OUTSOURCING DECISIONS AND PRODUCT CHARACTERISTICS REGARDING COMMERCIAL AIRCRAFT INTEGRATORS

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Abstract

The pioneering of the concept of outsourcing in the aircraft manufacturing industry was Embraer, followed by Bombardier Aerospace. Recently, Airbus and Boeing adapted this particular production strategy as well. The outcome of these companies' outsourcing decisions differs to a wide extent, from being very successful to having incurred severe delays and losses of product quality. This paper uses insights from these four case studies as well as theoretical considerations from management theory and institutional economics to analyze the different benefits and problems that arise from outsourcing. According to the latter theory, potential problems are incurred due to insufficient alignment of organizational, technical and process-related procedures. Combining the theoretical and empirical analysis, a framework is developed that specifies several categories including number of competitors or level of complexity against which various aircraft component categories are rated in regard to their outsourcing-specific criticality. It helps to depict those areas that are less critical when it comes to outsourcing as well as those areas which exhibit high complexity and specificity, and are thus rather ineligible for external production. The analysis shows that the focus and degree of outsourcing in regard to the different aircraft integrators differed, and secondly, the necessary thorough alignment of expectations and standards failed in several instances. A major recommendation of the presented analysis is that airframe systems and integrated utility systems are critical components in aircraft integration. They should be part of the Original Equipment Manufacturers' (OEM) core business and are not suited as being entrusted to external risk-sharing partners.

1. INTRODUCTION

Investments in new aircraft programmes feature substantial capital requirements (new product families' cost ranges USD 2.0B-15B), compared to the development of most other products. Furthermore these large investments are increasing significantly with every new aircraft programme. Therefore, production strategies of major aircraft producers have recently been characterized by the outsourcing of development and manufacturing activities to external contractors. Such partners had to bear an increasing share of investments in infrastructure and even in research and technology, and, design activities, which gave them the rights to future sales income of the products. This special form of outsourcing has been called a "risk-sharing partnership". Despite the assumed advantages, this strategy has produced quite mixed results. Embraer started to apply risk-sharing partnerships in order to reduce investments and the dependence on loans already in the 1990s with its ERJ-145 programme, which became one of the best selling regional jets worldwide. Due to this success Embraer pursued a similar strategy with its ERJ-170/190 aircraft family. Bombardier Aerospace's approach to outsourcing by engaging in close mutual cooperation and consultation with its risk-sharing partners has also been crowned with success. Boeing in turn started to extend outsourcing activities in a hitherto unseen way in order to save on both production and development costs of its B787 Dreamliner. This turned out to create severe problems for the company. Yet in spite of the problems that had been experienced by Boeing, Airbus increased the share of production contracts, assigned to external partners.

Several authors have analysed theoretical advantages as well as possible drawbacks of outsourcing strategies. Others have described outsourcing activities in aerospace in context of case studies, e.g. as cited by Figueiredo et al. (2008), or, from a competitiveness point of view (Pritchard and MacPherson, 2007). This paper combines theoretical insights from management theory and new institutional economics concerning benefits and problems of outsourcing and applies those to aerospace in order to systematically assess what kind of activities are suited for outsourcing, and which are not. It will be shown that beside the well known advantages of specialisation, information problems and opportunistic behaviour in the market place are the key problems that reduce the likelihood of outsourcing activities becoming

advantageous in the aerospace industry. The paper also provides an overview of the outsourcing activities of the different commercial aircraft integrators and outlines success stories and problems experienced within this process.

The paper is structured as follows; Section 2 of the paper will outline the historical background regarding outsourcing activities in aerospace. Section 3 describes theoretical benefits and drawbacks associated with outsourcing activities – especially the latter can be explained by the principal-agent and organization theory. These theoretical insights are then applied to assess in Section 4 product and competition specific aspects in aerospace in order to analyse critical aircraft components with respect to their suitability for outsourcing, while Section 5 concludes.

2. OUTSOURCING IN THE AEROSPACE INDUSTRY

Soon after the pioneering first flight of the Wrights in 1903 until the mid-1990s what are referred to as aircraft integrators today (formerly known as aircraft manufacturers) traditionally would assume the burden of total program cost, namely, design, development, testing, certification, tooling, manufacturing, production and the associated infrastructure to facilitate these activities. Since the development of the ERJ-145 (Embraer) family of regional aircraft so-called risk-sharing partnerships with suppliers has become commonplace within the industry (Cassiolato et al., 2002). An evolution that began as outsourcing of manufacturing activities (build-to-print), such as parts and sub-assemblies, has reached a level of maturity such that in general the aircraft integrator only performs final assembly and testing operations. In other words, each risk-sharing partner delivers major assemblies that are “stuffed” with aircraft sub-systems, i.e. already fully tested and certified. McMasters and Cummings (2002) offer a synopsis of the evolution of commercial aircraft product development over the last 100-plus years. It can be observed in BILD 1 that aircraft integrators adopted the concept of outsourcing during the mid-1980s, and, the posit is that the post-modern era will bear witness to increasing emphasis on systems integration.

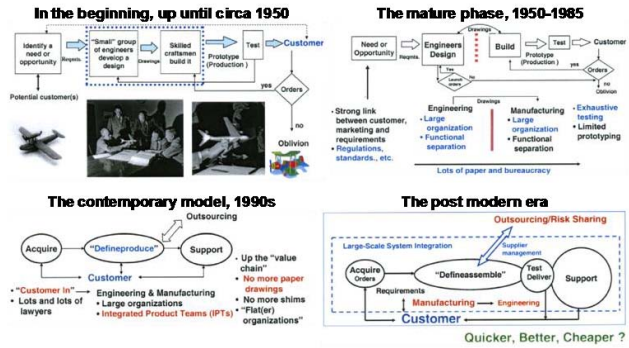

BILD 1. Evolution of commercial aircraft product development. (McMasters and Cummings, 2002)

Recent examples of major assembly tasks undertaken by aircraft integrators are cited as Embraer ERJ170/190, the Boeing B787, Airbus A350 XWB and A380, and, Bombardier Aerospace CSeries. In all instances each company has assumed responsibility for product specification, aircraft product development, sub-system integration, final assembly and program leadership.

2.1. Embraer

The Embraer aircraft types, ERJ-145 and ERJ170/190, were built during and after the company’s privatization in 1994. Due to the lack of financial funding, Embraer sought for strategic risk-sharing partnerships in order to acquire sufficient means both in technological and financial terms. Embraer defines three different types or levels of suppliers with the first being so-called risk-partners. These partners contribute to aircraft design and production by bearing a share of the financial risk as well as participating in the co-design process and adding technological value (Cassiolato et al., 2002). The second level partners include suppliers of components, parts and services. This relationship is characterized by an “information network” whereupon all partners engage in (Cassiolato et al., 2002). On the third level, there are sub-contractors which provide Embraer with project and engineering services as well as production services with a lower level of complexity.

The approaches taken in regard to the two aircraft types differ slightly. For the ERJ170/190 Embraer established greater integration and risk-sharing with the involved partners than it did with the ERJ-145 project. In the latter, Embraer set up a partnership with four companies which included risk-sharing, namely, a commitment to develop new sub-systems and profit sharing from aircraft sales. These kind of partners amounted to a total count of 16; BILD 2 presents a summary of the ERJ170/190 product development program risk-sharing partners/suppliers. Dedicated Embraer design and engineering work was declared for forward fuselage, fuselage centre section II, wing-fuselage fairing and wing assembly. Within both product development programs, efficient processes and product quality were ensured by establishing a system of integrated routines and coordination among partners (Cassiolato et al., 2002).

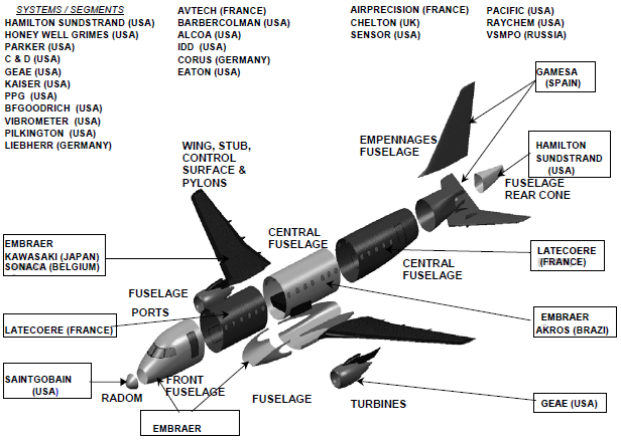

BILD 2. The ERJ170/190 risk-sharing partners. (Cassiolato et al., 2002)

Embraer defines its strategy towards aircraft product development as focusing on those technologies that are crucial for the final product. These include components and parts related to aerodynamics and fuselage. Furthermore, it is important for Embraer to concentrate on integration, i.e. integrate those components that cannot be fabricated and assembled in-house (Cassiolato et al., 2002). Its successful competitive strategy is based upon the coordination of a global network of partners and suppliers as well as adding value as a systems integrator.

2.2. Boeing

The development of the B787 has to be interpreted in the light of an increased competition in the airliner market and differing projections of air transport requirements in the 21st century by Boeing and Airbus. While Airbus projected air transport development to continue in the traditional hub-and-spoke system and therefore developed its A380 concept Boeing projected an increasing demand for point-to-point connections. Therefore, they decided to offer the B787 with an emphasis on fuel usage efficiency (Holzmann and Shenhar, 2010) and on the reduction of noise emissions as well as overall production and development costs.

Starting in 2003, several different approaches had been taken to adjust technological development and production to the company's internal projections. First of all, the budget for development and production was reduced, while simultaneously, the timeline for the development of the aircraft was tightened. Second, an integrated modular avionics approach was chosen which offered the potential to reduce the aircraft weight and afford flexibility for product upgrades over the lifetime of the platform. Finally, to align the modular production concept with the tight budget and production constraints, Boeing announced in 2004 that the majority of the components of its new B787 long-haul to ultra-long-haul airplane would be developed, engineered and manufactured by partners, leading to an external production share of more than 70% and close to 700 external companies (Holzmann and Shenhar, 2010)[1]. Only the final assembly of all the different components was to be carried out by Boeing in its role as a systems integrator.

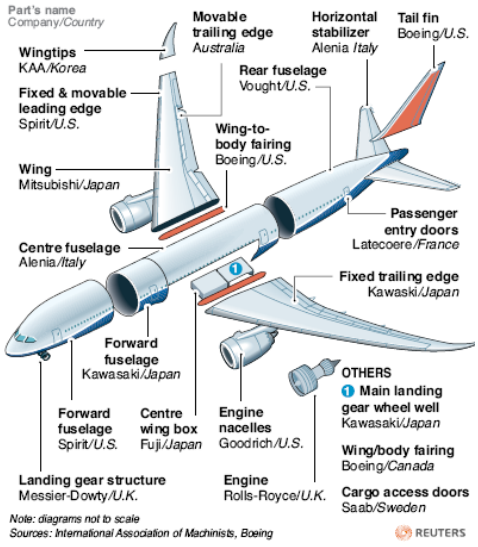

BILD 3. The B787 risk-sharing partners (Peterson, 2010).

BILD 3 (above) presents a summary of the B787 product development program risk-sharing partners/suppliers. Dedicated Boeing design and engineering work was declared for moveable trailing edge wing flap surfaces, wing-fuselage belly and vertical tail-fuselage fairings, and, forward and aft engine strut pylons.

Though obviously there have been many other firms in aerospace and other different industries who tried to use outsourcing as a way to increase profits, Boeing has pioneered it in a previously unseen extent in aerospace. The ambitious plan included the use of manufacturers from all over the world. As such, recognised companies from Italy, Japan, France, Canada and China had been commissioned to produce different parts of the B787. This included the manufacturing of the fixed wing section and the forward fuselage by Kawasaki Heavy Industries, of the center wing box by Fuji Heavy Industries, and of the main wing box by Mitsubishi Heavy Industries. Further, Italian producer Alenia Aeronautica was assigned the manufacturing of mid-fuselage sections and other body assemblies. Finally, Boeing retained only close to one third of the B787 total work share.

These examples reveal the risk-sharing approach that had been adopted by Boeing: it assigned its sub-contractors to do more assembly and deliver completed sub-systems. Boeing would then only perform the final assembly, and, ground and flight testing. The basic idea of this approach was to get a leaner and simpler assembly line, a lower inventory, as well as reduced risks and costs. To reduce financial risks, suppliers were asked to pledge absorption of all fixed costs of production and development, or more specifically, of all non-recurring costs that would arise during the production process. In exchange, intellectual property rights and patents of all the products developed by the respective partners remained with the sub-contractor, which was believed to offer an incentive for innovation (Horng, 2007).

Still and quite in contrast to what had been expected by Boeing, the outsourcing activities caused persistent problems such as long-term delivery delays (which were also worsened by a 57-day machinists strike) and massive qualitative hitches. Until 2010, the B787 product development program had already accumulated close to two years of delay (Holzmann and Shenhar, 2010). In January 2011, Boeing announced that the first B787 delivery was again further rescheduled to the third quarter of 2011. In July 2011, Boeing froze the B787 production for the fifth time, "...due to a few production areas in the supply chain that are experiencing temporary challenges.", according to Boeing spokesman Scott Lefeber.[2]

The delays were caused by a number of unexpected problems. For example, several parts produced by Italian Alenia Aeronautica such as horizontal stabilizers and the composite skin on the fuselage sections did not stand up to the organizational expectations of Boeing. In 2010 Boeing halted the assembly line four times largely due to quality problems with the horizontal tails from Alenia. Furthermore, problems arose not only in regard to quality aspects but also in terms of the supply chain management. These problems included unexpected production delays, ineffective planning of demand and production capacities or difficulties regarding design matching between the different partners. The cumulative production delays of more than three years caused the cancellation of several bookings by a variety of airlines.

[1] Holzmann and Shenhar (2010, p.6) point out that in the 1960s the share of foreign produced parts of the B727 was 2% while in the 1990s the respective share was close to 30% for the B777

[2] The Seattle Times, July 11, 2011, "Boeing freezes 787 production line in place for fifth time".

2.3. Airbus

In spite of these negative examples, Boeing's rival, Airbus, decided to change its strategy and adopt policy in the same direction. Similar to the Boeing B787, the Airbus A350 aircraft are intended for the long-haul to ultra-long-haul market segments. BILD 4 presents a summary of the A350 product development program risk-sharing partners/suppliers. Dedicated Airbus design and engineering work was declared for the composite upper wing panels, the complete vertical tail, composite fuselage panels, wing spars and stringers, wing-fuselage belly fairing, rudders, elevators, the so-called Section 19 (aft fuselage) maintenance doors, testing services including automated test equipment, and, exclusive landing gear systems testing.

BILD 4. The A350 risk-sharing partners. (Scotto d'Apollonia, 2010)

The sheer amount of risk-sharing partners and sub-contractors is not only relevant for an assessment of increasing outsourcing activities. The size of the outsourced work packages has also increased significantly. BILD 5 illustrates the decreasing number of work packages for several aircraft programs within Airbus.

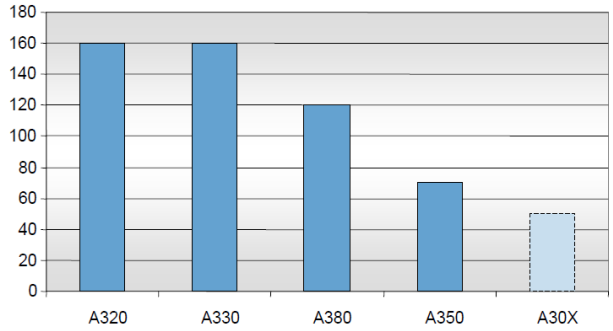

BILD 5. Average number of equipment work packages on Airbus programs. (Richter, 2009)

This has to be seen in context with a growing size of these work packages, which can be gleaned by the external purchasing volume within EADS: it had increased from 75% in 2002 to 86% in 2006 (Mundt, 2007). In its "Vision 2020", EADS sets the target to increase global sourcing to 40% of produced value added until the year 2020, partly by relocation of internal production. BILD 6 shows the intended increase in sourcing activities according to the respective components in the value chain.

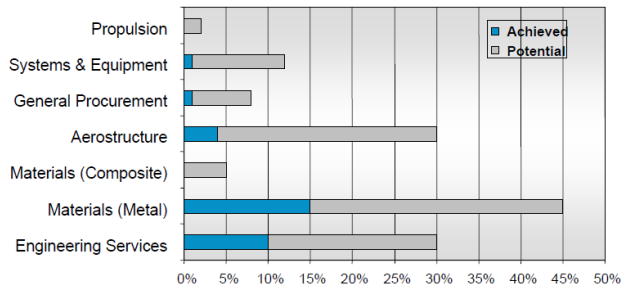

BILD 6. EADS Global Sourcing potential by 2020. (Richter, 2009)

It is obvious to conclude that these sourcing activities will not only occur by new internal production sites outside of Europe, but also with an increased reliance on sub-contracted external suppliers. In the course of these developments Airbus was even trying to sell its own manufacturing locations in France, Germany, and the UK, which turned out to be a difficult exercise. For the spin-offs Aerolia (F) and Premium Aerotech (D), founded in 2008, no investor was secured. However, since it became evident that their knowledge is of strategic importance, e.g. in the manufacturing of carbon composites, Airbus finally decided to keep them as wholly owned subsidiaries.

2.4. Bombardier

The Bombardier Aerospace CSeries aircraft are intended for the small to medium size narrow-body market segments. BILD 7 presents a summary of the CSeries product development program risk-sharing partners/suppliers. Dedicated Bombardier Aerospace design and engineering work was declared for the composite wing, and, forward and aft fuselage assemblies.

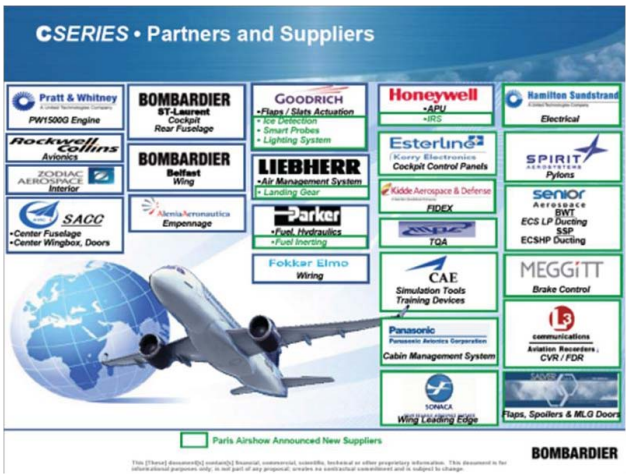

BILD 7. The CSeries risk-sharing partners. (Scott, 2009)

Although not considered to be the pioneer in this respect, Bombardier Aerospace has had an extensive amount of experience with regards to multi-partner programs in the past, e.g. CRJ 700/900/1000 regional jet family and Challenger 300 super-midsized business jet to name a couple. The company's now mature business model is a product of building up an organizational culture over many years and establishment of a reliable global supply chain. The CSeries is an excellent example of how this continually refined model and supporting infrastructure can be of great benefit, especially during the Joint Conceptual

Definition phase (JCDP). During this critical conceptual design orientated segment of the product development program, potential suppliers and risk-sharing partners are co-located, along with Bombardier Aerospace systems integrators in order to further develop basic architectures and functionalities. These activities not only assure technical readiness to launch, but also provide initial costing data for business case justification. One successful exemplar of this approach was the very close working relationship established between Pratt and Whitney and Bombardier Aerospace during the concept definition phase of the PW1000 series propulsion system.

Irrespective of having such a secure foundation, the amelioration of risk cannot always be assured. Innovations and the appropriate project management of, in particular, low-to-moderate Technology Readiness Level (TRL) engineering solutions (from the perspective of the aircraft integrator, Bombardier Aerospace) becomes the sole responsibility of the risk-sharing partner in question. For instance, extensive use of composites and other advanced materials like Aluminium-Lithium alloys in the CSeries aircraft had been during the concept definition phase flagged as being potentially problematic if the recruitment of partners and associated suppliers with tried and trusted processes does not occur. Early in 2008, Grob Aerospace was identified as a potential preferred partner when it came to development and manufacture of composite aircraft structures; in fact, Grob Aerospace was appointed as a primary partner of the Learjet 85 business jet development program at that point in time. The strategy for Bombardier Aerospace was to secure a preferred partner relationship, thereby, ensuring all technology research and development work with respect to composite structures would be available for other programs like the CSeries. In the end, owing to Grob Aerospace becoming insolvent in September 2008, it was decided that the composite wing structure for the CSeries would be designed and developed solely by the Bombardier Aerospace Belfast site. This is a good example where the business model of selecting risk-sharing partners can be compromised beyond common sensibilities of evaluating technical competency and project management acumen.

2.5. Insights about In-house Production Decision-making

Comparing and contrasting the design and engineering commitment made by each of the aircraft integrators discussed above produces a few interesting observations. Of prime importance for the companies appears to be procurement of major assemblies that are exposed to aerodynamically critical zones. Consequently, each aircraft integrator makes a point of engaging in some form of wing, wing-fuselage belly fairing, empennage and forward fuselage section design and integration. Secondly, emphasis is also placed on structures, materials technology and manufacturing techniques, e.g. Boeing commitment for the aft fuselage section of B787, although not within a critical aerodynamic zone this major assembly does interface with the vertical tail of which Boeing has assumed responsibility. These observations upon reflection are logical since each of the cited aircraft integrators have accumulated a long history of aircraft design and development including exclusive knowledge about aerodynamics and structures, software/analysis techniques, testing and certification. A beneficial aspect is that the multi-disciplinary nature of such work packages ensures continuity of in-house engineering design, analysis and integration competency.

3. BENEFITS AND CHALLENGES REGARDING OUTSOURCING ACTIVITIES

The reasons behind outsourcing are manifold. The following section will outline the intentions why firms consider the outsourcing of activities or products to external suppliers. In addition to that, the discussion will elaborate on the potential risks associated with this type of business model.

3.1. Specialisation and Cost Savings

Outsourcing decisions of many firms are driven by the aim to reduce overall costs. Increased production efficiency, and hence, cost savings can be realized due to specialization regarding production activities, and the division of labour. These concepts go back to Adam Smith (1776) and state that specialisation is linked to the division of labour, thereafter, leading to the accumulation of greater knowledge and better production skills. Since it is difficult and costly to acquire these special skills and knowledge for a wide range of activities in-house, expertise or special machinery is sought externally. Engaging in this kind of business model might generate time savings as well as efficient production processes. Accordingly, a reduction in production costs might also arise from economies of scale which denotes the situation when efficiency of production increases if operations take place at a larger scale. For example, if one doubles a firm's input, production or output of this particular firm may more (or less) than double, depending on the cost and production structure of the product. Another reason for lower production costs with external partners results from smoothing organizational processes. Smaller companies with fewer employees are believed to require a smaller amount of administration and infrastructure, which will in turn reduce overhead costs and increase the efficiency of internal organization. Finally, a lower level of administration cost may result from improved cost control and the fact that outsourcing offers the opportunity to turn fixed investment cost into variable cost.

Outsourcing may also be a result of strategic considerations which are linked to cost savings only indirectly and rather emerge from a company's intention to increase its flexibility (Kremic and Tukel, 2006). A company can thus adjust to changes in consumer demand and an altered market environment in a better way. As a consequence of globalization and reduced product life cycles, customer requirements need to be met without any major delay, and therefore, the alignment of production or supply activities to volatile demand in the market place is of increased importance (Kremic and Tukel, 2006). Furthermore, outsourcing in this particular context implies some form of risk-sharing among the partners in terms of research, development and investment. These are significant cost components in aerospace where the setup of a new aircraft or engine programme entails large investment efforts, and therefore associated risk. A company can hence concentrate on its core competencies by allocating increasingly scarce resources towards it and building a specific knowledge and skill base regarding particular competencies. Once again, a smaller and more focused business set-up is believed to add positively to the company's profits.

Outsourcing decisions might not only be driven by costs and strategic decisions but also by political motivations that invoke trade barriers; more specifically, offsets. It often depends on the intentions and agenda of the political party currently in power and rather follows a social than a political reasoning (Kremic, 2006).

These particular motivations that spur outsourcing also bear risks which have to be considered carefully and will be discussed in the next section.

3.2. Asymmetric information, individual rent seeking and transaction costs

Horng (2007), Earl (1996), and, Prahalad and Hamel (1990) highlight the fact that an enthusiasm for the benefits is often accompanied by the outsourcing of the wrong functions. As a result, focusing on core competencies goes along with diminishing internal synergies in terms of duties and routines within a company, for example. This has a negative effect on administrative processes and reduces the efficiency of internal organization. Hence, "...[i]f organizations outsource the wrong functions they may develop gaps in their learning or knowledge base which may preclude them from future opportunities." (Horng, 2007).

Apart from the problems that may result from strategy-driven outsourcing decisions, ex-ante outsourcing assessments often do not explicitly consider so-called transaction costs which in fact might bear some severe risks. The theory of transaction costs can be explained by applying new institutional economics and its underlying theories. Transaction costs are hence considered to be costs that emerge from any form of economic activity under different institutional arrangements, i.e. costs are incurred by the same activity being carried out within a new organizational environment. Accordingly, transaction costs include the costs of monitoring the compliance of the involved parties to the new agreements, the costs of setting up contracts, monitoring quality, or of specifying qualitative and other requirements. Further, costs that develop from the simple fact that the same economic activity will usually not run as smoothly in a new institutional framework are also considered to be transaction costs.

A company who decides to transfer part of its manufacturing activity to an external partner has to take into account that specification, setup and monitoring of the agreement will create costs. In (aircraft) product development, for example, problems might arise in the joint conceptual definition phase due to the implications going along with transaction costs. For example, the main product integrator has to make huge efforts to teach the other participants, e.g. suppliers, the relevant approach. The different parties involved may have underlying philosophies regarding structures and behaviour within their company which in turn require alignment in order to work efficiently. Furthermore, processes and procedures yield potentials for conflict and therefore have to be addressed thoroughly. In order to assess the profitability of any production process and its outsourcing potential, these transaction costs must be set in relation to the future benefits of any change in the organizational structure of the production process.

In addition to the more general causes leading to the existence of transaction costs, there are several other reasons that have to be taken into account. According to Williamson (1975), one of the basic reasons for the existence of transaction costs is the fact that markets will not function without a certain level of competition. This implies that in small number exchange relations where competition is flawed on account of the reduced number of participants, the outcome of the bargaining agreements will not be efficient. The reason for this rather surprising finding of markets producing inefficient results can be explained as follows: contracts that link different parties in the market place are usually not self-enforcing, which implies that neither state authorities nor business partners will be in the position to prevent deviations from it and thus enforce the respective agreements.

Within markets that are characterized by a sufficiently high degree of competition, deviators who show opportunistic behaviour can be punished by excluding them from future market interactions. In a situation where competition is flawed and certain market participants hold a position which is special and indispensable for the interaction, this is not possible. This is the case with suppliers that possess special skills, knowledge and machinery regarding specific processes or products and whose contribution is therefore rather valuable for the final product itself. Hence, market participants who behave opportunistically by not adhering to contractual agreements cannot be punished effectively. Due to the lack of competition, these partners and their expertise are essential to the whole production process, there is no possibility to prevent future opportunism in the market place. Accordingly, this allows a manufacturer whose input is crucial for a certain market transaction to use his position to bargain for a higher share of the jointly produced surplus, i.e. skim all the quasi-rents. Further, the partner can provide suboptimal quality and still enforce a high price for its intermediate good. In the present context, this can be interpreted as follows. The manufacturer of a component, whose contribution is essential to the whole production process in the sense that the final product cannot be assembled without the respective component, in all likelihood, will not be punished effectively if there are no other producers on the market or if waiting for other producers of the component would be too costly. This is the case, since the only threat the aircraft integrator can use to force the manufacturer of the component is not credible. The integrator could threaten to withdraw from the contract, yet the manufacturer would know that the component cannot be replaced on the market.

However, the reason for the lack of competition in certain market environments can be manifold. The unique position of a producer, which is determined by the number of comparable competitors, therefore depends on certain product specific characteristics. Furthermore, established relationships with a supplier and the resulting benefits also contribute to an integrator's choice. As outlined above, with each new competitor a product integrator has to raise efforts to align philosophies, processes and procedures in order for production processes to run efficiently. Therefore, many product integrators end up with preferred suppliers which cannot easily be replaced by any competitor.

4. ASSESSMENT OF OUTSOURCING DECISIONS IN AIRCRAFT DEVELOPMENT

The following section applies the theoretical findings from economic theory to the aircraft manufacturing industry.

Different aircraft categories are assessed in regard to specified parameters which will in turn help to identify critical components and processes which might pose problems when considered for outsourcing. The application to the aircraft integrators' outsourcing approaches highlights those aspects which contributed to an either successful strategy or the occurrence of problems and delays.

4.1. Qualitative outsourcing assessment of aircraft components

Within this section, a structured approach assists in identifying critical production areas in terms of their suitability for outsourcing. A qualitative survey was performed that establishes a link between technical areas of expertise required for commercial aircraft product development and aspects derived from the economic theories outlined above, i.e. market specifications. The survey dataset is based upon collation and subsequent categorization of information compiled from various references cited in this paper in conjunction with in-house expertise from industry experience.

Following this approach, TAB 1 depicts the different market specifications relevant for decision making in terms of outsourcing.

Number of Competitors	The probability of a sub-performing sub-contractor to be replaced in the next development program
Complexity	Specialization advantages are most valuable but the suitability of sub-contractors may be relatively low
Specificity	The missing capability of a process to be standardized, and therefore, easily available on the market (a transaction/production of an aircraft component that is more valuable to the specific production than to any other deployment – this creates a mutual hold-up situation)
Essentiality	The respective component is of critical relevance for the functioning of the whole product
Life Cycle Duration	The necessity of a sub-contractor to provide support and coverage over the entire life of the product platform

TAB 1. Market specifications (source: own depiction)

The relevant technical areas of expertise in TAB 2 are assessed against the market specifications. The framework developed in TAB 3 therefore represents an identification and evaluation of critical fields and components which will be elaborated below.

All entries provided in TAB 3 are declared as "H – high", "M – medium", or, "L – low". The colour coding adopted is not intrinsically linked with the annotations made in the table. The color "red" indicates a critical attribute in context of outsourcing, "green" is synonymous with acceptable or minor criticality, and, "yellow" denotes modest to moderate criticality and neutral in terms of desirability.

Design Tools and Methods	Aircraft design and visualization software programs
Materials	Alloys and composites
Components	Static and mechatronic sub-systems
Airframe Systems	Integrated major assemblies and cabin systems
Integrated Utility Systems	Avionics fully integrated with major power, kinematic, thermal, control, communications, instrumentation and navigation systems
Power Systems	Primary and auxiliary power sources including propulsion
Production	Tooling, fabrication, manufacturing and associated planning and monitoring
Testing	Virtual, physical including so-called "iron-bird" rigs

TAB 2. Technical areas of expertise (source: own depiction)

	Number of Competitors	Complexity	Specificity	Essentiality	Life Cycle Duration
Design Tools and Methods	L	L	L	L	L
Materials (Alloys and Composites)	M	L	L	L	L
Components (Mech. & Elect.)	H	M	M	L	L
Airframe Syst. (Asmbly & Cabn)	M	H	H	M	M
Integrated Utility Systems	L	H	H	H	H
Power Systems (Prim. and Aux.)	M	M	M	H	M
Production (Tool. and Manf.)	H	M	L	L	L
Testing (Virtual and Physical)	H	M	M	H	M

TAB 3. Qualitative survey of requisite technical areas of expertise versus market specifications.

According to this analysis, integrated utility systems (IUS) represent a technically critical area for outsourcing. First of all, the number of suppliers and hence the availability of competitors dealing with IUS is not large. This is due to the fact that the task of procuring a coherent and consistent tightly-coupled, complex avionic-mechatronic

systems design is very specialized, and as a consequence most often, is unique for a given product development program. Apart from that, the complete array of sub-systems and components that constitute the IUS bill-of-material can be provided by a sole supplier such as GE Aviation Systems or United Technology Corporation (UTC). Furthermore, the IUS is considered to be a critical feature within the production process and hence essential for the final product.

From a platform life cycle perspective, the IUS also is considered to be rather important. The tendency towards modular architectures also induce increased demand for product upgrades such as minor and major variants of the aircraft platform which typically take place every 7 years over a 20-25+ year life span. Modularity facilitates implementation of enhanced functionality of various systems for the existing product with associated benefits of lower weight, improved maintenance cost and reduced incremental product development cost burden. Outsourcing the activities related to IUS may therefore lead to heavy dependence on specific suppliers, opportunistic behaviour of the suppliers, production delays, and hence higher costs than initially anticipated.

In comparison, airframe systems, including major assemblies and cabin interiors, represent the second most critical technical area in terms of outsourcing. The number of suppliers that can handle all facets of airframe systems such as aerodynamic and structural design is growing and will become increasingly robust in future (rated as “M” in the table). Evidence shows that these suppliers possess the necessary technical expertise to design, develop, fabricate, build, test and certify such systems. This particular aspect is therefore considered to be of modest criticality. Regarding economic theory, a growing number of competitors in a certain field implies that a manufacturer might be less prone to opportunistic behaviour of suppliers. Still, airframe systems represent an area that is characterized by a high degree of complexity and specificity. The alignment of processes and procedures between manufacturer and supplier therefore requires high effort in terms of mutual technical and organisational approaches, organizational philosophies and contractual monitoring. These transaction costs may prevent a manufacturer from switching easily between airframe system suppliers.

In keeping with the clustering approach to information presented in TAB 3, a medium level of criticality could be assigned to Components, Power Systems and Testing. It was observed that availability of companies for such work packages range from middle level (Power Systems) to high (Components and Production). Although it is conceded problems related to complexity and specificity could generate conditions of criticality for any product development program, it is not regarded as being as important as the potential impact work packages related to IUS and Airframe Systems could have. Essentiality and life cycle duration are concerns when one addresses activities dealing with Power Systems and Testing. Notwithstanding this aspect, the above assessment of criticality indicates that there is clear evidence Components, Power Systems and Testing do not belong to a high level of criticality; it can be suitably reasoned this level is not on par with importance assigned to IUS and Airframe Systems.

Other areas addressed in the analysis such as Design Tools and Methods as well as Materials and Production depict rather less critical areas in regard to outsourcing decisions. Apart from the number of competitors, the other categories are ranked as being acceptable or of minor criticality. A low degree of complexity and specificity suggest that expertise and skills in this area can be acquired by various suppliers. Specialisation is therefore of minor importance and standardisation can be achieved more easily than with other technical areas outlined above. However, the count of available suppliers in both areas is the limiting factor, which implies that opportunistic behaviour or production delays cannot be easily alleviated by the threat of competition.

4.2. Comparing and contrasting Original Equipment Manufacturer outsourcing decisions

Evidence from the different aircraft manufacturers outlined in Section 2 shows that the approach towards outsourcing and risk-sharing and the technical areas under consideration differ.

Embraer, for example, defines its core competency as designing and integrating aircraft projects. This includes the integration and assembly of systems, structures, the fuselage and components (Cassiolato et al., 2002). Avionics are provided by Honeywell. Since this particular aspect is considered to be not as critical as the IUS when it comes to outsourcing, Embraer opted for this basic version in order to alleviate risk. Therefore, complexity and specificity and the associated transaction cost are reduced.

In regard to the B787 product development programme, Boeing also had the intention to take up the role as a system integrator which is responsible for the final assembly. However, problems with suppliers or partners arose in terms of demand and production capacity planning as well as the alignment of designs and expectations. These resulted in delivery delays and a loss of quality. The high degree of outsourcing, especially of IUS and Airframe Systems, requires thorough alignment of processes, procedures and expectations, both in terms of technical and organisational requirements in order to minimise transaction costs.

Bombardier Aerospace experienced initial problems with the outsourcing of aerostructures, i.e. the airframe systems, and in understanding the high degree of criticality of certain segments hence built up in-house competencies in these particular areas. Furthermore, it developed close working relationships and a thorough project management to mitigate potential risks and to engage in a mutual approach regarding the conceptual design phase.

Airbus intends to increase its global sourcing in regard to various fields of production and components. Regarding Airframe Systems (aerostructures), Airbus currently has less than five percent produced externally and intends to increase this share to up to 30% in 2020. As outlined above, Airframe Systems represent a critical aspect in terms of outsourcing. This approach therefore requires careful consideration of how to arrange and align associated processes and requirements to avoid problems and risks as in the case of Boeing. Furthermore, Airbus focuses its outsourcing activities on materials

(components and metal) whose global sourcing potential is to increase significantly. As can be seen from TAB 3, materials are rated as being rather non-critical in terms of outsourcing. Efforts related to organisational and technical alignment are therefore well below those associated with Airframe Systems.

This preliminary investigation has shown that notionally, owing to the critical importance of IUS to aircraft product development and the specialized nature of expertise required for successful implementation, a sensible risk mitigation strategy for aircraft integrators would be to undertake such responsibility in future and reduce the scope of attention paid to major assemblies associated with aerodynamically critical zones. The idea is to not necessarily engage in wholesale design and development activity down to every facet of component or even sub-systems level, but to at the very least serve as the progenitors of the IUS design philosophy and architectural schema – thereafter coordinating pertinent suppliers for the integration exercise.

The current and continued emphasis in the foreseeable future of aircraft integrators focusing on design, development, manufacturing, testing and certification of major assemblies that are exposed to aerodynamically critical zones is not amenable to an effective reduction of aircraft product development program risk. It is accepted that this recommendation is contrary to the decades of tradition accrued by major aircraft integrators and there will exist a certain measure of reluctance to adopt such a strategy, particularly within the ranks of technical professionals. Also, it should be borne in mind that such a dramatic change in design and integration project work requires a substantial amount of investment by aircraft integrators, not only from the perspective of equipment and facilities, but in terms of educational curricula offered to technical professional staff. This change in orientation requires engineering graduates to have a larger proportion of their university education devoted to avionics and fundamentals of IUS compared to the traditional core disciplines of aircraft aerodynamics, structures and integrated performance.

5. SUMMARY AND CONCLUSIONS

This paper offered an analysis of outsourcing and risk sharing activities in the aerospace industry in terms of implications for strategic product development approaches in the future. Advantages of outsourcing have been contrasted to potential associated problems. On the one hand, cost reductions, the opportunity to achieve a better product quality and the chance to spread development and investment risks among the various partners may convince a partner to outsource. New institutional economics, on the other hand, implies that outsourcing activities can be detrimental to a firm's success if markets are not perfect due to asymmetric information and individual rent seeking of the economic actors involved. Further, the concept of transaction costs shows that high specificity, complexity, and essentiality of intermediary goods and components as apparent in aircraft product development can put the success of outsourcing activities at risk. Accordingly, any business analysis of outsourcing activities that fails to consider the different problems, which arise on account of market failure and the transaction cost related problems of business relations and contracts, is likely to miss on important aspects of the economic problems.

This investigation has shown that aircraft integrators appear to favour procurement of major assemblies for new aircraft product development programs that are exposed to aerodynamically critical zones. Consequently, each aircraft integrator makes a point of engaging in some form of wing, wing-fuselage belly fairing, empennage and forward fuselage section design and integration. It was also found that emphasis is also placed on structures, materials technology and manufacturing techniques.

Considering the different outsourcing approaches of the four aircraft integrators in this paper led to the recommendation of advising against engagement in wholesale design and development activity down to every facet of component or even sub-systems level. Yet it appears necessary for the integrators to either coordinate pertinent suppliers for the integration exercise or to gather enough information on the market to make sure that the aim to reduce costs by outsourcing will not backfire. Integrated Utility Systems and Airframe Systems turned out to be most critical, and therefore, least suited for outsourcing.

The risk-sharing approach as a specific form of outsourcing, where partners also assume the burden of research and technology development turned out to be an important ingredient for the increasingly complex and expensive aircraft development programs. However, recent history has shown that when entrusting the production of certain components to external partners, a closer look into the criticality of these components is quite relevant. The original aim of this paper was to contribute to a better understanding of this criticality.

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