Proposal of an impact prediction tool for the environmental assessment of projects and spatial planning, based on LCA

Aldo Treville
PhD in Territorial Design and Government (GPT), Department of Architecture and Planning (DiAP), Politecnico di Milano, p.le Leonardo da Vinci 32, I-20133, Milan, Italy

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ABSTRACT

The paper reports research demonstrating the potential of using LCA methodology as a support tool for decision makers at various scales - from building to the territorial scale – through sustainable development.
The research attempts to define an assessment tool to be used by local authorities (i.e. municipalities) in order to evaluate the environmental impact of projects and spatial planning that needs preliminary approval, like the construction permit of a building, the EIA (Environmental Impact Assessment), the SEA (Strategic Environmental Planning).
The L.C.Inventory includes select database profiles of the different case studies included in the fields of spatial planning and urban design: residential and public buildings (construction or renewal), urban areas (new or renewal), industrial sites, infrastructure (roads, railways, electricity lines, water pipelines, etc.), waste treatment systems, etc.
The paper explores both the limits and benefits of using a tool that provides a quick evaluation of the environmental impact of public and private proposals through a software interface that links to a customized comparison (using different coefficients) of Life Cycle Assessments in the selected database.
More generally, these results show the potential of integrating LCA methodology into the environmental assessment of city policy, planning, urban design and project (i.e. SEA).

The **Introduction**

LCA methodology has the potential of being a support tool for decision makers, such as local authorities. However, specific competences are required and not usually found in using LCA tools.
The research made in collaboration with ENEA[1] and LCA-Lab[2], commissioned by the Municipality of Florence (January, 2011), had the aim to define an assessment tool to be used by local authorities (Florence and other surrounding municipalities) in order to evaluate the environmental impact of projects and spatial planning. In fact, they usually need preliminary approval or authorization, like the construction permit of a building, or more complex processes, like EIA (Environmental Impact Assessment) and SEA (Strategic Environmental Planning) processes.

[1] ing. Paolo Neri
ENEA Italian National agency for new technologies, energy and sustainable development
Via Martiri Monte Sole 4, I-40122 Bologna, Italy
Email: paolo.neri@enea.it

[2] dott. Ruggero Gallimbeni
LCA-Lab srl, c/o ENEA
Via Martiri Monte Sole 4, I-40122 Bologna, Italy
Email: ruggero.gallimbeni@onionx.com

The proposed assessment tool makes an estimation of the environmental impact, even if with approximation, without using life cycle software and methods (such as specific LCA), assessment methods (such as IMPACT2000) and other software that requires time and specific competences (such as using SimaPro software).
The proposed tool also estimates the externalities, which can be useful for public policies in order to help the decision making process (for instance, when deciding between two alternative projects).
In some cases, the assessment method is different for different processes, and the estimation can be affected by a range of error.
Database used is the Swiss Ecoinvent 2 for most of the common processes, while many processes are part of the database created by ENEA group (see references [1], [2], [3], [4]).

LCA methodology

A life cycle assessment (LCA, also known as life cycle analysis, and cradle-to-grave analysis) is a technique to assess the potential environmental aspects associated with all the stages of a product's or service's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA can help avoid a narrow outlook

on environmental concerns by:
- compiling an inventory of relevant inputs and outputs,
- evaluating the potential environmental impacts associated with those inputs and outputs,
- interpreting the results of the inventory and impact phases in relation to the objectives of the study.

When using LCA methodology, an estimation of many variables is made: emission to air, to water, to soil, natural resources (minerals, fossil fuels, water, wood, land use, solar and wind energy); then the characterization process is made using impact categories (such as global warming, acidification, eutrophization, ozone production, human health, ecosystem toxicity, land use, biodiversity, mineral consumption, non renewable energy consumption, etc.). Each impact category is measured with its specific unit. Damage categories are later indentified by giving weight to human health, ecosystem quality, resources, etc. Going from impact categories to damage categories units can be the same of differ. Finally, the damage categories are normalized, in order not to have units of measurement and obtain a value for the total impact of the process.

Choice of the variables

The choice of the independent variables to be considered as a reference for the study was the most challenging part of the research. The Criteria followed during the research work were the following:

1. choice of the reference process, or processes, for each sector considered (house, incinerator, etc.);
2. analysis of the main characteristic of the selected process, in order to understand from which data its impact its mostly affected;
3. Network assessment of the impact of the process: using the network, it is possible to analyze the process life cycle considering all the sub-processes involved.
4. Among the sub-processes, the ones that contribute the most to the total impact are selected and further studied, in order to obtain independent variables;
5. Variables have to be well-known and shared, according to the information available by the user, and to the lever of current knowledge (such as law requirement, protocol, etc.). It has to be underlined that the process is never related to a specific area: the environmental effects are referred to the European area for local impact, to the planet area for global impact (global warming, depletion of resources).
6. The first variable is the process unit, which is directly proportional to the impact of the sub-processes. This direct proportionality is an assumption that can be considered valid with a good grade of approximation.
7. A second variable considered is a different way of obtaining the process unit. For instance, a building can be conventional or eco-efficient, a car can transport a different number of passengers (in respect of the number used for the process in the database), etc.
8. A third type of variable is made up of other factors that affect the process unit. For instance, 1 kg of electric energy produced by a solar panel varies if the
9. efficiency is different, or if the power is different; in these cases, the area of the panel changes, since it is a sub-process of the photovoltaic power plant.
10. A fourth type of variable is considered after launching the LCA assessment of a reference process, and analyzing the impact generated by the sub-processes. For instance, electric energy and heating are often responsible of a relevant part of the total impact, and their consumption can be considered directly proportional to the total damage produced.
11. A fifth type of variables depends on the known characteristics of the process, such as environmental or energetic ones. For instance, for electric energy production, the “mix” can change, as well as the efficiency. A parameter called “energetic content” can be defined, as representative of the non renawabel energy calculated by LCA. Such energies, are responsible for C=2 emissions according to the type of resource considered, and LCA can calculate the value.
12. A sixth type of variable is taken also from the LCA, when some substances produce impacts on direct emissions. For example, the emission in air of a municipal landfill, such as methane and carbon dioxide, are responsible for global warming. Those emissions can be known a priori, since they depend on the waste composition of the landfill; consequently CO2eq become a variable of the waste composition, affecting Climate Change impact category in a direct proportional way.
13. A seventh type of variable is found in cases where the process unit is made up of two subprocesses with different percentage. The percentage of one process over the other becomes another variable to be considered proportional to the impact in every impact categories.
14. Another type of variable is considered when analysing the impact of different version of a building wall (1 square meter). In this case, the variables are the one selected by the designer (size, physical characteristic, climate data, durability, transmittance). Inputs are:

insulator type, weight, wall type, heating and electric energy required for indoor comfort. Outputs are: environmental indicator for the production and the end-of-life for one unit of insulator and wall, indicator for the unit of heating energy.

15. A final type of variable is related to the transformation of the unit process in a way that not all the sub-processes can be considerated affected with a direct proportionality. For example, for the processes of houses and civil buildings. If the process unit is the area or the volume, not all the subprocesses can be considered proportional. Also time in another variable than can change in a non proportional way from the unit process to the subprocesses (for instance, use phase with energy consumption can be considerated directly proportional with time, while components of the build can not). , .

It can be noticed that the selection of the variables is a challenging process, that provides new and interesting analysis of the database available. This new point of view is potentially useful for all LCA users: it makes possible to think at different variables of one process, and estimate the different alternatives by changing their values.

Choice of the indicators

Indicator preferred are the ones that assess the damage effect and not the cause. in the research the following indicator were selected:

- Human Health: unit DALY, number of years lost by the European population (384E6 abitanti);
- Ecosystem Quality: unit PDFm2yr, the percentage of European species disappeared, multiplied by the european area (2.16*1012m2) and the time of the emissions.
- Climate change: unit kgCO2eq;
- Resources: unit MJ primary;
- Total Impact: unit Pt, that is obtained by multiplying with a normalization factor the four above categories, normalizing and weighting the results.
- Total energy or Renewable energy or non renewable energy: in Eco-indicator 99
- External cost, unit ELU (year 2000);
- Internal cost;

In some cases appropriate indicators are ad hoc selected, in order to underline some peculiar characteristics.

Choice of the assessment methods

For the first five indicators, the assessment method used is IMPACT 2002, in a modified version that takes in account of:

- different water (standard version does not consider water use);
- different land use transformation (standard version does not consider land use)
- different dust (standard version does not consider all kind of dust used in the database).

When it is not possible to use IMPACT 2002, because the process uses a database with emissions and substances not considered by this method, Eco-indicator 99 is preferred and used. In order to obtain comparable results, weight “1” is given to all damage categories; with some approximation, the total impact calculated with the two methods is similar (with exception of cases where land use is the predominant responsable of the total impact, since Eco-indicator 99 gives a higher impact to this cathegory). From further analysis, it was verified that the subtracting Climate Change value to the total impact value, and adding the Global Warign value calculated with EDIP method, the approximation is improved.

However, Resources category is calculated differently for IMPACT2000 and Eco-Indicator and the final result of the two has a relevant approximation.

External costs are calculated by using EPS2000 assessment method, in a version modified by the Enea group.
Internal cost is calculated as a sum of the single components cost, and is indeed independent from the method selected.

Choice of the sectors

On the basis of the available database, of the local area characteristic (Florence and surrounding municipalities area) and of the purpose of the study, a selected number of processes is chosen:

- Building and Urban structure: new house (passive house), new house (type 1 and 2), emergency house, new public building, industrial building, renovation of existing house, renovation of existing public building, urban renewal;
- Infrastructure: roads, railways, electricity pipeline, water pipeline;
- Mobility: passenger transport, good transport, public transport (bus), urban traffic (management);
- Energy: electric energy production from natural gas, heating from natural gas, heating from solar energy, heating from heat pump, electric energy from photovoltaic panel Multi-Si, electric energy from photovoltaic panel CdTe, electricity energy production from hydropower powerplant, electricity energy production from biomass powerplant,

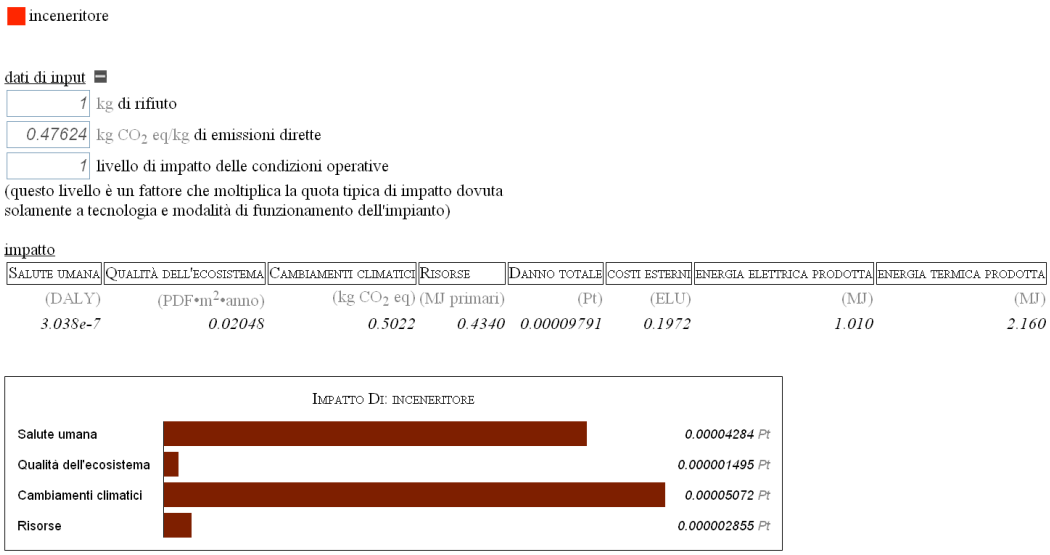
electricity energy production from wind powerplant;
- Waste treatment: landfill, incinerator, composting, iron recycling, aluminum recycling, sewage treatment, waste management;
- Industrial production: wood production, paper production, cement production, paint production, bricks production, plastic production, fabric production, mechanics production;
- Farming and agriculture: milk production, ham production, grass production, crop production, corn production, oil production, wine production, apricots jam production;

For each reference process the impact assessment is calculated using the software SimaPro and Excel spreadsheet in order to combine the indicators and calculate different options. The Excel spreadsheet results are proposed in a user-friendly interface, integrated in a software tool (see below).

The software tool

The software was created as support for an interactive and easy-to-use tool for the municipality decision makers, in order to have a preliminary assessment of projects/plans/programmes.

Fig.1 *A screenshot of the Software tool implemented (on top the list of the sectors chosen as reference)*



Using this software, it is possible to select one of the sectors chosen as reference, then to select the desired project/plan, and finally to modify the "input" according to the preliminary data available. The process is then customized, according to the pertinent data and available data; for example, for a new house they could be the floor area, in square meters, the life time, in years, performance characteristics (such as the difference between the minimum outdoor winter temperature and T indoor =20°C, or the difference between the maximum outdoor summer temperature and T indoor =26°C) .

Fig.2 *A screenshot of the "incinerator" process. It is possible to get a first estimation of the impact*

on human health, ecosystem quality, climate change, resources by typing the data available (kg of waste production, waste composition by its CO2 emission, etc.). An estimation of externalities, electric energy and heating is also provided.

The software tool also allows for the comparison between several projects, giving information about the direct comparison of their impact and the sum of their impact, as shown in the figure below.

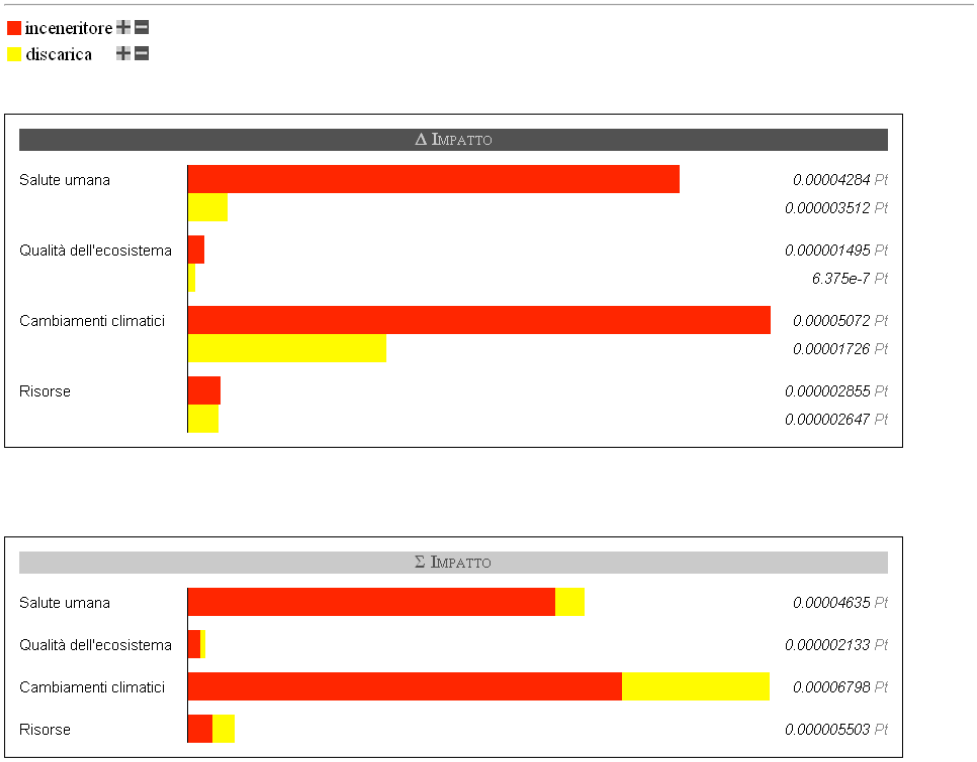


***Fig.3** A screenshot of the comparison between two customized processes, starting from the "incinerator" and "landfill" processes. It is possible to get a first estimation of the different impact on human health, ecosystem quality, climate change, resources. An estimation of their sum is also provided.*

The research project shows that a quick assessment is possible without using time consuming LCA evaluation, especially when detailed data is not available, or the project/plan is at its preliminary phase. A quick comparison of different alternatives can be made, by modifying some indicators and analyzing the different results obtained. Different options include different characteristics of the same project (such as several performances options of a building) or different alternative solutions (such as demolishing and building a new house or making the renewal of the existent house).

It is clear that errors and approximations are made at many levels, from the data level (SimaPro database contains errors) to the methodology level: some inputs contain errors in fact, as mentioned above, in some cases they are considered directly and linear dependent to the impact, while there is no experimental proof of that.
Additionally, some projects/plans can hardly be represented by the ones chosen in the study, but the research project could eventually grow, trying to include as many options as possible, in terms of more processes and more inputs/indicators. In other situations, however, it is not possible to assess or compare projects/plans that include non-quantitative options; if land use is assessed by the methods used (IMPACT), other factors, like "impact on landscape", "functions", "social impact", need a further research step to be integrated in this proposal. By giving to them some values and weights, a comprehensive multicriteria assessment method can be build, combining the results already explored to new indicators to be explored.
In EIA or SEA process, a multicriteria assessment, as mentioned above, would be a useful tool to help decision makers, at least at a preliminary project/plan phase.

Conclusion

LCA methodology has the potential to be used as a support tool for decision makers at various scales - from building to the territorial scale – through sustainable development.
It is possible to define an LCA assessment tool to be used by local authorities in order to

preventively evaluate the environmental impact of projects and plans.
The tool is able to provide a quick evaluation of the environmental impact of public and private proposals, but it is import to be aware of the limits and benefits of using such a tool.
More generally, the research project described in this paper shows the potential of integrating LCA methodology into the environmental assessment of city policy, planning, urban design and projects (i.e. EIA, SEA).

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