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INTEGRATION OF ENVIRONMENTAL CRITERIA IN THE CO-DESIGN PROCESS: CASE STUDY OF THE CLIENT/SUPPLIER RELATIONSHIP IN THE FRENCH MECHANICAL INDUSTRY

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1. Introduction

The product development process has widely evolved for the last decades. While this activity used to be mainly realised internally to a company, suppliers have been more and more integrated to their client's development process [Barreyre 1998]. This tendancy results in the increase of products complexity which leads companies to focus on their core activity [Stephan and Schindler 2011]. Delegating some stages of the developpment process is also a necessity to reduce development costs while maintaining a high level of quality [Clark and Starkley 1988]. If their role was limited in the manufacturing stage until the 80's, suppliers are nowadays more and more integrated from the early stage of client's product design process. A worldwilde survey on 238 companies shows thus that 50% of the "leader" companies in their industrial domain settle a "black box" design [Kearney 2004]. In this configuration, suppliers are in charge of the detail design according to the client preliminary specifications [Clark and Fujimoto 1991].

Integration of environmental considerations in such a development process where suppliers reached a high level of influence could be viewed as an important challenge. Indeed it is assumed that the majority of environmental impacts on the product along its life is heavily influenced by design choices made in early stages of development [Dewulf 2003]. Hence design choices made during the conceptual stage determine the potential influence of product on the environment across its whole life cycle. If we consider that up to 80% of components of a client's system may be provided by suppliers , the environmental performance of the system is tied up to suppliers' work. In order to be efficient, environmental issues must be dealt with all stakeholders committed in the design of the system at different levels. This influence has been identified by Johansson who highlights the potential benefits of suppliers' design choices on the client's system [Johansson 2002]. Stakeholders also become an important source of information which are required to bring the environment into the product design process [Aschehoug et al. 2012]. Because of the growing influence of suppliers on the client's product design, reaching consistent and efficient eco-design actions at the supply chain scale implies a minimal collaboration [Personnier et al. 2013], with at least the exchange of some environmental information. However studies concerning place of the environmental issue into the client/supplier relationship are scarce.

The research question of this paper is how is the environmental issue is incorporated in such a multi actor design process. It is assumed that this evolution modifies the classical taken into account of the environmental issue. In the section 2, a literature review enables to identify potential barriers that may occur and lead to the weakness of collaboration between clients and suppliers. In order to conclude on

the validity of the hypothesis, an empirical study has been performed with twenty companies of the French mechanical industry as described in the section 3. The purpose is to identify industrial practices concerning first (1) the integration of the environment in their design process, (2) the nature of the common environmental client requests and (3) difficulties to take into account this issue in the client/supplier relationship. Findings will be provided in section 4 and discussed in section 5.

2. Environment in the client/supplier relationship

Building a close partnership between the client and its suppliers is usually recognized as a strong necessity [Goffin et al. 2006]. The emergence of environmental issues in the client/supplier relationship reinforce this need of close collaboration. Life cycle thinking and the idea that design choices influence the impact of product on environment implies to broaden the design process consideration scope. But this multifaceted issue is complex to handle for a majority of companies [Vallet et al. 2013]. Designers have difficulty to appropriate this issue and to integrate it in their everyday activities [Lofthouse 2006]. The management of environment requires also a minimum of awareness, expert knowledge, human and financial ressources [Reyes and Millet 2013]. What are the characteristics of the barriers while suppliers are increasingly integrated in the client's design process? In such a configuration, the typology of companies involved in the same design project is various and their capacity to integrate such a complex issue is changing. If large companies generally have sufficient ressources and maturity towards the environmental issue, this is not the case for smaller strutures as SMEs [Le Pochat et al. 2007]. This may lead to a difference in the capacity of treatment of the environmental issue, especially with regard to one of the key activities being the environmental assessment. The first step of an ecodesign approach is indeed to make an environmental assessment to gain knowledge about environmental impacts linked to the product throughout it life cycle [Collado-Ruiz and Ostad-Ahmad-Ghorabi 2013]. Since it is standardized [ISO 2006] the LCA method is the most acknowledged environmental assessment method in industry. But performing an LCA is complex and time-consuming [Tingström and Karlsson 2006]. Because of wide range of necessary information concerning various parts and components, LCA is difficult to apply in practice, especially for complex systems [Arena et al. 2013]. In such a co-design context, the question is how integrated is the LCA methodology in the client/supplier relation: which type of company implements such an approach? Are suppliers requested to use LCA by their clients ? Which kind of data do suppliers provide? Do the suppliers succeed in providing the suitable information? How are the results of the assessment methodology implemented in the design process? Is this method adapted for all actors in such a design context?

This paper tackles an existing gap in literature, which is mainly focused, so far, on the way firms internally incorporate the environment into their design process. But the growing influence of suppliers in the client's design process requires to widen the scale of studies. It is proposed to identify by an empirical survey in the mechanical industry, means of integration of environment in such co-design process. The research question is thus: "How are environmental criteria implemented in the client/supplier relationship?". The objective is firstly to characterize means of incorporation of the environment in the client's design process and objectives targeted. Secondly it is to study how clients rely on suppliers to conduct their ecodesign actions. The nature of environmental requirements will especially be investigated. Our hypothesis is that the difference of maturity regarding the environmental issue limits exchanges of environmental information between the actors of the supply chain. This leads to the weakness of the integration of environmental issue in the client/supplier relationship.

3. Industrial Survey

3.1 Research methodology

An industrial survey has been conducted in order to test the aforementioned hypothesis. This was done by studying practices of some French industrial companies with the support of the Cetim (Technical Center for the Mechanical Industry) (Figure 2). Companies were selected to get a variety across three relevant features: position in the supply chain, size and sector. Concerning the position in the supply

chain, three main categories could be defined: (1) integrators which are on the top of the supply chain and which control the design of a system but delegate some stages of the design process to both; (2) systems/components suppliers which develop a susb-system from client requirements; (3) equipment and raw materials suppliers which sell their products to clients in a pure purchasing context. Another category clusters companies which are not integrated in a client design process as companies which directly sell their product to customers (B to C). It appears that 70% of the industrials interviewed belong to three mains sectors : aeronautics, automotive and railway.
Targeted respondents are environmental experts who are in charge of the management of environmental issues in the product design process and potentially in the client/supplier relationship. A total of fifty environmental experts have been approached, twenty of whom have agreed to answer a semi-structured open-ended interview. The profile of these experts may be classified into to three main categories. Firstly, eco-design engineers or LCA practitioners who mainly focus on environmental issues linked to the product. Secondly, environmental managers/engineers who are interested in a site approach but also manage product environmental issues. Thirdly, project engineers who manage environmental issues in addition to other activities (e.g. in small entities as SMEs).
The first part of the interviews aimed at defining the context of the company (size, type of product, partners, position in the supply chain). The second part was designed to identify environmental issues companies have to face up, methodologies or tools they set up and how it is done during the design process. The purpose is to analyze how clients rely on their suppliers in order to carry out the internal process. The third part is thus dedicated to the core question, i.e. the characterisation of the environmental data exchange between clients and suppliers through the identification of the nature of clients' requirement and the identified difficulties. The results of the three main parts of the interviews are presented in the next section.

3.2 Findings of the industrial survey

3.2.1 Integration of environment in the development product process in the French mechanical industry: Modalities and levers

The main driver for the integration of environmental issues in the design process appears to be the environmental regulation or sectorial norm conformity (Figure 1). Reaching the minimum legal requirement fixed by the EU regulations is the main objective for all surveyed companies, whatever their typology.

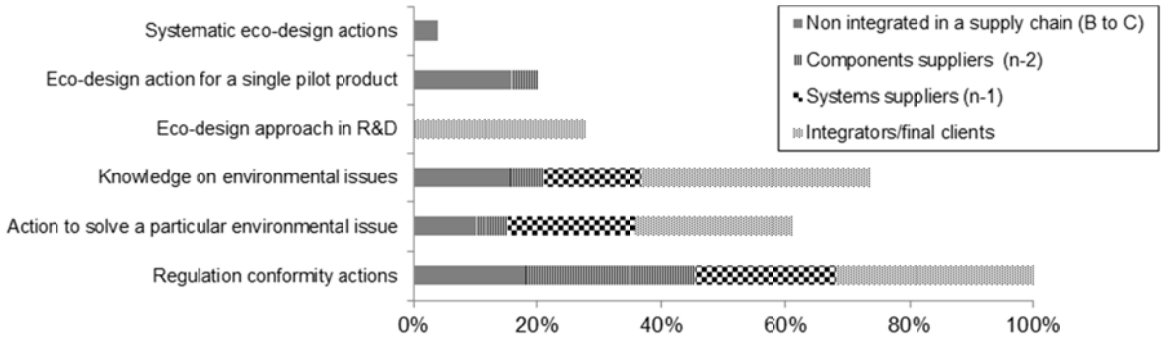

Figure 1. Typology of environmental actions

Then it appears that a majority of companies settle punctual actions to solve a particular environmental issue of the product life cycle. These actions are focused on the treatment of a specific environmental issue such as end of life, energy consumption reduction during manufacturing or management of hazardous susbstances obsolescence. Another frequent activity is the product environmental assessment to gain knowledge about the environmental performance of product. Evaluating the product and getting the awareness of environmental issues is usually considered to be the first step of an ecodesign approach.

Company	Size	Type of application	Sector	Position in the supply chain	Interviewees	Department/person in charge of product environmental issues	Department in charge of the relation with clients	Service in charge of the relation with suppliers
1	750 staff, part of a multinational group	Aircraft Components	Aeronautic	Component supplier : - of aircraft integrators - of aeronautic components manufacturer	R&D engineer	Local HQE department	None identified	None identified
2	Multinational, more than 10000 employees	Civil aircraft	Aeronautic	Integrator	Eco-design engineer	Eco-design department	Client portofolio and the project manager with the support of the eco-design department	Purchasing department with the support of the eco-design department
3	SME, 100 staff	Surface treatment	Aeronautic Automotive	Service supplier : - of aircraft and automotive integrators - of aeronautic and automotive components manufacturer	Manufacturing leader		None identified	None identified
4	Multinational, 7500 staff	Aircraft Systems	Aeronautic	System supplier for aircraft integrators	Eco-design engineer	Eco-design department integrated in the group technical management team	Client portofolio and the project manager with the support of the eco-design department	Purchasing department with the support of the eco-design department
4	Approx 1000 staff, part of a multinational group	Aircraft Systems	Aeronautic	System supplier for aircraft integrators	Sustainable development leader	Sustainable development leader	Client portofolio and the R&D department	Purchasing department with the support of the sustainable development leader
6	Multinational, more than 10000 employees	Automotive	Automotive	Integrator	Recycling leader	Eco-design department	None identified	None identified
7	Multinational, more than 10000 employees	Automotive	Automotive	Integrator	Ecodesign and LCA leader	Eco-design/LCA department	None identified	None identified
8	Multinational, more than 10000 employees	Automotive	Automotive	System/componant supplier for automotive integrators	Ecodesign and recycling leader	Eco-design/recycling department	None identified	Purchasing department with the support of the eco-design department
9	Multinational, more than 10000 employees	Raw material	Multi-sectorial	Raw material manufacturer	Head of department sustainability	Sustainable development department attached to the R&D	R&D department in charge of client portofolio	Purchasing department with the support of the sustainable development department
10	multinational, more than 10000 employees	Train	Railway	Integrator	Ecodesign leader	Eco-design department	Client portofolio and the poject manager with the support of the eco-design department	Purchasing department with the support of the eco-design department
11	Multinational, more than 10000 employees	Train	Railway	Integrator	Ecodesign engineer	Eco-design department	Ecodesign department with the support of the project manager	Ecodesign department with the support of the purchasing department
12	SME, 120 staff, entity of an european group	Train components	Railway	System/component supplier for railway integrators	Project engineer	Project leader	None identified	None identified
13	More than 10000 employees	Transport service	Railway	Final client	R&D environment leader	Sustainable development department attached to the R&D	None identified	Environment department with the support of the purchasing department
14	Multinational, more than 10000 employees	Power plant	Energy	Integrator	Ecodesign engineer	Eco-design department	Client portofolio and the project manager with the support of the corporate environment department	Purchasing department with the support of the support of the corporate environment department
15	Multinational, more than 10000 employees	Industrial equipments	Energy	System supplier for electricity producers and distributors	Ecodesign engineer	Eco-design department	None identified	Purchasing department with the support of the eco-design department
16	Approx 700 staff, branch of an european group	Industrial equipments	Multi-sectorial	Industrial equipment manufacturer	R&D leader	Environment department attached to the R&D	None identified	Purchasing department with the support of the eco-design department
17	Approx 1000 staff, part of a multinational group	Consumer products	Furniture	Equipment manufacturer for consumers	Ecodesign engineer	Eco-design department	None identified	Purchasing department with the support of the eco-design department
18	SME, approx 100 staff	Industrial equipments	Multi-sectorial	Industrial equipment manufacturer	Project engineer	Project leader	None identified	None identified
19	500 staff	Industrial equipments	Logistics	Industrial equipment manufacturer	Project engineer	Project leader	None identified	Purchasing department with the support of the project leader
20	SME, approx 100 staff, part of a multinational group	Consumer products	Multi-sectorial	Equipment/tool manufacturer for consumers	HQE engineer	HQE engineer	None identified	None identified

Figure 2. Characteristics of interviewed companies

A relatively small percentage of companies (exclusively large clients) has initiated an ecodesign approach in the R&D stage and more rarely in the commercial project. By ecodesign approach, it is meant that the knowledge acquired through the product assessment is reused to improve the environmental performance of the product. Distinctions have been made to separate (1) the moment when the environmental knowledge is reused in the design process and (2) the frequence of settlement of ecodesign actions.

3.2.2 Implementation of environmental assessment approaches in the supply chain

The survey shows that the LCA methodology is the most frequently used assessment methodology. Figure 3 highlights that it is exclusively used by large companies such as integrators and system suppliers. It must be noticed that only companies involved in a supply chain have been studied, those

which are in relation with customers or not integrated to their clients' design process have been excluded. It could also be said that component suppliers mainly implement simplified assessment methodologies based on easy-to-collect qualitative data.

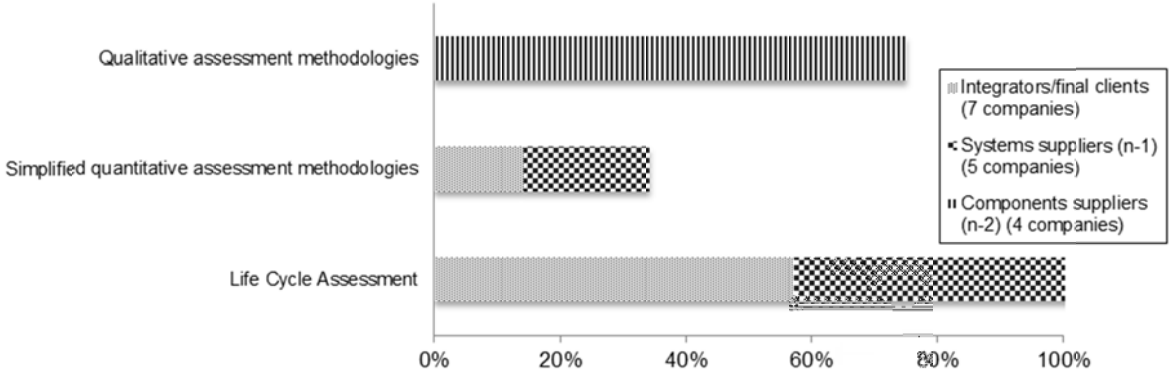

Figure 3. Use of environmental assessment methodologies according to the position in the supply chain

It is now focused on the exploitation of the LCA results by the 13 companies which implement this methodology (Figure 4). For the totality of the sample (large companies), LCA results are mainly used to commnunicate on the environmental performance of a product according to the ISO 14025 standard.The second main usage is to improve the knowledge on environmental issues linked to the product. A minority of companies implement this knowledge on the product developpement process in an ecocodesign perspective in their R&D stage, enabling developed technologies to be evaluated. Companies more rarely resort to LCA results for their current project, as opposed to R&D projects.

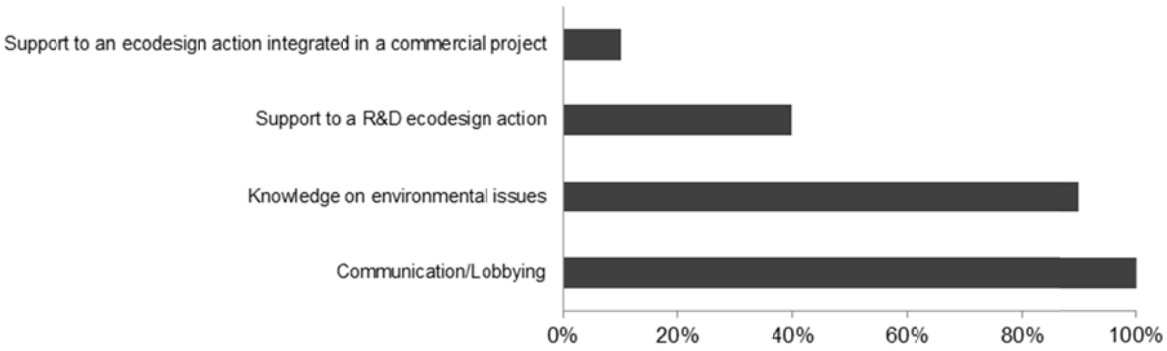

Figure 4. LCA results exploitation

3.2.3 Characterisation of environmental data exchange in the supply chain

This sub-section presents environmental requirements from clients to suppliers identified in the French mechanical supply chain (Figure 5). Major requirements concern the conformity to the environmental legislations, especially to REACH and RoHS. Suppliers are requested to provide a proof of conformity either by a simple declaration or by lists of substances contained in the product. Requests on recycling rate (related to the ELV), energy consumption during the use phase (related to the EuP), or end of life treatments (related to the WEEE) are clustered into the 'Information concerning some life cycle aspects' category. Client's requests are directly related to the environmental legislation constraints.

Even if the LCA methodology is commonly used by large clients, requirements concerning data for the LCA elaboration are relatively poor and incomplete. Data can be divided into 3 classes. Firstly data concerning materials (nature, mass, recycling rate) are named "bill of material" in Figure 5. An important discrepancy appears between sectors which automatically exchange information through a material database (e.g. the automotive sector) and those which do not as the aeronautics. Secondly, there is Life Cycle Inventory data (LCI) which consists in input and output flows linked to the product

during its life cycle. It concerns a wide range of data from the energy consumed for the raw material transformation to the emission of pollutants during the transportation stage or the manufacturing at supplier's plants. Finally, some large system suppliers (mainly from the automotive or the railway sectors) provide environmental impact data to their clients.
Some clients, especially from the automotive sector, directly integrate to their design brief some environmental objectives that the supplier needs to comply with. This relates for exemple to a mass reduction or to the performance of demontability.

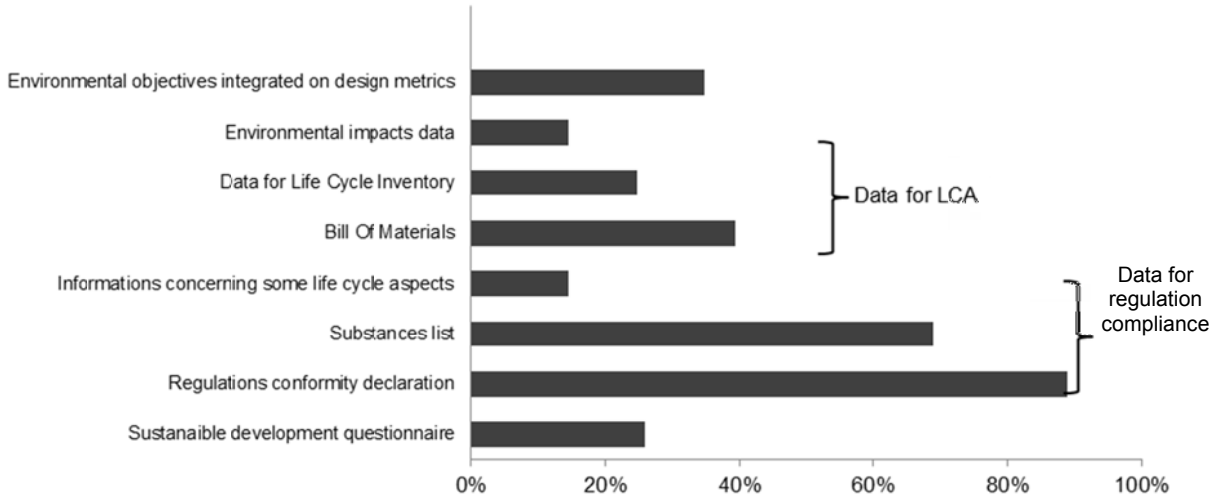

Figure 5. Environmental requirements from clients to suppliers

Except for regulation issues, environmental requirements from clients are relatively poor while methodologies they use require a large amount of data from their suppliers. Clients and suppliers have been interviewed concerning the weakness of environmental information exchanged. From the client's point of view, generic environmental databases are sufficient for the elaboration of LCA studies and demands to suppliers are not needed as a rule. Yet clients may have requests about some specific processes or materials, which are not covered by databases. In this case, clients point out the difficulty for suppliers to provide reliable data due to a lack of knowledge and resources (both financial and human). Data reliability arises when the supplier itself conducts an LCA study (with his own rules that are not sufficiently explicit) and directly provides results though environmental impacts data. The access to environmental data is also difficult when the supplier is more powerful than the client (e.g. for raw materials suppliers). The survey also hightlights a limitation due to the insufficient link between the purchasing department in charge of the relationship with the suppliers and the environmental department. Environmental issues are thus left to the margin and are not integrated to the client/supplier relationship.
For suppliers, the confidentiality issue is emphasized as they do not wish to provide information that is too closely related to their know-how. Futhermore suppliers (especially SMEs) do not have the ability to settle expert quantitative methodologies which are costly and time consuming, while the economic constraints are important. They also point out limited clients' requirements, which does not encourage them to settle ecodesign actions with a perilous return on invest. The lack of comon strategic vision shared with the client is also reported.

4. Discussion

4.1 Weakness of environmental exchanges in the client/supplier relation

As highlighted in the findings, suppliers are poorly sought by their clients except concerning environmental legislation aspects. It may be the direct consequence of (1) the weak integration of

environmental criteria in clients' product development process (both system integrators and large system suppliers) and (2) the limited capacity for small suppliers to manage the environmental issues.
Firstly, it appears that apart from aspects related to European regulations, the environmental issue is poorly integrated in the design process in the French mechanical industry. Generally, actions to integrate environmental considerations are limited to ensure the minimum legal requirements initiatives as investigated by Boks [2006]. It also confirms that environment is managed as a constraint or a design criterion and not as a functional requirement [Deutz et al. 2013]. For instance, the sector which has the higher degree of environmental commitment (the automotive sector) is also the one concerned with the highest regulation pressure. The main consequence is that, beyond the market position (B to B or B to C) or the firm typology (large or SME), the factor which mostly influences the eco-design practices is the belonging to an industrial sector and the associated level of regulation pressure. The survey shows a difference of regulation or norm pressure across the different industrial sectors. If regulations about hazardous substances (i.e. REACH and RoHS) are largely considered in all mechanical sectors, other regulations exclusively affect some specific sectors or type of products. For instance the average fleet pollutant emission norm and the ELV regulation specifically concerns the automotive industry. The WEEE regulation is limited to the electronics products. As mentioned previously, the automotive sector experiences the strongest pressure in the mechanical sector. On the contrary, because of security and reliability reasons, railway and aeronautics sectors benefit from exemptions. Futhermore, as hightlighted in the Figure 1, systematic and long term ecodesign actions are scarce especially for current projects where pilot actions are mostly funded by public or community budget. Moreover, the ecodesign actions established are often limited to the product environmental assessment. Assessment results are mainly used in a communication perspective more than to support an ecodesign approach through the product development. This weakness of systematic eco-design actions integrated in the whole development process (and not limited to the R&D stage) is predominant for large clients. Large companies of the mechanics industry are not sufficiently mature to internally integrate ecodesign actions beyond the R&D stage. Consequently, this issue is absent of the client/supplier relationship and the low environmental requirements materialize this weakness. Findings point out that small and middle size component suppliers in a B to C context are the ones who mostly set up eco-design actions for commercial projects. In a survey about economic benefits tied to ecodesign, it is argued that SMEs have a higher success rate than large companies [Plouffe et al. 2011]. It could be explained by the higher flexibility of SMEs in identifying potential benefits of eco-design opportunities. On the contrary, Plouffe et al. show that the B to B sector is more sensitive to eco-design products while in our survey it is shown that the more mature companies belong to the B to C sector. Face to the lack of clients' requests, B to B companies are poorly appealed to the clients while B to C firms could communicate easily on their eco-design approach toward consumers and get a higher rate of profitability. However, these results are mitigated by the limitation of the survey sample, which is relatively reduced comparing to its heterogeneity (in particular due to a lack of feedback from SMEs). Indeed this needs to be expanded in oder to confirm the last hypothesis.
Secondly, findings about the use of the LCA methodology points out an other important consideration: the difficulty for suppliers (especially for the smallest ones) to provide basic environmental information needed by clients. As shown in Figure 3, the LCA methodology is mainly used by large clients who have appropriate expertise. Smallest suppliers establish some qualitative and simplified methodologies in order to assess their products instead of using the quantitative LCA methodology. Hence it exists a clear link between financial and human capacities and the ability to settle the expert LCA methodology. In this context, providing the quantitative data needed by the client to conduct its LCA is difficult for suppliers. Consequently, face to the supplier's unability to provide reliable data, clients prefer using generic databases instead of asking suppliers. The weakness of LCA data exchanges is the most detectable symptom highlighted, but the survey also shows that information related to regulation constraints is identified as a barrier by some clients. Suppliers are indeed not sufficiently aware of the environmental issues and are devoided face to such basic requests. It is especially true for SMEs which do not have the ability (for financial reasons) to internally get the proper expertise.

4.2 Towards a deeper integration of the environmental issue in the client/supplier relationship

Findings point out the limited introduction of the environment in the client/supplier relationship, as assumed in our hypothesis. The low ability for suppliers to manage the environmental issue and the lack of clients' requests are identified as the two factors causing this situation. In this part we will focus on elements which might improve it.

Improving the ability of low mature suppliers to face up to the environmental requirements from their clients is an important challenge. From a reactive behaviour, suppliers should evolve towards a proactive one. They must outweight their passive role of environmental conformity providers to become a force for proposal towards their clients. It is also essential that suppliers could handle the potential economic benefit of the environment through a valorization of their proactive approach. Furthermore, client corporate buyers seem to be more aware of ecodesign products than consumers [Plouffe et al. 2011]. In a B to B context, suppliers may thus stand out against their competitors and thereby gain a competitive advantage. Beyond external drivers as clients' requests, internal drivers such as development opportunities are powerful incentives to eco-design [Van Hemel and Cramer 2002]. Furthermore environmental regulations quickly evolve: as the scopes widen, the exemptions that could benefit some sectors or typology of products would end in a near future. Some sectors, which were withdrawn as aeronautics, are more and more concerned by environmental issues. In order to face up to the future requests, suppliers may have the possibility to anticipate them. The challenge is to allow small suppliers reaching the minimum level of awareness in order to manage the environmental issue, while they are limited by low resources and unsufficient expert knowledge. Adopting a sustainable approach is long-term and unpredictable and firms as SMEs have difficulty in starting such an approach [Reyes and Millet 2013]. In this context, the need for both guidance and information is strong [Johansson and Magnusson 2006].

Clients' behaviour may also evolve. Suppliers are more considered as mere providers of environmental information than design partners who could, by their design choices, influence the environmental performance of the clients' systems. The classical client/supplier relationship confines supplier to be executants of tasks defined by the clients and enhances the reactive approaches toward the environment. In such a relation, the supplier's competencies and know-how are hidden. Findings uncover the fact that, without any client's requirement, some highly motivated suppliers have started with ecodesign approaches by themselves. Suppliers have thereby gained an experience that would benefit their partners. Clients should thus consider their suppliers as a potential driving force, as a ressource to help them achieve their own objectives. Accordingly, clients should be aware of the level of maturity of their suppliers for both (1) identifying how the supplier might be a resource and (2) adapting their level of requirements.

5. Conclusion and future work

In this paper we have investigated how the environment is taken in account in the client/supplier relationship. This issue is particularly important given the growing influence of suppliers' design choices on the environmental performance of the client's product. An empirical study has been performed with twenty companies of the French mechanical industry from SMEs to large multinational companies. The survey highlights the weakness of environmental information exchanges between the different actors, yet comitted in the same design process at different levels. This situation both results from the poor clients' requests, which are mainly focused on regulations conformity, and from the limited capacity for low mature suppliers to provide the basic environmental information to the clients. This lack of communication leads to an absence of ecodesign actions involving both the client and its suppliers. More empirical studies with other mechanical companies will be conducted in order to refine the findings. The sample size will be widened in order to avoid the limitation of the data interpretation, especially to corroborate findings about the B to B and B to C markets. Studies will also be more focused on SMEs, unsufficiently represented in the current study. In order to ensure the validity of the findings linked to the French context, the sample will be broadened at the European level. In parallel, some additional interviews will be carried out to study the integration of environmental criteria in clients' purchasing practices. Indeed it has been highlighted the insufficient link between the purchase department in charge of the relationship with suppliers, the environmental

department and the design team. The role of the purchase department seems to be an additional barrier which limits the integration of the environmental issue in the client/supplier relationship, and hence appears to be worth investigating.
This study has been carried out to identify global trends, to understand the research context and could be viewed as a first step towards our proposal. From a top-down approach where suppliers play a passive role, it is thus suggested a bottom-up approach where suppliers become a force for proposal and anticipate the future requests of their clients. Our future research work will focus on defining a roadmap to bring suppliers to this proactive statement. A two-step methodology and a support tool are being developed. The objective is to allow French mechanical companies, whatever their maturity, to autonomously use this tool, with the support of eco-design experts from the Cetim technical center at the beginning of the training phase. The first part of the methodology firstly consists in a diagnosis tool which allows companies identifying the potential clients' requirements regarding several factors such as: environmental legislations; sector initiatives and common practices; clients' and competitors' maturity towards environment and the product design context in which they are involved. Thanks to the diagnosis tool, companies are able to identify the future environmental issues they will face up to and to find guidance for their strategy and investments. The second part is a management tool to guide low mature companies to manage these requirements thanks to: a choice of relevant methodologies and tools; the internal resources they should mobilize; the nature of environmental information expected from suppliers; the way to promote actions towards their clients. We advocate that improving the supplier's environmental position is the first step for setting up an ecodesign approach at the scale of the supply chain.

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