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Proposal of an eco-design approach based on an inventory of fixtures: Case of agro-equipment SMEs in Benin

Jannot Hounsounou[1*], Gontrand Bagan[2], Emile Sanya[3] and Peggy Zwolinski[1]
[1]Polytechnic Institute of Grenoble, Laboratory G-SCOP, 46 avenue Felix Viallet, 38031 GRENOBLE Cedex1, France
[2]School of Rural Engineering, National University of Agriculture, Laboratory LEMA, 01 BP 2009 COTONOU, Benin
[3]National University of Sciences Technologies, Engineering and Mathematics, Laboratory LEMA, 01 BP 2009 COTONOU, Benin
hounscornet@gmail.com

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Abstract

The rise of environmental issues is encouraging mechanical manufacturing companies to integrate the environmental dimension into the design process of their products. In developing countries, small and medium-sized enterprises are recognized globally as the most job-creating and economic growth processors. However, they have shortcomings in using the eco design approach to eco innovate. In Benin, small units, agro-equipment developers, are facing enormous difficulties due to the lack of acquisition of sustainable design concepts. The present work aims to present in detail an eco-design approach and show how it meets the needs of OEMs. All this, in order to provide customers with particular values of use and appeal on the one hand and, on the other hand, to equipment manufacturers, competitive differentiation and economic value. The "Innovation for Breaking and Sustainability (IBS)" approach is a combination of "Design for Sustainability: D4S", "Conception of Equipment in Southern Countries for Agriculture and Agri-Food, Method: (CESAM) And "environmental assessment technique of standard NF E 01-005" with the traditional methods of design and manufacture of these units, in order to reinforce their efficiency.

Keywords: Eco-design, D4S, cesam, NF E 01-005, agricultural and agri-food equipment.

Introduction

Taking the environment into account from the product design stage has recently become a new requirement of the company's strategy, either because it integrates it as an additional constraint or because it makes it a competitive advantage by anticipating the future market evolution and pressure from society[1]. In Africa in particular, the integration of eco-design into product development and design is an under-exploited and under-researched factor. It causes socio-economic, technical and even political problems[2]. Field survey work in Benin, a West African country, has revealed that eco-design of agro-food equipment still poses major problems for small and medium-sized enterprises. The effective integration of such a design approach in a southern country like Benin must be incremental[3]. Standard NF E 01-005 proposes a standard environmental assessment technique for mechanics. This standard quantifies and reduces the use of raw materials, energy and waste production during product design and manufacture. In such a country of the South, by what strategic approach can we choose an agro-food equipment and quantify the three environmental aspects of the standard NF E 01-005?

In order to contribute to solving the question of integration of eco-design in the South, in Benin, this study focused on the proposal of an eco-design method. The method makes it possible to choose and evaluate the environmental aspects of equipment based on the standard "NF E 01 - 005" and other design methods such as "CESAM and D4S". This article, after introduction and conclusion, presents in detail the proposed eco-design method and shows how it meets the needs of manufacturers and customers in the parts: materials and methods and results.

Methodology

We carried out a methodological approach consisting of using two (02) information collection boxes: the Information Collection Matrix (ICM) and the Integrated Eco Design Method (ECM). The information collection matrix groups information from questionnaire and semi-directive interviews. As for the box of eco-design method, it includes information related to methods and tools of eco-design. An intelligent combination of information from the (ICM) and (ECM) boxes gives birth to a new IBS method, "Innovation for Breaking and Sustainability", adaptable to our realities. During the literature review, we selected three relevant methods: enriched D4S, enriched CESAM and standard NF E 01-005.

Design for sustainability "D4S" enriched: The enriched D4S method is an evolution of the D4S method. It allows the re-design and environmental assessment of equipment with a tool called SIMAPRO. The implementation of the enriched D4S method is carried out in Fiji on a backpack for schoolchildren. It facilitated the use of the backpack and reduced environmental impacts during the design and manufacture of the backpack. The SIMAPRO tool contains only European, Swiss and American databases. The method is also implemented in Benin. The execution time is approximately two (02) to three (03) months. The difficulties revealed the need to have a database to better implement the method.

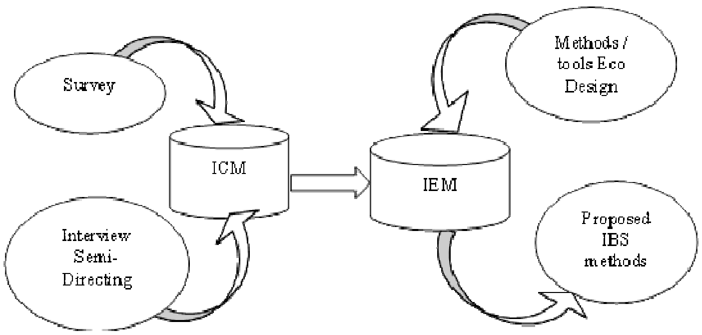

Figure-1: Graph of the research methodological approach.

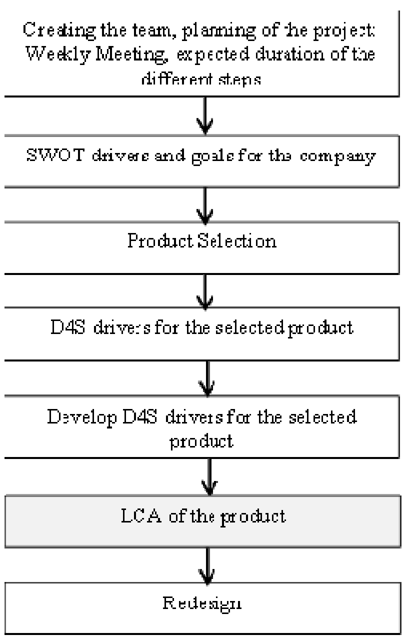

Figure-2: Graph of the "enriched" D4S method[4].

Equipment Design in Southern Countries for the Production of Agricultural and Agri-Food Machinery, Method (CESAM): The enriched CESAM method is a scalable method that provides integration of manufacturing into design. It allows the designer to integrate industrial engineering tools such as: Design for Manufacturing (DFM), Design for Assembly (DFA), Design for Economy and Manufacturing (DEM) and Quality Functional Deployment (QFD). It facilitates the optimization of the equipment as well as the manufacturing process. The enriched CESAM method contains advanced Industrial Engineering tools whose application in the South is complex. This is a method that does not take into account the environmental assessment of the equipment. The CESAM method is implemented in Burkina Faso and can also take about two (02) to three (03) months.

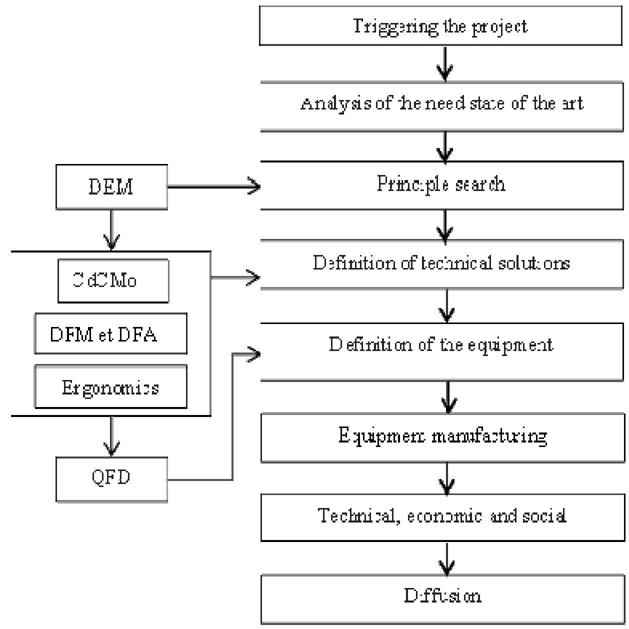

Figure-3: CESAM enriched by methods for integrating manufacturing[5].

Standard NF E 01-005: The standard NF E 01-005 comes from the project XP E 01- 005 which results from the discussions of the commission of the National Unions of the French Mechanics. The project is subject to final verification until January 31, 2009 before sending it to AFNOR for publication as an experimental standard. It proposes a pragmatic approach of eco-design particularly adapted to SMEs. It is addressed to companies already aware of the issue of integration of environmental aspects in the development and design of products. Standard NF E 01-005 is designed for mechanics and implemented in France in small and medium-sized enterprises on agro-food machines.

Results and discussion

We have proposed an eco-design method adaptable to the realities of southern countries in general and Benin in particular. The Innovation for Breaking and Sustainability (IBS) method stands for Innovation for Breaking and Sustainability (IRD). It is divided into three main parts: eco design approach, eco design tools and actions to perform. This is an approach that intelligently combines design methods for the developing country CESAM enriched, enriched D4S and a conventional and pragmatic method of analysis for mechanics (NF E 01-005). Without the use of costly methods or life cycle analysis software (SIMAPRO, EIMER, GABI, etc.), we can easily implement the IBS approach in small and medium-sized enterprises (SMEs). This will optimize the design process, manufacturing and reduce the cost of equipment to eco design.

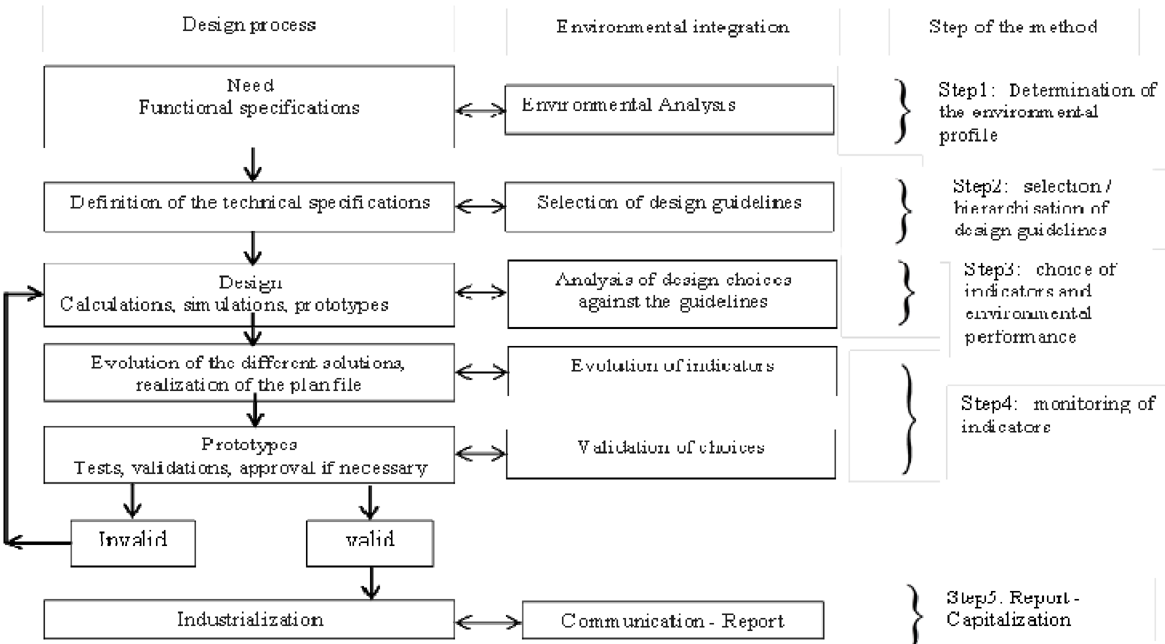

Figure-4: The Eco-Design Methodological Approach: Environmental Product Analysis[6].

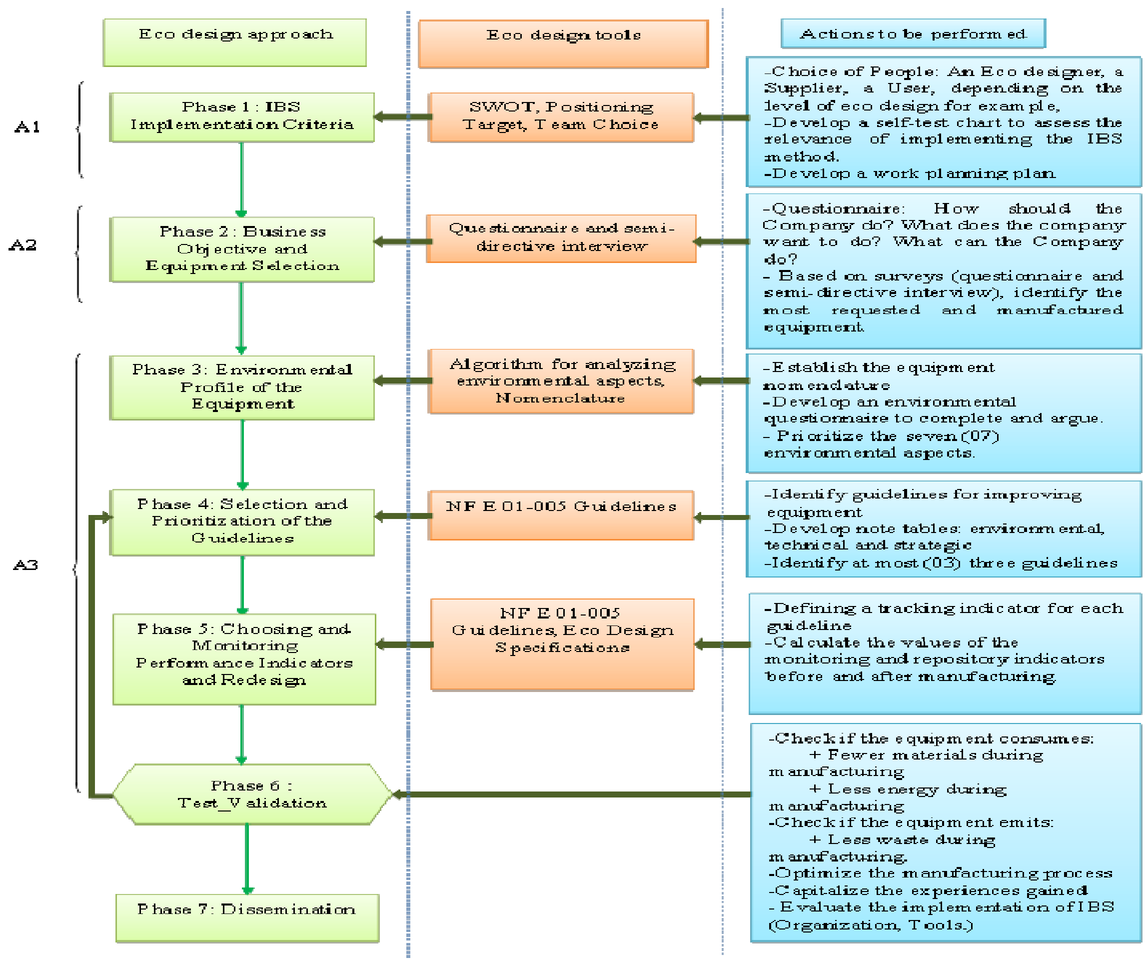

Figure-5: Organization chart of the "Innovation for Breaking and Sustainability (IBS)" method adapted to Benin (3E: Environmental Evaluation of Equipment).

Eco design approach zone: This is the part of the IBS method that includes seven (07) phases split into three axes.

Criteria for implementing the IBS method (First Axis): This involves establishing a questionnaire and reinforcing a semi-directive interview to get in touch with the company or companies that want to integrate the concept of eco-design into their design. Then evaluate the implementation of the eco-design approach. Finally, if possible evaluate the members of the eco design team.

Objectives of the company and choice of equipment (Second Axis): It's about knowing the purpose of the company or companies from the questions: i. How should the company do? Due to environmental law requirements or customer requests. ii. What does the company want to do? Due to reduced costs, improved market situation or corporate responsibility assumed. iii. What can the company do? Depending on the financial and human resources available and the product innovation capacity.

With regard to the equipment to be eco-designed, it is a question of choosing in the database and in complicity with the company or the companies the equipment to eco-design with accuracy.

Environmental Equipment Profile (Third Axis): In this phase, it is a matter of prioritizing the following seven (07) environmental aspects:

Raw materials (PM): appearance related to the choice of materials, components (purchased), fluids used in the composition of the product (excluding packaging).

Manufacturing (F): aspect related to all processes necessary for the development of the product and components (excluding packaging), internally and externally (number of parts, "polluting" operations).

Use (U): aspect related to all the resources necessary for the use of the product (energy-consuming product, energy source, energy interaction with a set, product requiring consumables, maintenance, service life of the product).

End-of-Life Recyclability (FV-R): aspect taking into account the reduction of the impact of the end-of-life product and its recyclability rate.

Dangerous substances (S): appearance related to substances contained in the product and likely to penalize the end of life of the product (heavy metals, flame retardants, fluorine atoms, bromine, chlorine).

Transport (T): aspect related to the geographical distribution (regional, national, global) of the number of suppliers and subcontractors, to the shipping volumes.

Packaging (Emb): aspect taking into account the number, reuse, recyclability, biodegradability of packaging.

The hierarchy of the seven (07) environmental aspects is carried out in four (04) stages namely:

First step: This is to establish the nomenclature of the equipment to be eco-designed using the matrix above.

Second step: At this stage, it is a question of filling in the environmental questionnaire by answering all the questions by the only choices proposed in the questionnaire (the "do not know" answer is considered as the most unfavorable case). Then, we must argue the answers used to establish the environmental profile of the product or equipment and to define design tracks. It should be noted that the answers to the questions indicated by an asterisk make it possible to realize the environmental profile of the product from the analysis algorithm. The answers to the other questions are used to feed the company's thinking about the design guidelines and intervene in the overall assessment. The environmental questionnaire that the company must fill out is based on standard NF E 01-005. It is recoverable through hounscornet@gmail.com for free.

Third step: This is the stage where the analysis algorithm has to be applied from the answers to the questionnaire questions. It is a pre-established flow chart that, based on environmental issues, identifies and quantifies the environmental level of the seven (07) environmental aspects. The analysis algorithm is shown as indicating the trees of Figures-6, 7, 8 and 9.

Table-1: Nomenclature of eco-designed equipment[7].

Piece	Quantity in the product	Unit weight	Total mass	Material	Associated coefficient of recyclability	Recyclability rate (%)	Identified Dangerous substance	Supplier address
Unit								
Total piece								
mass produced		Identified product mass						
% mass product identified				Product recyclability rate				

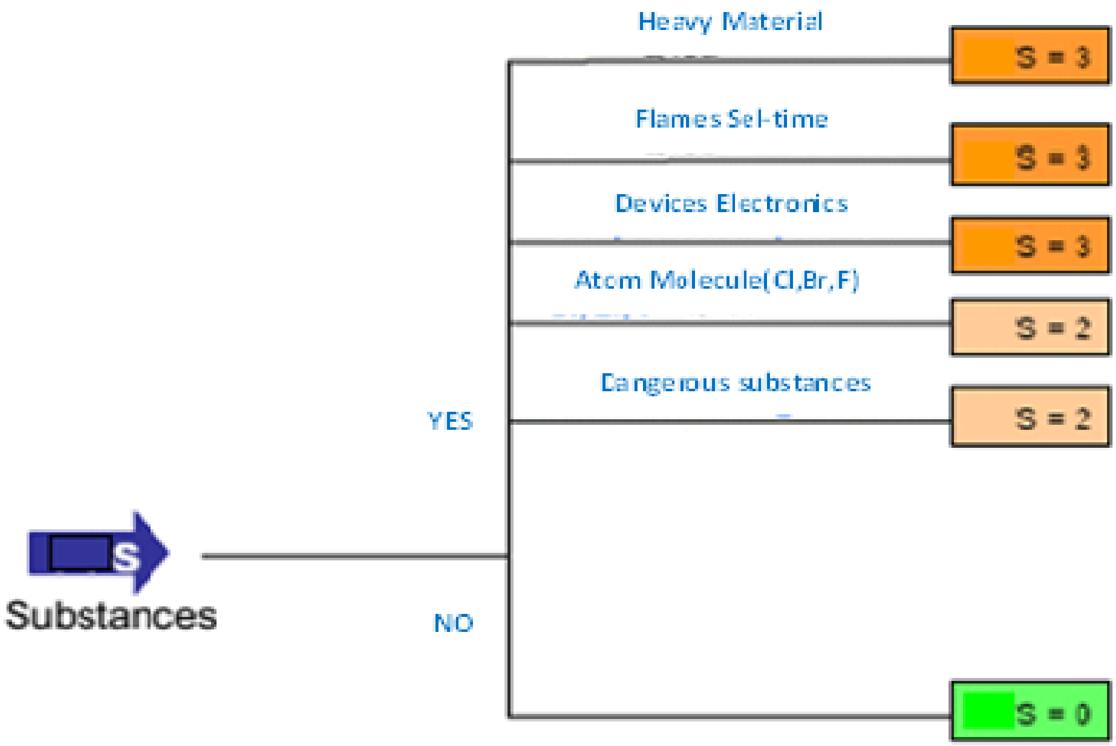

Figure-6: Decision tree for the environmental aspect S[7].

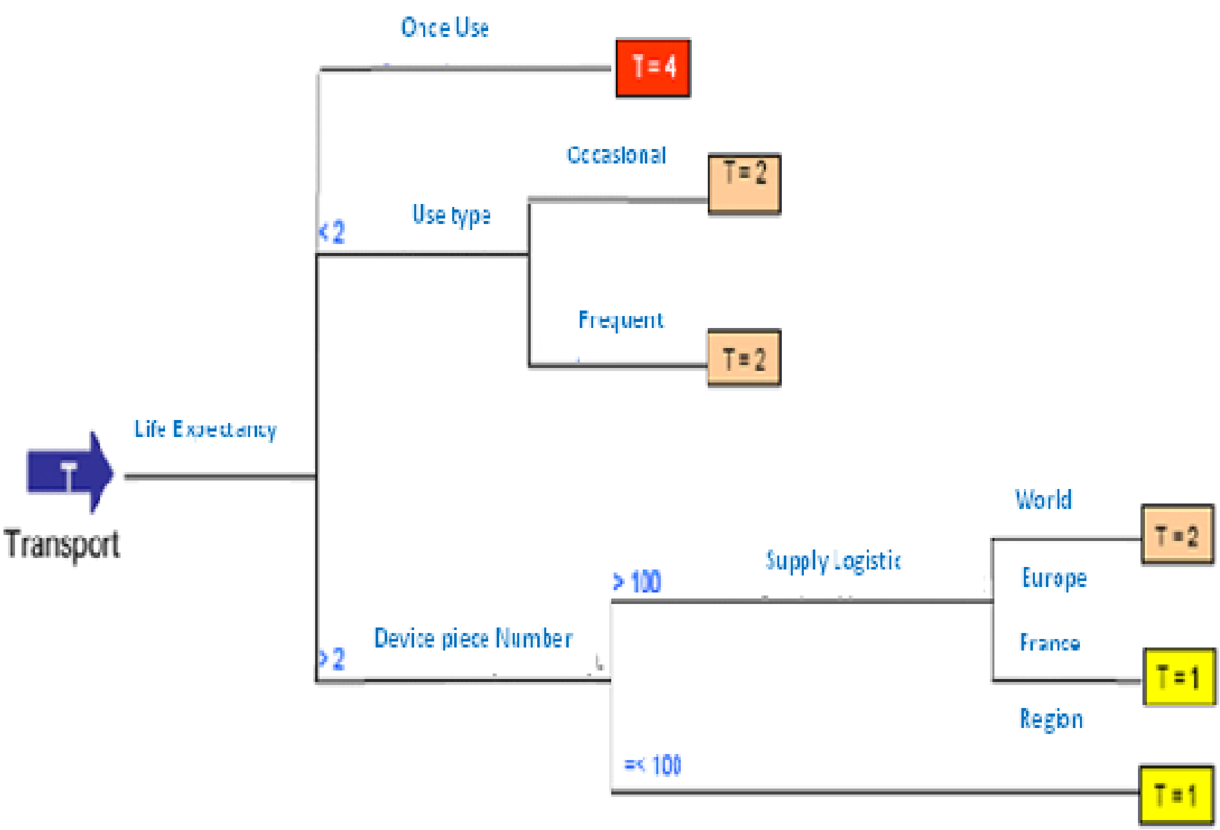

Figure-7: Decision tree for the environmental aspect T[7].

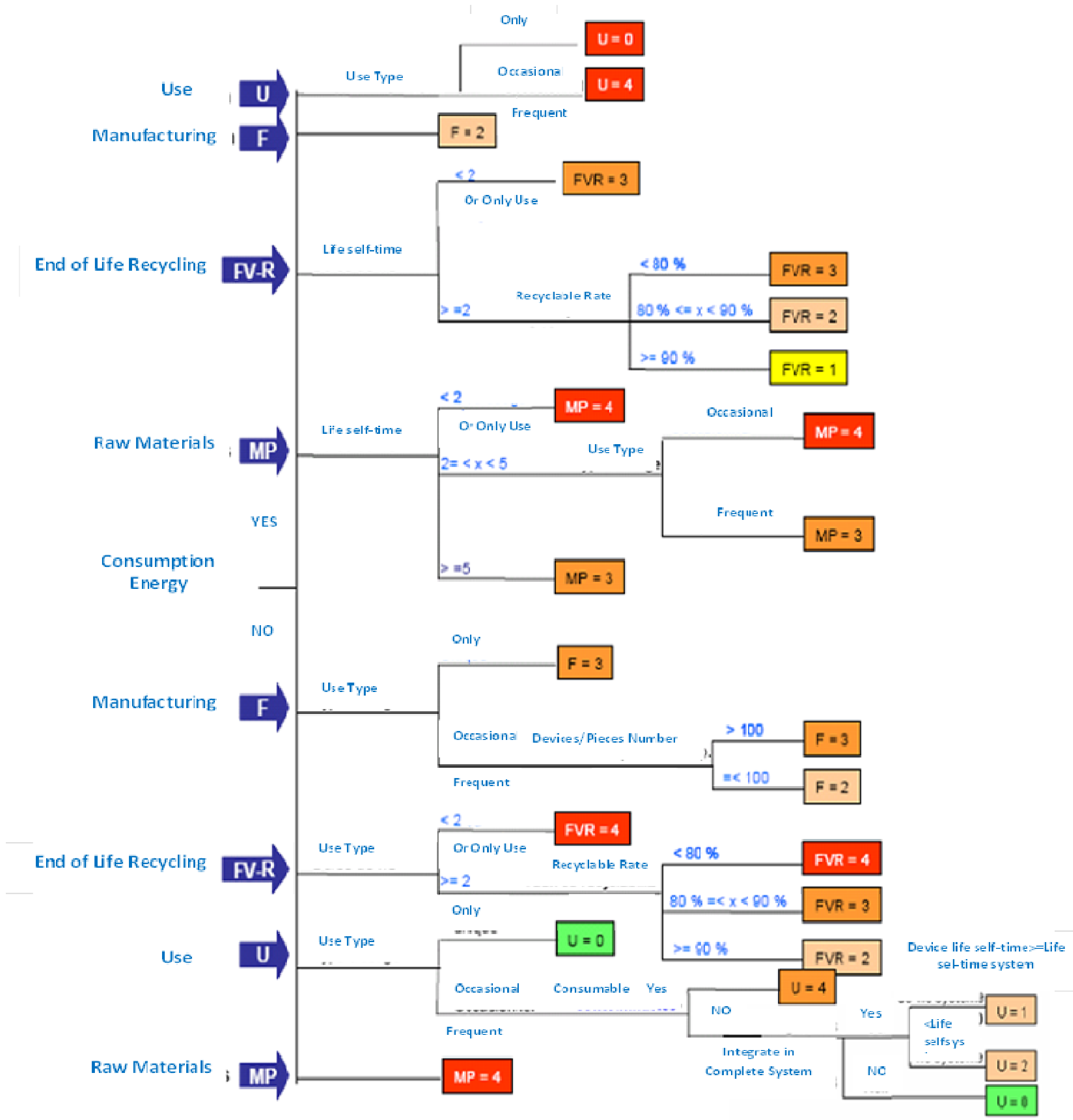

Figure-8: Decision tree for environmental aspects MP, F, U and FV-R[7].

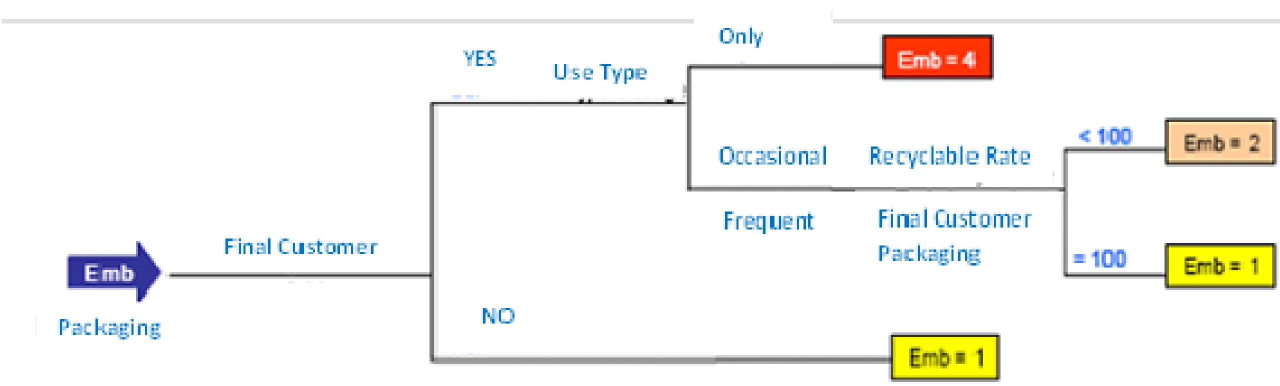

Figure-9: Decision tree for the environmental aspect Em[7].

Fourth step: This is the step that makes it possible to note the results obtained for each of the environmental aspects. Often the results are represented by graphs to express the level of impact of one aspect with respect to the other.

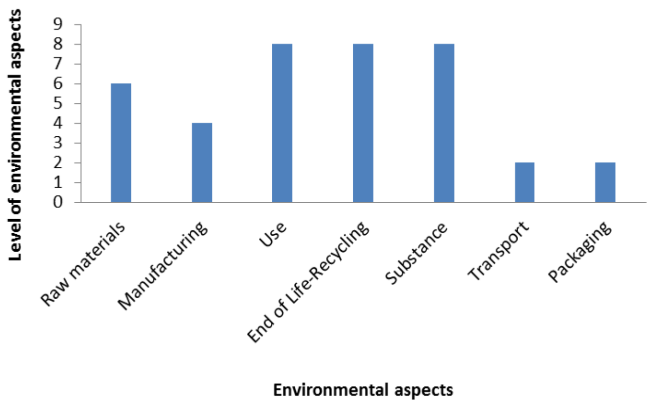

Figure-10: Hierarchy Graph of Aspects[7].

Selection and prioritization of the Guidelines: For each of the environmental aspects resulting from the environmental profile phase of the product or equipment, relevant Guidelines should be proposed for the environmental improvement of the product and prioritized taking into account other technical, economic, and technical constraints. strategic, related to the design project. The tables below summarize the strategies that can be implemented for each of the environmental aspects, and identify the Generic Guidelines (specifying, where applicable, the question numbers of the environment questionnaire). A choice of monitoring indicators and corresponding benchmark indicators is proposed. This phase of the IBS method is carried out in two stages.

First step: This step involves the selection of the applicable Guidelines for Environmental Improvement of Equipment taking into account the economic, technical and strategic constraints of the design project.

Second step: This step consists of prioritizing the relevant Guidelines that must be proposed for the environmental improvement of the product or equipment taking into account the economic, technical and strategic constraints related to the design project. The hierarchization of the Guidelines (LD) is done by a system of weighting. The weighting system consists of assigning three (03) notes to the environmental aspect concerned. These are the notes: The Environmental Note: assign to each Environmental Guideline (LO) the environmental rating of the environmental aspect to which it is linked as reflected in the environmental profile. The table below presents the environmental notes.

The Technical Note: eliminate technically irrelevant Guidelines (LD) from a technical point of view to keep only the technically feasible Guidelines (LD) even if this involves significant Research and Development (R & D) efforts. Note the Guidelines (LD) based on concrete ways of improvement for the product studied (these tracks can be identified from the knowledge of the product); also rely on the tools available in the company (Brainstorming). The technical notes are presented in the Table-3.

The Strategic Note: assign the strategic grade determined, a priori, by the management of the company and / or the members of the project group, according to the strategic interest of the guideline considered. The Strategic Notes are presented in the Table-4.

Table-2: Environmental Note[7].

Environmental note = Given by the environmental profile	0	1	2	3	4
	Guidelines not selected	Guidelines irrelevant	Guidelines moderately relevant	Guidelines can be selected	Guidelines selected in priority

Table-3: Technical Note[7].

Technical note	0	1	2	3	4
	Solution not technically feasible - no possibility in customer specifications	Solution that can't be eliminated from a technical point of view, but may face other heavy constraints (heavy investment, qualification / requalification, security, etc.)	Solution a priori possible but preliminary study in R & D necessary. Medium long term	Existing technical solution-feasibility to be tested - cost of implementation not insignificant	Solution technique achievable within a quick delay and an acceptable hit

Table-4: Strategic Note[7].

Strategic note	1	2	3
	Conflicting solution with other strategic areas of the company or with the customer's specifications	Solution "neutral" strategically in terms of image (compared to other sectors of activity, societal pressures...)	Solution of priority strategic interest: (regulation / specification / customer requests, savings on certain stages of the life cycle ...)

As the objective of an eco-design project is in principle to reduce the environmental impacts of the equipment life cycle, it is logical to attribute to the Environmental rating an importance at least equal to that of the technical and Strategic. The rating is to be repeated each new product design because the ratings, (including technical note) can change from one design to another. The Guidelines repository (LD), which represents the set of Guidelines (LD to follow, is established by retaining at least one Guideline (LD) with the highest Environmental score and possibly eliminating the Guidelines (LD) with the lowest rating to arrive at a reasonable number The definition of the number of Priority / Mandatory Guidelines (called LDPs) for the eco-design specifications is done according to the ranking in descending order for each of the environmental aspects It is advisable not to choose more than 3 priority guidelines (LDP) for more precise prioritization.

The final grade of each of the Guidelines is obtained by applying a formula chosen by the project group. The final grade reflects the importance that the project group attaches to each of the criteria and therefore assigns weight to each of the Environmental, Technical and Strategic ratings. The table below presents the final scores for each environmental aspect.

Choice and monitoring of environmental performance indicators: This phase of the IBS method consists of first choosing the environmental performance indicators and following the monitoring of the indicators:

First phase: This is the phase of the choice of environmental performance indicators. Each Priority Direct Line (LDP) must be associated with a qualitative or quantitative indicator, called the "Follow-up Indicator", which allows the various possible scenarios to be followed during the design phase. This indicator can be associated with a target. The target can be determined by comparison to equivalent products. Each of the relevant Environmental Aspects (EA) must also be represented by a so-called "Repository" indicator, which together forms the environmental reference of the product. The objective is to maintain a multicriterion vision of the environmental quality of the product in its evolution in order to detect possible drifts including on "Minor" Environmental Aspects. It is not mandatory to characterize each "Tracking Indicator" quantitatively for its definition for each Priority Guideline (LDP). A trend (increase or decrease) may be sufficient to make a decision. If applicable, the "Reference Indicators" of the insignificant Environmental Aspects (very low environmental score) and over which the company has no action (Technical Note = 0) should not be retained. A "Repository Indicator" can be a combination of "tracking indicators". If there is only one Priority Guideline for the Environmental Aspect concerned, the same indicator is used for the repository if it is representative of the environmental impact of this aspect. It must be ensured that the tools associated with the monitoring and reference indicators are developed and operational within the project. Also, the quantitative indicators must be calculated as soon as possible.

Second phase: This is the monitoring phase of the environmental performance indicators. The design choices should be evaluated using the monitoring indicators specific to each of the guidelines in order to confirm the defined orientations, to identify possible problems and to propose the necessary actions. Throughout the design process, it is important to take into account the monitoring indicators for the Priority Guidelines (LDPs) and to check their relevance. When designing, care must be taken not to degrade the "benchmark indicators" of the most significant Environmental Aspects (Environmental Rating = 4).

Test –Validation: It involves implementing the IBS method and making remarks from the point of view of organization and tools used. Then check if the equipment consumes less material during manufacturing, less energy during manufacture and use. Finally, check if the equipment emits less waste during manufacture and use.

Dissemination: It is about putting the eco-designed equipment within the reach of the user (s) or customers.

Eco design tools: This is the part of the IBS method that includes the eco design tools associated with the steps of the design approach part.

SWOT tool: The SWOT tool (Strength, Weakness, Opportunities, Threats) allows you to summarize the strengths, weaknesses, opportunities and threats related to the company concerned. The questionnaire and semi-structured interview facilitates this collection of information.

Table-5: Final Score Matrix of the Guidelines[7].

Final notes of the guidelines	0	1	2	3	4	5	6	7	8	9	10	11
Environmental aspect												

Table-6: SWOT Matrix[7].

Internal factor	Company Forces	Weakness of the company
External factor	Business Opportunities	Threat of the company

Positioning tool: When the positioning of the company is defined, it is necessary to act accordingly, and it is not systematically relevant to immediately embark on the implementation of eco-design. The success of the approach is based on the positioning of the company's strategy in a given context. From this fine knowledge of the global situation, we can size the project to the extent of multiple issues. In other words, the synthesis of opportunities and strengths or capacity of the company makes it possible to evaluate the relevance of investing in the eco-design approach and / or to identify the sensitive points to be improved before launching.

Team Selection Tool: Depending on the stakes, and the desired degree of eco-efficiency, it is interesting to select the members of a team based on the tool: Position statement. It is a tool that provides information on the degree of intensity of the eco-design approach: Low eco-efficiency (simple optimization) to strong eco-efficiency (system innovation). The team members vary from 1 to 10 depending on the intensity of the process. The tool gives the profile of the team members to involve. The figure below shows the team selection matrix.

Algorithm tool for analyzing environmental aspects: At this stage, it is a question of filling in the retrospective environmental questionnaire at hounscornet@gmail.com free of charge by answering all the questions by the only choices proposed in the questionnaire (the "do not know" answer is considered as the most unfavorable); to argue the answers, which are then used to establish the environmental profile of the product and to define design options.

Equipment Nomenclature Tool: It is a matrix that makes it possible to make an inventory of the various components of the equipment (nature of the materials, the number of the material in the equipment, the unit and total masses, the dangerous substances, coefficient of recylability associated, rate of recyclability, name of the supplier, location of the supplier).

NF E 01-005 Guidelines Tool: These are guidelines of the standard NF E 01-005 intended to choose the guidelines to be associated with the environmental aspects.

Eco design specifications: It is a matrix that makes it possible to take stock of the environmental aspect (associated guideline, total rating, priority, monitoring indicator, reference indicator, pilot function, associated tools, monitoring indicator value, reference indicator value, and commentary).

Table-7: Eco-design cluster decision-making tool[8].

-capacities+	Yes the company is mature enough, But there is a need for further studies on possible opportunities.	Yes, you have to start an eco-design process. Yes, provided you identify crucial issues in terms of eco-design.
	No, the priority is to build skills, structuring myself to better identify opportunities and be able to provide answers.	Yes, there is real potential, But, it is necessary to structure the approach, to sensitize and train the teams and to allocate a budget.
	-Opportunities+	

Table-8: Eco Design Team Selection Matrix[8].

Intensity of the approach	Low eco-efficiency Strong eco-efficiency Simple Optimization → System innovation									
Team choice n °	1	2	3	4	5	6	7	8	9	10
Team to involve	Designer +	Production +	Environmental service +	after sales service +	Commercial (Sell and return customer) +	Strategic marketing +	Others (Quality, Logistics, Purchase, ...) +	Supplier and sub-contractor +	Customer representative (s) +	Political and / or leading bodies
Contribution	Essential	Important	Important	interesting	interesting	innovative	specific	Co-design	Precision customer need	a new organization
	Investment of the leader In the eco-design approach							Eco-design pole		

Table-9: Tool Guidelines NF E 01-005[7].

Environmental aspects	Strategies	Guidelines	Tracking indicators	Repository indicators
Raw materials	Select materials with lower environmental impact	Use materials with lower CO_2 content	CO_2 content (Kg CO_2 equivalent)	Environmental impact % mass of recycled
		Use renewable materials (Q3)	Number, mass,% of renewable materials	
		Use recycled materials (see supplier) (Q2)	Number, mass,% of recycled materials	
		Use recyclable materials	Number, mass,% of recyclable materials	
		Use materials with lower energy content	Local energy content (MJ / product) or by material (MJ / kg of material)	
	Reduce the use of materials	Reduce in weight	mass (kg)	
		reduce in volume	Volume (l,m^3)	
	Develop new concepts	Dematerialize the product, offer services	Number of rented products	
		Plan for shared use of the product: 1 product = multiple users	Average usage rate (n use product / day) Number of people with access to the product (pers / product)	
		Integrate new features into the product	Number of functions by product	
		Perform a functional optimization of the product, reduce the number of components	Number of functions by product or by compsosant	

Table-10: Eco design specifications[7].

Environ mental aspect	Guide line	Notation	Priority	Tracking indicator	Repository indicator	Pilot function	Related tools	Tracking indicator value		Repository value		comme nts
Raw material												

Actions to be performed: This is the part of the IBS method that explains what to do during the implementation of each step. The first three tools of the IBS method (SWOT, Position Statement, Team Choice) provide a qualitative assessment of the criteria for implementing the eco-design approach. The results made it possible to have a database of agricultural and agri-food equipment manufacturers. The database reveals thirty (31) manufacturers, with parameters such as company name, region, type, manufacturing activity, number of personnel, turnover and contact. Benin has twelve (12) departments. A study of the geographical situation of the designers and manufacturers of agricultural and agri-food equipment is made. We had in the departments of Atacora and Donga a (01) manufacturer or 3.33%, in the departments of Atlantic and Littoral eight (08) manufacturers is 26.67%, in the departments of Borgou and Alibori two (02) manufacturers is 6.67%, in the departments of Oueme and Plateau seven (07) manufacturers is 23.33%, in the departments of Mono and Couffo three (03) manufacturers or 10% and in the departments of Zou and Hills seven (09) manufacturers is 30% (Figure-11). In summary the visit made, the location of the equipment manufacturers are parameters that allow to know the objectives and equipment most designed and manufactured.

Conclusion

In this article, we have proposed an eco-design approach: Innovation for Breaking and Sustainability (IBS) for small and medium-sized agricultural and agri-food equipment companies following an inventory of agricultural and agri-food equipment manufacturers in Benin. The IBS method is a method of assisting the development of products in Southern countries, particularly Benin. It provides answers to the need to master the process of integration of the environment, in a sustainable way, with measurable objectives. The IBS is a global design mechanism and a beginning of integration of eco-design in agro-food machines in Africa, especially in Benin. Although all the tools of the IBS method have already been implemented with their basic method, the next phase will be the implementation of the IBS method. This second phase of the work will design and manufacture agri-food equipment with one or more equipment manufacturers. A study will be done to analyze and quantify the environmental impacts of the agro-food equipment. During the analysis and quantification, we will make a comparison of the old equipment compared to the eco designed one. This will show the actual reduction rates of materials, energy and waste during the manufacture of the new equipment.

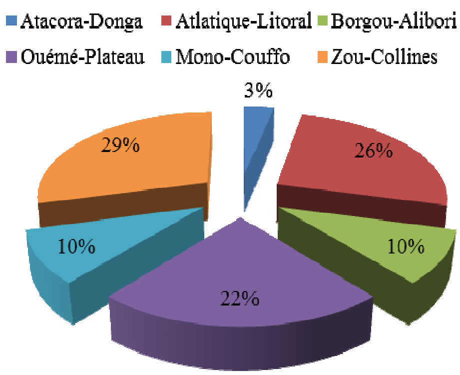

Figure-11: Geographic Distribution of Equipment Manufacturers in Benin.

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