Environmental assessment of sustainable urban projects (eco-neighborhoods) through NEST, a decision support tool for early stage urban planning

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ABSTRACT

Urban planners are facing a growing demand for high performance projects in terms of environmental quality. However, the theoretical concepts of sustainable urban development often lose their core substance when confronted to practice realities during the design and implementation of urban projects. The question arises as to how the effective consideration of the environment and the limitation of the project impacts can be taken into account as soon as the early design stages?

We developed NEST (Neighborhood Evaluation for Sustainable Territories) as an answer to this question. NEST is a tool that uses 3D models of urban projects to quantitatively assess their environmental impacts. NEST addresses early design stages and is mainly based on Life Cycle Analysis (LCA) to assess the environmental impacts of projects.

In this paper we propose a presentation of the tool, an application through the case study of a new development project for a peri-urban area and eventually a discussion on upcoming developments on bioclimatic design at district level.

INTRODUCTION

Urban planner are facing a clear demand for projects of higher environmental performance from both public and private sectors. This environmental performance is related to numerous interconnected issues such as resources consumption, waste production, water consumption, GHG emissions, biodiversity protection, air quality, etc. The district scale appears to be relevant to adress most of these issues (Charlot-Valdieu, C. Outrequin, P. 2012). This complexity and interdisciplinarity calls for appropriate decision support tools to perform such multicriteria analysis.

As an answer targeting urban planners, we developed NEST (Neighborhood Evaluation for Sustainable Territories): a tool for quantitative assessment of environmental impacts of urban project. NEST has been designed taken into account the operational practice of urban design and can be used from the sketch stage of a project. Based on a 3D model of a development project, NEST calculates a set of indicators reflecting major environmental issues urban planners are facing. Part of the indicators are based on life cycle analysis (LCA) to objectively assess the impacts of the project. All indicators are normalized to the user to facilitate comparison of alternative scenarios (a user is an inhabitant or a non-resident worker).

NEST has already been applied on several urban planning operations in France. Each time it enhanced the design process, allowing a continuous analysis of the project environmental performance with a life cycle perspective which is quite innovative in urban planning.

NEST TOOL

NEST was developed through a PhD thesis (Yepez-Salmon, G. 2011) focused on "Environmental assessment of eco-neighborhoods" in Nobatek and the GRECAU laboratory (ENSAPBx). NEST is a PlugIn for SketchUp. It uses the 3D model of a project to perform the assessment of a set of indicators that was developed associating a scientific approach as well as operational urban planning objectives :

– Environmental indicators deal with energy, CO_2, biodiversity loss, waste, air quality and water
– Socio-economic indicators address user's satisfaction and project investment costs

Energy, CO_2 and Biodiversity Loss indicators are based on LCA (Life cycle Analysis) methods. The neighborhood is considered as an "object" responsible for environmental impacts associated with its location, implementation, construction and operation. This "object" is analysed as an aggregation of components (buildings, infrastructures, green spaces, etc.) that are simplified in early design stages in which the focus is on: choice of the site, public spaces, basic building design (volume, orientation …), green spaces, roads and parking lots. The LCA at the neighborhood scale is a weighted aggregation of the respective LCA of its various components and subcomponents (Figure 1) with their associated lifetime. The analysis is performed over the entire lifecycle of the neighborhood with the exception of demolition/deconstruction. Lifetime of buildings is 50 years and lifetime of infrastructures is 30 years. NEST LCA-based indicators are detailed hereunder:

1. Primary energy consumption indicator (MJpe/year/user) is based on CML 2002 method (Guinée et al, 2002). It accounts for primary energy use for production of construction materials, for construction works as well as for transportation and building operation.
2. Climate change indicator (kgeqCO_2/year/user) is based on IPCC 2007 gwp 100a method (IPCC, 2007). It accounts for GHG emissions from production of construction materials, from construction works as well as from transportation and building operation.
3. Biodiversity Loss indicator (PDF/year/user) is a score of biodiversity loss related to both land transformation and land use. It is based on the land use indicator of the Eco-Indicator 99 method (Goedkoop, M. Spriensma, R. 2001)

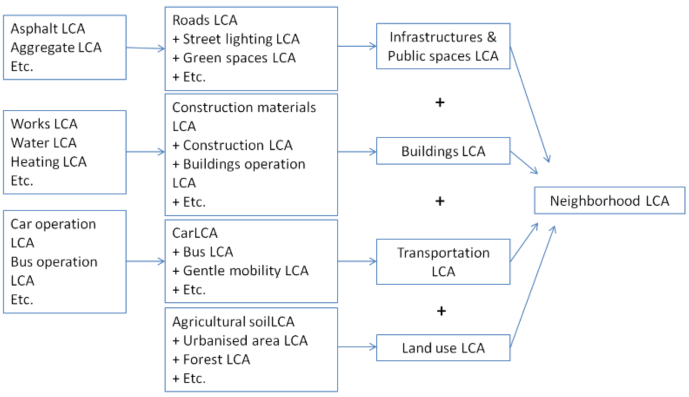

Figure 1 Neighborhood LCA principle diagram.

Other environmental indicators are flow indicators:

4. Air quality indicator (m^3 of polluted air/year/user) is based on the "air pollution" indicator of French NF P01 010 standard (AFNOR, 2004). It accounts for emission of polluted air from transportation and heating systems.
5. Waste indicator (t/year/user) deals with waste flows from neighborhood construction and operation stages.
6. Water consumption indicator (m^3/year/user) assesses water consumption for construction works,

during buildings operation and for maintenance of public spaces. Another indicator assesses stormwater infiltration on the plot.

The social indicator gives a score of user's satisfaction taking into account m² of housing, green spaces and parking lots per user, as well as the transportation offer and accessibility to everyday services

The economic indicator gives an insight on construction costs (buildings, public spaces, streets, etc.) and operation costs (lighting of public spaces, water for maintenance, waste management, energy and water consumption in buildings).

CASE STUDY, COMPARISON OF TWO SCENARIOS FOR A NEW DISTRICT

NEST was experimented on several urban projects in France allowing for its validation regarding both results and capacity to start and feed the discussions on sustainability between project stakeholders (urban planner, developer, mayor, technicians, etc.)

It enables a quick and wide comparison of scenarios for urban planners to improve their proposal. This type of analysis has been conducted with the design team of a new development project for a peri-urban area located in the French "Pyrénées Atlantiques".

Presentation of the urban project and alternative scenarios

The project aims at creating a new neighborhood (1.73 ha) close to the centre of a small community located 10 km away from the main agglomeration. The population carrying capacity of the site was set to 350 users; this information is critical for the impacts calculation and emphasizes the importance of density in an urban project. There is also a target of functional mixity with a majority of housing but also offices, shops and a school.

Two scenarios were established with the design team: one with a stronger investment on sustainability and higher density (sc.0) and another more representative of "business as usual" planning approaches (sc.1) with more individual houses. Both scenarios respond to the same initial program (regarding equipments, parks, roads, parking and housing) but in different ways, leading to different impacts, quality of life, usage and technical answers.

Sc.0 is more interesting at environmental level. The master plan is based on integrated urban gardens, pedestrian areas, smaller roads for cars, fewer parking spaces per dwelling, vegetated parks, more functional mixity (more offices and shops). All buildings are energy efficient (45 kWh/m²/year), most of them include solar energy production (PV and thermal). Regarding soil sealing and stormwater management, there are large areas of green spaces and green roofs. All buildings have dedicated spaces for waste "at source recycling", local bicycles shelters, and are equipped with water consumption reduction systems. Grey water reuse is considered in some buildings. Sc.0 has a capacity of 386 users (75% resident).

Sc.1 has a lower density with more individual houses. There are more mineralized surfaces and more parking lots per user. Buildings energy performance is lower (French RT2012 criteria). There is no renewable energy production and no green roofs. Sc.1 has a lower capacity of 291 users (67% residents).

Both scenarios have the same population distribution that is representative of a long term trend in the area of the project with 45% active people, 25% children and students and 30% retired people.

Considering local transportation statistics, the fact that the nearest town is located 10 km away and the fact that public transportation services are insufficient, both mobility scenarios are largely based on individual vehicles. However, sc.0 gives more importance to cycling and walking with dedicated facilities. Mobility scenarios are specified for different types of users; at the level of the whole community of users, scenarios are given below (Table 1).

Table 1. Mobility scenarios

Scenario	Car	Bus	Cycling	Walking
0	71%	5%	6%	19%
1	79%	5%	2%	14%

Both projects were modeled in NEST, which means 3D modeling (Figure 2) and input of scenario characteristics, in order to evaluate their impacts. Main results for each indicator are presented hereafter.

Primary energy comsumption (Figure 3)

The total level of primary energy consumption of sc.1 (33 000 MJpe/year/user) is 36% higher than for sc.0 (24 000 MJpe/year/user). In sc.0 buildings operation, buidling materials and individual transportation respectively account for, 37%, 26% and 33% of primary energy consumption. Even if buildings operation remains the main contributor, the strategy towards density, high performance builings and renewable enrgy production leads to 85% less impact (9 100 MJpe/year/user) than sc.1 (16 900 MJpe/year/user). It is also interesting to note the really high contribution of individual transportation due to the fact that the project is located 10 km away from the main employment and services area. We also observe the impact of a neighborhood facilitating walking and cycling with 10% less impact from individual transportation in sc.0.

Figure 2 NEST model of scenario 0 (left) and scenario 1 (right)

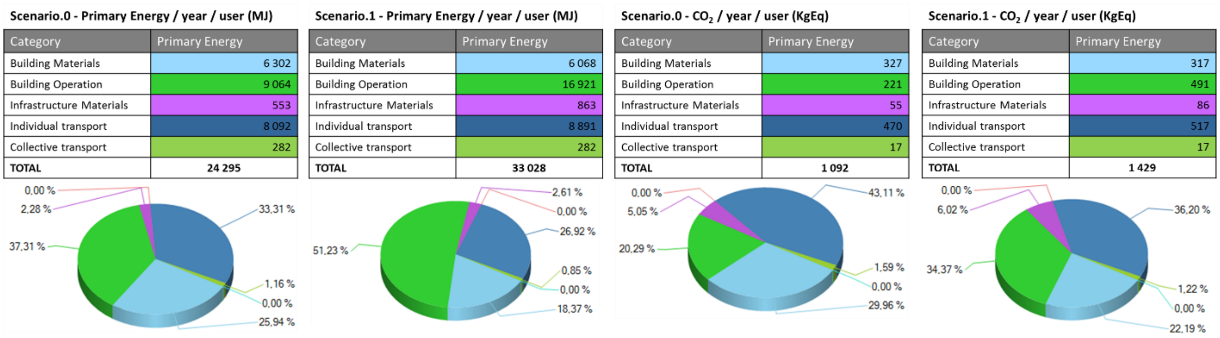

Figure 3 Energy and CO_2 indicators for scenario 0 and scenario 1

Climate Change (Figure 3)

With 1430 kgeqCO_2/year/user, sc.1 shows a 32% increase compared to sc.0. For both scenarios, individual transport is the most impacting contributor to this indicator with around 43% of the emissions in sc.0 and 36% of emissions in sc.1. This point is well representative of the importance of transport on the environmental performance of a project. If the site is in a rural or peri-urban area, the impact of transport might counterbalance the sustainability efforts realized at the scale of buildings, roads and other project elements. In sc.0, due to highly energy efficient buildings, the second contributor is building materials (30%) whereas in sc.1 it is buildings operation (34%). This distribution and difference between energy and Climate Change indicators is mainly explained by the 10 km distance between the site and the main economic area, and by the fact that electricity use is a low generator of CO_2 in France (for energy consumption in buildings).

Other Indicators

Biodiversity Loss: To evaluate the impact of land transformation, the initial land occupation is characterized as follow: 50% artificial, 30% agricultural, 10% urban and 10% vacant green land. The score of biodiversity loss related to land use is 33% higher for sc.1 (88 pdf/y/user vs. 67 pdf/y/user for sc.0) because of higher areas of mineralized public spaces and less areas of gardens. For both scenarios, the score of biodiversity loss related to land transformation is negative (-6.4 pdf/year/user for sc.0, -8.5 pdf/year/user fro sc.1) which means that through land transformation, the development brings biodiversiy potential.

Waste: Both scenarios have similar total waste production of about 4.5 t/y/user (87% from construction works). In sc.0 all buildings have a dedicated area for recycling and organic waste composters. Furthermore a specific “low waste agreement” for construction works is mandatory for all buildings to be contracted. These measures lead to 42% less non sortable waste for sc.0 than for sc.1.

Air pollution is essentially tied to individual transport (about 95% for both scenarios).

Water: In sc.0 strategies like water saving systems or recovery and treatment of drinking water and rainwater, leads to a quite low level of drinking water consumption (35 m^3/y/user) and a significant use of non-potable water (34% of total water consumption). Sc.1. is less engaged in terms of limitation of water consumption with 87 m^3/y/user of drinking water only. Regarding stormwater management, there is still more to do to manage rain water infiltration through the choice of pavement materials (65% runoff for sc.0 and 73% runoff in sc.1).

Social: Both scenarios show good results in terms of m^2 of housing and green spaces per user. Sc.1 is better in terms of parking availability but sc.0 is better in terms of transportation offer (with dedicated facilities for cycling and walking). In terms of accessibility to services both scenarios are similarly handicapped by the distance to the agglomeration and the fact that all services cannot be secured within the neighborhood.

COMPARISON OF THE “BASELINE” AND “SUSTAINABLE” SCENARIOS

Our analysis allowed visualizing the two alternatives based on two different urban principles and demonstrated the interest of such quantitative assessment. Sustainability is a complex matter for urban planning and quantitative assessment of environmental impacts in line with urban planning practice makes it more tangible and realistic to address.

In sc.0, the “sustainable scenario”, the inhabitant is clearly less energy consumer (-36%), emits less green house gases (-32%), generates less non sortable waste (-42%), consumes less water (-65%). It is also important to note that the neighborhood includes more comfortable buildings and host a user capacity 24% greater and an inhabitant capacity 32% greater than sc.1, the “baseline scenario”. Furthermore in sc.1, the low density model impeded reaching the 350 users target and the number of users is 291 only. Cost analysis is also a critical part of the assessment and may generate contrast with the environmental assessment. For now, NEST only accounts for an estimate of construction costs and some operation costs and requires further research to shift to an overall view of the project lifecycle economics.

At a more general level, this case study highlighted the relevance of an evaluation process for the early stage of urban project design. NEST tool allows for a new approach of knowledge-based design for urban planning. This evaluation proved to be really complementary to the planner's design skills and was a powerful mean to emphasize the dialogue about sustainability and particularly environmental performance between the design team, engineers and the local city.

CONCLUSION AND NEXT DEVELOPMENTS

NEST development was based on two observations:

1. Urban planners lack of resources to take into account the environmental impacts of their projects early enough
2. Urban sustainability cannot be addressed through a monocriteria optimization approach (e.g. building energy efficiency). It requires a multicriteria approach enabled by a quantitative-based decision support tool

NEST actual version has already been used on several projects and has proven its efficiency. However, to help urban planners make the best compromises between various sustainability dimensions, some new developments are in progress. Among others we are working on taking into account urban microclimate (solar radiation, natural light, wind, etc.) as design inputs. We are convinced that this is particularly relevant at the early design stage for two reasons:

1. It can put designers on the right path for an optimized design of public spaces and buildings layout
2. Microclimate through its interaction with urban forms sets up the comfort conditions in exterior public areas (determining usage) and interacts with buildings energy efficiency (through solar gains, wind exposure, etc.)

There are clear advantages in treating microclimate parameters as design inputs, however it remains challenging. At the design stage there is often a lack of budget, data and expertise to address these issues that usually require cost and data-intensive simulations.

The development of a decision support module to address these topics within NEST environment requires a significant amount of research that is currently being carried out in Nobatek through a PhD thesis with the CyVi research unit (Life Cycle Analysis Platform of Bordeaux University) as well as the CERMA laboratory (National School of Architecture of Nantes) and the GRECAU laboratory (National School of Architecture and Landscape of Bordeaux).

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