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Toward a Strategic Approach to End-of-Life Aircraft Recycling Projects

A Research Agenda in Transdisciplinary Context

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Abstract

The number of planes at the end of life is increasing. Innovative management practice of aircraft at the end of life can be considered as a transdisciplinary context. Moreover, regarding dynamics and multidimensionality of aircraft recycling projects, conventional management systems cannot be sufficient and responsive. The purpose of this paper is to address a research agenda that support various aspects of dynamics and transdisciplinarity of end of life aircraft recycling projects (EOLARP) by a strategic conceptual framework. Four sections of the framework including business model, market and industry, knowledge management and performance measurement make a basis for addressing the essential issues in EOLARP business ecosystem, which needs an incorporated approach of different disciplines and players. Further studies and works on each arena in this framework are valuable in overcoming difficulties facing managers and strategic partners in EOLARP.

Keywords: aircraft, end-of-life recycling project, strategic approach, transdisciplinary

1. Introduction

In the global market forecast of Airbus for the period 2009–2028, 8453 aircraft are projected to be retired (Heerden& Curran, 2010). Based on Boeing's report, the potential market for aircraft disposal will be nearly 6000 by 2028 (Green sky, aviation and the environment, 2010). A substantial and novel industry problem has occurred as a result of large numbers of useless aircraft and the related environmental issues (Heerden& Curran, 2010). Different research groups, companies, projects, associations or initiatives work on end of life aircraft problem. The solutions to this important topic must integrate the different disciplines, field of studies and expertise. End of life vehicle solutions are well developed during the recent decade. In contrast, a review of the literature reveals that little empirical research has addressed main issues in business ecosystem of aircraft recycling projects.The absence of relevant directives, size of treated materials from End-of-Life products, complexity in fleet recycling process, multilayered relationship among partners and players are only some of challenges facing the aerospace industry in relation to end of life aircraft problem.

Defining appropriate optimization tools, decision models and conceptual frameworks in business ecosystem of aircraft recycling with considering economic, social and environmental aspects is a smart way for dealing with these challenges.The purpose of this paper is to address a research agenda that support various aspects of dynamics and transdisciplinarity of end of life aircraft recycling projects (EOLARP) by a strategic conceptual framework.

The authors of the present paper are involved in one of these projects and the main idea of this study comes from the necessity of integrating approach for dealing with strategic aspects of aircraft recycling problem and the lack of literature in this area.The outline of this paper is as follows: In next part, we present an overview of aircraft end of life problem. Then we explain the transdisciplinary and strategic approach and provide a conceptual framework that addresses these approaches in four sections including business model, market and industry, knowledge management and performance measurement. Finally, we conclude with some comments and topics for further research.

2. EOLA Problem

Reducing resource consumption to preserving the natural environment for future generations is a goal for companies and countries in the sustainable development context. The motivations for designing align with environment come from different sources and pressures. The customer pressure, competitive forces and legislation are important reasons for companies in involvement in environmental efforts especially Eco efficiency design (Rose, 2000). Waste management is crucial as landfills close and populations grow (Pohlen& Farris, 1992). Therefore, reducing landfilled material, maximizing recycling, and controlling hazardous materials are important challenges in end of life treatment. Products with different characteristics experience distinct end-of-life strategies. Now, end-of-life treatment systems are developed by industry volunteers or as a reaction to legislation. However, solutions to this complex subject must integrate both technical and business aspects (Rose, 2000).

According to Heerden& Curran (2010), over the years the aircraft depreciate in value. The cost of maintenance and repair will be increased. Customer satisfaction and reduced fuel consumption are the other aspects of the decision that aircraft operation is no more acceptable.When the owner comes to this decision it faced by several options. After storage time, if the aircraft is worth more than its parts it can be sold as a flyer. If this option is not valuable the aircraft has to be dismantled, reused or disposed.

The overall process of parting-out an aircraft is shown in Figure 1. Numerous important components can be retained before dismantling, recycling or disposal. Engines, landing gears, avionics, and electronic motors are the most common parts which may be reused. Doors, wings, interiors can be used for training purpose (The Aircraft at End of Life Sector). Recycling the material is the other aspect of end of life solutions. Four major classes of materials ranging from low cost interior materials to high performance alloys and composites used in aircraft construction. For old models, the aluminum is main material with a high achievement in recycling technologies but in new models with using composites, the recycling is challengeable.

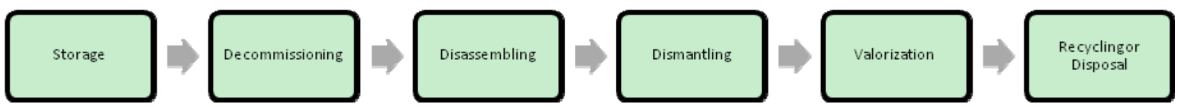

Figure 1. The process of parting-out an aircraft

Aerospace original manufacturers have a long history of looking for ways to reuse or recycle aircraft and their components. In the past, at least 50 percent of the material used in aircraft construction was reused or recovered (Watson, 2009). Different companies worked on this problem during recent decade. Based on the core business of these companies, they follow different strategies, practices and process for implementing the end of life solutions (Siles, 2011). The two largest airframe manufacturers, Airbus and Boeing, are at the head of research and main projects in this field. Airbus PAMELA project has successfully confirmed that as much as 85 percent of an aircraft by weight can be recovered for recycling (Watson, 2009). Boeing has taken a leadership role in aircraft life cycle and end-of-service recycling strategies for more than 50 years. Aircraft Fleet Recycling Association, AFRA, is a global consortium of more than 40 companies that provides environmentally responsible options for aging aircraft. This includes maintaining and reselling reliable airplanes and returning them to service. Safe parts recovery, scrapping and recycling services are available for airplanes that cannot be returned to service (Boeings environmental report, 2010). In addition to these initiatives, there are some different companies that provide services in this field. Table 1 shows key information regarding these initiatives.

Table 1. The relevant initiatives in Aircraft end of life solutions

Research Group; Company or Association	Location	Scope of work	Strategies
TARMAC AEROSAVE	France	Decommissioning-dismantling-	Disassembly by TARMAC sell by customer or TARMAC (Siles, 2011)
AFRA	USA	Accreditation Body, Developing Best Practices	In absence of directives, providing a framework and guidelines for end of life business solutions
AELS	Netherlands	Decision Making Solutions	Aircrafts are disassembled but remained the propertyof the client,it can find the market and sell the parts (Siles, 2011)
ASI	UK	Disposal –Parting Out-Dismantling	Aircrafts are disassembled and delivered to the customer (Siles, 2011)
EVERGREEN TRADE INC	UK	Disposal –Parting Out-Dismantling	Disassembly by EVERGREEN, sell by customer or EVERGREEN (Siles, 2011)
BARTIN AERO RECYCLYING	France	Disposal –Parting Out-Dismantling	Disassembly by another company and recycling by BARTIN (Siles, 2011)
WINGNET	UK	Material Research	Providing a research atmosphere for exchange the research regarding material recycling innovation

Regarding above description, environmental impact concerns, eco efficiency design, technical and business aspects, corporate responsibility and customers trust, legislation and associated authorities boundaries are only few various areas in EOLARP that should be addressed properly to achieve the objectives of these projects. In addition complexity and difficulties are growing more in swiftly changing these areas.

North & Macal (2007) believe that markets, particularly those far from the standard forms analyzed in economic theory (for example, perfect competition, monopoly, and oligopoly) and social systems, especially those within industrial and government organizations, are examples of system, which have been complex. Hence, second hand part market of aircraft components, the role of local or global authorities and the lobbying interface among different stakeholders are the other factors, which intensify the complexity in these projects.The conceptual framework presented in this study provides a starting point for a more structured analysis of thought-provoking issues in EOLARP.

3. Transdisciplinarity in EOLARP

"Transdisciplinarity is a collective understanding of an issue. It's created by including the personal, the local and the strategic as well as specialized contribution to the knowledge" (Brow et al., 2010, p4). Thompson Klein (2004) states that transdisciplinarity has become a main imperative across all sectors of society and knowledge domains and an important way of thought and action. Figure 2 presents the difference among interdisciplinarity, multidisciplinary, and transdisciplinarity. This illustration of transdisciplinary clears up that in interdisciplinary and multidisciplinary, current field of studies simply mutually impact each other, essentially making intersections in two dimensions. In transdisciplinarity, a new transdisciplinary discipline with its own theoretical structure is created over dynamic cooperation and amalgamation of different disciplines.

Chiesa et al. (2009) remark that transdisciplinarity is a dynamic approach by which different disciplines are linked and arise to a new discipline. Table 2 shows the unique characteristics of transdisciplinary and the related evidence in an EOLA research project.

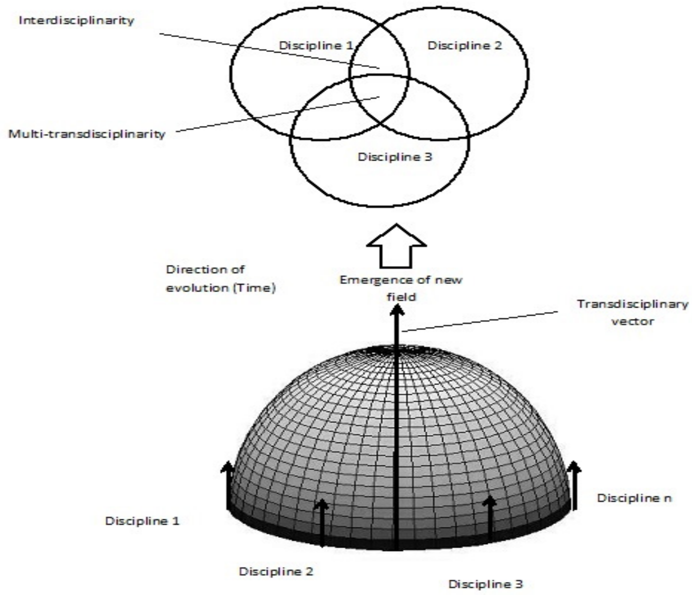

Figure 2. The difference in the concepts or transdisciplinarity and interdisciplinarity (multidisciplinarity)

Note: (a) Interdisciplinarity (multidisciplinarity). (b) Transdisciplinarity. Based on: Koizumi, 1999 cited inChiesa et al. 2009, p18)

Table 2. The transdisciplinary features in EOLA research project

	Transdisciplinary aspects	Author(s) (Cited in Brow et al., 2010, pp.18-19)	EOL aircraft research project
1	Complexity in sciences	Somerville & Rapport (2000)	Design for disassembly, material selection, dismantling and recycling technologies, separation techniques, sorting techniques
2	Defined from complex and heterogeneous domain	Lawrence (2004)	Mechanical engineering, aerospace engineering, material science, industrial engineering, business and economy, environmental science
3	Acceptance of uncertainty	Klein (2004)	Bogus part (uncertified parts in second hand markets), global trends, Global fleet growth, passenger traffic growth, aircraft models being offered on the market, investment in maintenance
4	Intercommunicative action	Klein (2004)	Knowledge exchange among industrial partners and research professionals by regular meetings, internships, workshops and so on, using the results of sub-projects in other tasks
5	Result of inter-subjectivity	Desprès et al. (2004), Klein et al. (2001)	
6	Close and continues collaboration during all phases	Desprès et al. (2004)	
7	Action oriented	Desprès et al (2004)	Validation and verification of the developed models and application in industry, building experimental platform for applying the results of research project
8	Linkage between theoretical development and professional practices	Lawrence (2004)	Participating of industrial partners in all phases of project from proposal definition to final pace of the project
9	Addressing real world problems	Pohl, & Hirsch Hadorn (2007)	New industry problem in dealing with large numbers of useless aircraft and related environmental issues

Max-Neef (2005) describes transdisciplinarity via comparison with the other approaches such as multidisciplinarity, pluridisciplinarity and Interdisciplinarity. He highlights that in multidisciplinarity approach the members perform their analysis disjointedly and the result being a set of reports attached together, without integrating synthesis. In pluridisciplinarity cooperation exists among disciplines without coordination. Interdisciplinarity is structured at two hierarchical levels. Therefore, it implies coordination of a lower level from a higher one.

The author introduces a pyramid graph to show the transdisciplinary approach. In this graph from bottom to top, the author illustrates the transdisciplinarity as a result of coordination among all hierarchical levels. He names the lower level, empirical level. This level refers to what exists. The second level is purposive level and refers to what we are capable of doing. The third one is what we want to do and names it, normative level. Finally, the higher level of pyramid refers to what we must do and the value level. He explains that any compound vertical relations containing all four levels, describes a transdisciplinary action. Based on this conception, we proposed a pyramid graph that demonstrates the transdisciplinary approach in EOLARP (Figure 3).

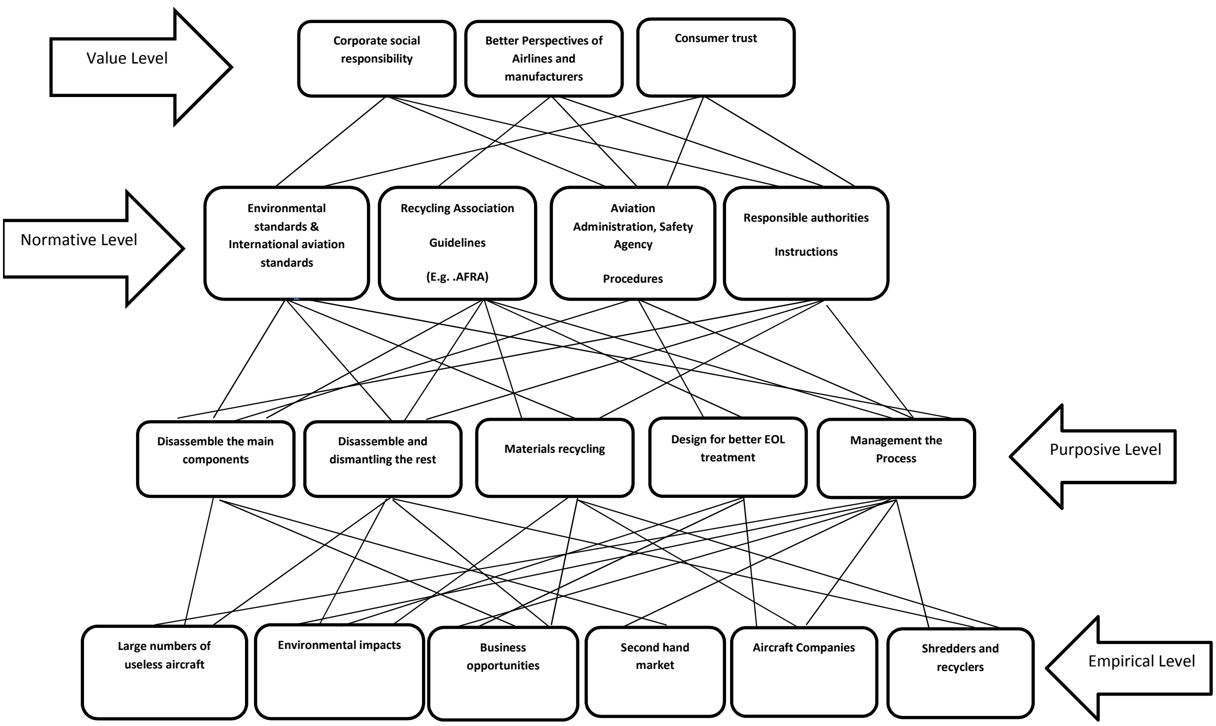

Figure 3. Transdisciplinary approach in EOLARP

At the lower level, we have the end of life problem and associated issues. Large number of useless aircrafts and connected environmental impacts, the second hand part market and related safety issues in monitoring, tracking and certification. In this level we have also the business opportunities related to end of life aircraft treatment, players in the problem and their opportunities and concerns. For example, for aircraft companies, the reputation or market image in one side and the design in the other side are concerns. The business profits or the technologies boundaries are the other aspects of what exits. The succeeding level is purposive level. In this level we have technological and solution disciplines such as the disassembly of components, the dismantling of the rest parts, recycling materials and management the whole process. The next level is normative level and what we want to do. This level covers all regulations, standards, instructions or guidelines that should be followed to achieve the harmless and even impeccable management process as possible. But it's not enough to meet the expectations of various stakeholders in the project. The higher level of this pyramid or value level involves the final aims of all players containing the social responsibility, better perspective of airlines and manufacturers and finally consumer trust.

4. Strategic Approach to EOLARP

According to Bower (1970) and Ackoff, (1970) “strategic decisions deal with novel and complex sets of interdependent problems facing the organization” (Shrivastava, 1985, p.98). In addition, we need to have attention in noneconomic factors in decision making. Svendsen & Laberge (2005) explain that new complex reality of the 21st century with increasing sustainability socioeconomic and environmental challenges needs the development of a new way of thinking and engaging with stakeholders. Traditional strategy frameworks were neither helping managers develop new strategic directions nor were helping them understand how to form new opportunities in the core of so much change (Freeman &McVea, 2001, p3).

Freeman &McVea (2001) believe that management should know the needs of stakeholders to set the boundaries of actions. Hence the conventional approach for project management, with focusing on efficiency aspect such as time, budget and quality cannot response the requirement of partners in the project. Project management is a complicated and multidimensional concept. In order to evaluate a project’s success, it’s needed to understand the different dimensions and address different time frames from very short to very long. Each project has its own specific dimensions, and their relevant importance will vary (Shenhar et al., 2001, p720).

Shenhar et al (2001) suggest that strategically managed projects are focused on attaining business results; however, operationally managed projects are focused on getting the job done. Stefanovic & Shenhar (2007) used a new three-dimensional maturity model, which evaluates projects according to the emphasis on operational excellence, strategic focus, and inspired leadership. They studied how the level of maturity of the project on each dimension related to project success. The authors believe that strategic focus seems to be a key element in achieving customer satisfaction, business success, future prospects, and overall success.

In a study by Shenhar (2004), the relationship between the type of the project and the importance of the strategic focus are explained based on four criteria: the level of novelty, complexity, technology and pace.

Concerning, the uncertainty, complexity and novelty of EOLARP, having a strategic approach can help managers to tackle with the difficulties and challenges in these projects. Figure 4 illustrates this approach. In first layer of this figure we have the key elements of strategic management. These elements based on Johnson & Scholes (1984) are in three interrelated categories including strategic analysis, strategic implementation and strategic choices. The second layer of this figure is the results of strategic focus in project management approach (Stefanovic & Shenhar, 2007).The third layers show four dimensions, which proposed as the elements of strategic approach to EOLARP in this research. In this layer the strategic management elements of each dimension as well as the results are shown. In the other word, the four aspects in third layer are the building blocks of our conceptual framework, which will be explained in more details in next part.

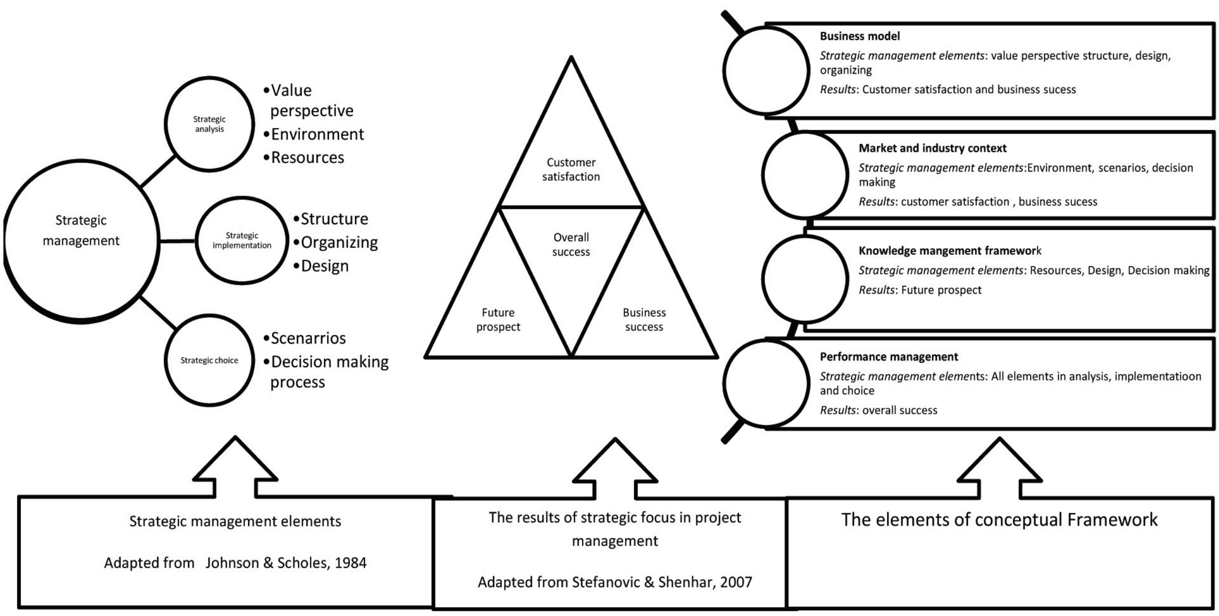

Figure 4. Strategic approach

5. The Conceptual Framework

Figure 5 illustrates the conceptual framework, which reflects strategic approach to EOLARP in transdisciplinary context. We focused on four elements in these projects: Business model, knowledge management framework, market and industrial context and performance management. Value proposition and operating model are two important aspects of each business model. Based on challenges in setting targets, the variety of stakeholders, their value perspective and the model for value chain and organization, business model is the first element, which should be considered in this conceptual model.

Addressing business issues in aerospace industry is more complicated and different rather than other industries. Several factors are involved in this complexity including the role and action of government, absence of normal competition to balance the supply and demand, lifecycle of products and important equipment such as engines, aftermarket sales, spare part and maintenance markets, intricate relationship between original manufacturers and upstream value chain partners and the effect of other macroeconomic factors such as oil price volatility, declining traffic and evaporating aircraft finance (Buxton et al., 2006).

As a result, market and industry context is the second portion of our conceptual framework. The knowledge structures, knowledge sharing among multiple players, the different field of sciences, skills and know-how and the barriers and limitation for effective intercommunication in EOLARP are the reasons for selecting knowledge management as a part of our model. Lastly, Performance measurement as an important element of effective planning and control with considering the different perspectives and metrics in a basic model is illustrated.

Hadornet al. (2007) in handbook of transdisciplinary research explained the complexity and diversity of transdisciplinary in the following way:

"Complexity is used for the interrelations among heterogeneous dimensions, or plural values and norms. Diversity: means that empirical dimensions relevant to describing and analysing processes are heterogeneous in the sense that they belong to different disciplines or to the perceptions of different actors and that there are plural values and norms that do not fit together in a systematic way."

Concerning different stakeholders in EOLARP, compound relationship among these players and policy making with parameters that changed with time, dynamics aspect is another feature for studying each element in our conceptual framework. As a result, in second layer of this framework we have three elements of complexity, diversity and dynamics. In third layer we have three aspects of sustainable development, which play an imperative role in EOLARP.

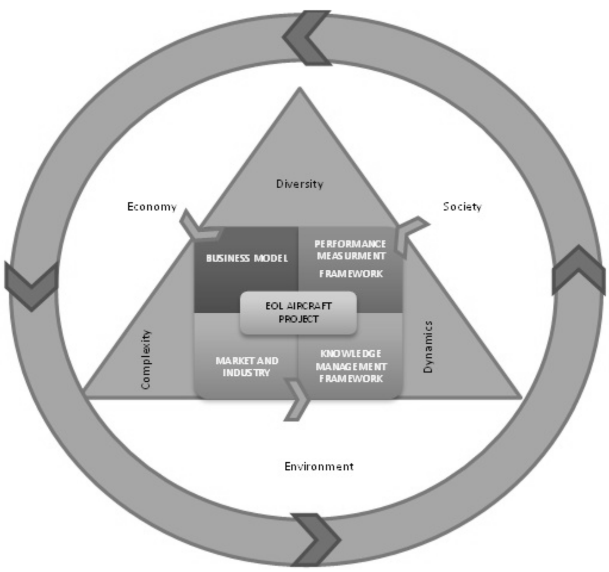

Figure 5. The conceptual framework

5.1 Business Model

The business model aids as a building plan that allows designing and realizing the business structure and systems that establish the operational and physical form of an organization (Ostenwalder et al., 2005). Business models aid to capture, visualize, understand, communicate and share the business logic among stakeholders (Ostenwalder et al., 2005). Visual system benefits in handling the complexity (Rode, 2000), the process of modeling social systems and understanding the relationship among its elements (Morecroft 1994; Ushold& King 1995) and helping managers to communicate and sharing their understanding of a business among other stakeholders (Fensel, 2001) are the advantages of business model (Cited in Ostenwalder et al., 2005).

In order to better understanding of the business perspective of EOLARP, we explain the stakeholders involved in this environment. Figure 6 shows the different players in a typical EOLARP. As shown in this figure, EOL enterprise is a main actor in this ecosystem. This body is responsible for designing, performing and managing the whole process of EOL aircraft treatment.

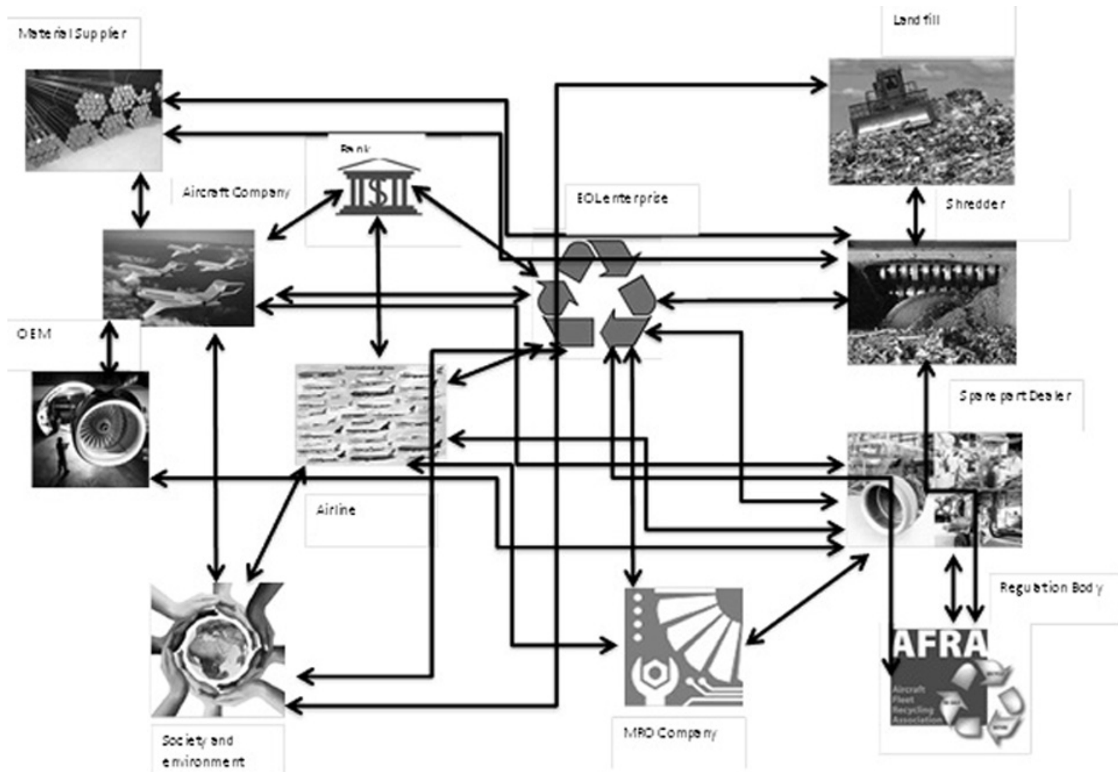

Figure 6. Stakeholders in EOLARP

Osterwalder & Pigneur (2004) introduced nine building blocks of a business model including value proposition, target customer, distribution channel, relationship, value configuration, core competency, partner network, cost structure and revenue model. For simplification, we defined four aspects of business model in Figure 7. Services reflect the proposed value by project. It's obvious that previous experiences or background of EOL enterprise influence the management approach of the project. For example, an EOL enterprise with background in spares part and services and another one, which is formed to provide EOL aircraft solutions, have not the same approach for dealing with the project. Regarding value propositions, various services are offered in these projects. Stakeholders address target customers, relationship and distribution channels. With the purpose of extensive perspective of customers we also considered social actors, regulation bodies and market actors. Hence the complexity of relationship, communication mechanism and lobbying with these players are apparent. Designing appropriate risk, revenue and costs model are another challenges in these projects. Costs factors such as skill workers costs, time, transportation costs, investment, required databases such as rates, materials property and capital equipment costs should be considered. Moreover, the revenue items, recovered energy, relationship between costs factors and revenue items, various EOL stakeholders, the type of contracts and agreements are some of elements, which increase the complexity of financial side analysis. Finally, infrastructure includes the core competencies of main player (EOL enterprise), developed processes, and the network of partners should be addressed in business model.

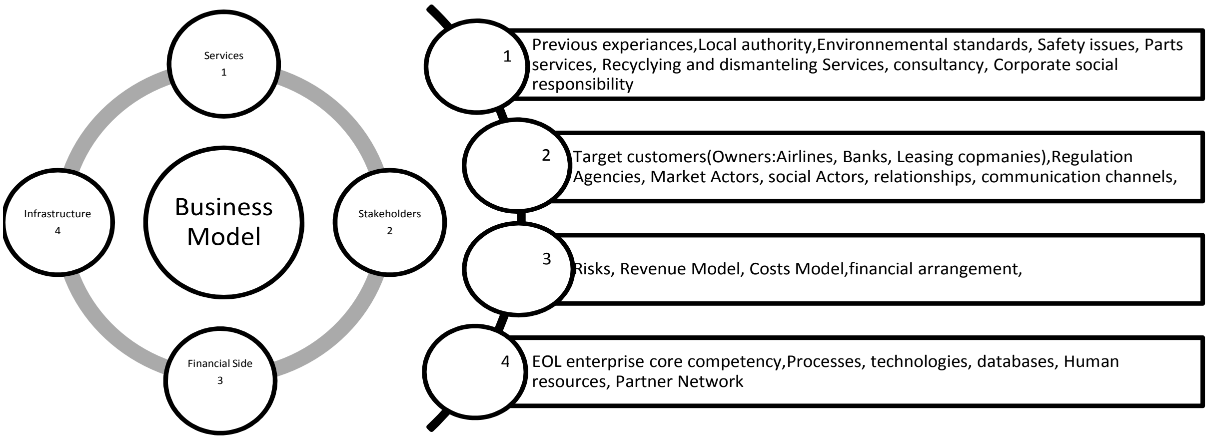

Figure 7. Typical business model

5.2 Market and Industry

Used aircrafts, used parts and components markets have the conditions that are challenging. Several internal and external factors are contributed to these challenges. Used aircraft inventories, equipment regulatory in the industry, financing and manufacturing issues are some internal factors. Increasing maintenance costs, outdated avionics equipment, noise compliance issues and parts availability limit operating these aircrafts and they are rapidly becoming economically unfeasible. The external factors include financial crisis, demand for used aircraft especially in India, Middle East, Eastern Europe, and especially Russia, reduced the supply of funds available (Smith, 2010).

The business of treating materials from End-of-Life products is a small slot of overall business of aircraft companies, and it's not feasible to commit reverse supply chain and related treatment channels for this problem. The total weight of aircraft entering the End-of-Life phase is small compared to the weight of other transportation means such as personal vehicles (Eco-Efficiency and Sustainability, p10).

Considering these issues we can come to this conclusion that applying general green supply chain practices cannot be effective for this purpose. Given these findings, developing new ways in deployment of supply chains of aircraft companies to achieving the operative outcomes is another interesting and challengeable issue. But the structure of supply chain in these companies are complicated and changed over time.

In aerospace supply chain, the large players are supported by a vast supplier base globally and these suppliers are supplied by a large base of tier 2 and tier 3 suppliers, which serve multiple industries (such as industrial manufacturing or automotive). These are followed by tier 3 suppliers, which include suppliers of machined components such as castings and raw materials suppliers for metals and rubber (Tiwari, 2005).

When some of aircraft parts are disposed of, it is important that they are destroyed beyond repair to avoid entering these parts to the market. The component that enters the market without the right documentation or without legal documentation is called a bogus part. From safety perspective, controlling and tracing these parts is critical to avoid the possibility of terrible consequences. The aviation sector follows the global economic trend and when economies slow down also travel by air slows down. And this matter can influence the demand of fleets and subsequently the end of life aircraft market. The role of component dealers, the demand for spare part component is the other factors that influence this market. Maintenance market can also affect the parking rate of aircraft and dismantling and disassembling options (Heerden& Curran, 2010).

Based on these facts, developing a model is needed to address the dynamic behavior of market and various aspects of economics of aircraft recycling.

5.3 Knowledge Management Framework

The aircraft end of life problem is a new field of study. Therefore, the literature, which addresses the models, optimization tools and techniques in different operational processes in this area, is limited. We addressed the key issues in aircraft end of life problem and gathered some works in this field or other related studies in automotive industry. Table 3 shows the key issues and the references. This simple summary can show the different areas and fields of study in EOLARP.

Table 3. The different field of studies in EOLARP

	Key issues in End of life operational process							References
1	Structure for end of life treatment	Infrastructure of collection centers	Designing facilities, location, size	Networks and key player relationship	Inspection	Risk assessments and identifying potential recognizing hazard	Substances of concerns	Madachy (1996), Paul (2001), Eco-Efficiency and Sustainability, Maguad& Jallon (2001), Sendijarevic et al. (2001), Grilc&Fabjan (2003).
2	Collection							
3	Pre-processing							
4	Inspection							
5	Re-using	Quality and reliability assessment	Sorting	Second hand part market issues	Cost and benefits evaluation	Maintenance issues		Anityasari&Kaebernick (2008), Maintenance et réparation aéronautique Base de connaissances et évolution (2010), Eco-Efficiency and Sustainability, Kovacs&Haidegger (2006), Bellmann&Khare. (2000).
6	Repair-refurbishing							
7	Disassembly	Process modeling	Sequence modeling	Automation of process	Requirements	Proper tools		Lambert (1997), Lambert (2003), Duta et al. (2003), Johnson & Wang (2010), Seo et al. (2001).
8	Material recovery	pre-shred materials-recovery technologies	post-shred materials-recovery technologies	materials identification technologies	technologies for the recycling of specific components	Advanced Materials Recycle Technology		Jody et al. (2009), Nissan Green Program 2005.
9		Design modifications for facilitation in disassembly	Material selection	Design for Environment	life cycle cost analysis			Horvath & Chester (2007),B.J. Jody et al. (2009), Marx et al. (1995), AeroStrategy Management Consulting report (2010), Nelson(2010) , Ilg (2006)
10	Life cycle analysis and Design for recycle							

11	Technology	Mechanical Separation Technology	Energy Recovery Technology	thermochemical conversion technologies	Other technologies		Winslow et al. (2004), Russo et al. (2002), Jong et al. (2005), Pomykala et al. (2003), Daniels et al. (2000), Kresta (1999), Fuchs(1999, Automotive Materials Recycle Bibliography.
12	Environmental/Energy Benefits	Footprint and landfill issues	CO2 emission	Use of metal and polymers	Energy Savings	Energy requirements Of recycling processes	Pomykala et al. (2007), Eco-Efficiency and Sustainability.
13	Reducing waste	Recognising the cost of waste	Design, innovation and technology	Sustainable business models			Waste reduction (2007).
14	Response to recycling law or regulation	Relevant regulations	Future regulations	Customers' requirements			Eco-Efficiency and Sustainability, The Aircraft at End of Life Sector: a Preliminary Study.
15	Human resources issues	Training	Labor costs	Health and safety issues			Eco-Efficiency and Sustainability, The Aircraft at End of Life Sector: a Preliminary Study.

Brand & Karvonen (2007) presented a concept that clarifies the knowledge characteristics in sustainable development context. The authors introduced four conventional forms of expertise and explained the ecosystem of expertise. In this approach, with the aim of deal with complexity of sustainable development problems we need “Sustainability expert” from a transdisciplinary perspective. They concluded with some advices to preserving the outlook on the whole system, pursuing strategic, transdisciplinary collaborations and preventing the institutional barriers with politicization.

In the other study by Komiyama & Takeuchi (2006) knowledge structuring introduced as an important principal pace in the effort to attain a broad view of sustainability issues. The authors explain the interconnection facet of sustainability problems in addition to complexity and emphasize that clarification of different aspects of these problems is only way to solve them. They believe that developing a platform of knowledge with allowing an outline of the whole network of problems and systematically organizing different fields of analysis provides comprehensive solutions to these problems.

Knowledge communication involves exchanging, sharing, transmitting, and cross-linking knowledge among members of different groups (Heinze, 2003, cited in Chiesa et al., 2009).

Effective Knowledge communication can help EOLARP in access to imperative breakthrough in processes, management practices or relevant technologies of EOL aircraft treatment around the world and this knowledge exchange can facilitate and accelerate the project and target achievements.

The distance between the knowledge units can demonstrate the complexity and diversity of knowledge sharing structures. For example, Figure 8 shows the AFRA members around the world. If we assume this community as a basis for designing knowledge network, it’s obvious that different cultural background, specialization, motivation for knowledge exchange, the probability for conflicts (Schüppel, 1996, cited in Chiesa et al.,2009) and lack of effective communication channels may be considered as knowledge sharing barriers and build complexity in knowledge management framework for EOLARP.

Figure 8. AFRA members around the world: based on information in AFRA official website

Not even in knowledge acquisition from different knowledge sources around the world, but also knowledge sharing mechanism among partners in the project raise some challenges related to diversity of knowledge units and complexity of sharing mechanism.

5.4 Performance Measurement Framework

The International Standards Office (ISO) has defined a method for calculating the performance of the recycling of Road Vehicles. However, no model has emerged for measuring performance within the aviation sector (Heerden& Curran, 2010). The ISO approach define recyclability and recoverability rates based on percentage of reused components, recycled materials, recovered energy from material and undefined residue versus vehicle mass. Heerden& Curran (2010) believe that recyclability and recoverability metrics are useful for the aviation sector as end-of-life performance indicators. However, they mention a number of challenges in computing these metrics. For example, the authors explain that when a component is reused, it is in turn replacing another component that needs to be disposed of. Hence this matter should be considered in the model. In addition, the quality of work related to first aircraft of a model is different from the last one. Because in first aircraft of model, all disassembled parts have the potential to be used in other aircraft in the same model which still flying but for last one this is not the case.

Furthermore, these aspects are only related to the operational aspect of EOLARP. It's obvious that the different internal/external pressures and types of metrics should be considered in planning performance measurement system. Health, safety and environment, operation, engineering, accounting and human resources as internal factors and regulation, community and suppliers as external factors should be considered in green context (Hervani et al., 2005). Corporate social responsibility is another aspect, which should be noted in developing performance management system.

As the balanced scorecard (Kaplan & Norton, 1996) is used widely in business and industry and has elements of design, planning and the learning, this methodology can present diversity, complexity and dynamics of performance management in EOLARP. Figure 9 illustrates the measures for aircraft end of life problem in four perspectives of balanced score card method. Some of these metrics have relations with each other and need to be addressed in context of stakeholders' value framework. This matter reflects another sort of challenges for designing a system for performance management.

The perspectives and measures have been derived from literature and the authors' opinions for developing a framework for performance measurement as a prototype for performance measurement in EOLARP. Some of them are new; however, the others are used and combined in different way.

The completed framework including the relevant objectives, targets and initiatives needs participating of industrial experts, which propose as a further study.

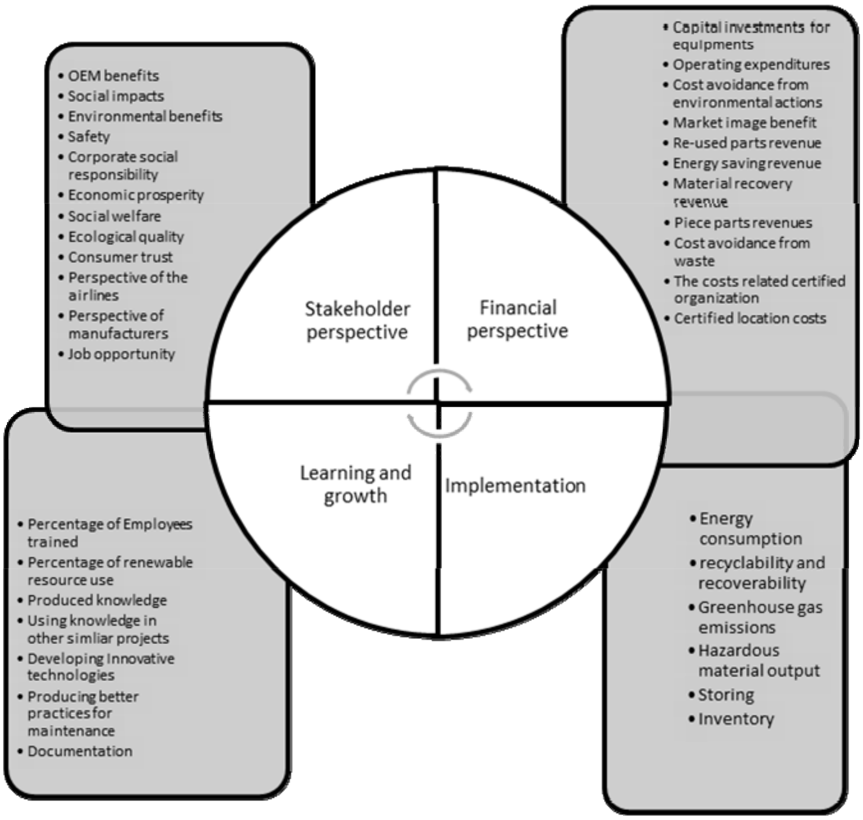

Figure 9. Basic balanced scorecard framework for performance measurement in EOLARP

6. Outlook and Opportunities for Future Research

During the recent decade, considering the directives and regulation in automotive industry, several models and solutions are developed for car recycling. Many studies address the management practices, ongoing innovation or limitation of end of life vehicles treatments in different countries and regions.

Several works address reverse logistics with different approaches such as network design and system dynamics. The other studies cover Economic and infrastructure, Shredder Management, Disassembly, Reuse, Recycling, Law and directives and Waste management. In addition, different modeling tools and optimization approaches are applied to end of life operational process. Some of these approaches are shown in table 4.

Treating materials from End-of-Life products in automotive industry is an important niche in their overall business. Therefore, the designing for reverse logistics and green supply chain can be a motivating choice for manufacturers. In contrast, we face a different, intricate and dynamic context in tackling to the EOL aircraft problem. The reasons are including the absence of relevant directives in aerospace industry, size of treated materials from End-of-Life products, the complexity and challenges in fleet recycling process and potential consequences, the multilayered relationship among partners and players, definition appropriate business model and considering social and environmental aspects.

Table 4. Modeling, tools and optimization approaches EOL operational process

No	End of life operational process	Modeling , tools and optimization approaches	References
1	Infrastructure for end of life treatment	Bench marking, Best practices, Computer Programs, Heuristics, Collaborative Database, LP and MILP,System Dynamics Modeling, decision Framework, Scenario analysis, Business process reengineering,	Madachy (1996), Paul (2001), (Eco-Efficiency and Sustainability), Maguad & Jallon (2001), Sendijarevic et al. (2001),Grilc & fabjan (2003), BloemhofRuwaard (1995), Chouinard et al. (2005), Fleischmann et al.(2000), Giannikos, I. (1998), Hu et al. (2002), Kumar & Yamaoka (2007)
2	Re-using Repair-refurbishing	(Multi) agent-based ICT solutions, Assessment Methodology, cost-benefit analysis, Hierarchical decision model,	Anityasari & Kaebernick (2008), Maintenance et réparation aéronautique Base de connaissances et évolution (2010), (Eco-Efficiency and Sustainability), Kovacs & Haidegger (2006), Feser et al. (2003), Ashayeri et al. (1996), Blumberg, (1999), Ferrer, G. (1997), Guide & Pentico, (2003)
3	Disassembly	Logic network modelling, Case Studies, Integer Programming, Mathematical programming methods, Adaptive planners, Heuristic algorithms, Precedence relations, Methods related to artificial intelligence, Petri nets, Design for life-cycle, The hierarchical tree approach, The reverse logistics approach, Disassembly Technologies and Case Studies	Lambert (1997), Lambert (2003), Duta et al. (2003), Johnson & Wang (2010), Seo et al. (2001), Boothroyd & Alting, (1992), Gungor, & Gupta (1998)
4	Life cycle analysis and Design for recycle	Environmental life cycle assessment, Economic life cycle assessment, Ecological analysis, Dynamic modelling, LP and MILP, Lessons learned	Horvath & Chester (2007), Jody et al. (2009), Marx et al. (1995), Lopes (2010), Nelson (2010), Ilg (2006), Boothroyd & Alting (1992)
5	Reducing waste	Lean, Six sigma, Neural models, Graphical representation, Waste-management-plan	Young & Cabezas (1999), Young & Cabezas (2000), Watts (1999)

With growing the number of useless parked aircrafts, dealing with this problem in a well-organized way is needed. EOLARP is a multidimensional and collaborative framework. Various types of values are extracted from these projects. Strategic approach can aid managers in these projects to achieve effectiveness in addition to the conventional performance efficiency targets in projects. In this work we studied the transdisciplinary concept in EOLARP and with applying this concept and strategic approach we presented a framework for further studies. In Table 5 we provide an outlook for some opportunities and prospects for future research based on proposed conceptual framework in this paper.

Table 5. Research agenda

	The proposed Model	Research highlights
Business Model	✓ Cost Model ✓ Value chain Model ✓ Logistics Model	✓ Value from owner perspective ✓ The revenue from different categories of parts and components (Serviceable component (after removal), Serviceable component (after shop visit), Salvageable component, Un-salvageable component, Rotable component, Consumable parts, Life-limited components, End-of-life components, Piece parts, Subassembly parts) ✓ The revenue from recovered materials ✓ Developing method for estimation expected market value and market size for these parts or components based on the model, commonality, and different factors, which affect the market value

		✓ The main actors in value chain (material and cash flow among actors, level of investment, value added) ✓ Value added operations ✓ EOL processing key decisions ✓ Developing different scenarios based on recovery, recycling or environmental targets and processing key decisions and evaluation method ✓ Inventory challenges ✓ Logistics issues based on the location of parting-out process
Market and Industry	✓ Market behavior Model ✓ Or Policy design Model	✓ Analysis of key parameters in behavior of second hand part market, Spare part markets, MRO companies Component dealers, Component brokers and Buying parties ✓ Global and local economy analysis (for example, global fleet growth, Demand for travel, Aircraft being offered on the market, Parked aircraft) ✓ The act of aircraft manufacturers ✓ Developing scenarios based on the above mentioned factors and evaluation of different scenarios
Knowledge management framework	Knowledge network model	✓ Developing an appropriate architecture for knowledge units ✓ Developing different scenarios in knowledge sharing among players ✓ Identifying the key results from knowledge model ✓ Optimization of knowledge sharing among players to achieve the key results
Performance management framework	Strategic performance management Model	✓ Identifying the needs of project in performance evaluation ✓ Identifying the appropriate perspectives ✓ Developing metrics and indicators

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