Cleaner production and life cycle design of upholstered furniture

Áurea Rapôso*

Department of Chemical Engineering,
Postgraduate Program in Industrial Engineering,
Polytechnic College,
Federal University of Bahia,
Professor Aristides Novis Street, 2,
2nd Floor, Federação,
Salvador, 40210-630, Bahia/Brazil
E-mail: aurearaposo@ig.com.br
*Corresponding author

Sandro Fábio César

Department of Construction and Structures,
Laboratory of Wood/LABMAD,
Polytechnic College,
Federal University of Bahia,
Professor Aristides Novis Street, 2,
2nd Floor, Federação,
Salvador, 40210-630, Bahia/Brazil
E-mail: sfcesarpaz@uol.com.br

Asher Kiperstok

Department of Environmental Engineering,
Network of Clean Technologies/TECLIM,
Polytechnic College,
Federal University of Bahia,
Professor Aristides Novis Street, 2,
4th Floor, Federação,
Salvador, 40210-630, Bahia/Brazil
E-mail: asher@ufba.br

Abstract: This article presents some results of the environmental and organisational aspects that were obtained from a preliminary analysis of the process of manufacturing upholstered furniture at the furniture cluster in the State of Alagoas, Brazil. The method is based on the concepts of pollution prevention and cleaner production that are associated to the concept of product life cycle design. Data were collected through interviews with employees and from direct observation in the company selected for the study case. The results indicate the need for further studies to identify possible modifications in the product and/or in the processes of development of the upholstered furniture produced by the cluster.

The partial conclusions suggest the need for the future application of life cycle assessment in one of the upholstered pieces of furniture to broaden the scope of analysis and improve the efficiency of production through cleaner environmental practices. The original character of the study is associated with the dissemination and incentive of the application of life cycle assessment in micro and small businesses in the Furniture Cluster in the town of Arapiraca in the State of Alagoas, in the Northeast of Brazil.

Keywords: environmental management; cleaner production; life cycle design; LCD; upholstered furniture; small companies.

Reference to this paper should be made as follows: Rapôso, A., César, S.F. and Kiperstok, A. (2012) 'Cleaner production and life cycle design of upholstered furniture', *Int. J. Environment and Sustainable Development*, Vol. 11, No. 3, pp.217–237.

Biographical notes: Áurea Rapôso is Architect and Town Planner and received her Masters in Development and Environment at UFAL in 2002. She is a PhD student on the postgraduate programme of Industrial Engineering in UFBA, with emphasis in development of sustainable products and processes. She is Teacher of Basic, Technical and Technological Education from the Department of Infrastructure and Design of the Federal Institute of Alagoas. She is a Researcher at the Laboratory of Wood and of the Network of Clean Technologies (UFBA), also in the Design Group and Interdisciplinary Studies (CNPq-IFAL) and Collaborator Researcher in the Group of Design for Sustainability of the Industrial Design Division, at the National Institute of Technology.

Sandro Fábio César is Architect and Town Planner at UEL in 1986. He received his Masters in Architecture and Urbanism at USP in 1991 and PhD in Production Engineering at UFSC in 2002). He is an Associate Professor I from the Department of Construction and Structures of the Polytechnic College of the Federal University of Bahia. He is the Coordinator of the Laboratory of Wood (LABMAD-UFBA) and Lecturer on the Masters degree course in Urban and Environmental Engineering and Collaborator Professor in the Doctor Degree Course in Industrial Engineering at UFBA. He is the Researcher at the 'Research and Development' of the Company of Electric Power in the State of Bahia and of the National Agency of Electric Energy.

Asher Kiperstok is a Civil Engineer, Technician – Technological Institute of Israel in 1974. He received his Masters and PhD in Chemical Engineering – Environmental Technologies from MIST University of Manchester, UK in 1996. He is Associate Professor in the Department of Environmental Engineering at the Polytechnic College of the Federal University of Bahia (UFBA), Coordinator of the Network of Clean Technologies (TECLIM-UFBA) and Professor of the courses of the Master and Doctor degrees in Industrial Engineering at UFBA. He is a Researcher in the National Council of Scientific and Technological Development (CNPq). He is the author and coordinator of the books: *Innovation and Environment*, *Pollution Prevention* and *Silver House: Introducing Cleaner Production in Bahia*.

This paper is a revised and expanded version of a paper entitled 'Cleaner production and product life cycle design of the upholstered furniture in the State of Alagoas, Brazil' presented at the 3rd International Workshop Advances in Cleaner Production, São Paulo, Brazil, 18–20 May 2011.

1 Introduction

The furniture industry is one of the most traditional industries in the world and involves the production of durable goods. In general, the production process is structured in systems of semi industrial manufacturing. The manufacturing processes of this type of system present limits regarding efficiency and rational usage of materials. It also shows limitations in the reduction of losses that occur. It is an industry that requires a wider diffusion of knowledge and technological innovation, as well as rethinking of the process of development of the pieces of furniture and their design (Vezzoli, 2010; Ferreira et al., 2008; Manzini and Vezzoli, 2005).

As Ferreira et al. (2008) show the Industrial Revolution and the successive modifications in production processes, with mechanisation and automatisation, have greatly altered the traditional handmade process of furniture manufacturing. And standardisation and increases in scale. Furthermore furniture products have migrated to industrialisation or 'semi-industrialisation'. Some aspects of this evolution are linked to improvements in design over time, as well as access to new types of technologies and tools that have modernised and accelerated the productive process in the furniture industry.

In parallel, according to (Kazazian, 2003), and more recently, (Vezzoli, 2010; Manzini and Vezzoli, 2005; Kiperstok et al., 2002), the incorporation of environmental requisites in the process of industrial (or semi-industrial) production has followed the trajectory of the treatment of pollution (policies, programs and 'end-of-pipe' techniques) to neutralise the negative environmental effects generated by productive activities. Now with the use of clean technologies the attention to productive processes has moved to the pollution prevention. The current action stimulates the interference in the pollutant productive processes through the proposals of implementation of clean technologies directly in the source of waste generation.

This entire trajectory aims to stimulate the redesign of products in a near future, in order to achieve cleaner production (CP), which is based on actions for pollution prevention and, further, industrial ecology (IE) which is based on the efficient use of resources.

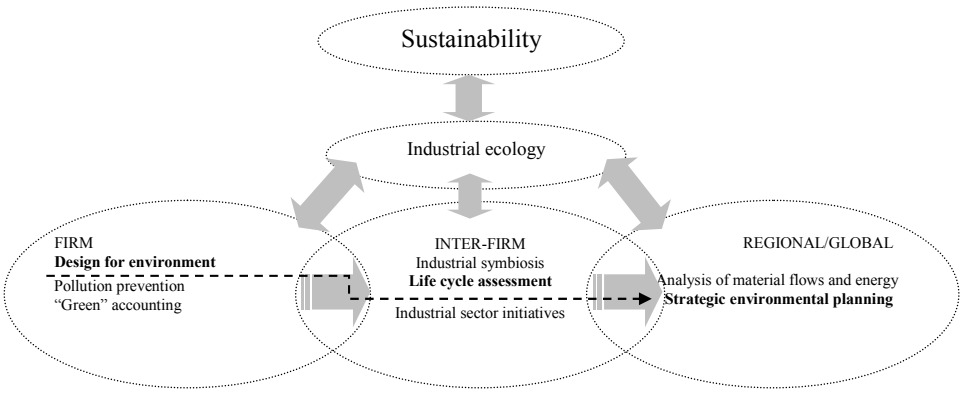
IE has been seen as a practical and systemic approach to sustainability and one of the ways that can provide concrete solutions in the medium and long term. According to Erkman (2001), IE explores the duality between positive and natural industrial system. The industrial system is regarded as some kind of industrial ecosystem, described as the specific distribution of material flows, energy and information. This implies that the entire industrial system relies on resources and services provided by natural systems, which cannot be separated.

For Chertow (2000) IE is defined as a systemic view of the industrial system which allows us to analyse it in an integrated manner with the subsystems that comprise it and the subsystems that surround them. It seeks to optimise the flow of materials from raw materials to processed materials, components, byproducts obsolete and/or discarded products.

IE suggests an interaction of industrial systems with the use of the biosphere and the application of design of ecosystems to guide the redesign of industrial systems. The idea is that a network of interactions between companies is established such that the loss of production may become a raw material for another. The interactions migrate beyond the industrial plant and intra-company boundary and reach the universe of relationships

between companies. All this is mediated by CP strategies. Industrial ecosystems apply CP to interactions among enterprises (in a specific region or industrial park) with the local and global ecosystems. The goal is to achieve better industrial performance associated to limitations of territory (Chertow, 2000; Lowe and Evans, 1995).

Figure 1 Application levels of IE



Source: Adapted from Chertow (2000)

IE operates at three levels: intra-company, inter-company and in the context regional-global as shown in Figure 1 (Chertow, 2000). Based on this figure, it can also be observed that the transition from an unsustainable situation to a sustainable one is a gradual evolutionary process and which is more likely to be introduced locally. First at the level of intra-company and after this, the situation migrates to other levels. If the company is situated in a context of micro and small businesses grouped in the cluster, this can be achieved.

Here we examine the possible contribution of a cluster as a cell to induce social, environmental, economic and organisational change to improve company performance at the levels:

a intra-company, through the design for environment + life cycle assessment (LCA)

b inter-company, through industrial symbiosis + LCA; and thus, gradually at the level of local-regional-global, through environmental strategic planning (see dashed arrow in Figure 1).

However, for this to happen, it is essential to have a cooperative and strategic consistent vision among enterprises to efficient management and collective production within the cluster. In summary, the improvement opportunities are situated in the dialogue between CP, IE and design tools, among them, life cycle design (LCD or Ecodesign and DfE).

Pigosso et al. (2010) point out that Ecodesign (European terminology) or Design for the Environment (US terminology) seeks to improve the environmental performance of product, whose development process is aligned to the concepts of sustainable development and life cycle. However, for the authors, this can be seen as a strategic design activity established to create and develop sustainable solutions. It can also be seen as a management approach that proactively addresses the development of products to

reduce environmental impact throughout its life cycle, without compromising other criteria such as performance, functionality, aesthetics, quality and cost.

This article aims to presents some results obtained with the preliminary analysis of the process of manufacturing of upholstered sofas at the furniture cluster in the State of Alagoas (Brazil), through the concepts of pollution prevention, CP and product LCD applied in the case study of a company in the cluster.

2 Method

The methodological procedures start with the review of the results that were obtained in exploratory research using a qualitative approach (Miguel, 2010). This was carried out in a study case of an upholstered furniture company in the Local Productive Furniture Arrangement in the State of Alagoas, in the town of Arapiraca, in the Northeast of Brazil.

Although the furniture cluster has been recently created (2004), the manufacturing of furniture in this area of the state of Alagoas (Brazil) is one of the most traditional economic activities in the region. Its origin comes from the creation and commercialisation of popular pieces of furniture in the Furniture Fair held fifty years ago.

Local furniture manufacturing has followed a long trajectory from handmade production in small factories and family joineries until now, with studios and factories of furniture-making companies, making semi-handmade and/or semi-industrially produced furniture.

This furniture cluster comprises about sixty (60) micro or small businesses that act mainly in the sectors of wooden and upholstered furniture in Arapiraca. In the sector of upholstered furniture there are twelve (12) companies among which nine (09) are formal companies and three (03) are not. Although wooden furniture is the most significant furniture type in the cluster of the Agreste region of Alagoas (NE, Brazil), upholstered production uses more materials and intermediate products in the manufacture, such as certificated wood and/or the plywood sheets, foam and fabrics (natural and synthetic). These have to be included in the assessment of environmental impacts associated to production.

The company in this study was selected through non-probabilistic sampling, but intentionally to privilege the qualitative collection of information that would guarantee the significant consistency in the diagnostic analysis of this study. For the selection, data in the database of the Program of Local Productive Arrangements of the State of Alagoas [Programa de Arranjos Produtivos Locais do Estado de Alagoas (PAPL)] – 2010 was used. These data were provided by the Local Management of this furniture cluster. Some of the data also came from consultation with the Local Association of Furniture Manufacturers [Associação dos Moveleiros do Agreste do Estado de Alagoas (AMAGRE)], and these data were about the small associated formal companies.

On the one hand, examination of the institutional data signalled the existence of only one company in the category of small firms (EPP), linked to the two entities and that volunteered to participate in the study, as a case company. On the other hand, besides this company, it is must emphasise that there are eight other upholstery companies that participate in the furniture cluster and that are formalised and micro businesses. Through a technical visit to the company it was observed that it is well best equipped in the production process. It even serves as a local reference for other companies. The

investigative tendency is that these companies become new study cases for the internal validation of an analysis script and the broadening of the initial scope of this study. This paper is part of the set of activities in ongoing doctoral research in the field of Industrial Engineering, developed in the Post-Graduate Programme in Industrial Engineering (PEI) at the Polytechnic at the Federal University of Bahia (UFBA)[1].

Once the company was chosen, materials and inputs, phases of the process of manufacturing of sofas (manufacturing of a new product), losses and emissions were identified. Inputs, outputs and fluxes were mapped and synthesised in flowcharts, tables, and/or synoptic pictures that can be verified, in detail, in the studies of Rapôso et al. (2010a, 2010b).

The method that was applied in this mapping was the one of UNIDO-UNEP (Senai-RS, 2003), for the implementation of CP Programs, through the simplified model of a report from the Network of Clean Technologies in Bahia (TECLIM), Polytechnic at UFBA. This model is validated by the recommendations of a Manual entitled *'Implementation of the CP Program'* of the National Center of Clean Technologies [CNTL (Senai-RS, 2003)].

The company that was selected for the case study manufactures new upholstered furniture and remodels used ones. The company supplies consumers from classes A, B, C and occasionally D, according to classification shown in Table 1.

Table 1 Social classes in Brazil according to total family monthly income

Class	*Monthly family income (R$)**	*Monthly family income US$ (November/2011)*
Class A	Above 15,300.00	Above 7,650
Class B	From 7,650.00 to 15,300.00	From 3,825 to 7,650
Class C	From 3,060.00 to 7,650.00	From 1,530 to 3,825
Class D	From 1,020.00 to 3,060.00	From 510 to1,530
Class E	Up to 1,020.00	Until 510

Note: The value for the American dollar, considered for Table 1, was of one (01) dollar to two reais (R$ 2.00).

Source: *Adapted from IBGE (cited by Coelho, 2010)

This investigative study, at this stage of analysis, only examined the process of manufacturing of new pieces of upholstered furniture. The process of remodelling was further analysed. The results that were obtained in the exploratory research – in which the emphasis was on the organisational aspects of the production line – constitute the object of diagnostic analysis of this study, besides the potential environmental aspects of the product and process. Moreover, in this phase of analysis the relationships in the intra-company process were observed. The relationships of processes between companies are not considered at this phase of study.

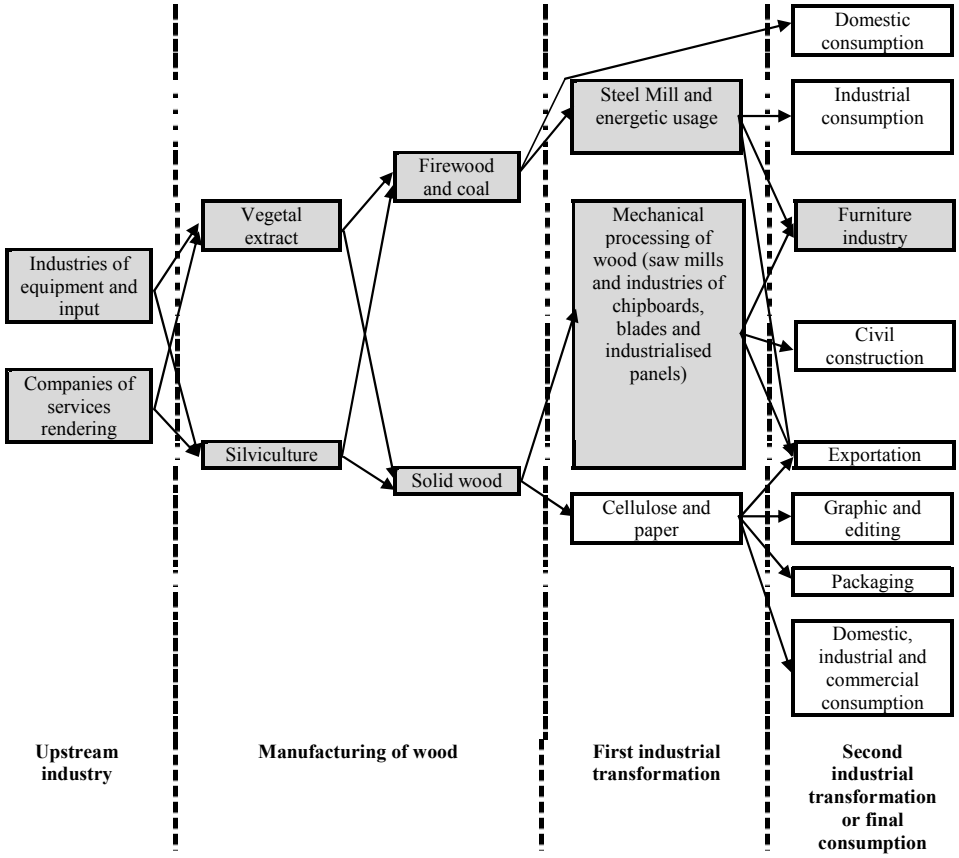
For the analysis we used, as a theoretical support, the concepts of the Product LCD, cited by Vezzoli (2010), Manzini and Vezzoli (2005), Kazazian (2003), Kiperstok et al. (2002) and Papanek (1995); and the principles of Pollution Prevention and CP that were synthesised by EPA-CP (2008), Kiperstok et al. (2008), Kiperstok (2000), Mello and Nascimento (2002) and LaGrega et al. (1994).

3 Results and discussions

3.1 The productive chain of wood and furniture in Brazil and in the state of Alagoas

Guéron and Garrido (2004) and Moraes (2002) classify the wood and furniture industry in Brazil as part of the industrial system of the forest. After the first process of industrial transformation, it is used in saw mills, and reconstituted and re-manufactured into wooden panels, paper and cellulose, firewood and coal. According to the cited authors, the furniture industry is the second process in the industrial use of wood, which produces products with a higher aggregate value, as illustrated in Figure 2 (check grey area).

Figure 2 Industrial system of forest-based products

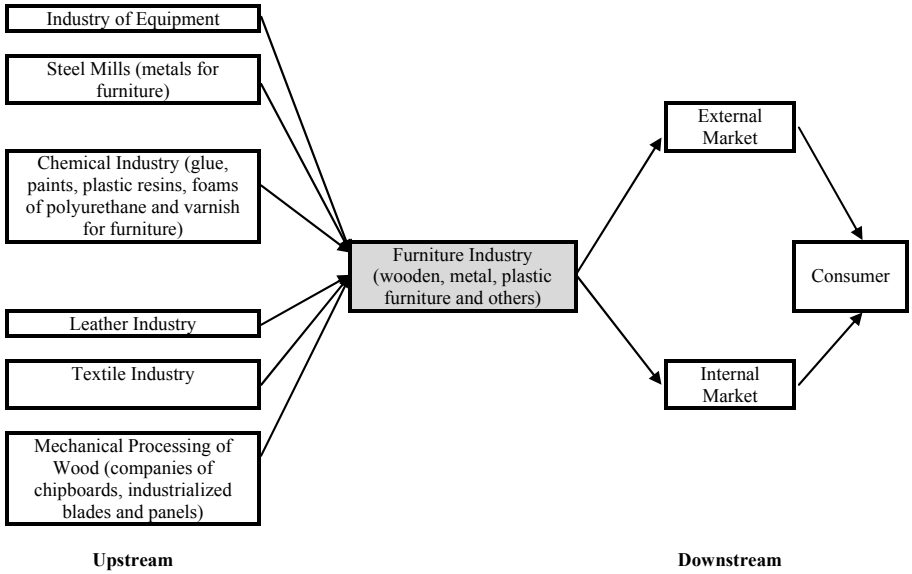


Source: Adapted from Moraes (2002, p.4)

Hillig et al. (2009) and Moraes (2002) synthesise the subsystem of furniture industry (cf., Figure 3) as upstream dependent on: wood processing industry, supplier of blades, chipboards, agglomerate, MDF, fibres, steel mills that provide metals to be used in pieces of furniture, chemical industry that provides glues, paints, PVC, varnish, glass, textile and leather industries for sofas and other materials for coating and industry of equipment that provides machinery and tools.

Downstream, it can be inferred, based on Figure 3, that the furniture industry feeds the wholesale and retail systems of furniture, in the internal and external markets, until it arrives at the consumer (Moraes, 2002).

Figure 3 Subsystem of the furniture industry



Source: Adapted from Moraes (2002)

Technical studies on the environmental requirements in the wood and furniture industry have been growing in developing countries, such as Brazil, in the last ten years and there are many focuses of analysis (Ferreira et al., 2008; Bachmann Associates, 2007; Guéron and Garrido, 2004; Moraes, 2002; Brazil-IPT, 2002). These environmental initiatives are effective instruments to develop the environmental awareness of producers, collaborators of the Productive Chain and consumers.

However, most studies on furniture production in Brazil have been into the wood manufacturing industry as for example the studies by Pêgo (2010), Hillig et al. (2009), Teixeira (2005) and César (2002). Yet, there are few the studies that evaluate the process of furniture manufacturing, like the one by Azevedo and Nolasco (2009a, 2009b) and also the study by Oliveira and Araújo (2009).

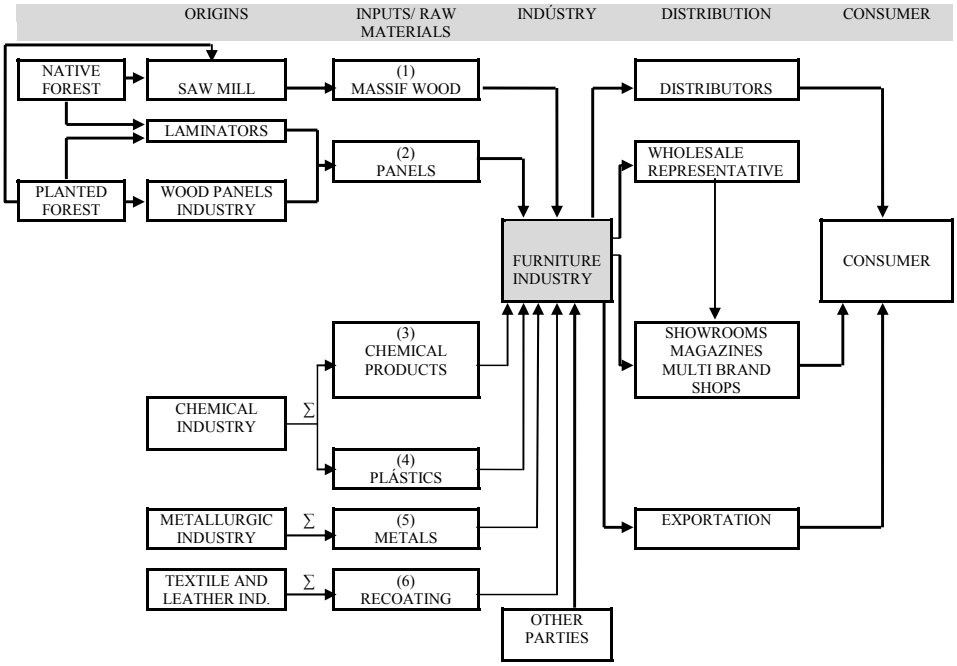
During this investigation, a significant gap in the literature on this type of furniture – upholstered furniture – that can support the design process and/or redesign, especially regarding the issue of the LCD was observed. There is practically no record of Brazilian studies on the production of upholstered furniture, with the exception of an experience reported by Pereira et al. (2006) about the application of standardisation for upholstered production in products of the furniture cluster of the town of Ubá in the State of Minas Gerais, Southeastern Brazil. At international level, few studies were found in the literature research carried out and considering the focus of discussion in this article. They include Martini et al. (2010), Spangenberg et al. (2010), Chivas et al. (2009) and Bovea and Vidal (2004). It reinforces the contribution of this study to the transfer of scientific knowledge in this subject in the academic world. Its uniqueness lies in the

analysis of a local reality of production – upholstered furniture production, based on the economic and socio-cultural context of micro and small businesses rather than large industries.

In the case of the productive chain of wood and furniture, applying the principles of a CP to optimise the use of the raw materials, especially non-renewable ones, for example, the native wood and foam (derived from petrol) and reducing the generation of losses (non-processed sub products), means improving productive efficiency.

CP attempts to satisfy the need for products in a sustainable way – it means using the materials, water and energy available efficiently. It considers the production systems and their processes as cyclical and able to use a lower quantity of materials, water and energy (EPA-CP, 2008; Senai-RS, 2003). The different types of materials that are used in the Productive Chain of Wood and Furniture, can be observed in the flowchart in Figure 4 (please see inputs/raw materials).

Figure 4 Flowchart of productive chain of wood and furniture



Source: Brazil-IPT (2002)

According to Guéron and Garrido (2004), the productive chain of furniture in Brazil is made up of micro, small and average sized companies that operate with high levels of informality and low technological innovation. This chain is characterised by the strong fragmentation, technological diversity and verticality, because of the reduced number of suppliers of furniture parts and components.

However, official data from Brazil's Ministry of Development, Industry and Commerce, indicate that the furniture sector is one of the most important in the transformation industries in the country because of the relevant level of production and its potential to generate new jobs. In the last ten years, the national furniture sector has

increased by around 200%. In 2010, there were registered 15,250.00 industries in this sector, with 275,600.00 formal employees and invoicing of 29.72 billion reais. Total exports in this same year were of US$ 789.3 million (MDIC, 2011).

In the State of Alagoas in the northeast region of Brazil, a similar picture is observed – it is mostly made up of informal, fragmented, micro and small companies, above all in the segments of wood furniture and upholstered furniture.

Although we can see the presence of furniture companies in most of the State of Alagoas, it is in the countryside of the state that the furniture production is concentrated and where the Cluster is. It was created in 2004 by the Program of Local Productive Arrangements (PAPL) of the State of Alagoas and was set up in the towns of Arapiraca and Palmeira dos Índios. However, it is the town of Arapiraca, which has the highest number of companies, including company case in this study. PAPL has provided mechanisms for training, through the Brazilian Service to Support Micro and Small Enterprises of the State of Alagoas (SEBRAE-Alagoas) and logistical support, with the partnership of the town council of Arapiraca.

SEBRAE-Alagoas has worked with the cluster conducting activities for the development of associations, promoting strategies, marketing and technology, including training and consultancy on improvements in production, safety, finishing furniture, among others. The goal is to guide and to equip small producers with basic concepts to improve the productive environment of the companies. There has been training in Basic Industrial Technology (TIB), 5S, CP and Program of Excellence in Quality for some companies with the highest level of local development, as is the case study company (PAPL, 2009).

Despite the work already done, in general, the processes of management and production in this cluster have low and/or medium technological potential and need a complete intervention in the product systems to improve the environmental management, especially in the production stage.

Because it is located in a privileged geographical area, in the central area of the State of Alagoas, the furniture cluster supplies the demand from practically all neighbouring localities, mainly the capital of the State, Maceió.

This furniture cluster has, as its strategic focus, the following actions:

a strengthening of the sense of cooperation

b increasing productivity and reduction of costs (raw material, inputs and logistics)

c development of products with quality and design

d increase in sales of products

e publicising products and brands from the Local Production Arrangement

f increasing income from furniture products

g generation of jobs and specialised work (Sigeor-SEBRAE, 2009).

The discussions in this study open new perspectives in the evaluation of action that is referred to in items (a), (b), (c) and (g) above and that can give rise to other future reflections that are referred to in items (d) to (f), also above.

3.2 The upholstered furniture of the furniture cluster in the state of Alagoas and the manufacturing of sofas

An upholstered product for example, a sofa, is made of three types of material

1 *wood:* structuring element and the model's framework

2 *foams and synthetic feathers:* upholstering elements of backs, arms and cushions whose densities vary between D23 and D28 for back and seat

3 *fabrics:* elements to cover and complete the piece of upholstered furniture – they can be natural and/or synthetic fabrics (see Figure 5).

Figure 5 Predominant materials in a sofa: (a) wooden rail in the seat with synthetic belt (b) synthetic foam (c) fabric showroom in the study case company

(a) wood and synthetic belts (b) foam (c) fabrics

Apart from these materials, there are others of a second order, such as springs and/or synthetic belts, as illustrated in Figure 5(a). These materials have significant roles in the lower support of the seat's cushions. Also, blankets of raffia and/or raw cotton's fabrics are used as lining and help to complete of pieces on the underside. Plastic wheels, wooden and/or metal arms and legs among other complementary materials are compositional elements in the aesthetical-formal and ergonomic scope of the upholstered piece of furniture.

Because of the everyday representativeness that a sofa has with its potential consumer-use for sitting, sitting-laying down and/or laying down, in various residential, commercial and/or corporative environments, this product is a significant model of reference for the analysis of the environmental and organisational aspects of the furniture manufacturing.

Figure 6 shows two types of sofas that are manufactured by the upholstered furniture companies in Arapiraca, the Furniture Cluster town in the countryside of the State of Alagoas. Figure 6(a) shows a model of rectilinear design with a pattern that is similar to the products that are found in the local market. Figure 6(b) shows a model that was designed for more specific consumer-user's demands, with additional style characteristics showing a diversification of styles of furniture in the local production, as shown by Gaia et al. (2010).

Figure 6 Models of sofas from the furniture cluster that are under analysis: (a) two seat sofa, conventional model, where the function 'sit' is highlighted (b) sofa with multiple seats in a modulated model, where the personalisation of the extension of the seat makes it possible for the simultaneous use of the functions: sit, sit-lay down and lay down

(a) Conventional sofa in the company's shop

(b) Modulated sofa in a local exhibition of tailored furniture

3.3 CP and LCD for upholstered furniture in the countryside of the State of Alagoas

According to Kiperstok et al. (2008, 2002) and Mello and Nascimento (2002), it is understood that the CP, like pollution prevention (LaGrega et al., 1994), consists of a technique that prevents the generation of residues (seen here as losses in the productive process), effluents and emissions. The implementation of techniques of CP must sensitise and mobilise the company in all its sectors and with all the stakeholders involved. It demands a rethinking of the process and/or of the product in all the phases of its production.

In this sense, CP joins with the Product LCD to make more efficient action feasible, in which design establishes a connection between the world of production and the consumer-user's world (Vezzoli, 2010; Morelli, 2006).

Manzini and Vezzoli (2005) affirm that the Product LCD is more advanced regarding the definition of the concepts to be followed than in practical applications. This is true, especially if we consider production in small businesses, as in the sector of upholstered furniture. In the scope of sustainability, Product LCD has a systemic approach that overtakes the concept of product and takes the concept of Product-Service System (UNEP, 2002; Mont, 2002).

Product-Service System (PSS) aims at optimising the available resources in its system as much as possible in order to minimise the environmental impact. It encompasses the manufacturing, the choice of materials, the suppliers, the usage and the post-usage of the

product, up to all the stages that can incorporate the environmental question in the development of a product during all its life cycle (Mont, 2002; Morelli, 2006; Pigosso et al., 2010).

In this sense, the process of mapping of fluxes of inputs and raw materials, stages and operations, losses of production and emissions from the system of manufacturing of sofas in the selected company in the Furniture Cluster is written in detail by Rapôso et al. (2010a, 2010b).

The main results of the mapping regarding raw materials, types of losses, their destinations, the use of sub products, the process of manufacturing itself, the assembly line and inputs/outputs (I/O), are synthesised in Table 2 and Table 3.

According to Table 2, the main raw materials used by the company are: certified wood (eucalyptus and pine), nylon belt, sealed foam (of various kinds and thickness), blankets of raffia, fabric (of the most varied types and fibres), and foam flakes (sub product/internal input that is derived from the residual foam) and accessories for sewing in general.

Table 2 Analytical-diagnostic synthesis of the types of raw materials or inputs (I), of the types of losses or outputs (O), of the destinations of the losses and of the usage of the sub products

Raw materials (I)	*Types of losses (O)*	*Destination*	*Usage (sub product)*
Certified wood (Eucalyptus and pine)	Wood chips	Sold or donated to bakeries and/or pottery factories	Burning in ovens
	Sawdust	Sold to chicken rearers	For chicken bedding
Nylon belt	Belt leftovers	Discarded in the trash	With no use
Blankets of raffia	Leftovers of blankets	Discarded in the trash	With no use
Sealed foam	Foam leftovers	Re-processing in flakes	Completion (stuffing for cushions)
	Foam flakes	Re-insertion in the process of manufacturing (Phase 3)	Application in seats and backs of chairs
		Selling off the excess	Other companies and/or handicrafts
Fabrics	Fabric scraps and cardboard tubes	Discarded in the trash	With no use
	Post usage fabrics (remodelling)	Reuse	Coating of work desks (internal re-use)
			Donation to scavengers
		Discarded in the trash	With no use
Accessories (sewing in general)	Residues	Discarded in the trash	With no use

About the losses, the following were identified (Table 2): wood chips, sawdust, belt leftovers, leftovers of blankets, foam leftovers, snippets of fabrics, and leftovers of cardboard tubes, and accessories and wrappings in general. Wooden chips usually are

sold and/or donated to be used in the ovens of bakeries and/or pottery factories, and sawdust is sold for chicken bedding to the local poultry producers.

There is neither follow-up done by the company regarding the routes and final destinations of the losses and/or sub products after they leave their environment of production, nor any precise quantification of the generated volume of losses.

Table 3 synthesises the main problems faced by the company regarding the manufacturing of sofas.

Table 3 Analytical-diagnostic synthesis in the manufacturing of sofas of the case company regarding the process itself and the I/O

Process	*Assembly line*	*Inputs and outputs (I/O)*
Fluxes of different materials in its assembly line	Materials used in one product are not necessarily the same as used in the next one	Absence of effort/planning to avoid losses
Manufacturing and assembly flexible to solicited demand (non-continuum daily flux)	Only one assembly line for two distinct fluxes of production: 1 fabrication and 2 restoration	Incipient initiatives to reuse the outputs in sub products processes and others
Physical space has not been planned for process-production	Available space needs a re-arrangement to improve the process	Lack of evaluation and control of routes and destinations of inputs and outputs and/or sub products
Need for a review of layout of sectors and compartments of production, stock and expedition	Waste of materials and/or a little expressive recuperation of materials and sub products in the internal and/or external processes	Lack of planning to reduce or re-insert the losses in production or in other processes

Based on the data shown in Table 2 and Table 3, a flowchart of the sofa manufacturing process was elaborated. It represents the interactions of materials and operations, services and characters involved in the process, and it also clearly allows for the spots of waste and the areas of opportunities for improvement to be found.

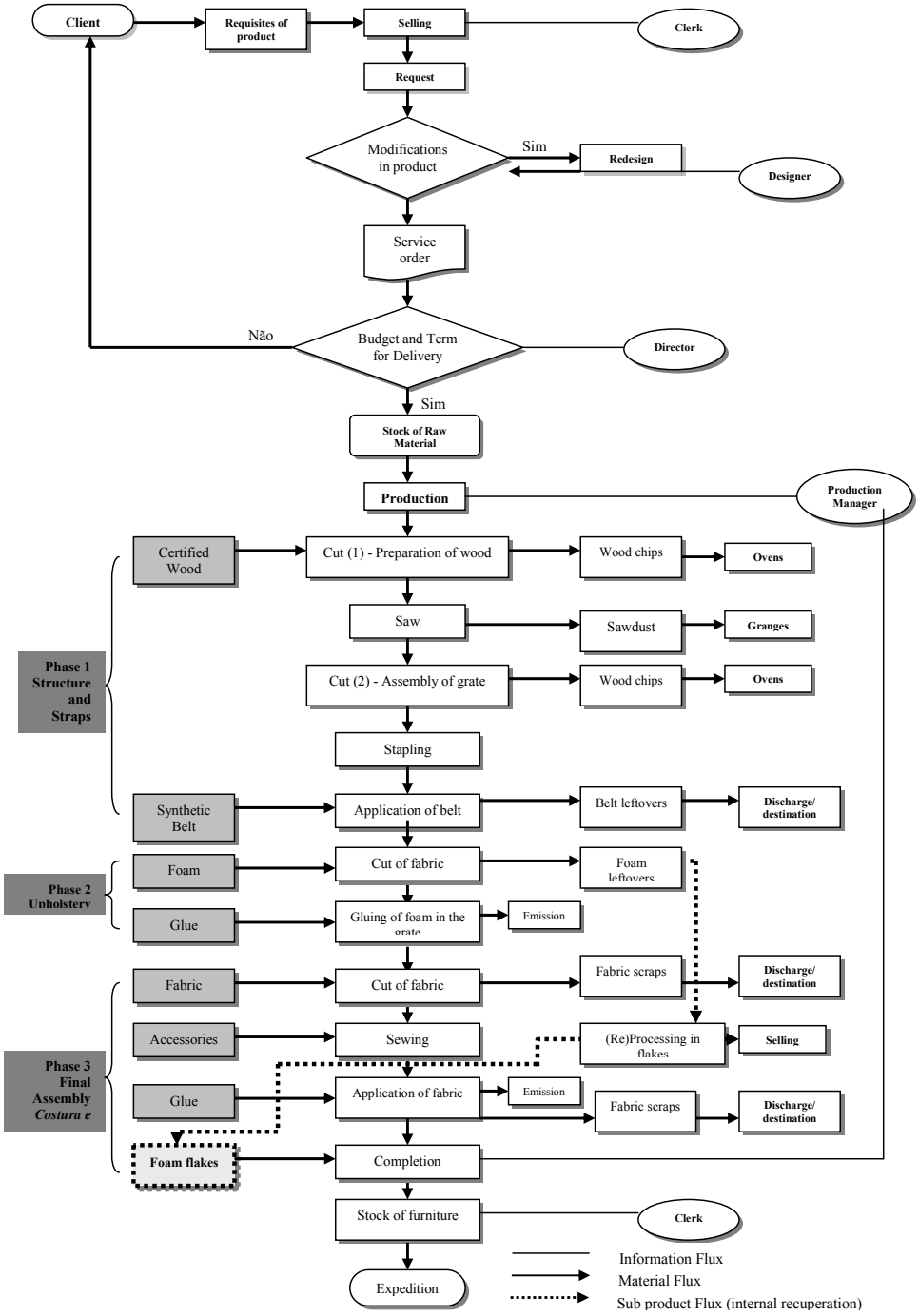
This information provides a general view of the current state of the process under analysis, for future application of CP and of Product LCD. Figure 7 shows the flowchart (Machado and Toledo, 2008).

3.4 Diagnostic and practical implications

As illustrated in Figure 7 the production flux presents phases that go from the fulfilment of the client's order regarding the requisites of the product, to its production and expedition. That is, it demonstrates the phases of the lifecycle of the intra company product (or, as it is better known in the scope of Product LCD, door to door).

Losses in production are considered proper results of the productive process itself and are minimised in a reactive way (after they are generated). This indicates an incipient level regarding CP (EPA-CP, 2008; LaGrega et al., 1994) and the Product LCD (Pigosso et al., 2010; Manzini and Vezzoli, 2005; Papanek, 1995).

Figure 7 Flowchart of the manufacturing of upholstered furniture – manufacturing of sofas (Alagoas-Brazil)



3.4.1 Product design and processes: environmental quality and specialised work

Part of this context is motivated by the reduced transfer of knowledge between the sector that is responsible for the development of the product (designer) and production (production manager). The scenario is aggravated because of poor professionalization in management and sustainability in the process of development of products and processes, and this hampers investment in clean technologies.

The training organised by SEBRAE-Alagoas has gradually provided some awareness to entrepreneurs as well as employees, but its scope is still not enough to promote more pro-active actions, mainly in labour.

One could also add the poor configuration of an assembly line with little technological basis – the sub-utilisation of the operative potential of the existing machinery and equipment, as well as the inadequacy of the physical space for the flow of the fabrication process that is used.

The companies see how important it is to incorporate environmental requisites in the manufacturing of their products, but few of them invest in or exploit available strategic and technological innovations.

The distance from learning and research institutions that these companies still have also contributes to this lack of specialised information on broader environmental and organisational practices.

3.4.2 Raw materials, inputs and logistics

Although there is no specific planning for more effective actions of internal and/or external remanufacturing, the incipient action on the assembly line cannot be ignored. There is some recovery of losses in its processing which is used as a sub product of another phase of the process, or for phases of processes of other companies, subsystems, systems and chains. For example, wooden chips to be burnt, sawdust as organic material for chicken bedding and foam leftovers as flakes for the finalisation of seat cushions and to be sold (the excess).

This demonstrates an indirect implementation of the principles of the CP. Initiatives carried out spontaneously and individually by the entrepreneur or small producer who responded positively to the guidelines given in the continuous and systematic training of SEBRAE-Alagoas. However, the potential environmental impacts that are associated to these destinations have not been evaluated yet. Much less, there is no mapping of the routes to upstream and downstream of the intra-enterprise subsystem.

Apart from this, we must consider that there are losses with no destinations for example, leftovers from raffia sheets, leftovers of belts and fabric scraps, as well as packaging (discarded in the normal waste) – and emissions to be neutralised or eliminated – for example the control of particulate material in dispersion and control of toxicity.

This opens positive perspectives for future LCA in upholstered furniture, like sofas, to broaden the analytical scope regarding the Product LCD that has been initiated in this study (Pigosso et al., 2010; Vezzoli, 2010; Manzini and Vezzoli, 2005; Kiperstok et al., 2002; Papanek, 1995).

3.4.3 Strengthening cooperation

The classic example of IE of Kalundborg in Denmark – eco-industrial park – in which different companies are integrated and use each other's waste as a source of energy and raw material – has resulted in an unplanned industrial symbiotic process whose development was gradual through cooperation between companies in the region and the city. Kalundborg has shown that the reuse of losses can reduce the environmental impact of businesses on the environment and can to generate business opportunities and profits (Chertow, 2000; Lowe and Evans, 1995; Côté and Hall, 1995).

It possible to see a certain resemblance of the upholstered furniture production to Kalundborg in relation to a future implementation of IE in the long term and gradually adapted to the regional productive context of the State of Alagoas. Despite the alternatives of internal and/or external recovery, it was observed that the production of losses (waste) is not derived from a broader scientific knowledge regarding the IE. Rather, these alternatives are derived from empirical action based on basic concepts of CP and the entrepreneurial vision of a small producer.

In fact, today there are initiatives that are very incipient and reactive, but somehow seem pro-active with regard to the recovery of what is produced and not used efficiently.

Implicitly, there are already voluntary interactions with enterprises in other sectors – bakeries, potteries – and with local agricultural producers. These companies are integrated into other subsystems and industrial systems. These interactions can be optimised in order to expand business opportunities and profits, and to reduce waste and improve environmental quality between them.

It will require the strengthening of cooperation, initially intra-company and inter-company in the Furniture Cluster, in the same productive sector or complementary and different sectors. In the sequence, the strengthening of cooperation will need a long preparation process, studies, research and knowledge transfer between institutes of education and research, companies from various sectors and the town of Arapiraca, the pole of the cluster.

4 Conclusions

The increasing demand for furniture companies to meet the need to adequate their products to the legal and commercial demands for the implementation of environmental requisites has motivated them to re-evaluate their productive systems as far as sustainability is concerned, more specifically about strategies for applied recovery.

However, the most practiced actions are still in the phases and sub-phases of discard, with emphasis on the correction of the process in the final phase of production, through reactive destination for losses and/or sub product remains, as exemplified in the present study, in a company of upholstered furniture of the Local Productive Arrangement of Furniture in the State of Alagoas (Brazil).

Based on the diagnostic analysis carried out for the manufacturing of upholstered furniture and the context that was observed in the company, we can infer that:

1 There were gaps in the interaction between the actors that were involved in the productive process, above all in the project-production. These gaps hinder the optimisation of the use of raw materials, inputs and their sub products through the product LCD for the non-generation of losses.

2 Strategic actions for the gradual implementation of opportunities of CP at a more desirable level, according to the organisational and environmental requisites – for example, planning for the reduction and/or control at source – will start being part of a repertoire of innovations for the sector of upholstered furniture. They can start through simple changes on the operational conditions, in the layout and handling of materials, as well as with more participation of researchers in the company for the transfer of technology (knowledge).

3 A study of the LCA in an upholstered piece of furniture can broaden the analytical scope started here, in order to indicate and to evaluate the main impacts of the process, making it viable in the future. Planned actions in the short, average and long run, for potential improvement of the product and process for the non-generation of losses and for better performance.

References

Azevedo, P.S. and Nolasco, A.M. (2009a) 'Environmental requirements on the product process development applied in furniture industries', *Proceedings of 2nd International Workshop Advances in Cleaner Production*, São Paulo, available at http://www.advancesincleanerproduction.net/second/files/sessoes/4b/1/P.%20A.%20Azevedo%20-%20Resumo%20Exp.pdf (accessed on 11 February 2011).

Azevedo, P.S. and Nolasco, A.M. (2009b) 'Incorporation of environmental requirements in the process of developing products in industries from custom furniture', *Ciência Rural*, Vol. 39, No. 8, pp.2422–2427, available at http://dx.doi.org/10.1590/S0103-84782009000800023 (accessed on March 2012).

Bachmann Associates (2007) 'Levantamento dos Gargalos Tecnológicos Cadeira Produtiva de Madeira e Móveis (Survey of Technological Bottlenecks of Production Chain Wood and Furniture)', 20 August, working paper, Brazilian Service to Support Micro and Small Enterprises of the State of Paraná – SEBRAE-PR, Curitiba, available at http://portal.pr.sebrae.com.br/FCKeditor/userfiles/file/BancodePesquisas%20/Madeira/GargalosMadeiraMoveis.pdf (accessed on March 2012).

Bovea, M.D. and Vidal, R. (2004) 'Materials selection for sustainable product design: a case study of wood based furniture eco-design', *Journal of Materials and Design*, Vol. 25, pp.111–116.

Brazil-IPT (2002) 'Prospectiva Tecnológica da Cadeia Produtiva Madeira e Móveis (Technological Prospective of Production Chain Wood and Furniture)', working paper, Forest Products Division of the Ministry of Industry and Commerce Development, Brasília, available at http://www.mdic.gov.br/arquivos/dwnl1196944420.pdf (accessed on May 2010).

César, S.F. (2002) 'Wooden vertical wall elements in industrialized wooden houses – conceptual design', unpublished thesis (PhD), Post-Graduate Program of Production Engineering, Federal University of Santa Catarina, Florianópolis, SC.

Chertow, M.R (2000) 'Industrial symbiosis: literature and taxonomy', *Annu. Rev. Energy Environ.*, Vol. 25, pp.313–337, Published by Annual Reviews.

Chivas, C., Guillaume, E., Sainrat, A. and Barbosa, V. (2009) 'Assessment of risks and benefits in the use of flame retardants in upholstered furniture in continental Europe', *Fire Safety Journal*, Vol. 44, pp.801–807.

Coelho, L.R. (2010) 'O Brasil, suas classes sociais e a implicação na economia (Brazil, their social classes and implication in the economy)', *Logística descomplicada*, available at http://www.logisticadescomplicada.com/o-brasil-suas-classes-sociais-e-aimplicacao-na-economia/ (accessed on June 2011).

Cotê, R. and Hall, J. (1995) 'Industrial parks as ecosystems', *J. Cleaner Prod.*, Vol. 3, Nos. 1–2, pp.41–46.

EPA-CP (2008) 'Principles of pollution prevention and cleaner production: an international training course. Participant's manual', working paper, United States Environmental Protection Agency, Region III, available at http://www.cleanerproduction.com/Pubs/EPA%20p2-CP%20training (accessed on 22 October 2010).

Erkman, S. (2001) 'Industrial ecology: a new perspective on the future of the industrial system', *SWISS MED WKLY*, Vol. 131, pp.531–538.

Ferreira, M.J.B., Gorayeb, D.S., Araújo, R.D., de Mello, C.H. and Boeira, J.L.F. (2008) 'Relatório de Acompanhamento Setorial – Indústria Moveleira (Setorial report – Furniture industry)', working paper, Vol. I, 13 November, Center for Industrial Economics at the University of Campinas (UNICAMP) and Brazilian Agency for Industrial Development (ABDI), Campinas, available at http://www.cgimoveis.com.br/economia/documento.2008-11-14.3971286229/ (accessed on March 2012).

Gaia, R.V., Rapôso, A., Silva, A.M.F. and Miranda, C.G. (2010) 'Design, cultura e produtos moveleiros alagoanos: do design anônimo ao desenho contemporâneo (Design, culture and furniture products of State of Alagoas: from an anonymous design to contemporary design)', *Proceedings of V Congresso Norte Nordeste de Pesquisa e Inovação*, available at http://connepi.ifal.edu.br/ocs/index.php/connepi/CONNEPI2010/paper/view/1442 (accessed on February 2011).

Guéron, A.L. and Garrido, V. (2004) *Requisitos ambientais, acesso a mercados e competitividade na indústria de madeira e móveis do Brasil (Environmental Requirements, Market Access and Competitiveness in the Wood Industry and Furniture from Brazil)*, working paper, available at <http://www.inmetro.gov.br/barreirastecnicas> (accessed on July 2011).

Hillig, E., Schneider, V.E. and Pavoni, E.T. (2009) 'Generation of wood waste and derivatives on furniture industry related to production's variables', *Produção*, Vol. 19, No. 2, pp.292–303, available at http://www.scielo.br/pdf/prod/v19n2/v19n2a06.pdf (accessed on March 2012).

Kazazian, T. (2003) 'The ecodesign process', in Bourg, D. and Erkman, S. (Eds.): *Perspectives on Industrial Ecology*, pp.82–90, Greenleaf Publishing, Midsomer Norton.

Kiperstok, A. (2000) 'Implementation of cleaner production practices with the support of a diploma course', *Journal of Cleaner Production*, Vol. 8, pp.375–379.

Kiperstok, A., Coelho, A., Torres, E.A., Meira, C.C., Bradley, S.P. and Rosen, M. (Eds.) (2002) *Prevenção da Poluição (Pollution Prevention)*, Senai-DN, Brasília, DF.

Kiperstok, A., Tanimoto, A.H., Fontana, D., Cohim, E.B., Mendonça, J., Pessoa, L., Pustinilki, L., Cardoso, L.F., de Kalid, R.A. and Teixeira, A. (2008) 'Fundamentos da Produção Limpa (the fundamental principles of cleaner production)', in Kiperstok, A. (Ed.): *Prata da casa: construindo produção limpa na Bahia (Silver House: Introducing Cleaner Production in Bahia)*, pp.19–42, Federal University of Bahia – TECLIM, Salvador.

LaGrega, M.D., Buckingham, P.L. and Evans, J.C. (1994) *Hazardous Waste Management: Environmental Resources Management*, McGraw-Hill, New York, NY.

Lowe, E.A. and Evans, L.K. (1995) 'Industrial ecology and industrial ecosystems', *J. Cleaner Prod.*, Vol. 3, Nos. 1–2, pp.47–53.

Machado, M.C. and Toledo, N.N. (2008) *Gestão do processo de desenvolvimentos de produtos: uma abordagem baseada na criação de valor (Management of the Process of Product Development: An Approach Based on Value Creation)*, Atlas, São Paulo, SP.

Manzini, E. and Vezzoli, C. (2005) *O desenvolvimento de produtos sustentáveis: os requisitos ambientais dos produtos industriais (The Development of Sustainable Products: The Environmental Requirements of Industrial Products)*, Edusp, São Paulo, SP.

Martini, P., Spearpoint, M.J. and Igham, P.E. (2010) 'Low-cost wool-based fire blocking inter-lines for upholstered furniture', *Fire Safety Journal*, Vol. 45, pp.238–248.

MDIC (2011) 'Cadeias Produtivas. Madeira e Móveis (productive chains. wood and furniture)', working paper, Ministry of Development, Industry and Foreign Trade, Brasília, available at http://www.desenvolvimento.gov.br/sitio/interna/interna.php?area=2&menu=317 (accessed on 28 August 2011).

Mello, M.C.C. and Nascimento, L.F. (2002) 'Produção mais limpa: um impulso para a inovação e a obtenção de vantagens competitivas (Cleaner production: a boost for innovation and an attainment of competitive advantage)', *Proceedings of XXII Encontro Nacional de Engenharia de Produção*, Curitiba, available at http://www.abepro.org.br/biblioteca/ENEGEP2002_TR100_0846.pdf (accessed on December 2010).

Miguel, P.A.C. (2010) *Metodologia de Pesquisa em Engenharia de Produção e Gestão de Operações (Research Methodology in Engineering Production and Operations Management)*, Elsevier, Rio de Janeiro, RJ.

Mont, O.K. (2002) 'Clarifying the concept of product-service system', *Journal of Cleaner Production*, Vol. 10, pp.237–245.

Moraes, M.A.F.D. (2002) 'Estudo da competitividade de cadeias integradas no Brasil: impactos das zonas de livre de comércio. Cadeia: Madeira e Móveis (Study of competitiveness of integrated chains in Brazil: impacts of free trade zones. Chain: Wood & Furniture)', December, working paper, State University of Campinas, Institute of Economics, Center for Industrial Economics and Technology (UNICAMP-IE-NEIT), Campinas, available at http://www.inovacao.unicamp.br/report/EstudoCompetitividadeCadeias070423.pdf (accessed on March 2012).

Morelli, N. (2006) 'Developing new product service systems (PSS): methodologies and operational tools', *Journal of Cleaner Production*, Vol. 14, pp.1495–1501.

Oliveira, M. and Araújo, F.A. (2009) 'The cleaner production applied to a small industry of the furniture sector: economic and environmental efficiency', *Proceedings of 2nd International Workshop Advances in Cleaner Production*, São Paulo, available at http://www.advancesincleanerproduction.net/second/files/sessoes/4b/1/M.%20Oliveira%20-%20Resumo%20Exp.pdf (accessed on 09 November 2011).

Papanek, V. (1995) *Arquitectura e Design. Ecologia e Ética (Architecture and Design. Ecology and Ethics)*, Edições 70, Lisboa.

PAPL (2009) 'Plano de Desenvolvimento Preliminar – APL de Móveis do Agreste (Preliminary development plan – furniture cluster of the agreste region of the State of Alagoas)', working paper, available at http://www.sebrae.com.br/uf/al (accessed on 23 October 2009).

Pêgo, K.A.C (2010) *Guia para inserção de parâmetros ambientais no design de móveis de madeira (Guide to Inclusion of Environmental Parameters on Wooden Furniture Design)*, EdUEMG, Barbacena, MG.

Pereira, A.F., Romeiro Filho, E., Carrasco, E.V.M. and Avelar R.S. (2006) 'Product project methodology and the factors standarzing organization and certification: application at sofa furniture', *Proceedings of do 7 Congresso Brasileiro de Pesquisa e Desenvolvimento em Design – P&D Design 2006*, Curitiba, available at http://andreafranco.com.br/blog/wp-content/uploads/2006_ped_f.pdf (accessed on March 2012).

Pigosso, D.C.A., Zanette, E.T., Guelere Filho, A., Ometto, A.R. and Rozenfeld, H. (2010) 'Ecodesign methods focused on remanufacturing', *Journal of Cleaner Production*, Vol. 18, pp.21–31.

Rapôso, A., César, S.F. and Kiperstok, A. (2010a) 'Identificação de oportunidades de produção mais limpa na fabricação de sofá em microempresa moveleira do APL de Móveis do Agreste do Estado de Alagoas (Identifying opportunities for cleaner production in manufacturing of sofa in the furniture cluster of the Agreste region of the State of Alagoas)', *Proceedings of XXX ENEGEP*, available at http://www.abepro.org.br/biblioteca/enegep2010_TN_STO_121_788_16612.pdf (accessed on November 2010).

Rapôso, A., César, S.F. and Kiperstok, A. (2010b) 'Produção mais Limpa e estofados: oportunidades para fabricação de sofá em microempresa do APL de Móveis do Agreste alagoano (Cleaner production and upholstered furniture: opportunities for manufacturing of sofa in small company of cluster of the Agreste region of Alagoas)', *Proceedings of V CONNEPI*, available at http://connepi.ifal.edu.br/ocs/index.php/connepi/CONNEPI2010/paper/viewFile/867/602 (accessed on February 2011).

Senai-RS (2003) 'Implementação de Programas de Produção mais Limpa (Program implementation of cleaner production)', working paper, National Center for Clean Technology (CNTL), SENAI-RS/UNIDO/UNEP, available at http://www.ifm.org.br/moodle/file.php/19/CNTL_guia_P_L.pdf (accessed on 22 September 2011).

Sigeor-SEBRAE (2009) 'Projeto: APL Móveis Agreste (Project: furniture cluster of the Agreste region of Alagoas)', working paper, Information System Strategic Management Results oriented (SIGEOR), available at http://www.sebrae.com.br (accessed on April 2010).

Spangenberg, J.H., Fuad-Luke, A. and Blincoe, K. (2010) 'Design for Sustainability (DfS): the interface of sustainable production and consumption', *Journal of Cleaner Production*, Vol. 18, pp.1485–1493.

Teixeira, M.G. (2005) *Aplicação de conceitos da ecologia industrial para a produção de materiais ecológicos: o exemplo do resíduo de Madeira (Applying Concepts of Industrial Ecology to the Production of Environmentally Friendly Materials: The Example of Waste Wood)*, unpublished thesis (MSc), Federal University of Bahia, Salvador, BA.

UNEP (2002) 'Product-service systems and sustainability: opportunities for sustainable solutions', working paper, United Nations Environment Programme – UNEP, available at http://www.unep.fr/scp/design/pdf/pss-imp-7.pdf (accessed on 11 July 2011).

Vezzoli, C. (2010) *Design de sistemas para a sustentabilidade: teoria, métodos e ferramentas para o design sustentável de 'sistemas de satisfação' (System Design for Sustainability. Theory, Methods and Tools for a Sustainable 'Satisfaction-System' Design)*, Edufba, Salvador, BA.

Notes

1 The doctoral research is funded by the Institutional Program of Teaching Qualification for the Federal Network of Professional, Scientific and Technological Education (PIQDTEC), through an agreement between the Coordination of Improvement of Staff at University Level (CAPES) and the Federal Institute of Education, Science and Technology of Alagoas (IFAL), with the allowance of a research scholarship.