ECODESIGN APPLIED ON NEW PRODUCT DEVELOPMENT IN AUTOMOTIVE DESIGN

Guido Muzio Candido, e-mail: guido.candido@usp.br
Paulo Carlos Kaminski, e-mail: pckamins@usp.br
Mechanical Department – Escola Politécnica da Universidade de São Paulo, São Paulo, Brazil

Abstract. *The aim of the study is to identify and apply ecodesign, or environment projects, on new products in the automotive industry in terms of technical and economical competences showed on product life cycle and how to contribute to sustainable development. Regarding to technical dimensional it is analyzed the automotive component designs referred to feasibility, remanufacturing and product life cycle issues. Related to economical context it is observed the questions about product costs, economical life and components life cycle. Based on current literature it is verified the evolution and importance of ecodesign on international and Brazilian automotive industries and how set new product development considering sustainable aspects. Real cases are presented of the automotive products developed in Brazil which environmental solutions were applied. The article ends with conclusions and directions for continued research.*

Keywords*: ecodesign, automotive product, cost reduction, product life cycle issues.*

1. INTRODUCTION

The automotive sector is going through a worldwide re-structuring process by emergence of the environmental paradigm since the 70´s due to oil shocks, following by the 90´s related to social and ecological concerns. This paradigm represents a technical, economical and social change that settled the basis for a sustainable development commitment among the auto-industry stakeholders'. Sustainable Development is a new option for development that outlines the eco-development on the social and economic growth models, incorporating environmental suitable strategies for fostering more equitable socioeconomic development.

For auto-industry, for instance, this commitment concerns not only car designers, car manufacturers and theirs suppliers, for technical and industrial aspects, but also governmental agencies and non-governmental organizations, for the political and legal aspects involved. It involves the redesign of the actors' network settled on new compromises driven towards an environmentally production and consumption systems. In this sense the strategies adopted by North American and European companies, for keeping and sustaining their share of the market, were focused on technical and organizational innovations, especially concerning the reduction of the time lag between conception and commercialization of new models as well as the adoption of environmental driven concept cars solutions. A wider range of options among standard cars and a great effort on improving the quality and reducing environmental impacts were the main goals. To produce vehicles which respect both people and the planet has been a constantly growing commitment (Medina, H. V. and Naveiro, R.M, 2003).

As environmental and health concerns continue to grow in society, governmental push on manufacturing companies to adopt "ecodesign" practice is expected to increase. Ecodesign is about integrating environmental considerations into product development, maintenance and disposal. This is especially true for automotive companies who must meet the ELV (End-of-Life Vehicle) environmental mandates in Europe, as well as similar initiatives in Asia and North America. On the other hand in South America, the ecodesign practices have been started in multinational assembler subsidiaries as a company strategy face to lack of governmental environmental initiatives or requirements. Nowadays in Brazil, for instance, there are an advanced environmental and emissions legislation, but they are so far away to be followed. Brazil is the only country which added the environmental governmental rules on its Constitution in 1988 but after more than 22 years, it only applies on CO2 emissions and battery and tires recycled related to all on automotive industry (Medina, 2003).

Any company who wants to operate globally must consider regulatory compliance as a matter of utmost importance. A failure to comply with the requirements can result in launch delays, recalls, fines, poor customer satisfaction, and damaged public image. Thus far, many companies have been reactive to environmental regulations where compliance reporting and analysis is done late in the product development cycle. This approach causes late-stage design changes to occur as compliance requirements are not readily accessible at every phase of the product lifecycle.

The paper begins with an introductory section that seeks to show how important the Brazilian automotive industry is important on the global scenario and presented the ecodesign considerations, showing technical and economical assessments. This is followed by two case studies on Brazilian automotives companies. The article ends with conclusions and directions for continued research.

2. BRAZILIAN AUTOMOTIVE INDUSTRY

Nowadays, the Brazilian automotive industry has achieved international cost and quality level. Some Brazilian units have become so competitive that workers in the original country of the company have made protests and strikes against Brazilian exportations of cars and trucks. Another international point which influences Brazilian automotive and auto parts industry is the relationship with Mercosul partners, mostly with Argentina. The other partners, Uruguay and Paraguay, have a secondary role due to the small size of their economy. With an industrialization process similar to the Brazilian one, Argentina automotive and auto parts industries faced a big crisis in the 1980s (worse than the Brazilian crisis). This crisis resulted in a technological stalemate. Besides, the Argentinean population is smaller than the Brazilian one and, therefore, the market is smaller, too. The last, but not the least point, is the exchange rate. The Argentinean government maintained the parity between the Peso and the Dollar. Most of the automotive companies established their headquarters and main factories in Brazil. Some automotive companies defined that Brazilian factories produce small cars (low price, high volume) and Argentinean factories are in charge of medium- sized cars (Amato, 2008).

Currently, the auto industry in Brazil offers the best economic performance throughout its history. Altogether, the 16 car manufacturers produce over 3,600 thousand vehicles, export about 12 thousand units, with over 110 thousand employees (ANFAVEA, 2010).

As environmental and health concerns continue to grow in society, governmental push on manufacturing companies to adopt “Ecodesign” practice is expected to increase. Eco-Design is about integrating environmental considerations into product development, maintenance and disposal. This is especially true for automotive companies who must meet the ELV (End-of-Life Vehicle) environmental mandates in Europe, as well as similar initiatives in Asia and North America.

3. ECODESIGN

Karlsson and Luttopp (2006) defined ecodesign as a method of product development that aims to reduce the environmental impact and that uses creativity to create more efficient products and developmental processes, from the point of view of sustainability. Johansson (2006) proposed the integration of environmental requirements into the process of the design, in which the technical and economical aspects usually prevail.

The ecodesign idea emerged in the 1990s, when the U.S, electronics industry was trying to minimize their negative impact on the environment. The American Electronics Association then formed a task force to develop projects with environmental concerns and to provide a conceptual base that would primarily benefit the members of the association. Since then, there has been an increasing interest in the subject, and terms as “ecodesign” and “design for environment” have become common in environmental management programs (Borchardt et al., 2007). In ecodesign, the designer selects and combines design solutions according to their impact on the different phases of product life cycle: manufacturing, packaging, use, exchange of parts and end of life. Tingström and Karlsson (2006) highlighted the multidisciplinary nature of ecodesign, since the development of a new product is not a linear and repetitive process, but instead a complex one, since unexpected interactions between the product and the environment may arise, requiring the use of nonlinear models. As factors that influence the implementation of ecodesign, Boks (2006) cited: i) external pressure of legal requirements, ii) domestic economic influences, iii) perception and customer value and iv) availability of new technologies. The adoption of ecodesign practices may help manufacturing strategy, by incorporating environmental control issues to the management process (Borchard et al., 2007).

As environmental and health concerns continue to grow in society, governmental push on manufacturing companies to adopt ecodesign practice is expected to increase. Ecodesign is about integrating environmental considerations into product development, maintenance and disposal. This is especially true for automotive companies who must meet the ELV (End-of-Life Vehicle) environmental mandates in Europe, as well as similar initiatives in Asia and North America.

As much as in other business areas, an important change brought about by the internationalization of the automotive industry has been the global organization and integration of Research and Development, R&D. This process has already gone beyond the economic frontier of Triad countries (US, Europe and Japan) and reached emerging economies. An evidence of it is the fact that Brazilian subsidiaries of multinational assemblers and suppliers have been enlarging R&D mandates in Brazil and stepping-up their product-related technological activities. Following these tendencies, it is reasonable to believe that in Brazilian automakers the ecodesign, for instance, can be applied on new automotive product development, joining technology knowledge with local natural renewable resources, such as natural fibers, recycled materials and combustibles. Topics that must be included in the development of a new automotive design are discussed below.

3.1. Environmental responsibility: from the conception to the end of life of a vehicle

The conception of a vehicle depends on the identification of a specific market demand. However, it is not enough just to develop a car economical, comfortable and with a futuristic design; it is also important to establish the environmental aspect as an essential criterion in designing a car. Then it comes a new set of forms, methods and tools for project development, known as ecodesign or Design for Environment (DFE). The Eco-Design consists on an approach that includes the environmental component in the design of new products and integrates approach tools, such as Design for Assembly and Disassembly (DFA /DFD) and Design for Recycling (DFR). The Table 1 shows these toolings and their practices (Salla and Cadioli, 2008).

Table 1. Ecodesign toolings (Salla and Cadioli, 2008).

Activity	Practice	Main Actions
DFA/DFD Design for assembly and disassembly	Make easier the identification of components Design for replacement Design for reuse	Reduce the number of parts for easy handling Avoid unnecessary glues, adhesives and welds Facilitate the cleaning of the components Facilitate the testing of the components
DFR Design for recycling	Design for separating materials for recycling Reduce the number of parts Avoid composite materials	Use compatible materials Identification of the material composition of polymeric parts Reduction of the variety of materials Use recycled materials Avoid pieces of metal inserted in plastic parts

3.2. The automotive product life cycle

It is a responsibility of the automotive industry to define technical and economical solutions for end-of life vehicles. There must be a disassembly line that allows the components of a vehicle to return to their suppliers. It implies that, in the life cycle of an automotive product, all the factors must be considered, from the appropriate selection of raw materials to the techniques of assembly and disassembly in the production line.

In general, the life cycle of a product involves five stages, as shown below (Graedel, 1998):

- Stage 1: production of materials and components;
- Stage 2: manufacturing operations;
- Stage 3: shipping and delivery of the product;
- Stage 4: purchase and costumers' use;
- Stage 5: end of life of the product, recycling of final disposal.

The analysis of the life cycle of a product is a tool to evaluate all the environmental impacts caused by the supply chain of the product. It should also include the product planning, extraction of raw materials, energy expenses, industrial processing, assembly and product manufacturing, use and disposal of the product. Generally speaking, the analysis of the product life cycle is developed in three major steps (Salla and Cadioli, 2008):

- Identification and measurement of the energy and raw materials applied on product creation, as well as the pollutants emission into the environment, during the production and use of the product;
- Evaluation of the environmental damages caused by the use of the energy and raw materials involved;
- Identification of possible improvements on the production systems and on the recycling or final disposal, leading to an optimization of the environmental product performance.

In the automotive industry, design and production phases are well-defined. The standardization of the main product, the automobile, is essential to determine the manufacturing process, as well as the materials and methods to be used. For an automotive product, the life cycle can be adapted according to the following steps:

- Extraction of raw material (concentration, separation, refinement);
- Chemical and metallurgical materials processing (metals, plastics, composites, glasses);
- Manufacturing of auto parts (mechanical, electrical, electronics);
- Vehicles manufacturing (final assembly line);
- Sales and maintenance:
- End of life of vehicles and auto parts – recycling;
- Recycling and reuse of materials;
- Non-recyclable materials to final disposal destination.

The analysis of the life cycle of the product in automotive industry has the objective to contribute and determine the key points to the conception of a so called greener car (or environmentally friendly car). It provides transparent decision-making support for identifying which technological alternatives present an improvement - in a technical, economic or ecological sense - compared to existing technologies, materials or processes:

- Comparison of technologies;
- Identification of the most favorable material, economically and ecologically, that still holds the required technical specifications;
- Evaluation and selection of the most efficient manufacturing processes, considering both economic and ecological aspects;
- Detailed analysis of parameter dependent manufacturing processes;
- Development of strategic benchmarks for production procedures and system alternatives;
- Efficient ecological optimization with lowest possible costs.

3.3. New material development

According to Clark and Fujimoto (1991), in terms of technological innovation, the search for new materials (including environmentally viable ones) has been considered an invisible innovation, since the costumer does not appreciate or realize its importance. Nevertheless, these innovations are extremely important, since they are part of a strategic project, capable of meeting performance, costs and deadlines objectives for the automotive industry.

Although the customers´ and the manufacturers´ view may differ sometimes, as seen before, the development of new materials has improved the performance on automobile industry. Another notorious and remarkable factor in the automobile industry is the cars´ weight variation among different periods, and to make it possible it is necessary to replace materials, adjusting their physical characteristics to the current needs. Table 2 indicates the weight of cars, according to the use of each specific material, in different periods. It is clear that, in some cases, there is a decrease of a given material and an increase of another, as a result of the search for the ideal combination of materials for an environmentally friendly and efficient vehicle.

Table 2: Weight of the vehicles (Salla and Cadioli, 2008).

	50´s kg	90´s Kg	00´s kg
Steel	1373	831	510
Zinc	25	10	15
Rubber	85	61	64
Glass	54	38	31
Lead	23	15	11
Copper	25	22	12
Fluids	96	81	48
Iron	220	207	150
Aluminum	0	68	77
Plastic	0	101	150
Total	1901	1434	1070

3.4. Recycling

Recycling process is the final step in the vehicle life cycle. The car is depolluted, dismantled and shredded. It is then separated into usable components, recyclable materials and waste that are incinerated to produce energy. When a car reaches the end of its useful life, and will no longer perform its function, the next step is recycling. The average useful life of a car varies greatly, and may be around 10, 15 or 20 years, depending on legislation and economy of the country and also on the conservation state of the vehicle. There are many parts and materials that can be recycled, and nowadays approximately 75% of the weight of the car is recyclable. The recycling process should be performed by a specific infrastructure that guarantees the adequate efficiency of the process, without compromising the environment. The recycle of a given material is the result of many factors, as:

- A new technological and competitive standard that include environmental innovations;
- A strong material development with less environmental impacts;
- New methods of product development, such as: ecodesign, DFR (Design for Recycling), DFE (Design for Environment);
- Clean technologies designed for production, processing and recycling of materials.

The industrial part reusing ends the economical cycle, and it happens when the secondary raw material, obtained from recycling, returns to be used in car production, or is used in production of other products within or outside the automotive industry. As an example of this process, Table 3 indicates technologies and materials developed by Toyota Motors Company from recycled material.

Table 3: Technology for materials recycling developed by Toyota (Salla and Cadioli, 2008).

Type	Original article	Recycled part
Thermoplastic resin	Bumpers fascias of TSOP (Toyota Super Olefin Polymer)	Bumpers fascias Luggage moldings Backseats supports Front and rear lens cover Engine lower cover Bumpers fascias support Fuel tank protector Fuel pump protector Seats lower covers Rear door trim coverage
	Interior trims, finish parts	Distribution belt coverage Fan deflector
Thermosetting resin	FRP parts (Fiber Reinforced Plastic)	Sun roof covers Valves covers
Composite resin material	Carpet	Carpet raw materials Carpet reinforcement pieces
	Car seats fabric	Exhaust pipe silencer
	Headliner coating	Luggage moldings
Rubber	Sealers	Sealers tubes protectors
ASR (Automobile Shredder Residue)	Urethane foam fibers	RSPP (Recycled Sound Proofing Products)
	Copper wire	Reinforcing materials for aluminum molding
	Glasses	Materials for reinforcement of bricks
Others	PET bottles	Sound absorbers materials

Automobiles are the most-recycled consumer product. The American auto industry works together through the United States Council for Automotive Research to optimize vehicle recycling, continually searching for solutions to reduce waste. Figure 1 show the main components of the vehicle which recycled materials can be applied on new automotive products.

Figure 1: Sustainable materials strategy from American automaker (adapted from Ford, 2011).

3.5. Energy considerations and Consumption Production Cycle in automotive projects

One of the major issues related to sustainability and the environment in an automotive design is the energy issue. In fact, the energy consumption of a vehicle and consequent pollutant emissions occur during the period of use by the customer. According to the type of engine of the vehicle (ethanol, gasoline, diesel, natural gas, electricity, hydrogen, among others), the consumption of fuel per kilometer driven is calculated. Moreover, considering the useful life of the vehicle plus the wear and tear, it is possible to determine the degree of pollutant emissions during this period. As illustrated in Figure 2, in the Production and Consumption Cycle, most of the energy consumption and emissions of pollutants of a vehicle occurs during the period of customer use. A remarkable jump in energy issues would be to assess and monitor energy consumption at this stage, which can provide substantial reduction of emission of toxic gases and reduce energy costs. Optimizing the project design and engine design and implementing renewable fuels in the automotive industry, as well as targeting the zero emission technology could be viable solutions for this major problem.

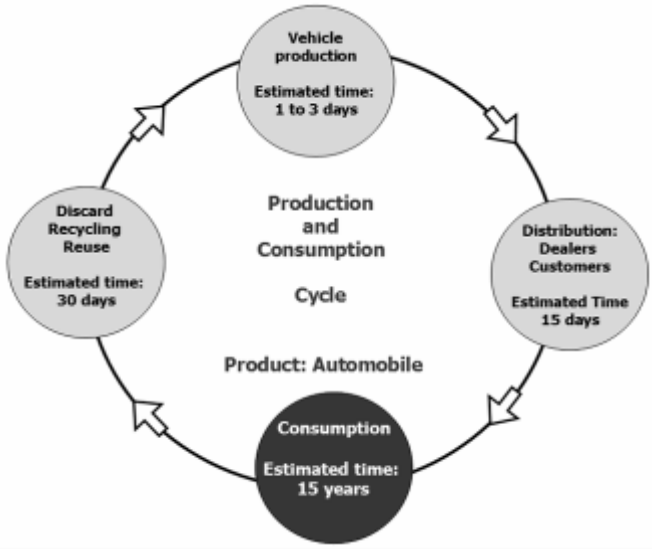

Figure 2: Representation of a production and consumption cycle of an automobile (Candido and Kaminski, 2009).

3.6. Economic considerations of ecodesign in automotive development

Given the complexity of cars, designers need to strike the right balance between the different demands of customers: safety, comfort, running costs, environmental protection, and so on. One of the major issues related to sustainability and environment in an automotive design is the question of production costs and lifetime of components.

During the development of new product with focus on ecodesign the main economical advantages observed in automotive industry are shown:

- Usually recyclable raw materials are cheaper than conventional;
- Using recycle materials extend its useful life;
- Reduce car weights by the application of natural fibers instead of synthetic fibers;
- The usage of biomaterials or bioplastics is made by natural renewable resources.

4. CASE STUDIES

This section provides two brief case studies of ecodesign applications from European and American automotive industries established in Brazil. The cases are neither exhaustive nor particularly detailed, but are intended to demonstrate feasibility solutions in terms of ecological automotive components production resulting in cost reduction too. In part, the point is to illustrate that there is not one definitive alternative available and that the degree of deviation from the existing ecodesign options may be more or less marked.

4.1. Case study #1. Implementing local alternative materials

Objectives: reducing product costs with alternative materials and maintaining product quality, in the passenger vehicle from North America automaker by applying a thermo-acoustic insulator of the engine compartment inner panel (Figure 3).

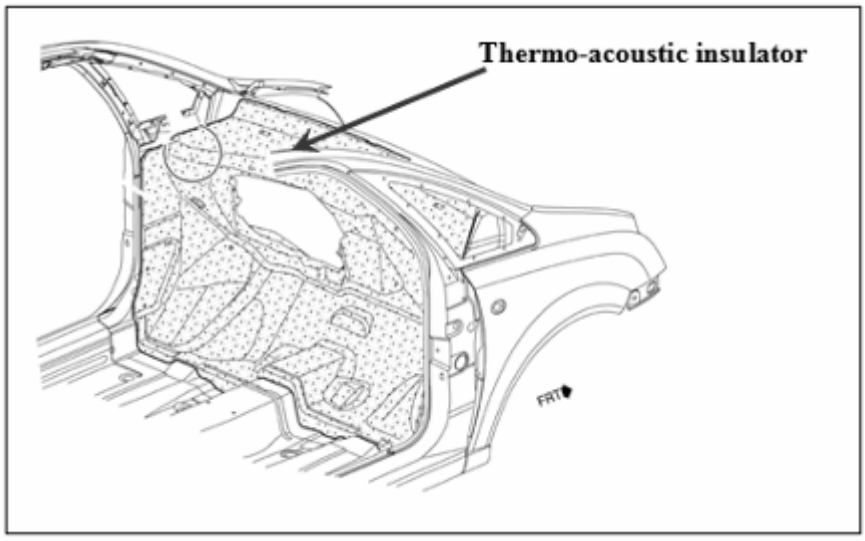

Figure 3: Vehicle insulator illustration (Candido, 2005).

Parts or systems description: the thermo-acoustic insulator is composed of an asphalt blanket coated with a layer of phenolic felt. It is assembled inside the front panel, between the dash panel and the inside panel of the engine compartment. The blanket allows greater rigidity of the product and greater insulation of heat from the engine. The felt has the function of acoustic coating, minimizing engine noise inside the cabin, according to the quality standards required for the assembly, and so providing greater comfort for occupants.

Savings achieved by the automaker: replacement of the phenolic felt insulator material fot thermo-plastic recyclable felt, with 20% reduction in the cost of the part, which represented a 0,05% reduction in the total cost of the vehicle

Benefits: use of local material of lower cost, lower weight and recyclable. The field performance has not been changed after this deployment.

4.2. Case study #2. Recyclable materials application

Objectives: reducing products costs with recycled materials and ensuring the same quality of the original components, through the use of recyclable material in the composition of passenger vehicles parts by an European automaker established in Brazil since 2000, as shown on Figure 4.

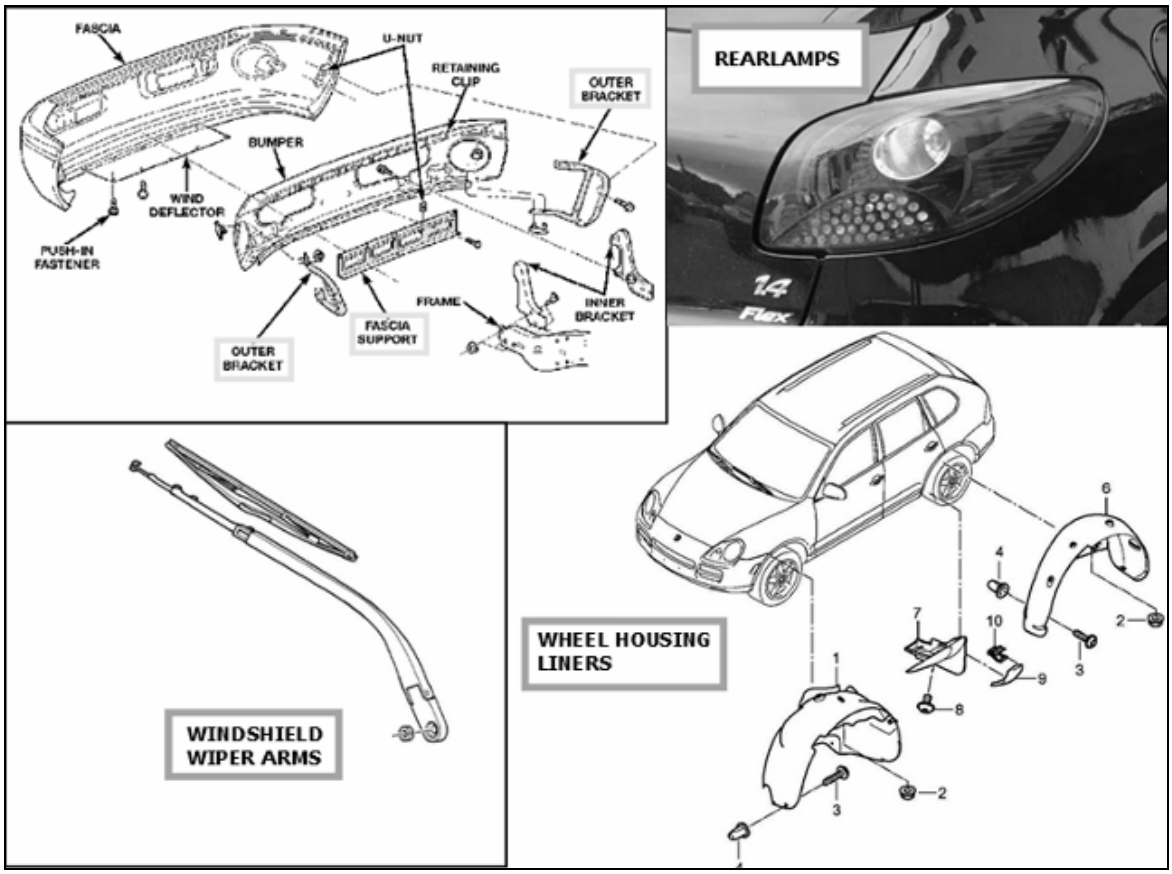

Figure 4: Recyclable materials applied on passenger vehicle components.

Parts or systems description: the tail lights lens or simply rearlamps, bumpers fascias supports, wheel housing liners and air deflectors are plastic injected parts, in which up to 5% of recyclable material can be applied in its composition. The windshield wipers arms and engine protectors are usually made of metallic materials from other processes, with the same material and performance specifications.

Savings achieved by the automaker: not disclosed.

Benefits: cost reduction of parts, increased materials useful life, reduced use of virgin materials, reduced pollution related to the production of virgin materials (petroleum refining, chemical industry, metallurgical industry).

5. CONCLUSIONS

The aim of this paper was to suggest that socio-economic and environmental concerns are taken into account in the development of new automotive products, so that the long-term sustainability of the automotive industry is feasible. As a result, the automakers and their production processes must be reviewed in terms of environmental quality. And this applies not only to the automakers, but to the entire supply chain as well. Thus, the suppliers´ adherence to the requirements of environmental quality standards is also an essential condition required for the certification of the automaker in the end of the supply chain. In this sense, the environmental certification through all the supply chain is a major aim for automakers these days.

As environmental and health concerns continue to grow in society, governmental push on manufacturing companies to adopt “Ecodesign” practice is expected to increase. Ecodesign is about integrating environmental considerations into product development, maintenance and disposal. This is especially true for automotive companies who must meet the ELV (End-of-Life Vehicle) environmental mandates in Europe, as well as similar initiatives in Asia and North America.

On the other hand in South America the ecodesign practice is just starts recently pushed mainly by their headquarter companies, with few governmental environmental initiatives or requirements.

It means that the theme is relatively new to most of the automotive sector companies operating in Brazil. When some social responsibility and environmental management practices are identified, these are restricted to some formal procedures (ISO 14.000 Environmental Management Standards; AS 8000 Social Assessment Norm; etc) and are imposed by the companies headquarters, in case the latter already counts on these practices in their countries of origin.

Any company who wants to operate globally must consider regulatory compliance as a matter of utmost importance. A failure to comply with the requirements can result in launch delays, recalls, fines, poor customer satisfaction, and damaged public image. Thus far, many companies have been reactive to environmental regulations where compliance reporting and analysis is done late in the product development cycle. This approach causes late-stage design changes to occur as compliance requirements are not readily accessible at every phase of the product lifecycle.

The case studies show that the automotive industry in Brazil is gradually implementing sustainable solutions in order to reach technical and economic feasibility by applying recycled materials or vegetable materials in place of mineral raw materials which also generates cost reductions with quality and functional assurance to the final customer. In Brazil there is a high potential for sustainable proposals to develop, validate and implement, supported by natural resources, establishment of centers of research and development and combined with new ideas for sustainable products came from the automakers, suppliers (tiers 1, 2 or even tier 3) and university researches.

Thereafter, the discussion is more closely aligned to the specifics constraints of the automotive industry, not least on the premise that the transition from generic understanding to specific solution requires embedded knowledge. Put simply, the solutions appropriate to the automotive industry may not necessarily be those appropriate to other aspects of sustainable production and consumption as recycling for instance. Note also that the approach adopted here is not determinist, in that new ways of making things (production technology) and new things themselves (product technology) are envisaged as enabling changes in, for example, the capital of organization or modes of consumption but not necessarily requiring them.

6. REFERENCES

AMATO NETO, J., 2008. Sustainability in the Brazilian automotive productive chain: a multiple case study. 16th. Groupe d'Etudes et de Recherches Permanent sur l'Industrie et les Salariés de l'Automobile (GERPISA) International Colloquium: The automobile industry and sustainable development: concepts and doctrines, public policies and company strategies.

ANFAVEA, 2010. Associação Nacional dos Fabricantes de Veículos Automotores, "Anuário Estatístico". Feb 13th , 2011. < http://www.anfavea.com.br/anuario>.

BOKS, C. 2006. The soft side of EcoDesign. Journal of Cleaner Production, v. 14, p. 1346-1356.

BORCHARDT, M. et al. 2007. Motivação para o emprego do ecodesign: um estudo de caso na indústria automotiva. In: International Workshop Advances in Cleaner Production, 1, São Paulo, SP. Anais… São Paulo: IWACP 2007. <http://www.advancesincleanerproduction.net/first/ptbr/Site/datahora2211.htm>.

CANDIDO, G. M. 2005. Product value optimization applied on current automotive component design. Master Thesis. Department of Mechanical Engineering, Polytechnic School. University of São Paulo, São Paulo.

CANDIDO, G. M.; KAMINSKI, P. C. 2009. Issues of sustainability applied in new projects in the automotive industry. SAE – Society of Automotive Engineering. Congress and Exhibition of Mobility Technology, São Paulo, Brazil. Paper SAE 2009-36-0158.

CLARK, K.B.; FUJIMOTO, 1991. T. Product development performance: strategy, organization and management in the world auto-industry. Boston: Harvard Business School.

FORD MOTORS COMPANY. 2011. Ford Focus Sustainable materials strategy. Feb 18th, 2011. < http://media.ford.com/article_display.cfm?article_id=32474 >.

GRAEDEL T. E., 1998. "Streamlined Life-Cycle Assessment", Prentice Hall, New Jersey, EUA cap.2, 306 pages.

KARLSSON, R.; LUTTROPP, C. 2006. Ecodesign: what´s happening? An overview of the subject area of Ecodesign and the papers in this special issue. Journal of Cleaner Production, v. 14, p. 1291-1298.

MEDINA, H. V. 2003. Eco-Design na Indústria Automobilística: O conceito de carro urbano. CETEM - Centro de Tecnologia Mineral - Ministério da Ciência e Tecnologia – Coordenação de Desenvolvimento Sustentável. CT2003-O59-00 – Comunicação técnica ao 2o Congresso Internacional em Pesquisa em Design, Rio de Janeiro, RJ, Brazil.

MEDINA, H. V. de; NAVEIRO, R. M. 2003. Design for Sustainability tomorrows'car encompassing environmental, 11th Groupe d'Etudes et de Recherches Permanent sur l'Industrie et les Salariés de l'Automobile (GERPISA) International Colloquium: The automobile industry and sustainable development: concepts and doctrines, public policies and company strategies. France.

PSA – Peugeot Citroën S.A. 2011. Les 10 Objectifs de Développement Durable. Feb 20th, 2011. < http://www.developpementdurable.psa.fr/strategie/engagements/actionsprioritaires.htm >.

SALLA, L. D., CADIOLI, L. P. 2008. Reciclagem de automóveis: um novo conceito na produtividade ambientalmente correta. Revista Ciência e Tecnologia, p. 77-86.

TINGSTRÖM, J.; KARLSSON, R. 2006. The relationship between environmental analyses and the dialogue process in product development. Journal of Cleaner Production, v. 14, p. 1409-1419.

TOYOTA, 2007. Toyota Motor Company, Sustainability Report 2007. Jan 18th, 2011 < http://www.toyota.com/ >.

5. AUTHORS INFORMATION

Guido Muzio Candido, Msc. is PhD student in Mechanical Engineering from the Polytechnic School of University of São Paulo, USP. Guido is graduated as Master in Automotive Engineering from the same university (2005), and graduated in Mechanical Engineering at Maua Engineering School (1998). He is product development coordinator at PSA PEUGEOT CITROEN in Brazil. He has published several articles in SAE Congress and in the International Journal of Automotive Technology Management. He works in product development in automotive industry since 1997.
E-mail: @ guido.candido usp.br

Paulo C. Kaminski PhD, is Professor in the Department of Mechanical Engineering of Polytechnic School of University of São Paulo, USP. Kaminski is graduated in Naval Engineering (1986) and Ph.D. in Mechanical Engineering (1992) from the same university. He is a researcher of the Brazilian Council for Scientific and Technological Development (CNPq), ambassador from Scientific Alexander von Humboldt Foundation (Germany) and visiting Scholar at Waseda University (Japan). He published several books and articles with 10 national and international awards.
E-mail: pckamins@usp.br.