



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering  
Vol. 67, Issue III, September, 2024

## FAILURE RISK ANALYSIS IN THE CASE OF AN AEROSPACE MANUFACTURING COMPANY USING COMPOSITE MATERIALS

Ștefania CHIRIBĂU-VITLINGER, Vlad VIZITIU, Alexandra MIHAILĂ,  
Diana DRAGOMIR, Mihai DRAGOMIR

**Abstract:** *The paper proposes a conceptual framework to assess the organizational risks that influence the activity of a manufacturing company producing components for the aerospace industry based on composite materials. The specificities of this niche domain are taken into consideration while performing the risk identification in terms of technological and quality issues, environmental threats, supply chain and organizational aspects and interactions with the well-developed regulatory framework in the field. A set of indicators developed by the Interreg DTP DanubeChance2.0 project to predict complex issues such as business difficulties, insolvency and possible resilience failures is applied in this case and the results are discussed in detail.*

**Keywords:** *risk management, failure risk, composite material, aerospace manufacturing.*

### 1. INTRODUCTION

Analyzing failure risk and implementing effectively risk strategies is imperative in the aerospace industry, particularly if their using composites materials in the manufacturing process and, regulations wise, it is a necessity to review and update them accordingly.

This process presumes in the first place, identifying the risks related to the raw materials, in our case composites: material defects, design flaws, supplier issues, production errors which all affect the production and the performance of the manufacturer, regarding the fact that in the aerospace manufacturing industry, which has a high complexity, stringent safety standards and a permanent need for precision and reliability in products are mandatory. After identifying the risks, the management must monitor and report them to all stakeholders to be able to develop effective strategies and corrective action plans, such as diversifying suppliers if it is possible and staying well informed about every regulatory change in the field.

As a result of economic globalization, there is a high intensity of changes in the production of aircraft components. Since there are many manufacturers of components for a single

product type, the importance of the suppliers is critical for product development [1] as they have more and more tasks and engagements in the successful completion of projects.

One of the major characteristics of the aerospace manufacturing industry is the intense competition, which prompts the need for innovation. Ensuring the quality of components is famously difficult and there are very strict protocols and tests to verify the quality of the components in the sector, thus leading to pressures on the purchase of adequate raw materials [2].

### 2. LITERATURE SURVEY

Using composites has become more common place in the past decades, as the industry must face environmental and safety pressures, with examples such as metal matrix composites, which have excellent mechanical, thermal and electrical properties, useful for the final product and convenient for manufacturing [3]. Another type of composites whose usage is becoming prevalent in aerospace manufacturing is the fiber reinforced polymers, which can deliver the required properties at a fraction of the weight of

traditional metals, significantly influencing operational costs and carbon emissions [4].

As of 2023, the aerospace industry uses composites materials in less than 20% of the of aircraft structures but this share it is expected to increase through the next years [5] because new products are developed and introduced that require enhanced static and dynamic characteristics [6].

Composites are used in the aerospace industry because they combine strength, stiffness, corrosion resistance and light weight properties, as well as other mechanical advantages such as high strength to weight ratio [7]. At the same time, their processing has a very high cost compared to classic materials, generating challenges and risks for the manufacturing sector. The traditional materials are cheaper, but they cannot provide the same quality of the final product nor the fuel efficiency performance because of the reduced weight. Also, composites can be more vulnerable to impact and can be challenging to repair if damaged. Despite these drawbacks, composites continue to play an increasing role in manufacturing aircraft parts such as: fuselage, wings, interior components, moving surfaces, etc.

According to another study, the most viable technical procedure in aerospace manufacturing is using metal additive technique which involves creating components by compounding successive layers of materials [8]. Besides this, the technologies more frequently used in aerospace manufacturing industry of composite-based components are: Automated Tape Layup (ATL), Automated Fiber Placement (AFP), autoclave molding (AM), filament winding (FW), and resin transfer molding (RTM) [9]. Traditional materials are more affordable than composites, although manufacturers may have the advantage to reduce the variety of operations, the deployment of workers in activities other than assembly, and the reduction in the complexity of its supply chain.

Supply chain sustainability is an issue which concerns most managers from every manufacturing domain. The success of a supply chain is measured in its total profitability and resilience, so it inevitably lies in the efficiency of its management [10]. It must always adapt

always to changes in technology and to customer requirements in order not to be dealing with disruptions. The most important issues, which may directly affect the manufacturing process, include creating delays, increasing production costs, safety issues, oversight in maintaining mandatory regulation and so on. If these risks are not monitored properly by maintaining a robust supplier network, staying up to date on regulatory changes, and investing in research and development, any company could lose control and suffer failure.

### 3. DC2.0 SELF-ASSESSMENT CASE STUDY

The Interreg Danube Transnational Programme project “DanubeChance2.0 - Embracing failure to facilitate second-chance entrepreneurship in the Danube region” (DC2.0) has developed a self-assessment tool for companies and entrepreneurs experiencing failure that wish to restart their business [11]. The model uses 10 categories of items to gauge the complexities of this endeavor (see Table 1). Each category contains three specific components and for each of them the evaluation score can go from 1 to 5. (1 for total disagreement and 5 for total agreement). We applied this questionnaire in the case of an aircraft components manufacturer in two scenarios, before and after confronting business difficulties (distress), to study the possibilities to boost the positives and diminish the negative traits that intervene. In the following, an analysis of these answers is presented for each of the lines in the table.

1. The score for family/friends/society support is high (4) but it can be improved. Knowing that your abilities are appreciated boosts confidence and morale because entrepreneurship can be very emotionally challenging. Also, the social circle is important too because it provides valuable networks for new opportunities, new clients, collaborators or mentors.

2. Keeping a good balance between business performance and personal life is very important for sustained success. Maintaining this harmony requires adaptability, good time management, self-awareness, good communication skills, fostering supportive relationships to create a

fulfilling equilibrium between these two. At first, when launching the business, the major effort is invested in business performance, but as the business grows, every manager gains experience in time management and efficiency, as we can see in the score improvement from one situation to the next.

3. Recognizing opportunities is vital for the success and growth of a business. The manager must be proactive and very adaptive to maximize every opportunity that arises. These opportunities can be a good partnership, government support, diversification of the products manufacturing or of the raw material sources, expanding in new areas, etc. It is very difficult to maintain equilibrium between diversification of the products, innovation, quality and efficiency but these are the key to reinvention and boosting a business in distress. The score here is similar in both stages, but with a little effort and support, it can be improved.

4. To ensure financial stability, the number of funding possibilities must be increased, as it tends to be poor at the beginning. There is a little improvement (from 2 to 3), meaning that the company identified some funding sources, such as governmental programs and supplier qualification programs. These are more efficient than bank loans because besides the capital, they come with mentorship, industry connections and the company risks and costs are shared at least in part.

5. When the funding need is urgent, these possibilities are not effective, so it is necessary to obtain a bank loan. When doing this, it is important to evaluate the interest rates and terms, based on a solid business plan. Creating a repayment plan and seeking advice from financial professionals can get improvement in this field, as observed in the scores allocated.

Table 1

Table 1. DC2.0 Self-Assessment Questionnaire for business diagnostic [11] applied for the case study

Contact information		The marks are from 1 to 5, where	
Name: John Doe		1 - total disagreement	
Company: Generic aerospace component manufacturer		2 - disagreement	
Email: office@genericcompany.com		3 - neutral	
Business situation: successful / failed / distressed / starter		4 - agreement	
Date of assessments: initial May 2023 / final October 2023		5 - total agreement	
BEFORE	Score	AFTER	Score
<b>Why start over? Overcoming fears and heading towards success</b>	<b>11</b>	<b>Why start over? Overcoming fears and heading towards success</b>	<b>12</b>
Family / friends / society support your business venture	4	Family / friends / society support your business venture	4
Business performance and personal life are well balanced	3	Business performance and personal life are well balanced	4
There are considerable favorable opportunities for the business	4	There are considerable favorable opportunities for the business	4
<b>Access to finance for those with failed business plan</b>	<b>5</b>	<b>Access to finance for those with failed business plan</b>	<b>8</b>
There is a large number of funding possibilities identified for your business	2	There is a large number of funding possibilities identified for your business	3
Debt repayment plans have an acceptable length of time	2	Debt repayment plans have an acceptable length of time	2
There is an emergency financing source available to the company	1	There is an emergency financing source available to the company	3
<b>Business planning with benefits of past experience</b>	<b>10</b>	<b>Business planning with benefits of past experience</b>	<b>11</b>
Your business has developed organizational vision, mission, values and competencies	5	Your business has developed organizational vision, mission, values and competencies	5
The business has developed contingency plans for unforeseen situations	3	The business has developed contingency plans for unforeseen situations	4
The business relies on the number of new products/service introduction to the market	2	The business relies on the number of new products/service introduction to the market	2
<b>Practical hints for establishing another business</b>	<b>11</b>	<b>Practical hints for establishing another business</b>	<b>13</b>
The business founder is critical to the success of your business model	2	The business founder is critical to the success of your business model	3
You have a good credibility and reputation in the marketplace	5	You have a good credibility and reputation in the marketplace	5
You understand that failure is a normal part of doing business	4	You understand that failure is a normal part of doing business	5
<b>How to keep entrepreneurs healthy and alive</b>	<b>12</b>	<b>How to keep entrepreneurs healthy and alive</b>	<b>15</b>
You are proficient in performing business environment and risk analyses	3	You are proficient in performing business environment and risk analyses	5
You have a clear understanding of the value chain regarding your products and processes	5	You have a clear understanding of the value chain regarding your products and processes	5
You have a well-defined planning methodology available for tracking business evolution	4	You have a well-defined planning methodology available for tracking business evolution	5
<b>Legislation</b>	<b>7</b>	<b>Legislation</b>	<b>11</b>
Internal early warning indicators for failure have been defined	1	Internal early warning indicators for failure have been defined	4
Specific institutions and market based mechanisms provide legal support	3	Specific institutions and market based mechanisms provide legal support	3
You are ready to adopt and implement a restructuring plan	3	You are ready to adopt and implement a restructuring plan	4
<b>Financial management</b>	<b>12</b>	<b>Financial management</b>	<b>14</b>
You are ready to take risks and deal with uncertainty in business	4	You are ready to take risks and deal with uncertainty in business	5
Within the business objectives, responsibilities, budgets are established adequately	4	Within the business objectives, responsibilities, budgets are established adequately	5
The business is sensitive to the length of the customer payment deadlines	4	The business is sensitive to the length of the customer payment deadlines	4
<b>Company resource management</b>	<b>13</b>	<b>Company resource management</b>	<b>14</b>
There is good documentation and monitoring of business processes	5	There is good documentation and monitoring of business processes	5
Your key value creation processes leads to operational performance	5	Your key value creation processes leads to operational performance	5
The business can outsource some activities in case of difficulties	3	The business can outsource some activities in case of difficulties	4
<b>Negotiation and communication skills</b>	<b>12</b>	<b>Negotiation and communication skills</b>	<b>13</b>
Employment of staff is performed according to skills and perspectives	5	Employment of staff is performed according to skills and perspectives	5
Your venture has proper crises management mechanisms	3	Your venture has proper crises management mechanisms	4
Sales and distribution channels are well established and profitable	4	Sales and distribution channels are well established and profitable	4
<b>Motivation of people around you</b>	<b>7</b>	<b>Motivation of people around you</b>	<b>11</b>
The different stakeholders of the business have mutually beneficial relationships	2	The different stakeholders of the business have mutually beneficial relationships	3
The company provides support for overall employee learning and development	4	The company provides support for overall employee learning and development	4
Former business failure led to better understanding of strategic intent	1	Former business failure led to better understanding of strategic intent	4
<b>TOTAL INITIAL</b>	<b>85</b>	<b>TOTAL FINAL</b>	<b>103</b>

6. In case of unforeseen challenges an emergency financing source available to the company is a necessity. At the beginning this is quite impossible, as it can be observed in the score (1), but in the meantime the company applied for some supporting programs. After the pandemic crisis, they became more aware and realistic about the probability of disruptions, so the firm created its own emergency fund and implemented assisting programs.

7. The company's strength lies in developing organizational vision, mission, values and competencies to define its identity and purpose of business. This is reflected in the high score of (5) in both time frames.

8. The business has developed contingency plans for unforeseen situations such as price volatility of raw materials needed for composites, or the lack of highly skilled employees. Supplier diversification and in-house training became more common place. This can be observed in the increasing of the score from (3) to (4), which means better risk and contingency management.

9. The score for the number of new products/service introduction to the market is low, and there is no improvement in this field because most of the manufacturing activity relies on customers' needs and pre-established technology.

10. Since the business has difficulties is hard to establish the contribution of the founder in the actual business model success, although, his business idea and vision shaped the company's trajectory so far. Of course, if this score was higher, maybe the need for second chance entrepreneurship could be avoided.

11. The good credibility and reputation in the marketplace were the key to restarting/re-energizing this business. A high score (5) is well deserved because of the increased customer's trust in the products and the good partnerships from the past. This reputation is maintained by the high quality of the products and by the on-time delivery of components. Since the specifics of this sector require it, good compliance with

standards and regulations is also a contributing factor here.

12. The improvement in understanding failure in every business is the ability to answer many "whys" through the 5-why tool, to find the root of the problems. This score improved from (4) to (5) by adding process value through robust quality control measures, investing in employee trainings, and analyzing all the supply chain vulnerabilities.

13. Since the initial distress was deemed a consequence of insufficient business environment scanning, this process was robustly changed through risk analyses and strategic positioning methods, raising the score from (3) to (5) in the second state.

14. A clear understanding of the value chain regarding products and processes is indispensable for the aerospace sector, starting from the customers' needs, yielding a (5).

15. The score for the well-defined planning methodology for tracking business evolution, was changed from (4) to (5) by implementing the provisions of advanced strategic business planning and APQP.

16. One of the best improvements made was in defining internal early warning indicators for failure, as the score shows (from 1 to 4). These include process, operations, financial and employee related elements that can be tracked over the evolution of the business in relation to the contracts with its customers

17. Specific institutions and market-based mechanisms that provide legal support in this field are quite reduced, as we can see from the score of (3). The only support obtained is from legal advisers or different consultants.

18. The company was determined to adopt and implement a modern restructuring plan to reorganize its activity, but this is still ongoing resulting in a score of (4).

19. The firm is ready to take risks and deal with uncertainty in a more coherent approach, rated at (5), because of the improved business plan which involves risk management tools.

20. The score for business objectives, responsibilities, and budgets went from (4) to



(5), as they are established adequately to the company's situation in accordance with the restructuring plan.

21. The business is very sensitive to the length of the customer payment deadlines (with a 5 score) because it is still redressing and because of the dependence of investments on timely payments. This dependence will be reduced once the emergency budget is created.

22. There is good documentation and monitoring of business processes thanks to the standardized management systems already in place and the employment of modern technologies such as enhanced inspection [12], [13] - evaluated as 5.

23. Some of the key value creation processes, which lead to a score of (5) for operational performance, are related to improvement and manufacturing innovation which helps the company to remain competitive and environmentally sustainable [14].

24. In case of difficulties, the business can outsource some activities, but this will have a great impact on efficiency, costs and on-time delivery since external suppliers are harder to monitor, therefore this issue is marked with (4).

25. Employment is performed according to skills and perspectives, as this is an important differentiator for the firm – the score is a (5).

26. The venture has proper crises management mechanisms, but they do not include failure risk (4 score). For example, crisis budget and externalizing some of the support processes can help to confront stressful situations.

27. Sales and distribution channels are well established and profitable because all the details are very well established in the supply contracts. Due to the characteristics of this industry, distribution and purchasing are very well defined and very strict (5 score).

28. Stakeholders' interests will be increasing in importance to overcome the current situation, so the score increases from (2) to (3).

29. The company provides support for overall employee learning and development through training, meetings and courses (4 score).

30. Learning from previous experiences in order to be more resilient and adaptive is vital to business redress and restart, with the score changing from (1) to (4).

After scoring every item, the evolution from before to after becomes visible, also revealing the improvement possibilities. The focus is on how the entrepreneur interprets and responds to firm failure and how operations' restart can be approached. For a better data visualization of the scores, a spider diagram can be created by the questionnaire template (Figure 1).



Fig. 1. Self-assessment tool for second chance entrepreneurs applied before and after

#### 4. CONCLUSION

As it can be seen, business disruptions in the aerospace manufacturing industry represent a critical challenge for the entrepreneurs because they affect their entire ecosystem and could compromise the timely delivery of components. Diversifying suppliers, developing strong long-term partnerships, and creating contingency plans to mitigate the effects of disruptions are part of a strategy that can alleviate this problem.

The self-assessment tool for second chance entrepreneurs from DanubeChance2.0 is designed to evaluate their skills, mindset, and preparedness for a second opportunity. In this way, the areas of strength and the areas which require more attention or development are identified and individuals can use the insights to guide their decision-making and planning process for their next venture after completing it. This is even more important in the case of

aerospace manufacturing that uses complex composites since the mix of conditions for business success and business revival is difficult to attain and necessitates careful planning.

## 5. REFERENCES

- [1] T. Song, Y. Li, J. Song and Z. Zhang, *Airworthiness considerations of supply chain management from Boeing 787 Dreamliner battery issue*, *Procedia Engineering*, vol. 80, pp. 628-637, (2014).
- [2] B. Blakey-Milner, P. Gradl, G. Snedden, M. Brooks, J. Pitot, E. Lopez, M. Leary, F. Berto and A. du Plessis, *Metal additive manufacturing in aerospace: A review*, *Materials & Design*, vol. 209, 110008, (2021).
- [3] X. Lu, W. Hao, S. Kuang, Y. Zhang, M. Wu and Y. Zhao, *High-strength, high-toughness SiCp reinforced Mg matrix composites manufactured by semisolid injection molding*, *Journal of Materials Research and Technology*, vol. 26, pp. 4219-4228, (2023).
- [4] H. Rocha, C. Semprinoschnig and J.P. Nunes, *Sensors for process and structural health monitoring of aerospace composites: A review*, *Engineering Structures*, vol. 237, 112231, (2021).
- [5] N. Ramawat, N. Sharma, P. Yamba, and M.A.T. Sanidhi, *Recycling of polymer-matrix composites used in the aerospace industry-A comprehensive review*, *Materials Today: Proceedings*, In Press, Corrected proof, (2023).
- [6] G. Kappmeyer and D. Novovic, *Production technology research – Building blocks for competitiveness and solution for future challenges in aerospace component manufacturing*, *Procedia CIRP*, vol. 101, pp. 62-68, (2021).
- [7] A. Tunı, W.L. Ijomah, F. Gutteridge, M. Mirpourian, S. Pfeifer and Giacomo Copani, *Risk assessment for circular business models: A fuzzy Delphi study application for composite materials*, *Journal of Cleaner Production*, vol. 389, 135722, (2023).
- [8] A.E. Coronado Mondragon, C.E. Coronado Mondragon, P.J. Hogg and N. Rodríguez-López, *A design process for the adoption of composite materials and supply chain reconfiguration supported by a software tool*, *Computers & Industrial Engineering*, vol. 121, pp. 62-72, (2018).
- [9] D. Jayasekara, N. Yeen, G. Lai, K.-H. Wong, K. Pawar and Y. Zhu, *Level of automation (LOA) in aerospace composite manufacturing: Present status and future directions towards industry 4.0*, *Journal of Manufacturing Systems*, vol. 62, pp. 44-61, (2022).
- [10] M. Ramirez-Peña, P.F. Mayuet, J.M. Vazquez-Martinez and M. Batista, *Sustainability in the Aerospace, Naval, and Automotive Supply Chain 4.0: Descriptive Review*, *Materials*, vol. 13(24), 5625, (2020).
- [11] DanubeChance2.0 - DTP2-012-1.2, *Output 3.2 - Methodology on Second-chance Entrepreneurship readiness*, (2019), available online <https://www.interreg-danube.eu/approved-projects/danubechance2-0>.
- [12] M. Bożek, A. Kujawińska, M. Rogalewicz, M. Diering, P. Gościniak and A. Hamrol, *Improvement of catheter quality inspection proces*, *MATEC Web Conf.*, 121, 05002, (2017).
- [13] A. Kujawińska and M. Diering, *The impact of the organization of the visual inspection process on its effectiveness*, *Int J Adv Manuf Technol*, vol. 112, pp. 1295–1306, (2021).
- [14] S. Popescu, M. Dragomir, D. Pitic and E. Brad, *Method for competitive environmental planning*, *Environ Eng Manag J*, vol. 11(4), pp. 823-828, (2012).

### **Analiza riscului de eşec în cazul unei companii producătoare din industria aerospațială care utilizează materiale compozite**

**Rezumat:** *Lucrarea propune un cadru conceptual de evaluare a riscurilor organizaționale care influențează activitatea unei companii producătoare de componente pentru industria aerospațială pe bază de materiale compozite. Specificul acestui domeniu de nișă este luat în considerare la identificarea riscurilor în ceea ce privește aspectele tehnologice și de calitate, amenințările de mediu, lanțul de aprovizionare și aspectele organizaționale și interacțiunile cu cadrul de reglementare bine dezvoltat în domeniu. În acest caz se aplică un set de indicatori dezvoltați de proiectul Interreg DTP DanubeChance2.0 pentru a anticipa probleme complexe, cum ar fi dificultățile de afaceri, insolvența și posibilele eşecuri de reziliență, iar rezultatele sunt discutate în detaliu.*

**Ștefania Chiribău-VITLINGER**, PhD student, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, stefania.chiribau@staff.utcluj.ro

**Vlad VIZITIU**, PhD student, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, vizitiu.vlad89@gmail.com

**Alexandra MIHAILĂ**, PhD student, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, malex\_alyna@yahoo.com

**Diana DRAGOMIR**, Associate professor, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, diana.dragomir@muri.utcluj.ro

**Mihai DRAGOMIR**, Professor, PhD advisor, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, mihai.dragomir@muri.utcluj.ro