Eco-design for Materials Selection in Automobile Industry

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Abstract

This paper aims at discussing the role of eco-design tools in materials selection presenting some results of a six-month case study on Eco-design and Recycling Strategy of Renault focusing on the mini Space Modus. Modus was the first model entirely conceived on the basis of the eco-design Renault internal rules for materials selection established to cope with European Legislation targets to 2015. Modus was designed at Technocentre Renault in 30 months, by a teamwork including people of Valladolid Plant that came from Spain, where it should be assembled. The different groups in charge of each automobile system worked together in simultaneous engineering at the design, prototyping and assembly line. Modus achieved a recycling rate of 95% and incorporated over 18 Kg of recycled plastic.

Keywords
Eco-design, materials selection, car recyclability

1. Introduction

Since the last decade automobile industry is redefining their product improving the engine performance as well as rendering the new models more comfortable, safer, easier to drive, and getting them environmental friendliness. And they do this by means of simultaneous engineering methods that enhance eco-design approach from materials selection to the end of life vehicles treatment. This is new design approach represent a means of integrating environmental criteria on product development as part of competitive corporate strategy. Eco-design practices are changing the way automobiles are being conceived enabling car companies to cope with the most restrict environmental regulations and even to anticipate them. In this context environmental friendliness has become an important criterion for materials selection. Clean and recyclable materials are responsible for automobile environmental quality, which is becoming a critical issue for the near future.

Materials selection is one of the strongest environmental drives to which engineering design seek to respond. According to Field III, Clark and Ashby “the four main factors upon which the designers relies when considering materials choice are the relationship between materials specifications and technical performance of the product, the economic performance of the product, the environmental performance of the product the practice of industrial design embedded in the product and its functionality” [8].

For automobile industry optimizing end of life vehicle recycling is a complex task since automobile is a multi-components products in which more than twenty thousand of different parts, made of a number of raw materials, are assembled by a wide spectrum of processes and techniques. And at the end of its life vehicles will represent a buck of multi-component materials that cannot directly be reconverted into new auto parts. So the complex interconnected materials cycles originating from recycled cars have to be optimized from a technological as well as an economic point of view [4]. And materials selection environmental oriented is the first step to facilitate end of life vehicles dismantling and an efficient materials recovery.

Nevertheless materials selection for environment is not as simple as it seems at first sight. In fact it may conduct to some dilemmas due to incompatible project targets. Eco-design methods and tools from conceptual design to detailed design- DFE, DFR, DFD, LCA, Eco Indicators, Eco-QFD- can be taken as a way out to acquire the dilemmas concerning car project decisions facing environmental demands. One of these dilemmas, for instance, is how to achieve lightweight materials and to improve cars recyclability as well.

Besides, selecting materials for recycling does not assure the choice of environmentally benign materials. In fact the best way to appreciate the role of environmentally benign materials selection is to consider the product life cycle by means of LCA that takes time and requires a huge and global data basis. Based on EN ISO 14040 LCA practices takes a lot of effort to be carried out during a car project development and requires most accurate tools and dedicated software to be integrated on project data bases throughout the designing phases.

In Europe, for instance car companies are putting a great expertise, time and money into combining environmental and quality evaluation with designing tools in order to settle permanent basis for eco-design practices.

The environmental European legislation concerning end of life vehicles –ELVs– (Directive 2000/53/EC) has established strict recycling targets that claims for optimization of materials selection and recycling systems at short time. Additionally, the European Directive has to be incorporated into project practices by means of standards and design tools.

Our case study, conducted at Technocentre Renault, verified that the diffusion of eco-design practices is participating in all vehicle development phases and altering the profile of project team. Multidisciplinary design teams were formed in order to accelerate as much as possible environmental criteria diffusion and to get contributions from different areas of expertise to validate the environmental friendliness materials choice. As a result they get both innovative and recyclables models that not only fits the present environmental regulation, but also anticipate future requirements. The Renault Modus launched in 2004 confirms the initial hypothesis on the central role of eco-design tools in materials selection and the contribution of recyclability to the environmental profile of new vehicles.
The Technocentre is an integrated Technical Center in which partnership is a key word. There the automobile designers share different knowledge and a multidisciplinary know-how is continuously created as a result of teamwork in “plateau” at both internal and external level. This so-called “plateau-projet” is devoted to research as well as designing and developing the vehicles of the future. Since 1998, design and development continues with a project team, which brings together everyone involved within the company, as well as suppliers. Its innovative organization put together over 500 people working on one new model, up to five projects simultaneously, speeding the project development as well as keeping cost down [10]. And it was exactly this model of organization that made possible to integrate environmental criteria, such as recyclability, at car projects.

Since 1998 Technocentre has had a remarkable growth from 8500 people (including 1000 who were not Renault employees) to over 12,000 people in 2004, with about 4000 external people, mostly suppliers [10]. According to Renault website it was the first European manufacturer to install a room for viewing projects via full-size digital images (grand écran 3D), a process that allows all those involved in a project to combine their expertise in real time.

2. European Environmental Legislation

In 1997, the European Commission adopted a Proposal for a Directive which aims at making vehicle dismantling and recycling more environmentally friendly, sets clear quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability. This legislation was officially adopted by the EP and Council in September 2000 and was published in Official Journal L269 on 21st October. (Directive 2000/53/EC - the “ELV Directive”).[3]

This Directive is supported by eleven other secondary legislation related on ELVs including Environmental Commission Decision, European Council Decision and a Commission Proposal for a Directive of the European Parliament and the Council on the type-approval of motor vehicles with regard to their re-usability, recyclability and recoverability amending Council Directive 70/156/ECC. And other five of them are on Annex II amending. Besides there is also secondary legislation at national level and the Commission services have developed a “Guide” on the legislative acquires which, aims at facilitating the implementation of the Directive and the secondary legislation at both level.

Concerning eco-design proposes the Directive [9] says:

- The requirements for dismantling, reuse and recycling of end-of-life vehicles and their components should be integrated in the design and production of new vehicles.

- Producers should ensure that vehicles are designed and manufactured in such a way as to allow the quantified targets for reuse, recycling and recovery to be achieved. The Directive also states that economic aspects of recycling have to be take into account in order to promote a market for recycled materials (...) The development of markets for recycled materials should be encouraged. And for this purpose Member States are required to enforce the provisions of the Directive mainly regarding the access of small and medium sized enterprises to collection, dismantling, treatment and recycling market. Nevertheless, carmakers are supposed to provide authorized treatment facilities with all requisite dismantling information, in particular for hazardous materials [9].

The Annex I [9] settles the minimum technical requirements for end of life vehicles treatment in accordance with the best environmental practices available in addition to the article 6. The Annex II of the directive seeks to remove gradually the hazardous substances from automobile, such as: Lead (not only from batteries but also including steel, aluminum and copper containing lead), cadmium hexavalent chromium, and mercury in bulbs and instrument panel displays etc. This annex is supposed to be revised (and it really was for three times already) considering the state of art of materials and the availability of substitutes as well.

3. Eco-design Concept

Eco-design is sometimes referred to as Clean Design or Design for Environment –DFE- or Sustainable Design, which means that the term is not yet clearly defined or well known. Clean Design most important concern is air pollution. It is about green cars in terms of low or zero emissions. It has to do with Clean Acts - California Clean Act and Clean Act for Europe. DFE and Sustainable Design are more boarder view since they are supposed to enlarge product life cycle from the raw materials and energy production up to final disposal and recycling. But, according to Tischner [2], sustainable design is more than eco-design “as it integrates social and ethical aspects of the product’s life cycle alongside environmental and economic considerations.”

Eco-design for instance is to get design activities environmental oriented from the first step of a product project up to its production and consumption phases. Recently this last phase was enlarged to cope with recycling end of life product. Eco-design is about to integrate environmental criteria on project and product development. Which means to balance environmental requirements with the basic project requirements as cost, quality, security, delay, since the products are firstly conceived to be produced and to be efficiently used by theirs customers and secondly to be dismantling and recycled.

So eco-design a product as complex as a car aiming to minimize its environmental impact over its whole life cycle is not an easy task. But car companies in Europe have to do it to encompass environmental legislation standards such as the ELV Directive and ISO 14000. And they are definitely putting a great effort on partnerships with not only their traditional supplier but also with materials producers and recyclers. In this sense they are co-designing new models sharing integrated software and data basis. Working on teamwork at internal and external levels is exactly what Renault is doing at Technocentre with their so-called “plateau-projet” organization, which facilitates the eco-design practices.

4. Eco-Design Practices and Recycling Strategy at Renault

“The Renault environmental organization is characterized by the development of cross-functional programmes to improve the exchange of information and expertise between the employees. Rather than training environmental professionals in all of its industrial processes, the company
has chosen, within the Renault Group, to integrate the environment in all of its functions.” (www.renault.com).

Renault recycling strategy is supported by this cross-functional organization. A Recycling Service is placed at Materials Engineering Direction at Technocentre and participates at all projects development simultaneously by means of special members (as many as the different phases of a project) of the teamwork that are supposed to act as a correspondent, linking the two groups in permanence. Doing so they can get a multiplier effect on the 12 people that are located at the Recycling Service.

Another means to enforce recycling strategy, and eco-design practices at Renault, is the development of eco-tools, which translate the Directive recommendations on car project language, promoting a more eco-efficient and cost effective materials choice, and facilitating the EVL disassembly for recycling as well.

Concerning recycling car eco-design has to do with the very first recycling phases of end of life vehicle: preconditioning and dismantling. Preparing dismantling the first step is draining all fluids and removing any component containing hazardous substances and listed in appendix 1 of 2000/53 Directive: such as batteries and air bags, and catalytic converters and other elements containing mercury, copper or aluminum that could not be separated out in the shredder. Next step the reusable parts and those made of recyclable materials are removed including tyres, glass, bumpers, dashboard and fluid containers. These two steps are crucial to optimize car recycling technically and economically as well.

Although the European Directive is very detailed concerning automotive materials and recycling recommendations it has no detailed instructions about how to do it at designing and production level. So it is up to carmakers to figure out how to match technical and environmental requirements to cope with safety, performance and many other client demands as well. In short, cars are produced to be a means of transportation, to provide people a better way of life, a place to live in, to work in, or even to be used for leisure. Made of about twenty thousand parts, and these parts are not only articulated but also integrated in a synergic way so every little detail affects the final result. So eco-design requires specific tools to assure car global sustainability. So each car manufacturer has to develop its own tools to integrate environmental concerns into project activities in order to guide an environmental friendly materials choice without jeopardizing the main functions of the vehicle.

4.1 Renault’s Eco-Design Tools

At the end of the 1990, Renault had created the Cap Eco game to improve environmental practices inside the Company. Training by means of eco-games Renault aimed to help the employees make progress on environmental issues and get special skills concerning environmental audits, recycling and materials choice. It was also supposed to help people to integrate environmental concerns into theirs day-to-day tasks.

Cap Eco first version was conceived in 1998 and was devoted to operators, technicians, engineers and managers at industrial plants. The second version Eco-Cap 2, initiated in 2001, was specifically devoted to project engineers to help them to incorporate ecological criteria in vehicle design by showing them the potential impact of their decisions on the complete life cycle of the car. Over 42 thousand Renault employees have been trained by Cap-Eco system. [9]. Nowadays Renault design and development teams make large use of eco-design tools and databases to define the best choice of vehicle features: comfort, performance, driving pleasure, life on board, safety, environmental friendliness etc.

One of the most used eco design tools at Renault is a data sheet to guide from the very earliest stage of the project the materials selection identifying the substances contained in materials employed for each vehicle function and to determine whether they pose a threat to the environment. If so, alternative solutions are examined.[9]

According to Renault [9] this data sheet has been used since 1999 with 13 suppliers, preparing the eco-declaration documentation, and by the end of 2004 all suppliers, around 500 people, from 190 companies, were involved. After this stage the data sheets from suppliers are integrated to eco-design activities at Technocentre Renault by means of a software called OPERA -Overseas Program for economic recycling analyses.-

In this sense we asked to Robert Lassartesses¹ how Renault recycling strategy is integrated with eco-design practices. And he answered that it was by means of OPERA—a powerful eco-tool- with which Renault integrates more and more recycled materials on new models. And it guides materials choice in terms of technical recyclability as well as in terms of economic feasibility. In his own words: “La stratégie recyclage Renault est d‘augmenter la rentabilité du recyclage. C’est donc d‘incorporer de plus en plus de matières qui peuvent être effectivement recyclées. L’OPERA est un outil d‘aide aux choix des matériaux dans ce sens là” En fait l’OPERA aide à concentrer le démontage par exemple dans ce qui n’est pas cher à démonter. Il a été utilisé par exemple dans le projet du MODUS pour assurer les 95% de recyclabilité et mieux guider le choix entre les pièces plastiques celles qui fallait garder comme démontables, ex : bouclier, passage de roues, grille avant etc… ou celles que ne le fallait pas tel que les tapis de revêtement intérieur, ou ceux du coffret.” … “En plus à l’extérieur de l’entreprise il y a les partenariats avec les fournisseurs, plasturgiste, sidérurgistes, Associations etc.…”

Actually OPERA is a means of integrating different materials selection criteria to car design, including materials recyclability, plastic compatibility, alternatives on jonings and other manufacture processes that can impact car disassembling and recycling phase, etc. This software also takes into consideration external information on recycling such as technological and industrial capabilities to assure recycling cost effectiveness and also the existence of a market for recycled materials.

Moreover knowing that selecting materials for recycling does not assure the global car environmental friendliness, Renault has a Car LCA team, working in parallel with project teams, gathering and analysing the new models in terms of environmental performance. Lassartesses talking about the role of LCA as an eco-design tool stated: “L’AVC n’est pas au service recyclage DIMAT. Il y a un groupe qui s’en charge en permanence et en parallèle aux projets.” In his opinion the OPERA is that indicated the best materials selection concerning disassembly facilities level to a more

¹ Entretien réalisé par l’auteur avec Robert Lassartesses, responsable du Service Recyclage à la DIMAT Direction de l’Ingénierie des Matériaux, au Technocentre, le 22 février 2005
cost effective recycling. It was this software that assured the 95% of recyclability rate at Modus by means of guiding its plastic materials choice.

So assisted by OPERA the recycled polypropylene evolution in Renault vehicles is expected to be speeded and to reach 50 Kg per vehicle in 2016, as showed at figure 1.

4.2 Materials Selection

Materials selection is crucial to Renault recycling strategy and is a core activity for its purposes on eco-design practices. As we have mentioned before, at Renault the project team organisation supports eco-design practices facilitating a balanced materials choice between technical criteria and the main constraints that one has to face in a car project. The figure 2 shows schematically this balance guided by internal norms and recommendations concerning materials choice for eco-design Norme Renault Conception en Vue du Recyclage 00-10-060/2002) [7]

Concerning plastics materials Renault strategy is to put polypropylene first, since it is already the most used on new cars since the 1990 and its recyclability is largely more cost effective than any other automotive plastic. Besides recycled PP has proved to be as good as the primary one in appearance as well as in mechanical resistance. So the PP recycling process evolution made possible to a few representative parts to came out in open, such as internal panels and drawers, and to some specific semi-structural ones to respond to high impact resistance usages such as rear skirt panel, under engine skid plate, front end trim etc.

4.3 The Case of MODUS

The monospace MODUS Renault was picked for this case study based on both secondary and primary information. Our secondary sources were the available information on the specialized revues and the primary information was provided by technical visits to Valladolid Renault Plant, which is exclusively responsible for Modus production, and to the Direction of Materials Engineering (DIMAT) laboratories at Technocentre Renault. Complementarily, an interview was also carried out by Cantero and Medina [3] with Robert Lassartesses, who is in charge of Renault recycling service of DIMAT. The primary and the secondary information were analysed and confronted with our conceptual framework.
Renault Modus inaugurated a new segment. It is the segment of the compact mono-space. According to its concepteurs it offers all the modularity of an MPV in a compact package and was the first Renault model conceived by means of eco-design most advanced tools. It reached 95% of recyclability thanks to materials carefully selected guided by OPERA software.

The dashboard of Modus, for instance, has around 50% of recycled polypropylene corresponding to almost 5 kg, the green area at the figure 3 above. Nevertheless it was able to join the five starts EURO NCAP club the most restrict European regulations concerning car security.

Figure 3: Modus Dashboard recycled materials parts represented in green by a digital image. [5]

Modus was designed to maximize comfort and convenience, associated at recyclability criteria. Its interior has numerous storage compartments – in the dashboard, the front floor and doors, among which we can find the environmental thought of eco-designed parts as the front drawer showed at the figure 4. The front drawer, located under the front seats, is made of recycled polypropylene (PP) can be taken apart in few seconds and all its elements can be easily dismantled, facilitating recycling processes later on. Moreover during its lifetime it can be easily cleaned since the carpet lining has no clue to avoid extra contamination on recycling.

Figure 4: MODUS front drawer located under the front seats made of 100% recycled PP [6]

 Actually Renault eco-design practices are resulting in what Ernser, Oberender and Birkhofer have called a win-town situation. "Improving product for the ease of disassembly also often leads to an ease of assembly. Every saved disassembly process, eg. Implies a saved assembly process in turn. In some cases also leads to a product, which is easier to clean and maintain."[1] One can says that Renault seeks to take technical and economic advantages from environmental improvements.

In our case study we have seen some examples of this strategy and its results at the Modus assembly line in Valladolid Body Assembly Plant in Spain, when we visited the Renault Plant [see more details in 3]. For Modus production this Plant was renewed to incorporate technological upgrades developed for the different stages of production: stamping, chassis-welding, bodywork, painting, final assembly, highly automated. The site renewed its 14001 certification in 2002. Environmental performance is assured by an evaluating and monitoring system that detects and corrects automatically any malfunction at the plant based on parameters concerning: water consumption, (recovery of process water and recycling of chemical baths) water borne effluents treatment, greenhouse gas emissions, (fuel-oil was replaced by natural gas and there is a system for energy recovery and for recycling of solvents), organic compounds emissions from painting (paint application processes were improved) and waste treatment and minimisation (separation and identification minimization of volumes of dangerous waste).

Being produced at a such a high level plant Modus got the EuroCarBody Award of 2004 at Frankfurt, in Germany. At this international award four criteria were adressés : the painted assembled body and its customer benefits; body design (crash performance, acoustics, impact resistance, etc) innovations ; methods and processes involved in the design and manufacture process.[ p. 9 R&D January 2005]

Besides Modus incorporated a number of parts made of renewable materials as well. The figure 5 shows in blue these parts, mainly made of rubber and of natural fibers as tyres, boot carpet, roof stiffener, and leather seats cover (option), and in green the recycled materials components such as: dashboard, engine sky plate, choc absorbers, radiator tank deflector, front and deflectors, battery cover, canister cover, rear suspension, spear wheel under tray ...

Figure 5: Renewable -in blue- and Recycled Material -in green- incorporated to MODUS [5]

5. Final Remarks

In the car industry environmental legislation are fostering eco-design practices strongly based on materials selection. Our case study, conducted at Technocentre Renault, verified that the eco-design tools – the OPERA and the Norme Eco-conception 00-10-060/2002- are integrating environmental criteria on vehicle development cycle and altering the profile and boundaries of materials choice. Modus project, for instance, enforced economic viability of recycling incorporating a number of recycled plastics
materials. It was also observed that Recycling Service DIMAT team has participated at all project phases, concerning materials selection and car recyclability, by means of the correspondents specially designated to.

At Renault this strategy has multiplied the efforts and accelerated the contributions shortening the project lead-time to arrive at results which are both environmental innovative and economically feasible. The eco-design practices utilized at Modus project confirms the main hypothesis of my post doctorate project on Eco-design and materials recycling which can be summed up as follow:

- Eco-design methods automobile industry is improving car environmental friendliness;
- Creating and developing eco-tools car designers are enabling the integration of environmental criteria in car projects from the materials selection to end of life vehicles recycling, and;
- Simplifying assembly for make easier and faster disassembling steps for recycling they are getting economic and technical advantages as well.

6. Summary
This paper states first, that eco-design is crucial to an environmental friendly materials selection in automobile project. And, secondly, that the most current environmental criteria used for eco-design proposes is recyclability. In this sense it shows how the European Legislation on end of life vehicles is compelling carmakers to eco-design practices and how they are reorganizing car project team and developing eco-design tools to cope with environmental regulations as well as to assure the best choice in terms of technical feasibility and economic competitiveness. The example of a study case conducted at Renault on the Modus is presented to confirm our statements.

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Key note :
1 This case study was developed as part of a one-year post doctorate project (2004/2005) on Ecodesign and Materials Recycling conducted by the author at Centre d’Etudes Interdisciplinaires sur le Developpement Durable –CREIDD- of Université de Technologie de Troyes –UTT-, supported by CAPES Brazilian Scholarship Agency.

References

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Figure 6: Categories of Plastics Chemical Compatibility
Légende: 1: Bonne compatibilité
2: Compatibles sous certaines conditions
3: Incompatibles
Source : Norme Renault [7]
Rio de Janeiro, 11 de agosto de 2006.

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