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European testing of the efficiency of TRIZ in eco-innovation projects for manufacturing SMEs

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Abstract

In this work a method for identifying the key points and supporting an eco-design activity for SMEs is presented. Amongst the different concurrent approaches in the literature, Active Innovation Management (AIM), is currently developing, jointly with the University of Bergamo, an integrated approach based on Life Cycle Assessment (LCA) and TRIZ eco-guidelines. The main goal of this integration is to simplify the eco-design approach in order to make it accessible to European small medium enterprises (SMEs). All activities are part of a European Community (EC) project called REMake. The proposed method consists of a preliminary scan of a given product or process in order to disclose all involved flows of material and energy, and to assess its environmental impact by means of traditional LCA indexes. The hot points of the process are then identified adding to classical LCA criteria a brand new index, called the "IFR index", conceived from the TRIZ "Ideal System" concept. Once key points are identified, a set of 330 eco-design guidelines are introduced to develop alternatives and modifications to the given system with the aim of providing a lower global environmental impact. A first version of those guidelines [3, 8, and 9] was conceived starting from the eight natural Laws of Evolution of Technical System (LTSE) introduced by Altshuller [10]. Here an extended version allows the user to work in each phase of the product life cycle, and integrates other TRIZ tools and best eco-practices. Preliminary results of the application in SMEs will be presented with a case study concerning a textile home-furnishings and bed linen painting company.

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1. Introduction

Nowadays, the importance of sustainable development no longer needs highlighting. The scarcity of resources and higher pollution levels are progressively orienting consumers and therefore industry towards cleaner production.

The EC through DG Enterprise & Industry financed various projects to test and promote new methodologies to be spread around European SMEs. Amongst these, the project REMake [1] (started September 2009 ending December 2012) has the goal to develop and test new approaches for eco-innovation, recycling and material consumption for manufacturing SMEs. The number of SMEs involved will be around 300, in six countries.

The first projects started in May, and the first results are expected at the end of summer 2010.

In this project AIM is strongly involved in the setting-up, testing and training of new eco-innovation approaches, adapted to a SME context. Performing an analysis on current existing methods for eco-design, we noted that Life Cycle Thinking (LCT) and LCA are recommended best practices for industries, but their penetration is still weak.

Amongst the causes of this poor penetration, some authors indicate the complexity [2]. This fact is strongly limiting the adoption of LCA in SMEs.

Moreover, we discovered that in eco-design it is a common practice to under-evaluate the role of resources; actually, most methods focus only on materials and energy and with quite a superficial attitude. For instance the "companies' guidelines" for the choice of material are limited to a simple classification that goes from good materials to be used freely to awful materials not to be taken into account [3]. More generally, all methods are very effective in the assessment phase or in the improvement phase, but not in both.

Based on this analysis, we defined the following research approach:

- Modelling eco-design activity as a two phase activity: a first phase of assessment, then a phase of improvement.
- Putting together the most ecologically efficient assessment tools with the most efficient problem solving tools based on TRIZ
- Performing a selection of alternative generated solutions based on a quantified but simple impact evaluation.
- Simplifying the global approach in order to make it accessible to European SMEs.

In the following paragraphs this approach will be described. Then, a case study will be presented with some results, considerations and perspectives. Due to the work in progress, more detailed examples will be presented during the congress.

2. An introduction to LCA

Amongst the best practices for eco-design, the use of Life Cycle Thinking-LCT and LCA is commonly accepted. According to the EC, JRC, LCT and LCA are the scientific approaches behind modern environmental policies and business decision support related to Sustainable Consumption and Production (SCP) [4].

Nevertheless, many authors identified some weaknesses in the LCA approach. According to the Swiss Agency of the Environment and the Dutch Ministry of the Environment: "Although LCA is a good tool to assess the environmental performance of a product, and although it is widely adopted by designer, is time consuming and costly…and results need to be interpreted and weighted" [2].

Some specific development projects have been supported by the EC in order to improve LCA, such as the CALCAS project (Co-ordination Action for Innovation in Life Cycle Analysis for Sustainability) whose goals are, respectively:

- deepening the present models and tools to improve their applicability in difficult contexts while increasing their reliability and usability;
- broadening the LCA scope by better incorporating sustainability aspects and linking to neighbouring models to improve their significance;
- leaping forward by a revision/enrichment of foundations, through the crossing with other disciplines for sustainable evaluation [5].

According to this project, the need to develop simplified LCA stems from the consideration that detailed LCA can be time and resource consuming and this is an obstacle to a wider adoption of life cycle approaches, especially among SMEs. Moreover, some authors suggest adopting these methods in the early product design phases [6].

The main difficulties identified are, then, the following:

- complexity of data collection and normalization;
- complexity of interpretation of results;
- expensive Software and databases;
- no support provided to designers to improve situation AS-IS.

Another EC project entitled E-LCA2 project [7] has been developed, from 2002 to 2005 with the following main goals:

- to develop the awareness among SMEs of the opportunities offered by green products;
- to promote the development of a green services market;
- to be the starting point for co-operation projects between stakeholders of various industrial sectors (public bodies, business associations, firms, consultants and service centers, etc.).

Amongst the outcomes of this project, there are some tools, such as:

- a simplified LCA methodology, with a related software tool and database (eVerdEE);
- a tool for eco-design, to support the designers in the first phase of product development integrated with Quality Function Development (QFD) parameters.

Some important characteristics of these tools are freely available: DB updated; limited number of indexes provided; sensitivity analysis allowed.

Even if these improvements have increased the ease of use, nevertheless the interpretation of results demands a LCA expert, therefore the access to this best practice is still limited by huge firms and almost absent in SMEs.

Therefore the first activity of this study has been to identify another approach, capable of providing complementary functions, and therefore to complete the support to companies.

3. TRIZ Eco-guidelines

TRIZ methodology has been evaluated as a potential ally for existing eco-design methods. Some TRIZ fundamentals, such as ideality, resources and laws of technical evolution [10], have been re-organized in the form of practical eco-guidelines. [3]

The main goal of the guidelines is not only limited to providing a tool to better understand what element of our system needs an intervention to reduce its environmental impact. They are also conceived to support designers improving a product, process or service according to the eco-parameters until the end of the problem solving process; suggesting the direction of work and the best tools at the designers' disposal; and the tricks and best practices.

GUIDELINES		RULES	
N. Name		**N.**	**Short Description**
ASSESSMENT			
G1 System modelling		R1.1	Main Function identification
		R1.2	Physical description
G2 Resource assessment		R2.1	Resources exploitation indexes
		R2.2	Analyze present/past system condition
		R2.3	Identify external resources
INNOVATION			
G3 Resource saving		R3.1	Use IFR concepts
		R3.2	Reduce Energy conversion to zero
		R3.3	Explore other technologies
G4 Components interaction		R4.1	Make the actions resonant
		R4.2	Coordinate Fields
G5 System dynamization		R5.1	Dinamyze the system
G6 System simplification		R6.1	Eliminates useless components
		R6.2	Solve contradictions
G7 External resources exploitation		R7.1	Merge technical systems
		R7.2	Shift to super-system
G8 Fields cooperation		R8.1	Increase S-Field involvement

Figure 1: Initial framework of TRIZ-based eco-guidelines conceived by the University of Bergamo for the phase of use.

These guidelines, being extracted from the TRIZ laws of evolutions [10], have a main theme that is to reduce resource consumption (mainly material and energy) increasing efficiency. This is possible by taking into account the best heuristics and theories of problem solving, and also taking into account new trends, technologies and best practices in green design.
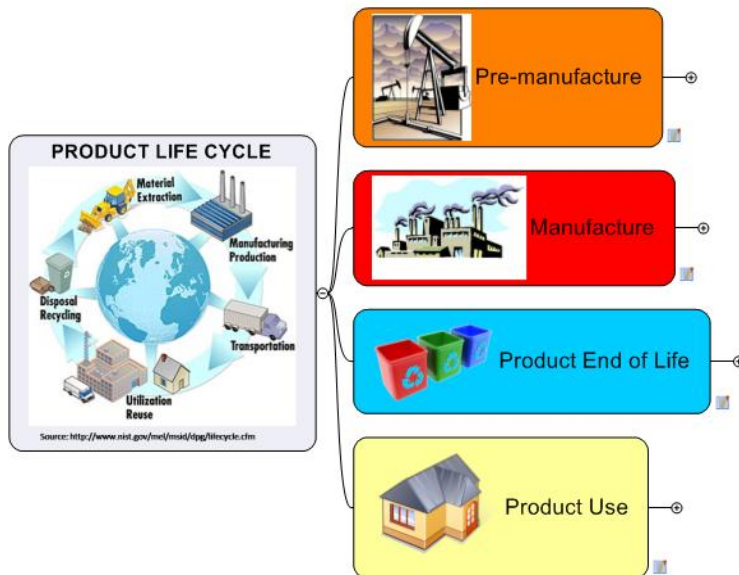

Figure 2: New TRIZ eco-guidelines framework. All directions are structured in the form of a tree-like diagram and firstly grouped by four Product Life Cycle phases.

In the first versions only eight guidelines, conceived mainly for TRIZ experts, were developed with the aim of improving the initial system in the phase of use.

Previous work was then extended to all phases of the product life cycle, and new directions for action were added. The guidelines actually constitute over 330 actions organized by pre-manufacturing, manufacturing, product use and end of life.

Each phase contains a set of the objects to which the guidelines refer to. For every object a list of goals to be achieved, opportunely translated in terms of resource abatement, is provided in order to design a better product.

Then, goals can be achieved by eco-design directions, that is detailed suggestions dealing with the way the "resource reduction" target can be achieved by specific problem solving paths, often inspired by classical TRIZ approaches and best green practices.

The last part of the directions contains examples of applications as a trigger to stimulate ideas by analogy.

As shown in figure 3 shown, the first level contains the objects to which the guidelines refer to, the second level deals with the kind of resource involved, the third level is a synthesis of the target to be achieved. Collapsible functions are introduced in order to ameliorate the diagram's usability.
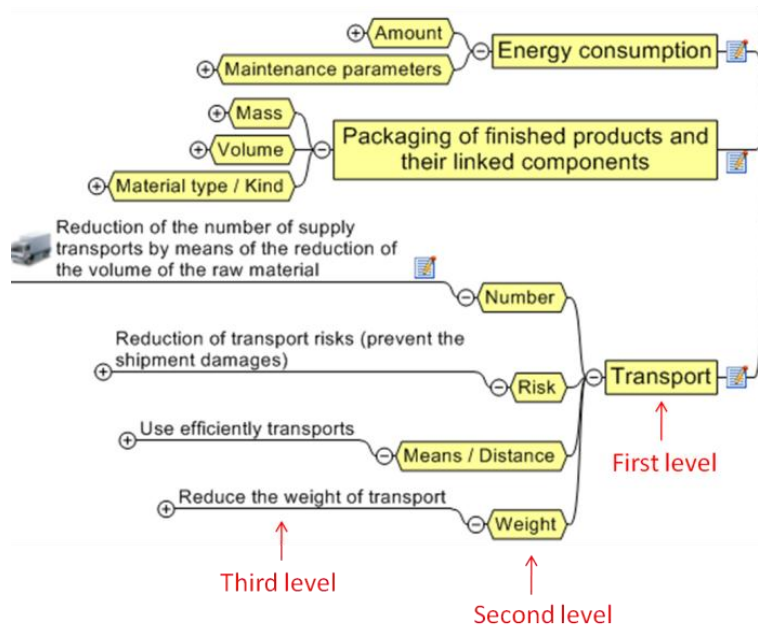

Figure 3: An example of product use from the eco-guidelines.

Examples

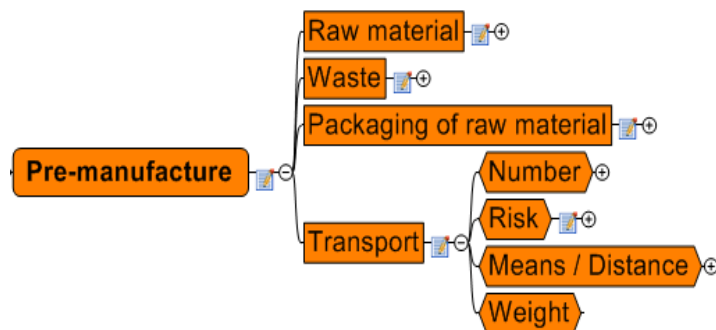The first example is taken from the object "transport" in the pre-manufacturing phase.

Figure 4: Pre-manufacturing phase main classification. The picture shows the list of objects that can be used as the target of the intervention.

Among all the directions from "Guideline # act on transport in pre-manufacturing phase" one of them suggests *finding the best supplier*. A further description supports the user in order to choose *the nearest supplier by using the most efficient means of transport*. To better calculate the distance a "Vehicle Routing Planner (VRP)" SW is

suggested, while in order to find the best means of transport a table of transport indicators is provided as shown in Figure 6.

Transport (in millipoints per tkm)

	Indicator	Description
		Including fuel production
Delivery van <3.5t	140	Road transport with 30% load, 33% petrol unleaded, 38% petrol leaded, 29% diesel (38% without catalyst) (European average including return)
Truck 16t	34	Road transport with 40% load (European average including return)
Truck 28t	22	Road transport with 40% load (European average including return)
Truck 28t (volume)	8	Road transport per m³km. Use when volume in stead of load is limiting factor
Truck 40t	15	Road transport with 50% load (European average including return)
Passenger car W-Europe	29	Road transport per km
Rail transport	3.9	Rail transport, 20% diesel and 80% electric trains
Tanker inland	5	Water transport with 65% load (European average including return)
Tanker oceanic	0.8	Water transport with 54% load (European average including return)
Freighter inland	5.1	Water transport with 70% load (European average including return)
Freighter oceanic	1.1	Water transport with 70% load (European average including return)
Average air transport	78	Air transport with 78% load (Average of all flights)
Continental air transport	120	Air transport in a Boeing 737 with 62% load (Average of all flights)
Intercontinental air transport	80	Air transport in a Boeing 747 with 78% load (Average of all flights)
Intercontinental air transport	72	Air transport in a Boeing 767 or MD 11 with 71% load (Average of all flights)

Figure 5: Transport table from the eco-indicator 99.

For various examples, Japanese software called MSTP "Modal-Shift Transportation Problem" is proposed.

With the aim of minimizing the resources used during the transport phase, in particular reducing the number of transports, the guidelines suggest reducing the volume of transported substances. To do this, some inventive principles are suggested:

1_Segmentation:
- dividing the object into independent parts or making the object divisible.

7 Nesting:
- one object is placed inside another. That object is placed inside a third one. And so on.

13_Other way round:
- turn an object upside- down.

15_Dynamicity:
- divide an object into elements capable of changing their position relative to each other.

17_Another dimension:
- transition one-dimensional movement, or placement, of objects into two-dimensional; two-dimensional to three -dimensional, etc.
- inclining an object or placing it on its side.

30_Use of flexible membrane and thin films:
- replace customary construction with flexible membranes or thin films, or isolate an object with flexible membranes or thin films.

35_Transformation of properties:
- change the physical state of the object (from gas to liquid).
- change the concentration or density (increase density).
- change the temperature (decrease).

36_Phase transition:
- use physical phenomena accompanying phase transitions: change of volume, emission, absorption of heat, etc.

Liquid oxygen, transported into pressurized cylinders. It saves space and improves the security of transport than gaseous oxygen one		Nested container:	
Rice vacuum: in addition to satisfy organoleptic requirements, eliminating the space normally occupied by the air		If it is possible, it is useful to compress the transported materials, for a better exploitation of the available space	Changing shape: the use of rectangular cans allows a better use of the space.
Compressed sponges: the expanded form, necessary for their use, is being acquired through the hydration, that will do the user		Powdered milk: rehydration takes place before the use by adding hot water.	
		Industrial cellulose: the cellulose fibres, for the transport, are compacted in bobbins, for reduce the volume. Only after the transport, the cellulose will be ground in fibres	

Figure 6: A picture from the TRIZ eco-guideline map. On the picture a list of examples are activated when the user expands the description about a specific branch about a suggested direction.

A further example is dealing with a guideline taken from the manufacturing phase.

Among all the directions from "Guideline # reduce the amount of auxiliary materials and components in manufacturing phase" one of them suggests *increasing* the *efficiency of current machine tools and service plants.*

Several suggestions can be checked in order to achieve this goal as follows:

Ideal Final Result- (IFR):

- choose machine tools and service plants that use no auxiliary materials (e.g. high speed machines, do not use refrigerants).

Explore other technologies:

- choose machine tools and service plants with high controllability of the field with which the functions are performed: shift from poor controllable fields to more controllable fields following the next fields list (the list moves from less controllable fields to the most controllable fields): gravitational, mechanical, thermal, magnetic, electric and electromagnetic (e.g. grinding machines use a magnetic field to block the working pieces – no protection materials for pieces).

Make the action resonant:

- choose/replace machine tools and service plants that use a periodic or pulsating resonant mode to use the auxiliary materials (e.g.: toilets with a pulsating water system).

Dynamize the system:

- choose machine tools and service plants adaptable to every change in conditions (e.g. toilet uses a flushing device with two buttons). Choose flexible machine tools and service plants: the amount of free

motion of auxiliaries has to be the maximum, if solid passes to liquid, gas and some kind of field; i.e., pass to a more flexible, rapidly changing, and adaptable structure (e.g. laser cut).

Increase the S-field involvement:
- • choose machine tools and service plants that replace auxiliary materials with a fields (application of TRIZ Standard 5-1-1-2).

4. The novelty of the TRIZ Eco-guidelines approach

The novelty of such new TRIZ-based guidelines concerns both the assessment and the improvement phase.

4.1. Assessment phase – IFR index

The evaluation of the environmental impact for a substance or a process is connected to two main factors, the quantity of material flows and the energy entering inside the cycle and their specific ecologic impact coefficients (eco-indicators). In the literature most available eco-tools mainly focus on assessing how a flux impacts on the environment without any suggestions on where to perform an improvement and how to do it. The easy pick approach is to start from the flow that generates the higher impact on the most environmental indexes (climate change, acidification, eutrophication) regardless of the amount of material it constitutes.

The novelty of the proposed approach is to introduce two complementary indexes in order to identify critical areas on which to perform redesign actions.

The first index is called IFR, as inspired by the homonymous TRIZ tool. The IFR index is calculated on the base of the following definition: "The technical system should not only be a suitable power conductor but should also operate with minimal energy losses (such as losses incurred by transformation, production of useless wastes, and withdrawal of energy with ready-made artifact). The IFR system should use energy and materials only to provide the main useful function in according to TRIZ IFR concept". Adopting this index we are capable of associating each flow of energy or substance in input with the maximum potential reduction that can be achieved theoretically. In this way we perform a sensitivity analysis on all flows based on realistic design criteria.

Beside the maximum theoretical reduction gap, we can consider another index, the "best in class", which refers to the maximum reduction known for analyzing best sector practices, from competitors or more easily taking into account all technological improvements the company has already achieved in order to optimize the specific flow.

Using these new indexes the assessment is then made not only on actual criticality of existing flows but also on possible future theoretical improvement.

4.2. Improving phase – eco-guidelines

Existing eco-improvement tools are too generic to provide effective help for eco-designers. Classical directions concern lists of substances and practices oriented to address material substitution, and so reduce the lowest environmental impact coefficient.

The target of new guidelines is to give to the user all means to limit the use of material and energy flow of the system; in order to do that, a set of guidelines based on theories and tools of problem solving are proposed. They work firstly on system efficiency, on technologies substitution and secondly on flows substitution and optimization.

From an operational point of view, the guidelines are organized in order to let an identification of hot spots using dedicated IFRs index and "best in class". Once indicated the hot spot on which, specific guidelines operate can be easily selected following the path inside the classification tree. Following these guidelines the user is supported to generate alternative solutions within the main goal of incoming flow reduction.

If the solution is obtained by reducing only existing flows (without introducing any new ones), automatically the reduction of environmental impact is given, if new flows are added to the previous system, then it is necessary to realize a variant analysis in order to verify the global effectiveness of the improvement action.

For this purpose the guidelines have been designed in order to facilitate an integration with a simplified LCA software, capable of quickly providing a quantified analysis of different improvement strategies.

5. The integrated approach

Therefore, LCA software and eco-guidelines have been integrated in order to jointly provide a quantitative assessment of product or process ecological impact, and relevant improvement strategies to designers.

The LCA assessment approach has been chosen as a foundation system in order to integrate inventing TRIZ capabilities to provide a complete approach; then, guidelines have been structured following the life phases decomposition, as in eVerdEE SW. The phases are, respectively, as follows:

- Pre-manufacturing, i.e. the identification of all elements bought and that will be transformed inside the company later on.
- Manufacturing, i.e. the industrial operation of transforming the components into a product.
- Operation (product use), i.e. the time during which the product operates, including maintenance activity and consumptions.
- End of life, i.e. the recycling part of the product.

This approach has then been mapped using the TRIZ eco-guidelines, both using the assessment part and the improvement.

Concerning the improvement, the guidelines have been declined including various traditional TRIZ tools, in order to support the designer when faced with specific product ecological weaknesses, as identified by eVerdEE assessment.

In order to map the process, previously to the use of LCA software, we adopted an IDEF0 modelling approach, specifically set-up for this application. More precisely, the input flows have been added on the left part of the boxes, and mechanism, controls and calls were translated in input flow or deleted from the map. Employing such a model allows us to show clearly the AS-IS situation; in particular it is easy to define all flows as well as their loops, with the values really used into eVerdEE-LCA software during the quantitative analysis.
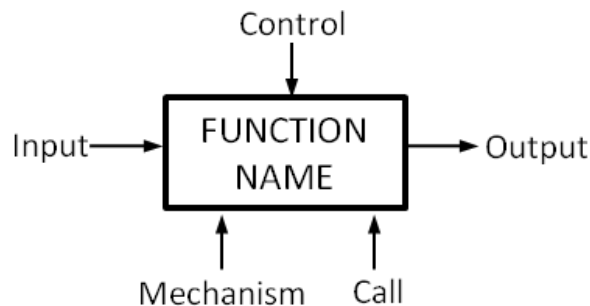
Figure 7: A process can be decomposed in functions or phases by means of an IDEF0 diagram.

Then IDEF0 modelling is used again after the eVerdEE calculation and enriched of specific indicators associated to the flows and the operations inside each phase.

View Results > First Level of Detail

Indicator	Total	Pre-manufacture
BASE CASE REMOTE OPEN VERTICAL CHILLED MULTI DECK		
Consumption of mineral resources (kg antimony eq)	0.0738	0.0738
Consumption of biomass (kg)	62.4	62.4
Consumption of fresh water (m³)	5.78	5.78
Consumption of non-renewable energy (MJ)	$5.67 \ 10^5$	$2.81 \ 10^5$
Consumption of renewable energy (MJ)	70200	36500
Climate change (kg CO_2 eq)	36400	18000
Acidification (kg SO_2 eq)	307	126
Eutrophication (kg PO_4 eq)	10.8	5.39
Photochemical oxidation (kg ethylene eq)	49.2	13.4
CFC-11 emission (kg)	$3.06 \ 10^{-4}$	$3.06 \ 10^{-4}$
Production of hazardous waste (kg)	33800	133
Total waste production (kg)	48800	14100

Figure 8: In the picture a partial view of "results" from eVerdEE SW.

Finally, the IDEF0 diagram can be used in order to highlight the hotspots for each indicator, using as an example the side of the arrow and putting inside the maximum potential reduction for any indicator. Every input arrow contains an IFR potential reduction index, the percentage rate of the impact on CO_2 eq. and the element it refers to. Percentage impacts are calculated by simplified LCA software.
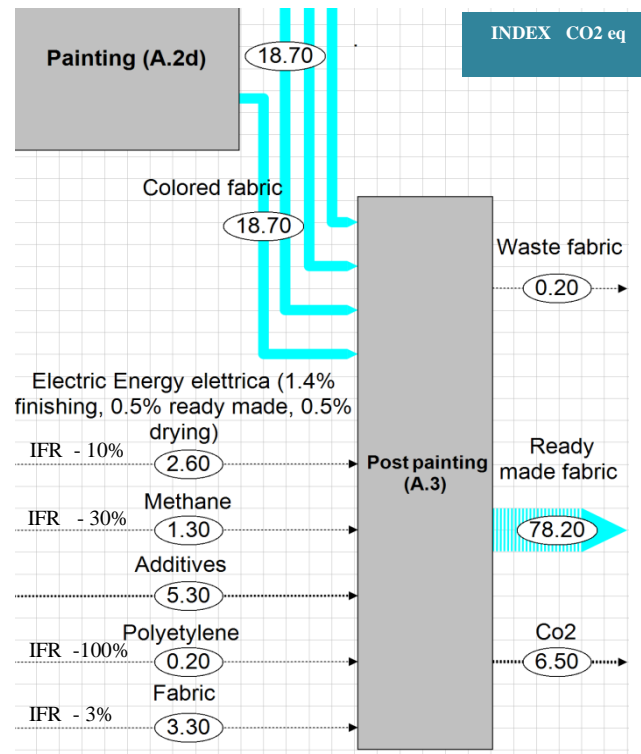
Figure 9: The IDEF0 diagram for hot points identification.

6. Case study

The case study concerns an industrial textile home-furnishings and bed linens painting company.

The company itself produces the machines for painting and produces over 30 million m^2 of coloured fabric.

Actually the process can be synthetically described by four different phases:

1. Pre-manufacturing. Pigments and varnishes are prepared combining additives and other substances with water. Then auxiliary devices mix and transport the colours into the painting machines.
2. Manufacturing. Four painting machines manage the colour delivery onto the fabric; another device recovers extra painting and cleans the dirty parts of the machines and auxiliaries. Another important phase of the manufacturing is post painting: here all processes dealing with drying are grouped: polymerization, vaporization, surface treatment, extra colour removal, and packaging).
3. Use: the phase of use of the fabric is not taken into account, all other related aspects were put into the manufacturing part.
4. End of use: this phase concerns all treatments of wastes, polluted water, solid/liquid chemical substances, exhausted colours, gas etc.

All the main functions of the painting process have been filled into the IDEF diagram decomposing in energy flows and used substances.

Compatible with the availability of data (type of substances and energies) of our simplified LCA software database, the quantitative data associated with each flow has been broken down as much as possible, to ensure better accuracy of the analysis (for example, instead of entering an aggregate date relative to paint flow, it has been broken down in each chemical substance that composes the paint).
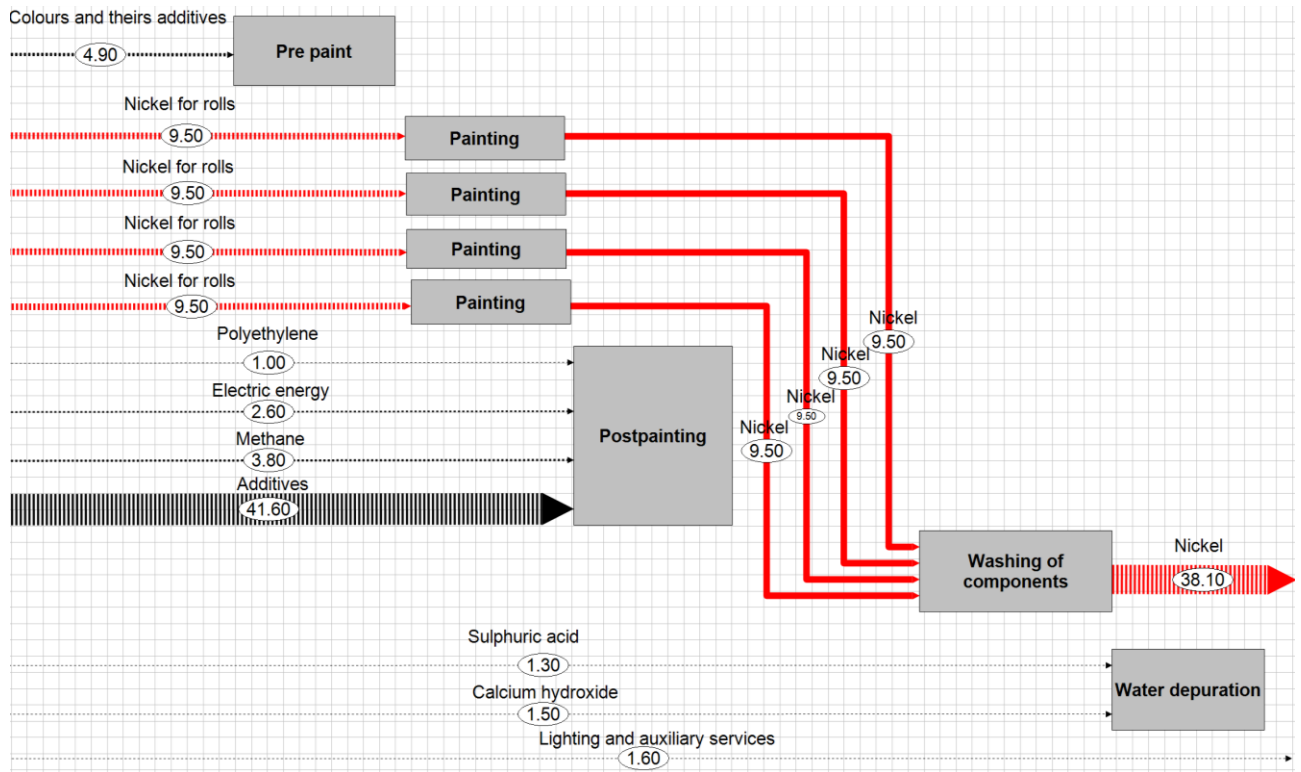
Figure 10: The IDEF0 shows the SO_2 production. In the diagram all the fluxes are depicted with a relevant impact on SO_2 production, with their relative percentage rate.

Once the diagram is complete, all collected information mapped as input in the diagram was put into eVerdEE in order to generate results of the impacts of every flow.

The authors decided to focus only on a set of potential indexes as criteria to determine the hot points:

- amount of material flow (kg);
- amount of energy flow (MJ);
- consumption of non-renewable energy (MJ);
- consumption of fresh water (m^3);
- climate change (kg CO_2 eq.);
- acidification (kg SO_2 eq.);
- eutrophication (kg PO_4 eq.).

Looking at a classical result from the simplified LCA software, elements that have the highest environmental impact are methane, fabric and some chemical substances used in post painting treatments. The fabric in particular is highlighted as a hot point because its quantity is high, but in reality it is the product of the entire process, and for an economic point of view the company wants to increase this amount.

Here it is important to introduce for any flow the IFR index in order to evaluate flows according to the potential maximum reduction.

Results can be shown by IDEF0 of impacts. Here a new perspective of the given process is provided, just substituting input flows by impact flow. A set of diagrams was built for every index taken into account. In this case, new elements appear in the top ranking, for example nickel.

Nickel is used for micro-perforated rolls employed in the painting phase. Every year over 1,500 rolls of nickel are substituted and thrown away because small local deformations appear on the external surface.

Every roll is longer than 3 meters, it is constituted of a very thin sheet of nickel and it works in contact with the fabric that over time can make a dent that compromises the right functionality. Moreover, every roll is a very expensive component.

In Figure 10 the acidification diagram of impacts is shown.

As it is possible to see, nickel represents a strong impact on the global amount of SO_2, (over 38%) and its IFR index indicates a high potential reduction until zero % in the cases where we are able to introduce a recovery cycle inside the manufacturing process.

This means if we introduce a recovery cycle for nickel tubes, we can obtain a maximum global reduction from 21,200 to 12,300 kg of SO_2 eq. per year.

The eco-design goal can be achieved by introducing directions suggested by the eco-guidelines. Looking at maintenance parameters, the main goal is to optimize the maintenance of this system. Some guidelines are advised, in particular:

- a) the re-design/use of products with the highest reliability and requiring the lowest maintenance;
- b) the re-design/use of reparable products;
- c) the re-design/use of modular products.

Eco-guidelines for direction "a" suggests thinking about a self- repairing/self-regenerating tube.

A spiral inside of the tube can perform this function, keeping in traction the tube and avoiding wrinkles on the external tube surface. Also the heat can be used to make a deformation in opposition to those that arise during painting deposition.
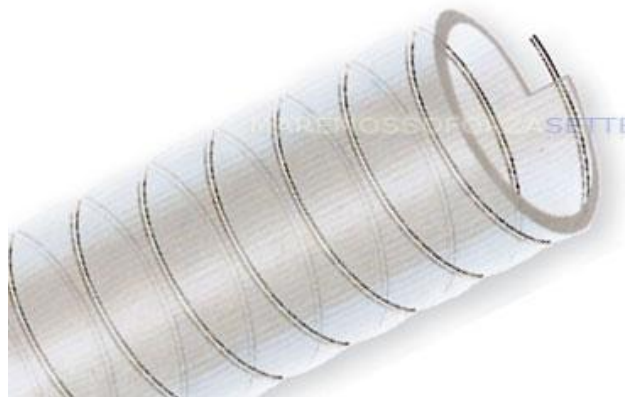

Figure 11: Tube with an internal spiral that is maintained in traction with the tube.

In this way the increase in the useful life of the product has a positive impact on the reduction of the number of pieces used per year.

The detailed description of guideline "b" suggests using segmentation. It can be achieved by avoiding employing a monolith tube and substituting it with a tube in more parts. So only damaged parts are removed and parts with the highest wear or with the highest probability of damage are made independent.

Segmentation can be achieved in different ways: a longitudinal segmentation and a transverse one, as shown in the picture:
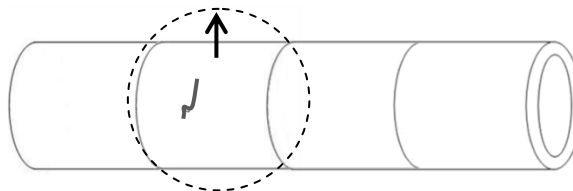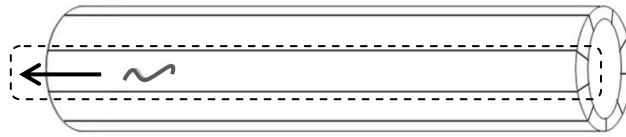
Figure 12: Schematic representation of the application of the segmentation. On the top there is the transversal segmentation, on the bottom the longitudinal one.

All proposed solutions are currently under study and evaluation.

7. Future developments

During the next months, the approach will be tested broadly, over the six countries engaged in the REMake project: Germany, France, Italy, Spain and England, Belgium.

This large panel of test cases will enrich the approach and will allow the refinement and finalization of the eco-guidelines tools.

The end of the deployment phase is 2012.

At the end of the REMake project, various dissemination activities are foreseen. This will support the diffusion of eco-design best practices around European SMEs. These guidelines will suggest the most adapted methodologies according to specific SMEs' needs.

8. Conclusions

Once again the pertinence and actuality of TRIZ theory has been proven, in fact several TRIZ fundamentals have been adopted in this research in order to complement state of the art environmental assessment tools.

The proposed method consists of a new way to assess eco-problems taking into account not only environmental impacts by means of traditional LCA indexes, but adding new indexes taken from the TRIZ "Ideal System" concept to them. In order to manage this index a combination of LCA software and a modified IDEF0 diagram is shown.

Once hot points are identified on the diagram a set of 330 eco-design guidelines, developed by the University of Bergamo are introduced to develop alternatives and modifications to the given system with the aim of providing a lower global environmental impact.

Preliminary results of the application in SMEs are shown in a case study concerning a textile home-furnishings and bed linens painting company. For the elimination of wastes of nickel during the painting phase, a solution is under testing and could potentially produce a saving of 9,000 kg of SO_2, contributing significantly to the reduction of eutrophication problems in the environment.

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