New Materials Characterization into the Aerospace Supply Chain

Embraer Case Study

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Abstract

Aerospace supply chain are complex systems that have been subject along the years to tremendous technological changes with high R&D costs and associated inherent risks. In an increasingly globalized landscape, this industry main players have become more aware of the supply chain impacts in their competitive position. To contribute to the improvement of such competitiveness is important to understand such supply chain. This paper then characterises the aerospace supply chain considering: its evolution; existing supply chain models; and current industry challenges, accounting for topics as cooperation, sustainability and resilience, which are put into perspective. From such characterization, it is concluded that product manufacturing at a reasonable cost is no longer a viable strategy for airplane manufacturers. Therefore, new challenges such as sustainable development, production and distribution arise. In this context, the introduction of new composite materials and new manufacturing process have been disrupting the existing supply chain. The autoclave production – presented as the standard technology to the production of high performance composite materials – carries excessive costs associated to the acquisition and operation. Therefore, OEMs have been exploring new materials and technologies outside of the autoclave scope (OOA). The present document provides a holistic approach of the economic and environmental differences associated to the OOA implementation. The ultimate goal is to use this information to foster the development of project and planning analytical models as decision support tools.

Keywords: aerospace supply chain; new product development; composites material and processes; design and network planning; sustainability.

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1. Introduction

The Aerospace Industry is nowadays one of the biggest sectors of high technology, recognized by its great intensity of research and development (R&D), the integration of innovative technologies and the propagation of knowledge to various domains, areas and sectors (OCDE,2011). Over the last years, there has been many evidences of its strategic role, crucial in the socioeconomic development of the countries by ensuring the right and sustainable mobility of the passengers, contributing to the security of people and goods as well as to the commercial balance and promoting the development of new companies and the creation of highly qualified manpower (European Commission, 2011).

According to Esposito (2004), the success of most of the companies in the Aerospace Industry relies on the existence supply chain (as complex networks of long term relationships) that influence the variety, productivity and quality of the products produced. The evolutions of such supply chain has been led by a strong competition between companies in the industry, high development costs as well as by long delivery lead times and the risks inherent to the projects. These, allied to the delays in the development of recent airplane models and the increase in the costs, has taken the complexity of the supply chain to the next level and led to its reorganization over the years (Alfalla-luque et al., 2012). These changes bring new challenges to the suppliers and their supply chain where aspects like collaboration, sustainability and resilience become crucial (Brandeburgh et al., 2014).

The production of high quality products at a reasonable cost is no longer a strategy used to the increase of competition once that the aerospace supply chain are globally dispersed due to the increase in complexity, the globalization and the outsourcing of some activities. This way emerged new concerns related to the decision-taking that take into account the adoption of new development initiatives and sustainable production and distribution (Markley e Davis, 2007). The need for innovation related to the introduction of new materials in the airplane structure become crucial for the sustained success (Calantone et al., 2006; Avlonitis et al., 2001). In this context are presented the composite materials that have led the evolution of aerospace materials and the development of new products and processes over the last two decades.

The leveraging of the advantages associated with these materials as well as the comprehension of the implications related to its introduction in the supply chain in the long term is seen as a way to reduce costs, improve productivity and products quality. This must also be reflected into an optimized aerospace supply chains making them more sustainable.

Thus, this paper has two main goals: on a first stage it aims to characterize the aerospace supply chain, identifying its main challenges, motivations and behaviour under the context of new product developments. Later, the main purpose is to systematize the economic and environmental characteristics involved in the process of introduction of new composite materials as well as the production technologies present in the supply chain. Consequently, it will be used as a starting point in the development of new studies and analytical models of project and planning as tools to support the decision-making process.

The paper is structured as follows: On section 2, the aerospace supply chains are characterized through the use of a literature review. Then, on section 3 a complete problem statement is presented, applied to the case of Embraer. On section 4 the scenarios of introduction of new composite materials in the supply chain are characterized as well as the main economic and environmental differences are identified. On section 5 the results are compared. Finally, in section 6 some conclusions are drawn.

2. Literature review

2.1. The overview of Aerospace Industry

In the aerospace industry, there are two main market segments: The commercial and the military segment (Niosi & Zhegu, 2005). These do have different economic, technological, productive and logistic dynamics. However, the common technological development and the cross-sectional suppliers, as well as the complementary way they react to most of the change factors, encourages companies towards the creation of synergies and definition of balanced portfolios between products with commercial and military application. The commercial airplanes segment may be divided in three main sub-segments (Cassiolato et al., 2002): Commercial airplanes with large vessel (the biggest out of the three sub segments, dominated by two main players: Boeing and Airbus. These airplanes are used in the transport of passengers and are characterized for having more than 120 seats and a high flight autonomy; Regional airplanes (medium vessel airplanes used to cover small and medium routes with capacity to transport between 10 to 120 passengers) where Embraer and Bombardier have assumed a leadership position; Executive jets (smaller sub-segment, with a considerable increase over the last years characterized by a high number of companies that produce small dimensions airplanes and that compete in different market niches. Thus, Boeing, Airbus, Embraer and Bombardier come forward as the four main airplane manufacturers worldwide (Guerra, 2011). Over the years, due to the changes in the market dynamic, the traditional definition of sub-segments presented below has evolved and nowadays the big manufacturers of regional airplanes already produce some models that can be compared to some commercial airplanes with large vessel. The growth trends presented by the industry have boosted the productivity and the efficiency of the manufacturers, focused currently in increasing their performance through the stock reduction, plants rationalization, process automation, systems digitalization and the development of new products, processes and materials (New Product Development, NPD) (Capgemini, 2011).

2.2. The Aerospace supply chain

The main airplane manufacturers produce accordingly to a make-to-order strategy, typically in a pull environment where there is uncertainty in the demand. In order to meet the requirements demanded by the market, the aerospace supply chain need a dynamic structure that will allow to have competitive advantages in the development of programs and airplanes families. Big manufacturers, known as OEMs ensure the final assembly of the airplane through the integration of the main systems, which lead in a later stage to the process of commercialization and sale to the final customers, always supported by a large network of suppliers hierarchically structured in levels (Niosi e Zhegu, 2008). In this context it is important to highlight the level 1 suppliers (main ones) that focus in the conception, development and production of modules, and in the integration of some main aeroplane systems. These suppliers have gained an important role in the supply chain becoming responsible by the management and coordination of the lower supply chain levels (Tang e Zimmermen, 2009). The relationships and dependencies between the suppliers of the aerospace supply chain (from the first level to the lower ones as well as the high flexibility and the responsiveness have contributed for a lean supply chain and for a reduction in the variability and in the production risks (Michaels, 1999). It is notorious the development of integrated relationships between buyers and suppliers (Graham & Ahmed, 2000). In fact, these relationships between different entities involved in the development and production of airplanes, have driven, over the time, the evolution of the supply chains and consequently the adoption of structured models adapted to the specific challenges of the sector. Currently there are two main aerospace supply chain models: The model led by the OEM (that is currently part of Bombardier and Embraer's supply chain) and the Large Systems Integrator Model - LSSI (identified as a future trend, boosted by the development of the Boeing 787 and Airbus A380 models) (Figure 1) (Beelaerts et al., 2011). The LSSI model is seen as an evolution of model led by the OEM, where the main differences are related to the coordination requirements needed to reach the success which carries several challenges in terms of collaboration, resilience and sustainability.

2.3. The development of new composite materials in the aerospace industry

The need for innovation, related to the introduction of new materials in the aerospace supply chain adopts a crucial relevance and is identified as one of the main factors for the sustained success with significant impacts in terms of costs, quality and in the achievement of competitive advantages (Avlonitis et al., 2001). According to McAdam et al., (2008), the NPD is currently focused in searching for solutions that enable a reduction in the operational and service costs as well as a reduction in the emissions and in the airplane's weight while increasing the operational

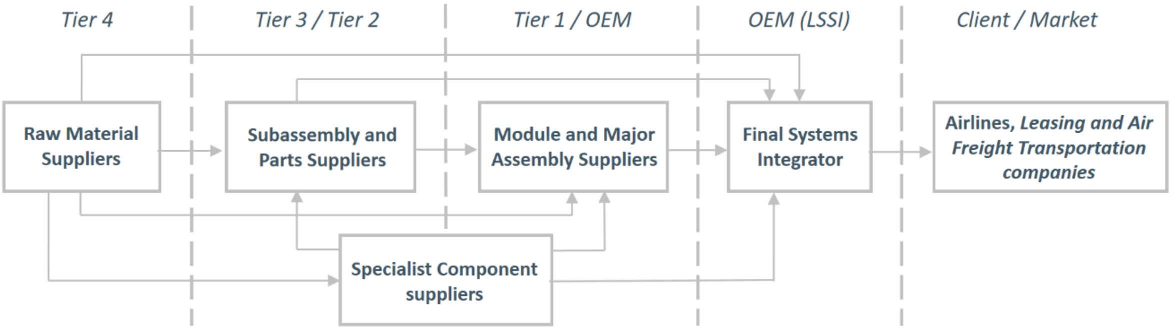


Figure 1 – Aerospace Supply Chain (model led by the OEM and LSSI model) (adapted from Beelaerts et al., 2011)

performance parameters. Thus, the aerospace industry has been looking for alternative materials to the traditional metallic alloys focusing over the last decades in using composite materials. Nowadays, the composite materials are in the forefront of the evolution of the materials used in the aerospace industry, in the innovation and in the NPD, present in the airplane structure through a wide range of applications (Chouvion et al., 2011). The main manufacturers of the aerospace industry are looking for the development of new composite materials as well as new production processes, integrating them in their supply chains optimizing them and making them more sustainable.

3. Problem Statement

Embraer is nowadays the third largest airplane manufacturer in the world and market leader in the commercial airplane market concerning airplanes with a maximum capacity of 130 seats. With the development of their new airplanes program E-Jets E2, the company intends to reduce costs, improve productivity and quality and increase the flexibility and speed through the optimization of the supply chain in order to keep the leadership position and the competitiveness in the sector. This way, emerges the need for innovation related to the introduction of new composite materials and respective manufacturing technologies in the supply chain.

However, the products' innovation based on new materials and its processing technologies presents nowadays a high period of development, implementation and selling in the supply chain (10 to 20 years) evolving risks, uncertainty and high costs (National Science and Technology Council, 2011). In this way, it becomes necessary to perform an analysis of the supply chain through a holistic approach where sustainability is considered.

In the literature there is a lack of work related with the development of new products, focused particularly in composite materials that explore in a realistic way the main goals of aerospace supply chain and that consider the main strategic decisions regarding its design and planning. Thus, this will be the problem in study in the present work that reflects the main concerns of the aerospace industry and the Embraer in particular. It is intended to quantify and compare the main economic and environmental differences associated with the integration in the aerospace supply chain of several composite materials and production processes, presenting a data systematization and information that will allow to leverage the development of analytical models as tools to support the decision-making process. The IAMAT project intends to explore new alternative processes to obtain the current composite materials, which allow a reduction of the associated costs and that have a lower environmental impact. In this context, four scenarios are defined and studied below.

4. Introduction of New Composite Materials: Scenarios Characterization

4.1. Scenarios Definition, Product and System Boundaries

To new materials introduction the present work considers the study of four scenarios, as represented in Table 1. Scenarios B, C and D consider new materials and processes OOA (Out-of-Autoclave), alternative to the standard process used nowadays which is a process of thermoset composite where the cure stage occurs in autoclave (scenario A).

Table 1 – Scenarios under study

Scenario	Production Process	Matrix' Type
A	Autoclave	Thermoset
B	Resin Infusion (VARI)	Thermoset
C	Vacuum Bag Only (VBO)	Thermoset
D	Hot Stamping Thermoforming	Thermoplastic

The production process of composites in autoclave (scenario A) is presented as the base scenario of the present study. It is used for comparison and it is currently the most common technique in the aerospace industry regarding the production of structural components of high precision and performance. This process is used in the cure and consolidation of stacked layers of thermoset prepreg (Prepreg HexPly M21) in autoclave where cycles that combine vacuum, temperature and high pressures are conducted. Scenario B considers a process of Resin Infusion (VARI), an OoA process that allows the attainment of high quality thermoset composites with a low number of imperfections. This process is considered a variation of the Resin Transfer Molding (RTM) process exhibiting the replacement of the counter-mould by a vacuum bag during the stage of resin infusion (allowing a high design flexibility through the projection of composites with complex and customized geometries). In the infusion process considerer, a liquid resin epoxy rtm6-2, is injected over the dry fibre tissues (strengthening the carbon fibres Hitape), on an open preform, flowing through own channels in order to fill the empty spaces. When the fibres are soaked in resin, it is used a stage of cure in an oven. On scenario C it is considered a process of Vacuum Bag Only (VBO), an OoA process that relies essentially on the vacuum operation to remove every gaps stuck in the raw material (Prepreg OoA HexPly M56) before the stage of cure, as well as in the differential pressure between the inside and outside of the vacuum bag to consolidate the different layers during the cure process. This process has a group of processing stages similar to the production process in autoclave (scenario A). However, in this process the cure stage happens at lower temperature levels, in a simple oven and subjected to air pressure without the need for the autoclave involvement. In contrast to the scenarios mentioned above, applied in the production of thermoset composites, scenario D considers a process of Hot Stamping, used in the production of thermoplastic matrix composite. This process occurs by thermoforming, through a set of stages similar to the ones in the industrial processes of sheet metal processing – where a semi-crystalline prepreg OOA PEEK material is moulded between the plates of a press.

In order to better understand the particularities inherent to the considered scenarios, as well as the implications related to their integration in the aerospace supply chain, the fundamental concepts related to the classification and characterization of composite materials and respective production technologies were introduced. Lately its mapping was developed and presented, based on the main production stages. Subsequently the scenarios were characterized through a data survey and the respective study and analysis of the main economic and environmental differences – for further detail see Santos, (2017). The considered data are adapted to the production of a test-bed (with the dimensions of 500 x 150 x 4 mm), as function unit of small scale. It represents a family of possible products with aerospace application where this component may be integrated in the future. Many assumptions and simplification are considered through the use of some data in laboratory context, which means that the values in use do not correspond to the real values of a large-scale situation and are only valid in the scope of this dissertation. However, it considers that the data show the same relation and magnitude in the different scenarios, enabling the solutions and conclusions obtained. The supply chain considered for the production of the test-bed represents a segment of Embraer's supply chain, centralized in Embraer PT as a level 1 supplier (Figure 2). Its generic representation involves main tiers that include: The supply of raw materials through tier 2 suppliers; the respective production of composites in the plants of Embraer PT through the several processes considered; the consequent shipment of final product to the OEM, the Embraer Brazil. The supply of raw materials is made by two suppliers (due to the strict certification requirements of aerospace industry): The Excel, responsible for every thermoset raw materials used in scenarios A, B and C; and Cytec (Solvay Group), supplier of the thermoset raw material of scenario D.

In the identification of the main data, relevant for the economic and environmental characterization, was considered the main costs associated to each scenario in four fundamental categories as represented in Figure 3.

4.2. Economic characterization

Regarding the obtainment of raw materials, are considered the unitary costs for the minimum order quantity. As a common practice in the industry, the values presented

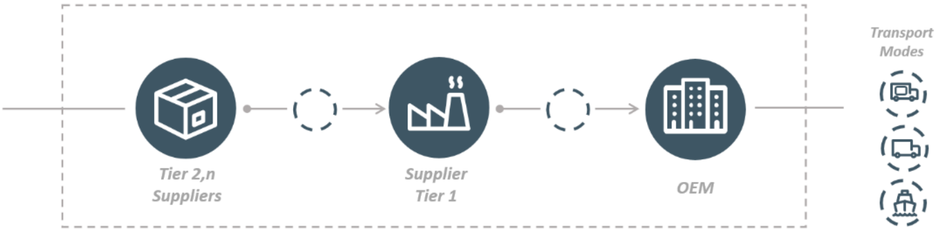


Figure 2 – Generic Network Representation

take into account the transportation costs. To perform the calculation of the quantities needed for the production, it is considered for prepreg materials (scenarios A, C and D), the area and the average number of layers needed to reach the thickness required.

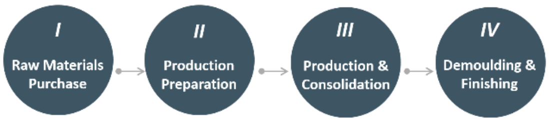


Figure 3 – Main phases to obtain a composite material

For the case scenario B, the needed quantities are achieved based on the concentration of fibres in volume (58% as recommended by the manufacturer) considering the value of mass density. The values obtained may be found on Table 2. Based on the mapped production processes, every relevant operations are identified as well as the main equipment, technologies and labour needed to the production of the test-bed.

Table 2 – Production Bill of Materials

Scenario	Raw Material	Quantity
A	*Prepreg* HexPly M21	1,63 m^2
B	Carbon Fiber Reinforcement Hitape AS7	3,19 m^2
	Epoxy Resin HexFlow RTM6-2	0,14 kg
C	*Prepreg* (OoA) HexPly M56	1,55 m^2
D	*Prepreg* (thermoplastic) APC-2-PEEK	0,40 kg

Subsequently, for the discrete activities identified, the durations are estimated (consider the processing of the layers of raw materials involved). The time period of the cure and consolidation stages considered in each scenarios reflect the suppliers' recommendations. The laboratory technologies present similar dimensions and production capacity for the composites with the identified dimensions, whereas in an industrial context of large scale, some of the identified times may become lower. It is consider a heating rate for the oven and autoclave of 1,5ºC/minute and a cooling rate of 2ºC/minute. It is also assumed a combined heating and cooling time of 10 minutes for the press. The costs of each activities are estimated based on the technologies involved and in the time and labour allocated. It is also considered laboratory operation levels and the time costs of each technology is assumed, based on the values charged by INEGI to the client as final consumer, most precisely: Expert technician – 25€/h, autoclave – 70€/h, oven – 20€/h, press-90€/h, vacuum – 5€/h.

4.3. Environmental characterization

There are in the literature many methodologies available for the assessment of the environmental impacts of the supply chain. The Life-Cycle-Assessment (LCA) methodology is identified by the European Commission as the best framework for the assessment of potential environmental impacts of processes and products (European Commission, 2003). However, the difficulty in obtaining representative data of some categories, allied to the fact that the considered data bases (such as Ecoinvent database) do not contain yet any information regarding the acquisition of raw materials, restricts the use of the referred tool. Thus, in the present work is also included a partial evaluation of environmental factors, considering only the CO_2 emissions.

The considered functional unit is a unit of final product – a test-bed – with the referred dimensions and produced in different ways from the raw materials considered in each scenario. The scope defined in the present evaluation (i.e., the borders considered in the supply chain) is known as gate-to-gate, where are only considered the average levels of the supply chain, namely the transportation of raw materials from the supplier to the plant of Embraer Portugal, the processing of these matters and the transportation of final composite for the OEM's installations. Additionally, and in order to make the raw materials from different scenarios comparable through the analysis of the same stages, are also considered the CO_2 equivalent emissions associated to the production and impregnation of these raw materials (carbon fibres and epoxy resins). Regarding the conversion of the energetic consumption (in kWh) for equivalent emissions of CO_2 (kg CO_2 eq) is used the conversion factor of 0,537. The emission associated to the production of the carbon fibres and resin cannot be found in any database used by LCA methodologies. For this reason, the values obtained by Suzuki and Takahashi (2005), with application to the mass production in the automotive industry are used: 286 MJ/kg of carbon fibres produced and 76 MJ/kg of epoxy resin produced. For matters of simplification, these values are considered in every scenarios in study, ignoring the differences in the environmental impacts associated to the use of fibres and resins with different characteristics and properties. Still according to Suzuki and Takahashi (2005), it is considered the environmental impact related to the stage of impregnation where is used an energetic consumption of 40 MJ/kg for the production of prepreg (related to scenarios A, C and D) and only 10,2 MJ/kg for the impregnation through the process of infusion (as done in scenario B).

For the assessment of the environmental impacts associated with the production of the final component, it is considered an autoclave with 0,75 m^3 of capacity and 27 kW of power; oven with 0,79 m^3 of capacity and 4,8 kW of power; press for applications with a limit of 250mm x 250mm, with 3 kW of power. It is also considered in the autoclave operation, the use of 60% of its power during the stages of heating (pre-cure) and 20% during the stage of cure, as stated in the work of Scelsi et al., (2011). For the oven and the press it is assumed a constant rate of 60% of the technology power during its usage period. For the calculation of the total energetic consumption for each scenario, are taken into account the activities of aggregation, heating and cure (or consolidation) and the respective durations. It is also considered the energetic consumption in the activities that involve the presence of vacuum, for which is estimated an approximate power of 1 kW according to the data of Roos and Szpieg (2012).

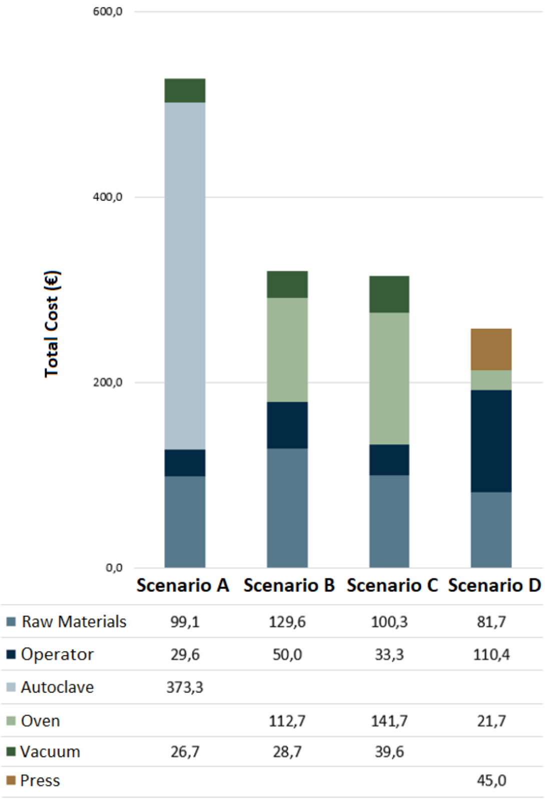
Regarding the assessment of the environmental impacts related to the transportation of raw materials and final products, is used the distances between different entities and are considered the emissions available in the database SimaPro Ecoinvent version 8.2.3.0, using the ReCiPe Midpoints (H), regarding the impact category “Climate Change”, in kg of CO_2 eq. (per km).

Concerning the transportation done by refrigerated truck is considered the average value of CO_2 emissions of 3,73x104 kg of CO_2 eq (per km). For the transport done using a normal truck it is considered the value of 2,07x104 kg de CO_2 eq (per km) and for the transportation by ship the value of 2,16x105 kg of CO_2 eq (per km).

5. Results Discussion

5.1. Economic Assessment

The values obtained in the scenario characterization allow to evaluate the economic scenarios (Figure 4).



	Scenario A	Scenario B	Scenario C	Scenario D
Raw Materials	99,1	129,6	100,3	81,7
Operator	29,6	50,0	33,3	110,4
Autoclave	373,3			
Oven		112,7	141,7	21,7
Vacuum	26,7	28,7	39,6	
Press				45,0

Figure 4 – Total estimated cost for each scenario

The main costs estimated for production of a test-bed are represented, where it is considered the raw materials, labour and technologies used for the processing in each of the scenarios under study. Scenario A, corresponds to the production process of thermosetting matrix composites in autoclave. This represents the base scenario taken for comparison with the remain scenarios. The overall cost associated with this scenario is the highest, with a total value of 529 €. On the other hand, scenario D, representative of the thermoforming process of thermoplastic matrix by hot pressing, presents the lowest cost, with a reduction of 50%, for a total of 259 €. Scenarios B and C show a similar overall cost and have a reduction of approximately 40% of the Scenario A value. The high costs in Scenario A are in large part due to the use of the autoclave, which represents 70% of the process cost. In scenario C, labour costs are identical to the base scenario (since the steps developed by the operator are similar), although with a higher relative proportion (equal to 10%). In scenario B these costs are 40% higher, due to the necessity of manual cutting of the fibre tissues, to the assembly of all necessary equipment and connections in the preparation of the infusion and to its subsequent time spent during the infusion step. In scenario D where human intervention is more valuable, the related cost of 110 € - due to the requirement of precision in the placement and alignment of the different layers of material (a time-consuming process) - represents 40% of total costs of the scenario.

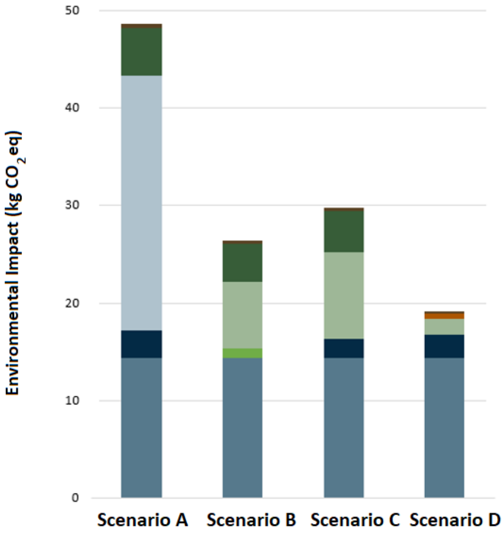
Scenario B is the one with the highest raw material costs, with a total of 130 €. Although the dry fibres and resin used in this scenario have a lower unit cost when compared to the prepregs used in the other scenarios, relative higher raw material quantities are required. The best economic performance verified in scenario D is explained by the nature of the raw material that in a short period of time is deformed in a press, acquiring the shape of the final composite (not requiring long stages of cure as verified in the other scenarios, in an autoclave or oven). Its production and consolidation phase assumes a cost of only 67 €, which is 80% lower than the corresponding stage in the base case, autoclaved and vacuum assisted.

5.2. Environmental Assessment

To carry out the environmental assessment, the equivalent emissions of carbon dioxide associated with the production of fibres and resins, the production of prepregs or infusion, as well as the energy consumptions inherent to the technologies used and the transport activity of the supply chain are taken into account, as shown in Figure 5.

Scenario A, the reference scenario, has a global environmental impact of 48 kg of CO_2 eq. All other scenarios, related to OOA production processes, show improvements in environmental performance, with a reduction of 45%, 38% and 60%, corresponding to scenarios B, C and D, respectively.

The environmental impact related to the production of the raw materials corresponds to 31% of the emissions verified in scenario A, 54% and 58% of the total emissions of scenarios B and C and 87% in scenario D. The infusion phase, only present in scenario B, has a 67% lower impact than the prepreg stage, performed by the raw material supplier, in scenario A. The environmental impact related to the use of the autoclave for the curing stage, has the highest level of emissions considered: 31 kg of CO_2 eq, when vacuum assisted. In scenario C, where it is considered the replacement of the technology used to cure the prepreg material, using two curing cycles, carried out in vacuum in an oven with an environmental impact of 13 kg of CO2 eq, corresponding to a reduction of 60% in the energy consumption.



	Scenario A	Scenario B	Scenario C	Scenario D
■ Raw Materials	14,386	14,386	14,386	14,386
■ Prepreging	2,867		1,905	2,389
■ Infusion		0,940		
■ Autoclave	26,061			
■ Oven		6,900	8,893	1,670
■ Vacuum	4,876	3,829	4,248	
■ Press				0,489
■ Transport	0,418	0,333	0,319	0,250

Figure 5 – Total environmental impact for each scenario

Scenario D, which contemplates the use of a thermoplastic prepreg, does not require the use of vacuum, oven or autoclave for curing and its consolidation (in a low energy consumption press). This process represents only 11% of its environmental global impact. The transportation of raw materials and final product has a residual contribution to the total emissions verified in each scenario (approximately 1%), despite of the distant locations of the different entities.

5.3. Discussion and Recommendations

The main indicators analysed in the present work are summarized in Figure 6 highlighting the importance of an integrated analysis that involves the results of the economic evaluation and the environmental assessment as well as the overall duration of the production processes considered in each one of the scenarios under study. In this radar diagram the different scenarios results are normalized by the highest value, on a scale between 0 and 1. This allows an intuitive representation of the main results obtained in each of the scenarios considered.

As discussed previously, scenario A assumes the highest cost and also the highest environmental impact associated with a production process, with an overall duration of 6.5 hours. The other scenarios, representative of the out-of-autoclave production processes, have lower environmental costs and impacts, strengthening their position as economically and environmentally viable alternatives.

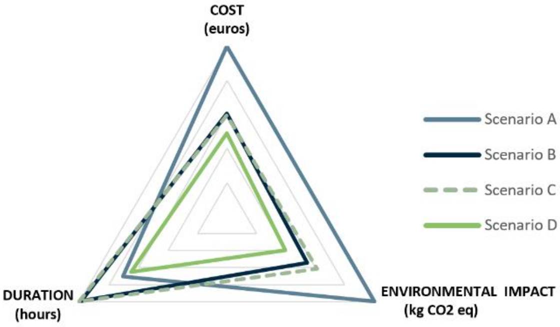


Figure 6 – Normalized Obtained Indicator Results

Scenarios B and C, as OoA processes, require a longer production preparation period, in which there are specific operations performed manually and compaction cycles of the various layers of material, developed to overcome the absence of pressure (characteristic of the autoclave). As such, these processes have a 40% higher global duration than the baseline scenario.

Scenario D is the one with the best overall performance, with a 50% reduction of total costs and a 60% reduction of total environmental impacts (compared to Scenario A). Furthermore, its process presents the lower total duration, with a reduction of approximately 8%, and as such, is presented as the best alternative for the selected indicators.

However, the results presented are quite interesting is important to note that a large part of the data considered for analysis were obtained from estimates or collected in the literature and applied in a laboratory environment. Thus, it must be validated by manufacturers and suppliers in an industrial environment and considered as a starting point of analysis to other strategic and decision-making issues.

In fact, the adoption of the OOA scenarios for the production of primary structures of an airplane in a large-scale context is still dependent on the analysis of several factors and challenges. Among these are the investment costs associated with the acquisition of the referred technologies, the productive capacity and corresponding satisfaction of the demand levels of the sector, and the final quality of the structures produced. Also other obstacles and challenges should also be considered in the scale-up of the supply chain as the variation in the analysis borders plays a crucial role in representing the challenges of Embraer Portugal when introducing these new composite materials and production processes into their supply chain.

In the work developed, it is analysed and characterized the context of development of new materials, where the concepts of collaboration, sustainability and resilience are fundamental. To do so an integrated and holistic vision is imperative, which refers to the importance of issues related to the definition of the border of analysis, the limits of study and, ultimately, the border that should also be considered by aircraft manufacturers in the management of their supply chains.

The aerospace supply chain is global and the collaboration between the different entities involved is decisive in controlling costs, in the synchronized flow of materials and information, in the visibility and transparency of communication, in reducing lead time, in optimizing production and consecutively on the quality and success of introducing these new materials into the aerospace supply chain. It is incumbent upon Embraer PT - as Embraer OEM Level 1 Supplier - to assist, manage and coordinate all production, assuming a key role in the collaboration between OEMs and downstream suppliers.

6. Conclusions

In the present paper a characterization of the aerospace supply chain is made, where the several identified challenges highlight the need to develop new products based on composite materials. The most recent trends are identified in the development of new composite processes and materials. Based on that, in the scope of the IAMAT project, are considered three scenarios that take advantage of new OOA materials and processes, alternative to the current standard curing process of autoclave thermoset composites. These scenarios are quantified and compared based on the systematization of the main economic and environmental differences. The main results unveil superior performance of all OOA scenarios when comparing to the current autoclave production scenario. After an integrated analysis, the thermoplastic composite production scenario reveals the best overall performance, presenting lower costs, lower environmental impact and lower total processing time.

As future work a few suggestions arise. Studying and developing databases used by Enhancing the knowledge about components and processes used in the production of raw materials and corresponding suppliers, from the extraction phase is very important, insofar as their contribution to the global impact of the scenarios under consideration may exceed 50%. LCA methodologies (which currently do not include data on the acquisition of raw materials and their respective production processes of composite materials) is essential for an effective environmental analysis. Furthermore, the development of analytical network planning models - focused on the development of new composite materials and encompassing a holistic approach, where sustainability aspects are considered, becomes quite relevant.

It is also important to note the importance of obstacles and challenges that should be analysed in the scale-up of the supply chain considered in the present study, through a correct definition of the border of analysis. The collaboration between the different entities involved is fundamental and essential for the success of the introduction of these new materials in the supply chain and consequently for obtaining the competitive advantages of the main OEMs of the aerospace industry.

7. References

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