Extended Producer Responsibility in the Aviation Sector

Marisa P. de Brito, Erwin A. van der Laan and Brijan D. Irion

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Email address corresponding author	elaan@rsm.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

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EXTENDED PRODUCER RESPONSIBILITY IN THE AVIATION SECTOR

Marisa P. de Brito
OTB, Delft University of Technology, Delft, The Netherlands
m.p.debrito@tudelft.nl

Erwin A. van der Laan
RSM-Erasmus University, Rotterdam, The Netherlands
elaan@rsm.nl

Brijan D. Irion
RSM-Erasmus University, Rotterdam, The Netherlands
b.irion@aels.nl

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In this paper we investigate recent initiatives with respect to extended producer responsibility in the aviation sector. We compare those with the existing practices in the automobile sector and the emerging regulations in the shipping sector. We describe the challenges and the lessons to be learned from the evolution and state of extended producer responsibility in these two industries.

1. Introduction

During the last two decades, we have witnessed a growing awareness of extended producer responsibility issues in transportation, parallel to the sustainable development movement. Those issues relate, among others, to congestion, pollution (CO2 emissions, noise, etc) and scarcity of resources.

The European Commission (EC) is very active in bringing forward extended producer responsibility legislation. Extended producer responsibility (EPR) is a principle widely used as a basis for government policy aimed at reducing waste and the environmental impact of the end-of-life (EOL) disposal of products. This principle has stimulated the End of Life Vehicles (ELV) European Directive in 2000 and, the waste electrical and electronic equipment **(**WEEE) Directive. In addition, end-of-life regulation for the shipping industry is being introduced by the International Maritime Organisation (IMO), under the observing eyes of the European Commission, which does not exclude future legislation (Dimas, 2006). Therefore, it is not implausible that, sometime in the future, the EC will draw attention to the aviation industry putting in place a directive for the recovery of end-of-life airplanes.

With or without end-of-life legislation, opting for value recovery instead of disposal of end of-life aircraft may prove to pay off economically too, if managed efficiently. Large players such as Boeing and Airbus are well aware of this, as they recently started independent initiatives on the dismantling of end-of-life airplanes for recovery.

In this paper we investigate new initiatives with respect to extended producer responsibility in the aviation sector. We compare it with the existing practice in the automobile sector and with the emerging regulations in the shipping sector. We describe the challenges and lessons to be learned from existing end-of-life recovery practices in other industries.

2. End-of-life responsibility and sustainability

Extended producer responsibility (EPR is a logical extension of the "polluter pays principle" (PPP). This principle implies that the polluter should bear the cost of pollution. This cost should be reflected in the costs of goods and services that cause pollution in production and/or consumption. EPR can also be seen as a strategy to internalize the environmental costs into the market price (Forslind, 2005).

Haskell (2005), states that the ultimate goal of EPR is sustainable development through environmentally responsible product development and product recovery. The rationale is that by making producers pay for the waste and pollution they create, they will have an incentive to incorporate a broader range of environmental considerations into their product design, packaging and choice of materials. The objective is to reduce consumption of resources at all stages of the life cycle of a product or package, stimulating cleaner production and waste prevention.

The correct implementation of the EPR principles demands a policy instrument. The choice of a policy instrument determines the specific character of the EPR principle. According to Lindqvist (1992), the EPR principle can be implemented through three forms of policy instruments: administrative (collection/take-back regulations, recycling quota), economic (taxes, subsidies, deposit-refund schemes) and informative instruments (reporting to authorities, marking/labelling of products and components). Forslind (2005) adds a fourth policy instrument, namely the agreements policy instrument (social contracts, gentlemen's agreements).

As defined by the *Sustainable development* is meant to meet "the needs of the present without compromising the ability of future generations to meet their own needs." (UN Division for Sustainable Development, 2005). Sustainable development has three dimensions: an economic, a social, and an environmental one. When considered simultaneously they are often referred to as the 'triple bottom line', or the 3 P's (profit, people, planet). It implies that economic growth should be balanced against its social and ecological impact.

3. Methodology

We use input from the aviation industry on the end-of-life issue, comparing the two distinct approaches of Boeing and Airbus. Furthermore, we draw lessons of two industries: the automobile and the shipping industry. Studying the impact of the European end-of-life vehicle directive may provide an indication of the performance of future extended-producer-responsibility regulations (Gerrard and Kandlikar, 2007). In addition, the shift of focus to more environmental friendlier methods and procedures for the disposal/ recycling of end-of-life vessels makes the shipping industry a suitable industry for comparison.

We make use of a SWOTER analysis. Furthermore, we use the triple-p concept (people, planet, profit) to comment on the sustainability of the different approaches. The whole study is enriched by a review and analysis of literature related with the topic. In addition, we use direct input from stakeholders of the aviation industry in the end-of-life (EOL) phase. The comparative analysis in combination with the literature on end-of-life aircraft management and interviews will provide the basis for assessing the state-of-the-art on extended producer responsibility in the aviation sector, and which lessons are important to learn. To identify the technical and economical challenges in making recovery of airplanes at the end-of-life a successful business

4. Current end-of-life handling in the Aviation Sector

The life span of an aircraft is roughly 30 years. Currently, when an aircraft has reached its end-of-life, it is stored at one of the aircraft storage fields such as the Evergreen Air Centre (EAC), established in 1975 and located in Pinal Air Park Marana in the Southern Arizona desert of the (USA). The EAC is the largest commercial aircraft storage field in the world, accommodating storage for more than 400 aircrafts. (www.evergreenac.com). The dry, non-corrosive climate of the Southern Arizona desert provides an ideal environment short and long term storage.

EAC dismantles between 24 and 48 commercial aircraft a year (www.airspacemag.com). Europe's alternative to aircraft storage, the France based Châteauroux Air Centre (CAC) is since its establishment in the early 1990s trying to capture a significant share of the European market for storage and dismantling aircraft. As the age of an aircraft increases, the aircraft will require more unscheduled maintenance downtime, hence an increase in maintenance cost. This increase in maintenance hours has a major impact on the aircraft's operating cost and availability. When an aircraft has an operational life of 30 years and the wear and tear has taken its toll, the maintenance costs are typically more than the double of what they were at an operational life of 5 years (World aircraft sales magazine, 2005). An increase in fuel and maintenance costs for aging aircraft place their owners with the decision to either keep the aircraft in operational service or replace the aircraft with a more efficient type. Globally there are only two companies, the European based Airbus and the North American based Boeing, that manufacture commercial aircrafts. Commercial aircraft are classified as aircraft with more than 100 seats. Airbus and Boeing use different estimates regarding the volume of aircraft that will be retired over the next 20 years. Airbus estimates that the number of passenger aircrafts in service will more than double from 12,676 at the end of 2005 to 27,307 in 2025. Airbus predicts that passenger airlines will replace 12,071 aircraft during this period. Of these, 4,842 aircraft will become active again in passenger service, 2,777 will be converted to freighters and the remaining 4,452 will be permanently withdrawn from service (Airbus global market forecast 2006-2025). Boeing estimates that the 2005 passenger fleet of 15.540 will increase a total passenger fleet of 32.400 by the year 2025. Over this 20 year time period Boeing estimates that a total number of 7360 aircraft will be permanently retired from service.

Market conditions combined with the quality of the aircraft decide whether an aircraft is (temporarily) withdrawn from service. A reintroduction in the market mainly depends on changes in economic circumstances or competitive position. Usually, older generation aircrafts, such as the Boeing 707, 727 and early 737, which are noisy and fuel inefficient, are unlikely candidates for reintroduction into the market.

With some 390 aircrafts, the Boeing 727 accounts for 40% of aircrafts in storage (www.ainonline.com). Historically, 90% of aircrafts returning to service were stored for less than 2 years and 75% are aged less than 20 years. Less than 10% of older generation aircrafts have temporarily returned into service (Airbus EHS report, 2003). The cost for storing aircrafts is an important factor. The monthly fee at e.g. Châteauroux airport ranges between $2,500 and $3,000 depending on aircraft size (www.aviationtoday.com). However, also the costs of transport to the storage field and the costs of storage preparation should be taken into account. The preparation or induction costs are $7-8000 for narrow bodies and $15-18000 for wide bodies (SH&E International Air Transport Consultancy, 2004). The time needed to dismantle an aircraft depends on the type of aircraft, a Boeing 747, which is currently the largest commercial aircraft in active serve, is reduced into a pile of aluminium in just two days, plus another two days to remove all materials before the site can be cleaned by a mechanical sweeper. (www.aviationweek.com). The aluminium remains of a 747 are worth at least $20.000 (www.airspacemag.com). Keep in mind that the total time required to dismantle an aircraft is depended on aircraft type but also on the total amount of equipment used take the aircraft apart. Furthermore, parts disassembly on a Boeing 747 requires on average about 3000 hours.

Components may be re-used for aircrafts within the same type (wings, tail pieces, fuselage sections) or the same family of types (power units, avionic boxes) and they may be reused by the same airline operator or sold to other operators. For certain older types of aircraft it is financially more attractive to disassemble and sell the re-usable parts rather than selling the aircraft as a whole. A big concern for the aircraft manufacturers, however, is the uncontrolled sales on secondary markets. Vice president of EAC states that, especially in the US, without a paper trail, those parts are a lawsuit waiting to happen. Bootleg parts are a big problem today, especially in third world countries (Mecham, 2006; Tegmeier, 2007).

Aircraft disposal is getting more attention in the aviation industry, the proper scrapping of older types of aircrafts and recovering their materials for re-use is becoming more and more important now that an increasing number of aircraft are retired since they are no longer safe and/or cost efficient to operate. The residual value of an aircraft can be increased if it becomes possible to efficiently separate the various grades of aluminium and other materials from an ELA (Arkell, 2006).

Currently, Airbus and Boeing have both shown initiatives in designing and developing standards and procedures for the safe and environmental friendly dismantling of end-of-life airplanes. What is interesting is that both manufacturers maintain a considerably different business approach with respect to end-of-life and a different perspective on potential legislation.

The AFRA Initiative

Officially launched and introduced by Boeing at the first of June 2006, the Aircraft Fleet Recycling Association (AFRA) aims to provide owners of aircrafts with integrated fleet management services extended to the end-of-life. Two of AFRA's founding members, Evergreen Air Centre located in the Arizona desert USA and the Châteauroux Air Centre located south of Paris, France, have two operating sites.. The latter offers an alternative in Europe, providing about 50 storage positions for aircraft. This aircraft storage and dismantling site, built in the early 1990s, captures a significant share of the European market for storage and dismantling activities, which before its establishment was mainly performed at American facilities (www.aviationtoday.com).

The AFRA association brought together about ten U.S. and European companies with different expertises covering disassembling of aircrafts, salvaging parts, and materials' recycling. To start with, AFRA aims at developing a code of conduct for retired aircraft management procedures. The establishment of next-generation standards and practices is envisaged for within a year of the code's launch, and the follow-up goal is to expand those standards into the general market. AFRA strives for a more effective management of current end-of-life activities in the aviation sector, and to address the future.
Thus, Boeing has no intent to recycle any aircraft itself, the rationale in supporting AFRA is to set out standards so they will be a basis for industry and perhaps to governmental action.

Currently the aircrafts reaching the end-of-life have aluminium frames and recyclers are easily able to breakdown aluminium alloys. However, the quality of the recycled aluminium is not conforming to the standards for new aircraft production. Regulations state that all new aircrafts must be produced from virgin materials (www.easa.eu). Metal recyclers can breakdown aluminium alloys into lesser or higher grades, but the material is not reused for new aircraft manufacturing because its quality is not high enough (cleaning up, 2006). It is challenging to effectively separate the variety of aluminium alloys used in aircraft manufacturing, especially when riveted together. With cars and house siding, up to 90 percent can be separated by alloy type (thus increasing value). But with aircraft, only about 30 to 40 percent of metals can be separated (Boeing Frontiers, 2006)

An additional challenge is recycling composites. The use of composite structures in the aircraft frame may allow a reduction in the total weight of 40-60% (Ye et al., 2005), thus its use is very likely to increase. For instance carbon fibre, due to its light weight and high strength, is largely employed in the new developed aircrafts such as the Boeing 787 dreamliner, expected to enter in service in 2008 and employing about 50% of carbon fibres (www.boeing.com) and 22% of components of the A380 will be manufactured using composite material Due to the rising price of composite materials and the volume of predicted end-of-life aircraft over the next decade, new technologies that can sort aluminium by alloys and recover carbon fibre from composites are extremely timely. Aerospace grade carbon fibre currently sells for about $25 per pound (www.airspacemag.com). Boeings aircraft and composite recycling manager Bill Carberry acknowledges that properly salvaged scrap composites can sell for between $20 and $25 per pound (Boeing Frontiers, 2006).

Besides the benefits this material offers, the current capabilities within the industry to recycle carbon fibre materials are still limited. Nonetheless some breakthroughs are already being achieved. Milled Carbon, a founder AFRA member, has a process to recycle carbon fibber, which output is just below virgin material carbon. While Boeing is optimistic about using recycled carbon, in the future, in the production of new airplanes (Milled Carbon Ltd, 2006; Ledgard BBC News, 2006), others remain sceptical (Mecham, 2006)). Nonetheless, AFRA is active in seeking to develop best-practice standards for the management of retired aircraft parts.

PAMELA

In March 2005, Airbus has initiated an aircraft recycling project named PAMELA (Process for Advanced Management of End-of-life Aircraft). The project was set up to test environmental friendly recycling procedures and the disposal of end of life aircrafts. This is a multi-million project, partly sponsored by the European Commission, and aims at developing aircraft disposal procedures that comply with the environmental and health rules dictated in the European Aviation Safety Agency standards. On 24 February 2006 the first aircraft was flown to the specially set up centre at Tarbes Airport located in the Southwest of France where procedures for the decommissioning and recycling of aircrafts in a safe and environmentally responsible way will be tested.

The consortium of PAMELA partners consists of waste management specialist SITA, European Aeronautic Defense and Space (EADS), and the regional government of Préfecture des Hautes-Pyrénéesare, among others. PAMELA's first experimental aircraft is an old A300B2-200, which entered service in 1982 and accumulated 53,489 flight hours (Coppinger, 2006). The pilot project is scheduled to end in October 2007 and Tarbes plant plans to start industrial-scale operations in the summer 2007 with the goal of treating 10 airplanes a year from now to 2010. Within this time frame the project wants to demonstrate that 85 to 95% of aircraft components can easily be recycled, re-used or recovered (Turner, 2006).

Determining the current aircraft (material) recycling percentage is an important factor for establishing any form of future aircraft (material) recycling targets. The aircraft (material) recycling percentage may be determined in a similar fashion as is done for the automotive industry by combining the material (aluminium) recycling percentage and the percentage of re-use of components into one percentage. Another way is taking only the percentage of recycled aircraft material by weight of an end-of-life aircraft and thus not combining this percentage with the re-use of components. Current literature presents different estimations of this recycling percentage without directly identifying how this recycling percentage is measured. As recyclers and aircraft operators see it, about 80% off all commercial transport aircraft material that can be re-used one way or another (www.airspacemag.com). According to the Dutch firm AELS (Aircraft End-of-Life Solutions) established in April 2006 and located in Delft, The Netherlands, the current aircraft material recycling percentage is between 60 and 80%. This percentage is measured by only taking the recycled material percentage of an end-of-life aircraft and is thus not combined with the re-use of components. AELS managing director, Derk-Jan van Heerden believes that this is a more correct method of determining the recycling percentage of an end-of-life aircraft while this percentage gives a clear indication of the materials recycled by weight of an end-of-life aircraft which is the first step in determining viable recycling percentages for the future.

On the first experimental aircraft used for the PAMELA project, an old A300, which entered into service in 1982 and accumulated 53,489 flight hours, the aircraft structure consisted out off 77% aluminium and only 4% of composite material by weight. With the PAMELA project the commercial aircraft manufacturer wants to evaluate the costs and benefits of recycling up to 95% of the structures, materials, and components of end-of-life aircraft and provide recommendations for improvement in tracking extracted parts and equipment from end-of-life aircraft (Aerospace America, 2006).

PAMELA aims to increase this recycling percentage to 95% by the year 2015. This increased percentage is similar to the 2015 recycling percentage set out by the end-of-life vehicle Directory for the automotive industry. The PAMELA project attempts to set up a new standard for safe and environmentally friendly management of end-of-life aircrafts combining this with the launch of a European network to disseminate information concerning this new innovative process.

The initiators want to export their skills and technologies to other regions of the world. The plant will not be restricted to Airbus planes only; aircrafts of Boeing will also be accepted as well as military planes. By working together with recycling expert like SITA, Airbus wants to incorporate more environmental friendly parts in the early design stages of aircrafts in order to improve the entire aircraft life cycle. Airbus itself will not be involved in developing recycling processes but as an aircraft manufacturer, the company is able to provide the precise location of different materials and the knowledge to assist disassembly. Disassembly in this case involves the identification of equipment or parts that are in a good enough condition to either reuse directly or after refurbishing.

Contrasting approaches

In the previous subsections, we introduced the two recent approaches to EPR by Boeing and Airbus, namely the AFRA and the PAMELA projects. Boeing's approach contrasts with that of Airbus by not getting directly involved in the end-of-life activities. Boeing is not going to directly recycle aircrafts itself but has organized the AFRA group to disassemble planes, salvage parts and recycle materials. In contrary to Boeing's approach, Airbus is also using the expertise of recycling specialists but is getting directly involved in end-of-life operations. Besides the difference in approach between the two manufacturers, there is also a difference in funding. The PAMELA project is partly financed by the European Union environmental funds. Specific figures are that the project is for 53% funded by industry and 47% by the EU's LIFE (L'Instrument Financier pour L'Environment). The AFRA project in contrary to the PAMELA project is fully industry funded. Overall, Airbus has similar goals as Boeing but the main difference in approach is that Airbus is controlling the process, rather than collaborating with the partners.

5. End-of-life handling in other industries

EPR legislation for end-of-life vehicles (EOLV)

Driven by environmental concerns about the ever-growing car dump sites, the debate regarding car recycling schemes has been going on since the late eighties. Most cars never made it to the dismantler due to high landfill costs, low scrap value of cars and badly organized markets for spare parts (Field et al. 1993). European ELV legislation was installed in 2000, but voluntary initiatives had been developed in several European countries (France, Italy, The Netherlands, Austria) before the proposal was even put forward in 1997. Currently, some 7.6 million vehicles are recycled annually in the EU-15 countries of the 11.3 million cars deregistered (ACEA, 2004).

The ELV directive endeavours to (Gerrard and Kandlikar, 2007):

1. reduce the use of hazardous substances when designing vehicles;

2. design and produce vehicles which facilitate the dismantling, re-use, recovery and recycling of end-of-life vehicles;
3. increase the use of recycled materials in vehicle manufacture;
4. ensure that components of vehicles placed on the market after 1 July 2003 do not contain mercury, hexavalent chromium, cadmium or lead.

The following recovery and recycling targets are enforced at member state level: 85% (including energy recovery) by 2006 and 95% by 2015; 80% (excluding energy recovery) by 2006 and 85% by 2015. A numerical study by Ferrão and Amaral (2006) shows that "removing up to 14% of the ELV mass results in a recycling rate higher than 80% and this can be performed economically by well organized dismantlers", this provided that there is a steady flow of end of life vehicles, free of charge, and steel scrap prices do not go below 120 €/ton.

In the Netherlands the recycling of ELVs is coordinated by ARN (Auto Recycling Nederland), an initiative of the Dutch automobile branch as of 1993. Its management board consists of representatives of several branch organisations (manufacturers, importers, dismantlers, service stations). Dismantlers that are certified by ARN process 89% of all end of life vehicles in the Netherlands (about 275.000 vehicles a year). ARN currently realizes a recovery percentage of 85% by weight of which 82% is recycled; the remainder is energy recovery. The system is financed through a dismantling fee that is paid upfront by new car buyers. This fee has decreased from € 110 at its introduction in 1997 to only € 15 in 2007 (ARN environmental report, 2005). In the mean time, ARN has built a considerable financial reserve to guarantee its services in the future.

Before shredding, components such as engines, batteries and airbags and fluids such as oils and fuels are removed from the vehicle. The shredded material contains some 75% of ferrous metals, 7.5% of non-ferrous materials are recovered and recycled, 2.5% is incinerated for energy recovery and the remaining 15% is land filled. Since with current technologies and market conditions re-use and recycling is at its limit and as of 2009 it is illegal to landfill unprocessed automobile shredder residue (ASR), ARN has recently invested € 20 million in a post shredder factory. ARN expects to achieve a recovery percentage of 90% in its first operational year (2007). However, upgrading the technologies for shredder residue recovery is not enough to satisfy the targets for 2015. Markets need to be found for the recovered material as well to actually increase the recycling rates.

The economical challenges that ARN and its dismantlers face is that the number of cars offered for dismantling has decreased by 30% in the last 6 years. This is due to the fact that less new cars were sold, the average car life has increased, more and more cars are exported to Eastern Europe, and the market price for car wrecks has increased due to rising metal prices. A related concern is that the average age of cars in Easter Europe is much higher than in Western Europe. For example, in 2004, 74% of all passenger cars registered in the Czech Republic were over 10 years old, while in Ireland it was only 13.8% (CEC assessment report, 2007). To counter the expected surge in ELVs, the largest shredding site in central Europe will open in Hungary in 2007 with an annual capacity of 30,000 cars.

Although ARN has been successful in satisfying the 2006 recovery rates imposed by the EVL directive, the question remains in what respect the directive has reached its predefined goals in Europe as a whole. Considering the goals of the directive, we should expect changes in material composition, car design, recycling and recovery percentages and information provision (Gerrard and Kandlikar, 2007).

In their study, Gerrard and Kandlikar conclude that ELV legislation has indeed led to innovations in recycling methods and shredder residue separation techniques, but not in design for recycling and reuse. This may be due to the large time between initial investment and ultimate pay-of as the average lifetime of vehicles surpasses 15 years. It seems, however, that ELV legislation is leading to a reduction in toxic substance use and the number of different plastics. Gerrard and Kandlikar postulate that the use of aluminium will increase as it is easily recycled. The current estimate, however, is that the content of ferrous metals for an ELV in the UK will decrease from 68 to 66% and the plastic and polymer content will increase from 6 to 8% by 2015 (EU assessment, 2007, p.46). The impact of ELV legislation on design for re-use and remanufacturing at the end of life is limited, mainly because relatively high investments are not expected to be balanced by direct benefits for the manufacturers. Finally, it seems that the ELV Directive is resulting in improved collection and dissemination of data that enables efficient material and part identification, but data needs to be standardized and available across models and brands to be beneficial to the customer.

The automobile industry itself views the current ELV Directive as bureaucratic, inflexible, partly contradictory to other environmental regulations, too costly and too ineffective. (ACEA, 2007). Especially the 2015 target of 95% is seen as problematic.

The EU agrees that the environmental impact of the ELV directive is small compared to the total waste context: waste generated by ELVs constitutes less than 0.7% of the total amount of waste generated in the EU annually, with ASR representing between 3 and 4% of all hazardous waste generated in the EU, but in absolute terms the impact is substantial. At the same time, the higher recycling rate may result in a very limited increase in total life cycle cost.

Moreover, the ELV directive has not yet led to design changes that affect the weight or environmental performance of cars. Since most cars that will be dismantled in 2015 have been designed before 2002, future design changes will not affect meeting the 2015 target. The past trend towards heavier cars is due to customer preference for bigger and safer cars. According to the EU, the directive has no effect on the competitive position of the European car industry, as the directive holds for all cars registered in Europe (CEC assessment report, 2007).

Shipping industry and end-of-life

Globally, some 700 vessels are recycled every year, mainly in Bangladesh and India The practice of recycling ships is a lucrative one as 95% of a ship's material, such as scrap steel or equipment, can be recycled or reused.. The dismantling of ships at the end-of-life is mainly done by developing countries. This is because the capacity and cheap labour are there, as it is the demand for raw materials such as steel. (Nithingale, April 2005). Ship breaking industry supplies 5% of the global demand for metal, 80% scrap steel demand in Bangladesh is met by ship breaking, while in Turkey this is 11% (Glisson and Sink, 2006; Neser et al., 2006). There is clearly a strong economic incentive behind ship scrapping as profits can be as high as $500 per ton, and ships weight several thousand tonnes (Peele, 2006).

The idea of reusing resources already deployed is *a priori* environmentally favourable, especially when one minds the reduction of CO2 emissions when compared with extraction of virgin materials through mining. There is however a global shortage of facilities undertaking ship recycling in a safe, healthy and environmentally sound manner. Currently there is a long-list of hazardous activities in ship breaking, carried out with minimum or no safety (US department of labor and occupational health, 2002). In developing countries workers often walk in their bear feet, climb anchors with bear hands and work in intoxicated atmospheres with no masks (Buerk, 2006) Waste generated during ship scrapping can amount to more than 10 kg/m2, including toxic waste, which is left to be carried away by the tide, or eliminated by open burning (Reddy, 2003).

The unsafe practices within the industry have received a great deal of attention from diverse international organizations and interest groups such as environmental NGOs. The committee for the environment of the International Maritime Organisation (IMO), the Marine Environment Protection Committee (MPEC) addressed the ship recycling issue first in 1998. In 2002 the Conference of Parties to the Basel Convention (primarily concerned with the control of hazardous waste migration) put forward guidelines for environmentally sound management of ship dismantling. MPEC agrees the same year that guidelines for proper recycling of ships at the end-of-life should be developed. The first IMO guidelines were discussed in July 2003 and adopted December that year, on a voluntary basis, but some members have expressed the desire of having a compulsory instrument. A fund was established in May 2006, the International Ship Recycling Trust (ISRT) to support training and advisory activities, and to assist authorities in preparing legislation and implementing the standards, especially in the developing countries. Several agencies are cooperating on this, as IMO is collaborating with the Basel Convention (on the control of hazard waste migration) and ILO (International Labour Organization), both under the umbrella of the United Nations (UN). They have established the working group on Ship Scrapping, who is working on the convention on ship recycling. This is work-in-progress but the preliminary ideas are as explained next. Guidelines are going to be extended to the design phase (recyclability should be minded at the source), the recycling facilities and operations, including guidelines on inventory of prohibited/restricted hazardous materials, for certification, for inspection, and for communication of information. Every recycling yard will have to submit a recycling plan before recycling operations can take place, and every vessel has to be accompanied by a resource-passport listing the inventory of the ship in terms of the materials in the structures of the ship and wastes generated during use. Existing ships will have to be inventoried during the next five years (yet this period might have to be extended), while new ships will bring their descriptive passport already from the manufacturer. Alterations during the life of the ship are to be updated in the passport, and a last inventory is to be made when the ship is decommissioned. IMO aims at setting common global standards giving the opportunity to recycling states to stop ships from being recycled if there are valid objections (see Mikelis, 2006)

Currently however by simply re-flagging a vessel to a flag state which does not enforce rules on environmental friendly ship dismantling, a significant amount of costs can be saved for the final ship-owner who can leave the vessel with all its hazardous materials still on board without having to worry of the environmental damage or bear the cost of handling the hazardous materials in an environmental friendly manner. Thus guidelines are not likely to be enough to achieve environmentally sound ship scrapping. To do so, the way may very well be international biding law.

EU is approaching potential legislation with care, examining potential fireback of environmental regulation. For instance, environmental disasters with single hulled oil tankers such as the Prestige and the Erika led to the phase-out of single hulled oil tankers. However, this phasing out scheme will result in increase supply of end-of-life vessels reaching an expected peak in the year 2010. The problem is that the capacity to handle this volume of more than 2000 tankers exists only in Asia (Nightingale, 2005). Thus this increased volume of tankers, if not handled properly, may create an extra burden on the environment, while regulation was meant to reduce the environmental impacts. Furthermore, some voices claim that *the stick* is not enough, but that *the carrot* is also needed. E.g. Glisson and Slink (2006) suggest that ship owners who present a 'green' ship for dismantling could be praised by benefiting from being able to charge higher freight rates to government shipments. In addition, the whole socio-technical system has to be reviewed. It is not only a matter of imposing better design, but is also about developing better management structures, so environmental inefficiencies can be mitigated.

Increasingly ship-owners and shipbuilders will have to adopt 'cradle-to-grave' approach in the design and construction of ships, as part of the sustainable shipping approach. Developing countries are also showing some environmental initiatives or environmental consciousness regarding ship breaking, as they are already stopping polluted ships from coming in (Recycling Today, 2006).

6. Challenges and future research

Our findings regarding the aircraft, automobile and shipping industries are summarized through the SWOT analysis in Table 1. Focusing on improved sustainability through end-of-life recovery of commercial aircraft, the table shows that the industry's main strength is that are only two major manufacturers. In that sense it should be relatively easy to negotiate (voluntary) recovery targets and regulations and to set up supply chain alliances. The latter of course already showed through the AFRA and PAMELA initiatives. Another strength is the already prevalent focus on cleaner air-travel and the absence of a negative image regarding end-of-life operations, as is the case for the shipping industry.

A weakness with respect to economic sustainability is that there are no clear numbers yet on potential recovery yields and associated costs and benefits. The large variety in aircraft size and composition adds to the complexity. The aviation sector's strong focus on safety issues may form a barrier for end-of-life recovery.

Considering the recent manufacturer initiatives AFRA and Pamela, with the opportunity to build upon the experiences regarding the effectiveness of the ELV directive, the aircraft industry may have a head start in designing sustainable end-of-life recovery practices well before EOLA legislation may be in place. Similar to EOLV recovery, threats are volatile material prices, the absence of a steady flow of disposed aircraft and the transition from aluminium to composites. Furthermore, with respect to safety issues it is essential for the aircraft industry to avoid bootleg parts to enter the market. This should actually be an incentive for the manufacturers to take the CLSC management into their own hands. Still, also for the aircraft industry, the focus seems to be on recycling rather than product reuse.

There are several lessons to be learned from the automobile and the aviation sector. If regulation is to be in place, its design should bear in mind issues such as: the steady flow of aircrafts versus potential peaks (in relation to recovery targets); to introduce economic incentives (‘the carrot’) side by side with ‘ the stick;’ the importance of the future market for recycled materials or recovered parts (with respect to economic sustainability). However, more research is needed on the costs and benefits of end-of-life recovery of aircrafts.

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Aviation industry	Automobile industry	Shipping industry
STRENGTHS		
P1: Manufacturer initiatives enable an economically sound implementation; Limited number of manufacturers. P2: High aluminium content enables easy recycling; constant focus on cleaner air-travel. P3: Sector does not have the 'negative-image' pressure of end-of-life operations like the shipping industry has.	P1: no negative impact on the competitive position of the European automobile industry. P2: Effective recovery targets w.r.t. reduction of landfill volume, use of natural resources in the production of new vehicle, prohibition of hazardous materials, and the use of better recyclable materials	P1+P2+P3: inter-agencies effort P2+P3: existing voluntary guidelines will be beneficiary in the long term.
WEAKNESSES		
P1: No clear picture of costs and benefits of end-of-life solutions P2: The use of recycled aluminium is currently prohibited; recycling of composites is very challenging while their volume is increasing; no incentives for design-for-remanufacturing P3: Focus is on life-cycle performance (safety & fuel efficiency) which may form a barrier for investments for end-of-life recovery	P1: needs a steady-flow of EOL cars to be profitable P2: No incentives for design-for-remanufacturing; small environmental impact relative to whole life-cycle; P3: focus on life cycle performance (comfort, safety) inhibits investments for end-of-life recovery.	P1: Lack of economic incentives (just the stick, what about the carrot?). P1+P2: limited capacity of certified sites P1+P2+P3: too cumbersome to implement in short-time P2+P3: Possibility of re-flagging; limited impact of current guidelines in the short-term; Problem of outsourcing: who is liable? How to monitor if safety practices are being followed?
OPPORTUNITTIES		
P1+P2+P3: Experiences from existing ELV legislation + voluntary guidelines for the shipping industry can be used to design effective and efficient ELA processes and procedures; Pamela and AFRA initiatives	P2: Post shredder technology	P1+P3+P3: Government can have a supporting role (for the 'carrot')
THREATS		
P1: volatility of material prices P1 + P3: Bootleg parts are a threat both to economics and safety P2: Transition from aluminium towards carbon fibre use.	P1: Volatility of disposed EOLV's; Lack of markets for recycled materials inhibits investments in new technology	P1+P2+P3: Phasing out of single-hull vessels will result in peak of EOL vessels. P1: Eco-sites in Europe, but demand is in Asia.

Table 1: SWOT analysis regarding sustainability of end-of-life recovery (P1=profit; P2=planet; P3=people).

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