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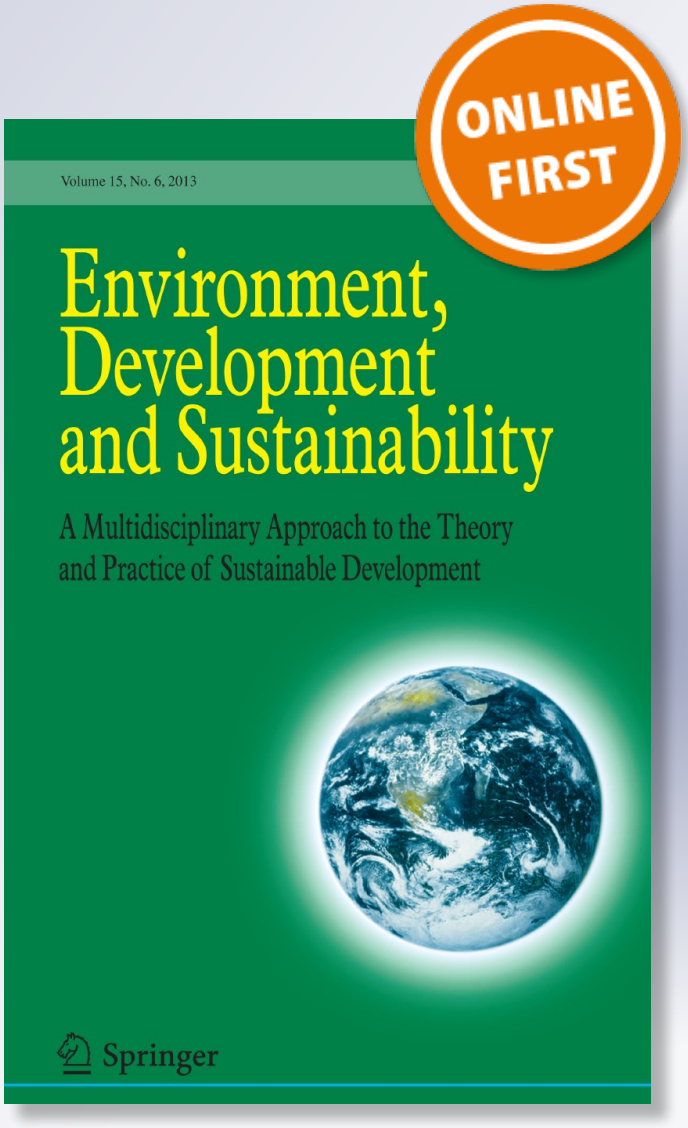

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Abstract Despite more than 20 years of economic progress, especially in emerging economies like Brazil, the gap between developed and developing countries is still large, and environment problems have risen significantly. In this context, this paper aims to make the Brazilian furniture production cleaner, analyzing the environmental requirements considered by the micro and small enterprises (SMEs) in made-to-order furniture industry during the product development process (PDP). Another attempt was to identify the internal and external factors that led to the incorporation of these requirements. In this regard, a comprehensive review of eco-design concept that consists of composing environmental requirements into the PDP, through methods, tools, guidelines and techniques, was carried out. The data were collected using semi-structured interviews and in loco observations, analyzing each activity of the PDP and the environmental requirements on 18 SMEs in Brazil. The outcomes show that the economic factors determine the way in which the enterprises respond to the environmental issues and how adequate their companies according to laws and regulations. Moreover, the small number of qualified professionals in this field lead to difficulties to structure the sector, in other words, to produce with less environment impact.

Keywords Design tools · Eco-design · Environmental design · Environmental requirements · Furniture industry

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1 Introduction

While developing countries, such as Brazil, need to expand and improve in many ways their industries, the unsustainable economic growth is leading to a resource rarefaction and environmental problems. These countries need to increase their industrial sector to alleviate social problems, but many of them have resource depletion and serious environmental degradation, which threaten chances for sustainable economic growth. UNEP (2011, p. 1) related that most economic development led to a fast accumulation of human, physical and financial capital, "but at the expense of excessive depletion and degradation of natural capital, which includes our endowment of natural resources and ecosystems." This pattern has had prejudicial impact on the life of current generations, but especially for the future ones. Dittrich and Giljum (2012) reinforce this issue indicating the consequences of the increasing extraction, use of resources and the associated environmental impact, such as global warming, which are increasing. More and more, the use of resources exceeds the generation capacity of our ecosystems.

Recently, the Brazilian market expansion and a high consumption of lower income have driven to the growth of the furniture industry in that country (Massote and Santi 2012). So, this research is appropriate, since it helps to prepare the sector to answer to the current and future environmental requirements, facilitating the adequacy process of the manufacture systems, control and correction, creating suitable products to the emerging demands. Moreover, this will adjust the main environmental requirements that must be integrated and adopted by the sector.

This paper aims to analyze the environmental requirements considered by the micro and small enterprises (SMEs) in made-to-order furniture (MTO) industry during the PDP. It will also benefit the understanding of the motive factors for this inclusion, the environmental requirements accepted by the companies, the agents involved in the process, its attributions and challenges for the best handling of the environmental issues in the product development in this sector in Brazil, one of the "big five" material consume countries (Dittrich and Giljum 2012).

2 Literature review

2.1 Environmental requirements

In this topic, techniques and methodologies related to environmental requirements is presented.

Eco-design is a response to our actual environmental situation, combining creativity, innovation and ecological responsibility, and its main goal is the reduction in the product environmental impact during its life cycle, composed of raw material, production, distribution, use and final disposal and is a set of practices to create eco-efficient process and products (Borchardt et al. 2011).

Many authors wrote about the influence of eco-design requirements on product environmental impact, as follows: "No external factors other than economic or legal could influence the implementation of eco-design in a company" (Plouffe et al. 2011, p. 573).

The returns for the companies that project and produce according to the eco-design principles are (1) great satisfaction to consumers sensitive to environmental issues; (2) to be selected as a supply due to environmental issues; (3) many times the product gets more

simple design and longer life cycle, thus helping it to stand out from the competition (Plouffe et al. 2011).

According to Valle et al. (2012), the main steps to eco-design are (1) environmental assessment, to provide a good initial understanding of the environmental problems; (2) solution finding, to create concepts which can lead to environmental improvements and (3) environmental strategy, a general plan of action.

There are many terms and methodologies used to incorporate environmental criteria, including design for the environment (DfE), sustainable design, clean design and eco-design and environmentally conscious design (ECD). Koskela (2011) and Ammemberg and Sundin (2005, p. 405) cited the Standardised Environmental Management System (EMS) companies, i.e., the ones that fulfill the requirements of ISO14000 and/or the European Union's regulation Eco-Management and Audit Scheme. EMS is linked to DfE that is defined as "practices are meant to develop environmentally compatible products and processes while maintaining product, price, performance and quality standards." Product-oriented environmental systems (POEMS) are EMS requirements with special attention to the continuous optimization as a product's eco-efficiency in terms of ecology and economy, along its life cycle.

Cleaner production (CP), on the other hand, is a pollution prevention program based on the waste management and in the misuse of energy and materials (UNEP 2011). The improvement of operational practices, the technological evolution and the reduction in waste amounts "through reuse, recycling and remanufacture already represent a move toward a cleaner production" (Massote and Santi 2012 p. 1). The same authors applied CP methodology in a Brazilian furniture industry and concluded that "CP programs are a powerful tool in the quest for eco-efficiency, as they can result in big reductions in material, water and energy waste."

Greening industries is a concept described in a UNIDO (United Nations Industrial Development Organization) report as a policy framework to support the greening of SMEs industries in developing countries and countries in transition. It is a new school of thought that goes beyond the life assessment. This concept is part of the Green economy, which is defined as the one that results in well-being and social fairness, and lessen environment risk and ecological shortage (UNEP 2011), or a tactics to generate an industry that does not pollute and require even more natural resources (Dittrich and Giljum 2012).

The aim of the green industries report is "to promote sustainable patterns of production and consumption, i.e., patterns that are resource and energy efficient, low-carbon and low waste, non-polluting and safe, and which produce products that are responsibly managed throughout their lifecycle" (UNIDO 2011, p. 9).

Figure 1 shows the sustainable manufacturing concepts evolution.

The concept of decoupling is very important in the process of greening industries. It occurs when the "growth rate of an environmental pressure is less than that of its economic driving force over a given period. Absolute decoupling occurs when the environmental pressures are stable or decreasing while economic growth continues to increase. Relative decoupling occurs when environmental pressures are continuing, but at a lesser rate than the economic variable" (UNIDO 2011, p. 15).

Dittrich and Giljum (2012) stated that decoupling refers to the environment impact in relation to material consumed. This methodology seeks redesign processes and decline impacts. It would be a new version of "cradle to cradle" analysis. This shift is characterized by a multi-disciplinary approach with a change in focus toward "systems" of production and use. It is a more integrated and systematic method; it is a good start onto sustainability, but not enough in long term. That is because the ambiance problems are

Pollution Control	*Treat* ↓	**Implementation of non-essential technologies** End-of-pipe solutions
Cleaner Production	*Prevent* ↓	**Modify products and production methods** Process optimization; lower resource input and output. Substitution of materials: non-toxic and renewable
Eco-efficiency	*Manage* ↓	**Systematic environmental management** Environmental strategies and monitoring, Environmental management systems
Life cycle Thinking	*Expand* ↓	**Extending environmental responsibility** Green supply chain management, corporate social responsibility
Closed-loop production	*Revitalise* ↓	**Restructuring of production methods** Minimising or eliminating virgin materials
Industrial Ecology	*Synergise* ↓	**Integrate systems of production** Environmental partnerships, eco-industrial parks

Fig. 1 Evolution of sustainable practices. Font: OECD (2010) apud (UNIDO, 2011)

already upward sustainable standard. Rich and poor countries must respond differently to the absolute decoupling (or dematerialization). Rich ones must act objectively. For poor countries, growth in material consumption will be needed, in order to achieve a minimum material standard. Just few countries, like Canada, Japan, Germany, Italy and the UK achieved an absolute decoupling. This does not mean green growth, "but also be the results of outsourcing material-intensive production to other parts of the world" (Dittrich and Giljum 2012, p. 34).

Eco-efficiency and eco-effectiveness are terms very important in this context. According to Gorobets (2011), there is a key difference between them. Eco-efficiency begins with the supposition of a linear flow of materials through industrial process. In this system, eco-efficient methods seek only to diminish the volume, speed, and toxicity of the material flow system, but are powerless in altering its linear progression. In contrast to this approach of minimization and dematerialization, the idea of eco-effectiveness proposes the process of products and their material flows, in a way that they form a supportive relation with ecological systems. The aim is not to avoid the cradle-to-grave flow of materials, but to create cyclical, cradle-to-cradle systems that enable materials to keep their status as resources and collect intelligence over time (upcycling). Van Caneghem et al. (2010) affirm that eco-efficiency is the way of production of useful, efficient and competitive products and services that progressively reduce ecological impacts and resource consume throughout the life cycle to a level of the earth's estimated capacity.

For this research, it was analyzed the methodologies and concepts above, and adopted the requirements more important for this case, according to PDP, before, during and after development, as follows. Before development: information on clean technologies; planning of product life cycle; acquisition of renewable raw material; and plan development process. During development: alternatives for raw material; forecast impacts of products; environment requirements in the project; alternatives redesign; design package; reuse system, subsystem and components; lifetime extension; processing with less impact; evaluation of existing impacts; eco marketing; and guidance for use and after use. After development: reuse system; reuse of part end components; reassembly, recycling, and proper post-conditioning use.

2.2 The product development process (PDP)

In the 1980s, environmental requirements began to be integrated in the (PDP), as an answer to the increasing social pressure for the incorporation of environmental management inside the strategic planning area of the industrial sector, looking for the sustainability of the production systems. PDP is a preventive and continuous strategy, with emphasis on the product, with the objective of assuring an improvement of the environmental performance of the company and the reduction in operational expenses, aside from enabling the socio-environmental certification and the access new market targets (Vezzoli 2007). The inclusion of environmental requirements to the PDP tries to answer the internal and external constraints of the company, such as the public policy for the rational use of the natural resources (the ones that occur naturally on environment) and for the pollution control. That is expressed in the form of (1) norms and laws; (2) the market will, formed by consumers and investors, which are gradually changing their values, becoming more "green"; (3) to the community interests; (4) convey through citizens and third sector actions, the need of reducing water and power consumption in the manufacture processes; (5) the adoption of less toxic supplies on the manufacture process; (6) and the volume reduction in hazardous waste, among others (Eshun et al. 2012).

When the environmental requirements are properly used in the PDP, they can contribute strongly to attend the new market demands. However, they turn the planning activity even more complex, making necessary that the professionals involved in the project become more trained and updated (Malaguti 2005).

In terms of economy, an increase in resource efficiency in production has become a core determinant of economic competitiveness and sustainable growth. Since resource is costly, efficiency improvements can be a significant point for competitive advantage (UNIDO 2011).

2.3 Brazilian furniture industry characteristics

According to capita income and material consumption, Brazil is classified between industrializing and service-oriented economies, and resource-based emerging economies (Dittrich and Giljum 2012). Its furniture sector is expressive, formed by more than 17,500 enterprises, source of 322.8 thousands jobs. These enterprises are in general familiar business, from the national capital, strongly segmented and straight. The industries are mostly located in the south and southeast of Brazil and produce house and office furniture (Movergr 2013).

The SMEs is inside the forest-based sector, which due to its characteristics is center of strong environmental references and requests, resulting from the public policy development toward the conservation of the natural resources. UNIDO (2011) stated that this kind of industry have considerable pressure on the environment. These companies are taking a long time to adopt efficiency measures, and the reasons are (1) they are often unaware of their negative impact on nature; (2) they do not know the environmental legislation affecting them; (3) they lack the professional to indentify and apply environment changes; (4) they have less access to loans end credits.

Plouffe et al. (2011) also wrote about the company size and its relation to the ecological issues "… adopting environmentally responsible strategies still elicits skepticism from industry, whose leaders question its cost-effectiveness. This is particularly true in SMEs which, because of the very nature of their operations, do not have the means necessary for integrating new constraints beyond their field of knowledge." Borchardt et al. (2011) also

observed that is not common to have small and mid-sized enterprises using eco-design and low-impact PDP process in their production. Market research revealed that the "key reason for lack of waste reduction by SMEs is due to the perception that there is low cost benefits in wood waste management, a lack of awareness and understanding and little or no direction about how to recycle the waste" (Daian and Ozarska 2009, p. 1594). Ammenberg and Sundin (2005) highlight that SMEs have very special needs to adapt environmental requirements to their productions.

Regarding to the professional issue, Massote and Santi (2012) and UNEP (2011) wrote that the adaptation (to a greener production) asks for structural change to adapt the system to the environmental requirements which demands changes in the training of professionals in this area for these functions. In order to support the progress in the application of CP, at least one person that operates these processes, the concepts and the phases must be appointed to execute the program, to lead the CP team, to monitor the CP program development, and to report on improvements and accomplishments. According to the staff qualification, Borchardt et al. (2011) wrote that some technical difficulties in production were related to a lack of qualified professional on eco-design tools and waste treatment technologies.

A good operational practice is to plan, implement and control the industrial process, and to do so, the production management team needs to have a good level of technological knowledge and abilities to bring the planned output level, cost quality with the objective of reducing wood waste among others of low impact (Eshun et al. 2012).

For EMS and DFE practices, it is mandatory to train and motivate the right professional to get involved (Ammenberg and Sundin 2005).

In relation to the raw material, there is a predominant use of wood from native and planted forests, plywood and reconstituted panels, such as fiber plies, chipboards, MDF (Medium-density fiberboard) and others (Gorini 1998). According to Daian and Ozarska (2009, p. 1595), "despite the fact that wood is the most abundant biodegradable and renewable material available, there are numerous reasons to optimize its utilization."

That is an important issue when environmental requirements on furniture industry are discussed, as found on important studies, as follows.

Eshun et al. (2012) studied wood waste in timber process and concluded that to reduce it is fundamental to decrease the contaminant environmental impacts such as global warming, eutrophication, acidification, smog and human toxicity. They also predict that the consumption of industrial wood worldwide will increase by 45 % in 2020.

Actual practices used for wood waste minimization are (1) the use of CNC machines; (2) the use of automated cutting equipments; (3) solid wood and panels ordered in specific sizes; (4) simple design that do not require excessive machining; (5) use good techniques and technology to provide good bonding such as high tech glues, finger joint, biscuit joints and lightning jointing (Daian and Ozarska 2009).

Eshun et al. (2012, p. 77) concluded in his research that combining "technological changes, good operational practices and recycling measures could reduce wood waste by approximately 50 %."

The wood waste generation is influenced by some technological-based factor, such as equipment size, type of equipment and efficiency. Obsolete and inefficient machinery consumes more wood, when compared with new technologies that are less polluting, uses all resources in a more sustainable manner and reduces waste in a more acceptable manner than the technologies for which they were substitutes (Eshun et al. 2012, p. 70).

3 Methods and material

This research took place in 2007, as part of Ph.D. research at São Paulo University.

3.1 Industries analyzed

The kind of furniture industry analyzed in this work produces MTO products, i.e., the consumer creates the size, design and decide the raw material, according to his necessities and budget. This kind of production process causes more preparation time and planning, comparing with the operation time, producing small batches of a great variety of commodities. Hills (1995, p. 490) defined: "MTO products can be characterized by their inherent complexity and by their nature as prototypes produced to an individual customer's requirement. (…) The characteristics of MTO products and the associated manufacturing and operational considerations imply a necessity for a wide range of particular design methods and tools."

3.2 Location

This study was developed in 18 companies that allowed the dissemination of the information, located at Itatiba municipality, 80 km away from the capital of São Paulo state, Brazil.

3.3 Research methodology

For this research, the case study methodology was used, i.e., an empirical study of the activities inside the job routine. This type of research is the best to carry out a study where there are complex and a variety of events and factors (Bonoma 1985).

For the data collection, it was made surveys and semi-structured interviews with open and closed questions with the three strategics levels of the company: direction (strategic planning), designer (project) and the production manager (execution), totalizing 54 interviews, and observations "in loco." It was verified, in each enterprise, all development stages of the furniture, since the arrival of inputs and raw materials, cutting planning, cutting, drilling, finishing, assembly and expedition shipping. At the end, a flowchart of the furniture processing is generated.

The method of company selection was intentional and non-probabilistic in an effort to help the qualitative collection of the information. For this purpose, they were selected using data from the Labor Union of the Furniture Industry, and from the database of "Itatiba furniture" program, carried out in 2004 by SENAC "*Luiz Scavone.*" Among the 20 companies founded, 18 agreed to take part of this research. The adopted sample size represents properly the Brazilian MTO furniture industry in an exploratory way. In order to avoid any inadvertent damage to the enterprises studied and to provide full confidentiality, all company names were coded as E1, E2, etc.

3.4 Characterization of the product development process (PDP)

A characterization of the PDP was made based upon a chronological analysis of the activities, with inputs and outputs, having as objective the development of a new product (Davenport 1994). Starting from this approach, it was possible to clarify the critical links

between this process and the environmental demands from internal and external factors of the company, as well as the interactions between the designer abilities and the information provided by the several functional sectors of the company, essential for the development of the products.

The stages of the PDP were designed sequentially, although, in the practice, this stages overlap and interact continuously. The modeling of the PDP includes other aspects as information flow for the decision-making and for the resources used in the process. This formal and integrated description of the process is useful for the construction of a reference model.

3.5 Identification of environmental requirements

The identification of requirements was based on the applied activities in the PDP. For each input and output system, the appropriate environmental requirements to minimize the impacts and enhance the product lifecycle must be presented (Malaguti 2005).

To do so, based on the specific literature related to the efficiency of the systems of product development, it was found the main environmental requirements related to PDP activities, as shown in Table 1.

Table 1 Stages of PDP, the professional responsibility and environmental requirements

Responsibilities	PDP activities	Environmental requirements
Director	Strategic planning	Information on "clean" technologies
		Planning of product life cycle
Designer	Project planning	Acquisition of renewable raw material
		Plan development process
	Informational design	Alternatives of new materials
		Market for sustainable products
		Forecasting impacts of products
	Concept design	Environmental requirements in the project
		Alternatives redesign
		Design package
	Detailed design	Reuse system, subsystem and components
		Lifetime extension
		Processing with less impact
Production manager	Preparation for production	Prototypes renewable materials
		Evaluation of existing impacts
		Alternatives to the process
Sales manager	Product launch	Eco marketing
		Guidance for use and after use
	Track product	Improve product performance
		Reuse systems
		Greater interaction with market
Director	Discontinue product	Reuse of parts and components
		Reassembly
		Recycling
		Proper post-conditioning use

Table 2 Concepts for estimating the environmental requirements

Concepts	Criteria for estimating the environmental requirements
Very bad	Not known and do not apply
Bad	Conceptual knowledge and fails to apply
Regular	Conceptual knowledge and applies partially
Good	Conceptual knowledge and to completely
Excellent	Implements innovative environmental practices and serves as a model

A list containing qualitative concepts to estimate the degree of the applied requirements according to the established criteria was used, as shown in Table 2.

On the final assessment, an average of every professional among the enterprises studied will be done. The association of the environmental requirements and the PDP stages allowed to analyze the motive factors related to the application of these procedures in the companies. This permitted the identification of which sectors and who managed the decisions inside the job routine of the enterprises, creating the integration process of environmental requirements in Brazilian MTO furniture industry.

4 Results and discussion

4.1 Characteristics of the studied furniture industry production system

According to the obtained data, the PDP of MTO furniture was identified inside each activity of the macro stages, responsible for the stages flow.

Since it is a production based on the MTO system, according to the customer needs, those requirements must be identified and transferred as project requirements, and this should be named the first step of the PDP. As soon as the enterprise is able to fulfill the customer requirements, the sales sector looks for some information to begin the manufacture of the project. The information that sales sector searches is: type of raw material, finishing, dimensions, preliminary budget, delivery deadline, suppliers.

It was sighted that the furniture production in the MTO enterprises uses hardwood as well as reconstituted panels randomly, or both types of material integrated, using the hardwood for the finishing grooves and ornaments and the panels for the main structure of the furniture such as doors, lateral sides, and coverage.

In Fig. 2, a flowchart represents the studied furniture industries development process down the MTO system, characterized by the pre-development, development and post-development macro stages.

The production flow (Fig. 2) represents the process stages, which begins with the customer, who talks with the sales department introducing her/his requirements for the furniture project, commonly based on personal opinions or decoration magazines, or even in some cases, they present a pre-design project. After complying with the customer needs, her/his requirements are communicated in the form of designs or sketches available in catalogs or magazines to the project sector. The salesmen interfere very little with the costumer decisions and desires.

In the project department, the design is remade with specialized software or manual tools, verifying the dimensions of the furniture, and when necessary, "in loco." The participation of the designer is restricted to the adjustment of the design to the standardized

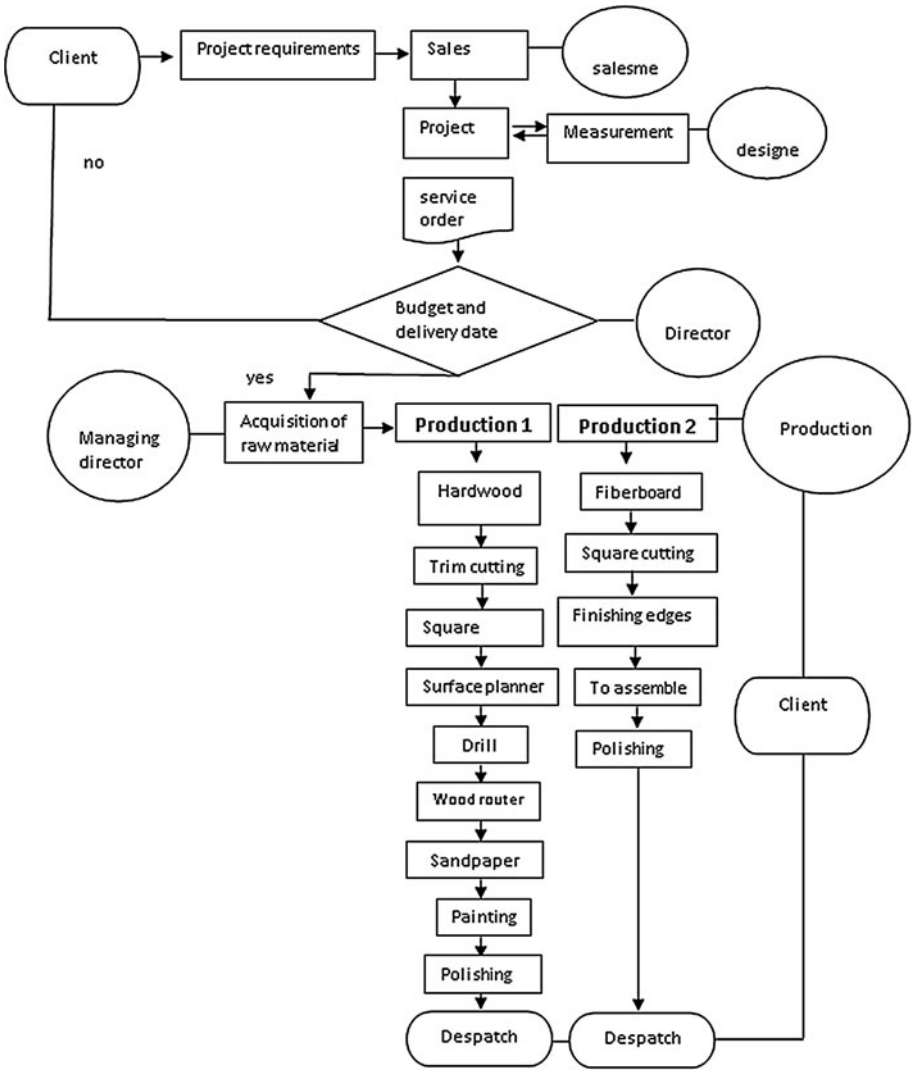

Fig. 2 The flowchart of furniture production process

lecture on the production system, accompanying a job order where the materials and the finishing of the furniture are specified. With all these things listed, the order is then given to the director, who makes the budget of the product and returns it to the sales department. After having the budget, the sales department gets in touch with the customer and informs s/he, about the price and the delivery deadline. If the customer wants to change something in the design or does not agree with the budget proposal, s/he will talk directly with the director until they make a deal.

When the job order and the project are in the production department, the manufacturing process begins. The first step is to classify the project inside the production line (1) or (2), according to the raw material needed for its manufacture: hardwood and panels. For the hardwood line, the pieces are cut, following with the surface planer and the flattening.

After, the piece passes through the wood router, the router and the drill. Finally it goes to the assembling and finishing steps, where the sanding, the painting and the assemblage of the furniture piece are made.

In the production flowchart, the stage containing more steps occurs in the hardwood furniture production (1). This enlargement of the number of steps reflects more costs, processes and waste generation, compared with the panel furniture production (2), which uses standardized pieces, with surface finishing, what makes it easy to work with, being necessary only to cut, stick and assemble. This shows how these companies are still concerned with the satisfaction of the customer needs and requirements related to the project. But the customers do not always demonstrate knowledge about sustainability processes or decide to buy a product with innovative solutions or that causes less environmental impacts. That is why the enterprise must improve the structure of their productive system and must create strategies to plan proactive actions.

4.2 Incorporation of environmental requirements in the PDP stages

About 60 % of the visited companies showed lack of initiative by joining the environmental requirements in the PDP, because they do not know these requirements or simply because they are not interested in adopting these practices. However, this outcome shows that there are plenty of possibilities to work with environmental practices in this sector.

Among the most important environmental requirements, these were found: the reuse of systems and manufacture components and the purchase of renewable materials originally from forestry management areas with official documents issued by governmental organizations that allow the exploration and transportation. Even more, because this is a MTO production system, one of the most important requirements for the customer is quality, durability and lifetime of the product. Marketing is another important component of these companies, looking for market place recognition, but this is not always reflected in an ecological efficiency in the production system.

The frequency of environmental requirements (Fig. 3) founded in the form of practices inside the enterprises is illustrated as follows.

The reuse of parts and components in the sector of furniture manufacture in Brazil is a wide-spread practice, being practiced in all the studied companies. This occurs because there is an awareness of the waste of the expensive raw material.

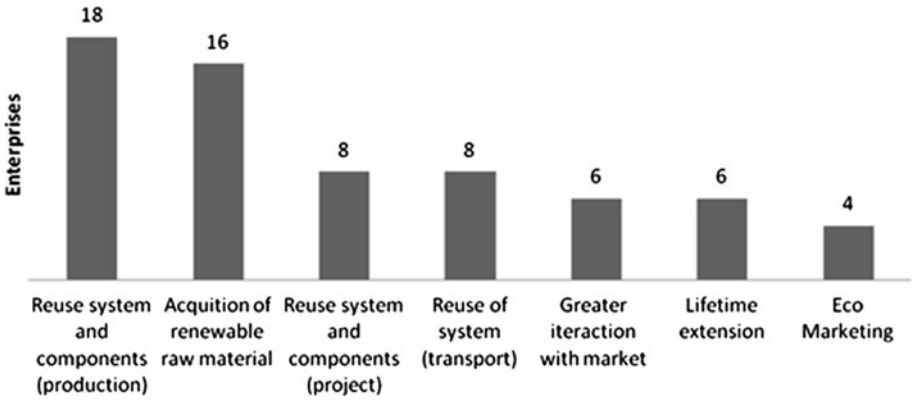

Fig. 3 Frequency of environmental requirements

Among all companies analyzed, 16 highlighted that the wood comes from renewable sources. On the other hand, the owners diminished themselves of any responsibility related to the other supplies used in the process derived from petroleum, largely used in the finishing stage, which are the main pollution factor in the process, because of the emissions (caused by lack of proper painting booths, extractors and filters). Most of the micro enterprises use painting booths with water curtains, not caring about the disposal of the untreated water, commonly directed to the public sewage lines.

Among 8 companies, it was identified two environmental requirements, looking for more efficiency: the reuse of systems, subsystems and components in the project and transport department. In the project department, it is common the use of computer software to model furniture or to adapt a demo project to the customer project, or from a previous project developed by the company. At the same time, there are some actions practiced at the transport department, like the reuse of parts from pieces damaged in the stocking stage. In some cases, they also reuse the logistic delivery systems and furniture maintenance, making a better planning that promotes time and expenses economy. This will also lead to the extension of the product lifetime, caused by the proper usage of suitable materials, looking for the best physical, chemical and mechanical functions that the product will have to bring, not putting at risk the esthetic of the product.

Only four enterprises studied mentioned the use of ecological marketing as an environmental requirement in the PDP. This occurs because of lack of information or because occasionally they exhibit projects at national and international events, in partnership with architects who use certified wood.

Most importantly, in practice, the requirements mentioned demonstrate how the company realize the lack of efficiency of production, generating high volumes of waste and by the end of the process, reuse or recover materials without compromising its image. Thus, verification of management control and evaluation of the manufacture stages of the furniture should be corrected or improved.

Table 3 presents an assessment of the environmental requirements mentioned above related to the macro stages of the PDP, qualified by insertion concept, and the people in charge of those involved sectors as well as their activities. The rating used is called Likert Scale, in which qualitative data is used to measure the enterprise application. The valuation is an average of the enterprises researched. See Table 2 for criteria.

The issue identified as "High," as seen in Table 3, was the reuse of parts and components because when the PDP ends, the quantity of materials used and the generated waste are calculated, then they are disposed near the enterprise and burned, to decrease the volume. Rarely, this waste is stocked for specific purposes, like small parts of small objects of decoration or from the structures as a way to reduce the waste.

When the theme in the furniture industry is the renewable raw material, the discourse is detoured to the harvest of hardwood coming largely from the north of the country, where most of them does not have a management forestry certification, needing extra care for its transportation due to the intense inspection and the consequent payment of fines. The issue is even worse when the topic is the use of plywood and reconstituted panels that in the first moment do not cause trouble, but after a time of use the disposal of these pieces becomes a problem, due to its hazardous components of them: adhesives made from urea–formaldehyde (UF) or phenol–formaldehyde (FF), harmful at the end of the product lifetime, when the material is burned or used for soil coverage or simply discarded in landfill sites.

For the directors of these enterprises, the waste use can be reverted as profit, looking again from an economic point of view overlaying their economic interests rather than the environmental ones. From the answers given by the companies regarding the

Table 3 Assessment of environmental practices within the PDP

PDP macro stages	Responsibilities	PDP activities	Environmental requirements	Concept
Before development	Director	Strategic planning	Information on "clean" technologies	Very bad
			Planning of product life cycle	Very bad
		Project planning	Acquisition of renewable raw material	Good
			Plan development process	Bad
Development	Designer	Informational design	Alternatives of new materials	Very bad
			Market for sustainable products	Bad
			Forecasting impacts of products	Very bad
		Concept design	Environmental requirements in the project	Very bad
			Alternatives redesign	Bad
			Design package	Bad
		Detailed design	Reuse system, subsystem and components	Regular
			Lifetime extension	Regular
			Processing with less impact	Very bad
	Production manager	Preparation for the production	Prototypes renewable materials	Very bad
			Evaluation of existing impacts	Bad
			Alternatives to the process	Bad
	Director	Product launch	Eco Marketing	Regular
			Guidance for use and after use	Bad
After development	Designer	Track product	Improve product performance	Bad
			Reuse systems	Regular
			Greater interaction with market	Regular
		Discontinue product	Reuse of parts and components	Good
			Reassembly	Bad
			Recycling	Very bad
			Proper post-conditioning use	Very bad

Table 4 Factors motivating and environmental requirements applied in enterprises

Requirements considered	Motivating factors for incorporation of environmental requirements	Type factor	No of Enterprises
Reuse of systems and components	Savings in design and process	Internal	10
Product durability (longer life)	Requirements of the consumer market	External	6
Raw certified or registered	Environmental legislation and resolutions	External	4
Eco Marketing	Increased competitiveness	External	2

environmental requirements, it was possible to establish the most important factors in the decision-making process of requirements inclusion. Important factors that motivate the SMEs to integrate environmental requirements inside the furniture projects are shown in Table 4.

The main internal factor mentioned by ten enterprises was one of the expense reduction in the project and in the process, relating it to systems and component reuse. This is visible in the direction, which is always looking for the reduction in expenses. Six companies presented as factors of the market requirements mainly related to the durability of the products adding environmental and quality values of the raw material as an exigency in the furniture manufacture.

As an external factor, the adequacy to environmental laws and regulations was mentioned, regarding the use of environmental requirements for raw material, demanding certification as well as harvest registrations and transportation licenses. This competition must be promoted by the use of ecological marketing, because "ecodesigned products provide greater satisfaction to consumers, who are increasingly sensitive to environmental issues" (Plouffe et al. 2011, p. 574). However, the benefits generated by the use of environmental requirements inside the PDP are noticeable, not only because of the market tendency, but as a form to optimize the production, reduce expenses, inclusion of actions to rationalize tools and materials used, and mainly, to be respectful to the natural capital that generates energy and supplies.

4.3 Professional qualification

As said earlier in this work, the adoption of PDP methodologies requires qualified staff. This is important due to the tasks involving the management of the activities in the PDP, and the changes in the current system are not simple.

The product designer is highly qualified to analyze processes, identify detours and production risks, include proactive practices inside the company, look for the innovation of the products and services and even manage projects and work groups. In Table 5, the professional performance, the sector and the MTO PDP model, largely used in these enterprises, are presented. All these aspects express a reality away from the ideal one.

A facilitator from model 1 (hardboard) works between the customer and the project designer, helping them to speed up the production processes, suggesting requirements and decreasing the production risks. For model 2 (panel), the project designer works redesigning the pre-projects from the sales department, not having the power to interfere in the decisions made on the previous stage. This scene difficults the inclusion of environmental requirements, causing at the same time a delay to release the project for the production process, because in most of the cases, the information from the sales department is

Table 5 Professional profile of Itatiba designers

Professional performance	Education program	Sector	PDP Model	Enterprise
4 years	Architecture	Project	2	E8
5 years	Industrial design	Commercial or sales	1	E5
5 years	Civil engineering	Commercial or sales	1	E14
7 years	Physical education	Commercial or sales	1	E1
7 years	High school	Project	2	E18
7 years	High school	Project	2	E18
8 years	High school	Project	2	E2
8 years	Mechanic engineering	Commercial or sales	1	E11
15 years	Civil engineering	Commercial or sales	1	E4
15 years	Architecture	Commercial or sales	1	E6
15 years	High school	Commercial or sales	1	E17
16 years	High school	Commercial or sales	1	E13
17 years	High school	Commercial or sales	1	E12
18 years	Accountant	Commercial or sales	1	E9
20 years	Law school	Commercial or sales	1	E7
20 years	High school	Commercial or sales	1	E15
21 years	Mechanic engineering	Commercial or sales	1	E16
35 years	Administration	Commercial or sales	1	E3

inadequate and new visits to the place where the furniture will be installed have to be done in order to confirm the information. In some cases, new visits of the customer to the store have to be done in order to solve doubts.

At the furniture center of Itatiba, among all enterprises visited, 15 are managed according to the model 1 of the PDP, and only one employee has a technical degree in industrial design. In other enterprises, the staff members have degrees in a variety of knowledge fields, such as physical education, management, engineering, law, accounting, or even, employees with a high school degree. These people can work with project because it was transmitted by the previous generation, or constructed over years of experience in the field (until 35 years).

In the enterprise E8, with model 2 of the PDP, even the professional of the project department (architect) has less experience (4 years) than those working in the other enterprises of the furniture center. The architect is able to include environmental requirements in the product project, without disappointing the customer demands, because he has autonomy to change the specifications and to look for innovative and less expensive solutions for the enterprise and for the environment. This happens because the enterprise has a strong organizational structure that integrates the work teams, assessing the activities and registering the mistakes.

Having qualified professionals as part of the staff of these companies is important because they are able to deal with the project development process and to interact with the production processes and systems to make feasible the insertion of environmental requirements and the change of consumption patterns. These will lead to the decrease in the impacts caused by the sector.

These results prove that the main challenge of the MTO furniture industries studied is the organizational structure of the companies, which has not yet identified the importance of hiring qualified professionals in product design, which enables the interaction between sectors in macro-phases of the PDP, favoring the improvement of the production system linked to the environmental sustainability.

5 Conclusions

From the indications found, it is possible to infer about the studied furniture industries that

- The environmental management is peripheral to core business, although operative policy can lead to great cost savings and trade opportunities for industries.
- There are gaps on the insertion of the environmental requirements in the PDP down the MTO system. Furthermore, there are possibilities of improvement and optimization of these systems for the furniture manufacture.
- The size of the enterprises causes the lack of investment in "clean" technologies for the final disposal, or responsibility for the post-sale of the products.
- The studied industries have not recognized the importance of appointing qualified professionals in the product design, and the professional responsible for project has other education program.
- Practical recommendations to achieve the sustainability for these industries are listed on Table 3, at the "Environmental requirements" column.
- The studied companies are fairly far from the relative decoupling, when the environmental pressures of their production are continuing, but at a lesser rate than the economic variable.

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