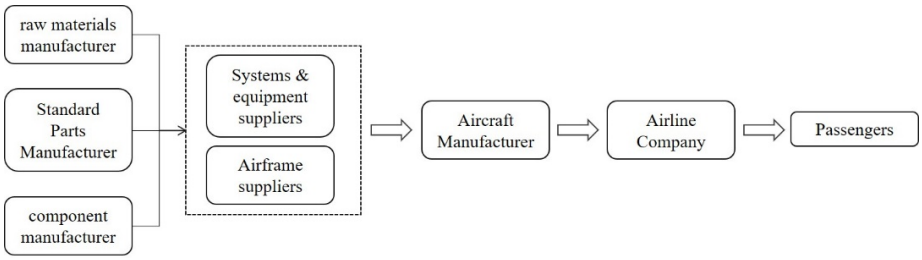

Fig. 1. The civil aircraft supply chain structure

Globally, the development of commercial airplanes is dominated by Boeing and Airbus, which have adopted different supplier strategies. The development of the Boeing 787 airplane is the international mainstream system and equipment suppliers are responsible for product design and manufacturing, and Boeing carries out the overall integration of the airplane. In this model, the master manufacturer is highly dependent on its suppliers, and the core competitive capabilities of some products are held by its suppliers. In addition, there are also development risks, such as the risk of over-investment in research and development of aircraft products, unmanageable progress in product delivery, and product quality problems. The Airbus A380 airplane development is that the main manufacturer is responsible for the product design work, and its suppliers manufacture the products according to the design specifications, drawings, interface documents and so on[7]. Under this model, the main manufacturer can master the core competitiveness of the product, but the research and development cost of the whole aircraft will be mostly borne by the main manufacturer, and it cannot fully utilize the latest technology and high-quality products in the global market. The Boeing B787 and Airbus A380 are representative of the supplier model comparisons used, as shown in Table 1:

Table 1. Boeing & Airbus supplier model comparison [8]

Primary manufacturer	Supplier model	Vantage	Inadequate
B787	Product development and manufacturing are carried out by the supplier, while the main manufacturer mainly carries out system integration.	The costs and risks of aircraft development are shared between the primary manufacturer and the supplier.	It is prone to problems such as over-budgeting, delayed progress, product quality problems, and reduced competitiveness of the main manufacturer.
A380	The main manufacturer is responsible for the product design (drawings, product specifications, detailed interfaces, etc.) of the relevant systems and equipment, and the supplier is mainly responsible for manufacturing according to the drawings.	The competitiveness of the main manufacturer will be enhanced.	Difficulty in accessing the latest technologies and techniques, R&D costs to be borne by the main manufacturer

Whether it is B787 or A380, the main manufacturer has to manage sub-suppliers. However, under the B787 model, the main manufacturer has higher requirements for the management of sub-suppliers, which not only includes basic management system requirements such as selection and evaluation of sub-suppliers, but also needs to control the related design, manufacturing, configuration, airworthiness, etc., and if necessary, the main manufacturer needs to directly control the sub-suppliers. The A380 model requires only that Tier 1 suppliers have a well-established sub-supplier management system in place and implement it effectively.

With the continuous change and development of the supply chain management mode of civil aircraft main manufacturers, risk sharing has become the mainstream mode of cooperation between main manufacturers and suppliers nowadays [9]. Domestic large aircraft development is also currently used in the main manufacturer-supplier model, where the supplier carries out product development and manufacturing, and the main manufacturer mainly carries out system integration, with the main manufacturer and supplier sharing risks and benefits [10]. With the gradual deterioration of relations between China and the West, the supply chain of domestic civilian aircraft is at great risk, and China urgently needs and must gradually shift its core competencies from foreign to domestic suppliers. Under such circumstances, on the one hand, domestic suppliers need to vigorously improve their own technical and management capabilities; on the other hand, the main manufacturers need to strengthen the management of their first-tier and sub-tier suppliers.

Combined with the experience of international mainstream Boeing and Airbus in supply chain management mode, the following section will analyze the management ideas of the main manufacturers of civil aircraft on sub-suppliers from the actual supplier management in the development of domestic civil aircraft products. Through sorting out the requirements of the main manufacturers for suppliers in the process of civil aircraft development, establishing sub-supplier evaluation models and evaluation criteria for different product types and different stages of development, and formulating targeted cultivation strategies based on the evaluation results of different suppliers, thus providing reference for the control and management of sub-suppliers of civil aircraft.

2 SUB-SUPPLIER MANAGEMENT

In the automotive sector, AIAG (Automotive Industry Action Group) had released a CQI series of manuals in 2012 based on industry best practices, including a CQI-19 Sub-tier Supplier Management Process Guideline. This manual gives a workflow for overall supplier development and management in the automotive industry and provides best practices for automotive OEMs to manage sub-suppliers. However, in the field of commercial airplanes, the current sub-supplier management documents applicable to major manufacturers are mainly AP-21-AA-2019-31 airworthiness regulations and AS9100 aerospace quality management system and other top-level supplier control requirements, and there is no applicable authoritative standard for sub-supplier control.

Aircraft involve a large number of supply chain tiers, especially the number of suppliers further down the tier. In the traditional civil aircraft supply chain model, the main manufacturer focuses more on the management of its first-tier suppliers, while the management of the suppliers of the first-tier suppliers, i.e., the sub-suppliers, tends to be low-transparency, uncontrolled, and unappreciated, and the whole supply chain level lacks a unified management requirement. On the one hand, it is due to the problem of internal resources of the main manufacturer that it is not possible to know in a timely manner how the first-tier suppliers manage the sub-suppliers; on the other hand, the sub-suppliers also lack the appropriate management system and third-party supervision and inspection. Sub-suppliers affect the progress of the project to a certain extent, and the prime manufacturer should consider how to manage sub-suppliers to reduce the risk of sub-suppliers to the development and delivery of the project [11].

Generally, civil aircraft sub-supplier management mainly includes two aspects: one is that the main manufacturer requires the first-tier suppliers to manage their sub-suppliers to meet the requirements of civil aircraft, and the other is that the main manufacturer carries out direct control over the key sub-suppliers. As for other less important sub-suppliers, it is necessary to help first-tier suppliers improve their management systems and assist them in cultivating sub-suppliers. The requirements for supplier management at all levels of the civil aircraft supply chain are shown in Fig 2.

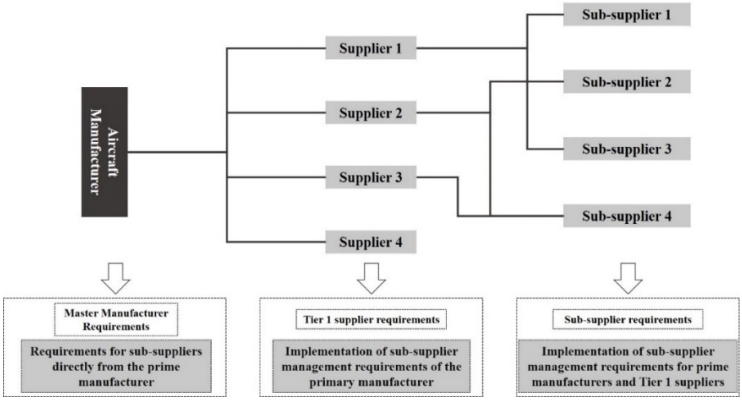

Fig. 2. The requirements for supplier management at all levels of the civil aircraft supply chain

For prime manufacturers, requirements for tier-1 suppliers and sub-suppliers should be established in accordance with a hierarchy of security levels based on the types of products undertaken by different suppliers. For the first-tier suppliers of airborne systems/equipment, airframe structures, etc., the main manufacturer can require them to establish a civil aircraft development system and management system that meets the requirements, so as to carry out strong control over the sub-suppliers, and for the identified critical and important parts, they can directly carry out supplier management as needed. In view of the fact that the domestic civil aircraft industry has just started and most domestic suppliers do not understand the requirements of civil aircraft development and management, it is very necessary for the main manufacturers to set up a corresponding cultivation mechanism to enhance the relevant capabilities of the first-tier suppliers.

For the first-tier suppliers, a set of requirement documents for assessing the development and management capability of sub-suppliers shall be established, and the applicable requirements shall be passed to the sub-suppliers through technical agreements, contracts and other document carriers in view of the requirements of different civil aircraft products, and the implementation of the requirements shall be inspected, which include, but are not limited to, the technical requirements, quality requirements, airworthiness requirements, customer service requirements, and requirements for the management of the suppliers, and so on. Tier-1 suppliers need to cultivate and guide the systems and capabilities of their key sub-suppliers when their systems are complete, so as to ensure the product development and management capabilities of the entire supply chain.

The ability of first-tier suppliers to manage sub-suppliers needs to be evaluated and monitored by the primary manufacturer, which is necessary for the management enhancement of the entire civil aircraft supply chain. Therefore, the following is a list of issues to be considered when evaluating a first-tier supplier based on the master manufacturer's control of sub-suppliers, and the corresponding evaluation checklist and model are developed to provide lessons and ideas for the master manufacturer's management of sub-suppliers. In addition, Tier 1 suppliers can also refer to this assessment model based on the importance of their own products and incorporate it into their own sub-supplier assessment requirements.

3 SUB-SUPPLIER MANAGEMENT ASSESSMENT MODEL

The following discussion will focus on four aspects: the idea of establishing a sub-supplier management evaluation model, sub-supplier evaluation model, sub-supplier evaluation criteria and sub-supplier cultivation in the development of commercial aircraft products.

3.1 Assessment Modelling Ideas

Based on the concept of forward design, and according to the characteristics and requirements of the development of civil aircraft products, the idea of establishing a sub-supplier management assessment model with requirements sorting-module division-applicable scenarios-assessment model-assessment criteria is formulated, and the idea of establishing an assessment model is shown in Fig 3.

Comprehensively sort out the specific requirements of sub-supplier management involved in the development process of commercial aircraft, mainly including bureau regulations and requirements, general standards of supply chain management, applicable standards, specifications and procedures of the main manufacturers, etc., and integrate and de-emphasize the sorted out requirements to form a specific list of requirements. Based on the requirements for suppliers in the process of commercial aircraft product development, the requirements are divided into modules according to the dimensions of project management, quality system, design and development, production and manufacturing, airworthiness management, customer service, configuration management, reliability control and so on. The scenarios applicable to each requirement are clarified, and the assessment scenarios include the applicable product types (airborne system equipment, structural parts, material standard parts, electronic components), the applicable supplier categories (Class A, Class B, Class C et), the applicable product development phases (preliminary design, detailed design, product trial production, product delivery, etc.), and the applicable assessment modes (document auditing, on-site auditing, etc.), and other aspects. The requirements for the assessment of the sub-supplier management capacity of domestic first-tier suppliers were finalized, including 9 modules and 62 requirements, and 38 assessment question items were formulated based on the assessment requirements. Understanding and reading the identified assessment questions, matching each question with a score weighting based on the importance of the question item, and developing the appropriate assessment criteria.

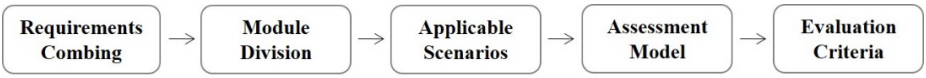

Fig. 3. The idea of establishing an assessment model

3.2 Content of the Evaluation

The evaluation and selection of suppliers plays a crucial role in improving the sustainability of their products[12]. Sub-supplier management capability assessment for Tier 1 suppliers can be carried out by the prime manufacturer in nine areas: program management, quality system, engineering development, material selection, configuration management, manufacturing, airworthiness management, customer service and reliability. The sub-supplier management assessment module is delineated in Fig 4, and the assessment can be conducted around the following elements:

In terms of project management, sub-supplier management requirements can revolve around the understanding of the main manufacturer's supplier requirement documents

and their transmission to sub-suppliers, supply chain management organization and personnel structure, supplier management plan, supplier management platform, and the establishment of supplier management tools. In terms of quality system, it mainly evaluates the establishment of procedural documents for sub-supplier management by first-tier suppliers, including but not limited to supplier selection, contract signing, procurement implementation, performance management, qualified supplier catalog, product acceptance, outsourcing, and distributor control requirements, etc. For civil aircraft products, it also pays special attention to the control requirements of sub-supplier's prevention of counterfeit parts and excess materials. For engineering research and development, it mainly evaluates the transmission and control of design information, test verification management requirements, and software control requirements. In terms of material selection, the main assessment includes the selection of material/standard parts specifications and suppliers, the selection of component specifications and suppliers, and the control requirements for key materials. In terms of configuration management, the configuration control of sub-supplier management can be centered around the transmission of the main manufacturer's configuration requirements, the understanding of sub-supplier's configuration requirements, and the sub-supplier's requirements in the CMP (Configuration Management Plan). In manufacturing, the main assessment is the control requirements for secondary process sources, process qualification requirements for outsourced processes and products, and process control requirements. Airworthiness management is mainly concerned with checking the transmission of the main manufacturer's airworthiness requirements. In terms of customer service, the main assessment is on the customer service information of sub-suppliers and the management of customer service facilities. In terms of reliability, the main assessment is the evaluation of the reliability system of sub-suppliers, the development of reliability work plans, the transmission of reliability work requirements, and the verification of reliability tests.

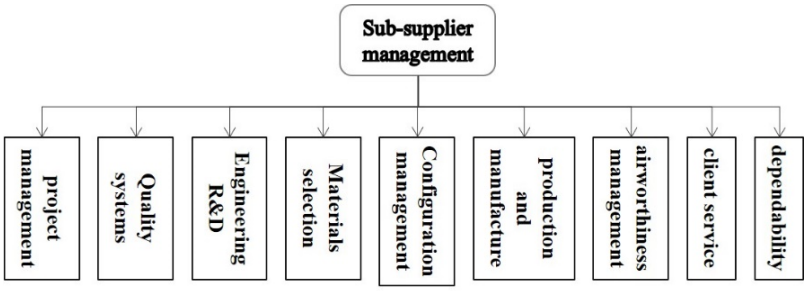

Fig. 4. The sub-supplier management assessment module

When assessing the sub-supplier management capability of a first-tier supplier, a master manufacturer can filter the applicable assessment question items according to the type of supplier and its stage of product development and score the assessment according to the scoring guideline, which is based on the following filtering principles:

(1) If the product type is an airborne system/equipment or structural component, all evaluation check items apply.

(2) If the product belongs to material standard parts and electronic components, the inspection items related to configuration management, airworthiness and customer service are not applicable.

(3) The evaluation team may screen or add or subtract check items for applicability depending on the stage of development of the product.

3.3 Assessment Criteria and Weighting

The default scoring weights for the nine modules of the Sub-supplier Management Capability Assessment for Tier 1 Suppliers conducted by the prime manufacturer are shown in Table 2. The assessor can reset the scoring weights for each module based on the type of project product.

Table 2. Individual module score weightings

serial number	module	weighting
1	Project management	20%
2	Quality systems	50%
3	Engineering R&D	5%
4	Material selection	5%
5	Configuration management	3%
6	Manufacturing	7%
7	Airworthiness management	3%
8	Customer service	2%
9	Reliability	5%

The evaluator can sort out and form an evaluation checklist for the project based on the project's situation and calculate to obtain the final evaluation score based on the evaluation guidelines. The assessment score is calculated in accordance with formula 1:

$$N = \sum_{i}^{9} \left\{ \left(X_i \div aY_i \right) \times k \times 100\% \right\} \tag{1}$$

Formulas，

N——Total score for supplier evaluation；

i——Supplier assessment module；

k——Scoring weights for modules；

X——Supplier's actual score；

Y——Number of question items in each dimension；

a——Full marks for each question item.

3.4 Supplier Cultivation

Due to the lack of experience of domestic suppliers in the development of civil aircraft products and their lack of understanding of the requirements related to the development of civil aircraft, as the main manufacturer of the aircraft, it is very much obliged to cultivate and guide the sub-supplier management ability of the first-tier suppliers in order to improve the management ability of the first-tier suppliers, and the first-tier suppliers also need to cultivate the management ability of the sub-suppliers accordingly, so as to achieve the effect of passing on help and teaching. Through the cascading transfer of requirements and cultivation, it will lead to the improvement of the entire civil aircraft supply chain management capability.

Main manufacturers and Tier 1 suppliers can implement different nurturing intervention strategies based on the scoring results of the Supplier Management Capability Assessment (SMCA). For suppliers with poor capabilities, the main manufacturer and the first-tier suppliers directly guide their supplier capabilities; for suppliers with medium capabilities, the main manufacturer and the first-tier suppliers work together with external consulting organizations and experts to improve supplier capabilities; for suppliers with strong capabilities, the suppliers carry out continuous improvement of their capabilities on their own with the help of external trainings and conferences.

4 CONCLUSION

This paper researches the supply chain management requirements of international mainstream manufacturers, analyzes the mode and content of sub-supplier management of civilian aircraft manufacturers, establishes the requirements and evaluation model of sub-supplier management of manufacturers based on the actual experience of domestic civilian aircraft manufacturers, and explores the mechanism of sub-supplier control and cultivation of domestic sub-suppliers by combining with the concept of supply chain management, so as to lay a foundation for the stability and sustainability of the supply chain of civilian aircrafts. In the future, based on the practical experience of supplier management in actual projects, we will continue to improve the requirements for assessing the sub-sub-supplier management capability of the main manufacturer for the first-tier suppliers, and explore the possibility of direct control of some sub-sub-suppliers by the main manufacturer.

In this works, for the sub-suppliers, which are less concerned by the main manufacturers, we discuss the methods and requirements of sub-supplier management in aircraft development. I hope this paper is suitable for ICMSEM 2024. This article has the following three innovative points:

1. Based on the concept of forward design of civil aircraft system engineering, combined with the requirements of different categories of products, we have established the idea of establishing an evaluation model for the control of sub-suppliers of commercial aircraft from the sorting out of requirements to the evaluation criteria.

2. Identify the main concerns and assessment weights for sub-supplier management in civil aircraft product development, focusing on the characteristics of civil aircraft development.

3. Pioneering guidance on sub-supplier cultivation and establishing different supplier cultivation strategies for suppliers with different capabilities.

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