Environmental performance assessment for urban districts

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1. Introduction

There are two main types of environmental impact assessment at international, European and national level: the strategic environmental assessment (SEA) and the environmental impact assessment (EIA). SEA is a decision-making support process the main aim of which is to estimate the environmental effects of plans and programs before their approval (*ex ante*), during their implementation and at the end of their period of validity (*ex post*). Currently, the SEA is applied in Italy in fields such as: water management, telecommunications, tourism, town and country planning or land use. It also supports the planning process on a large-scale (at city, regional and national level).

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EIA is referred to the design and authorization of specific projects, even on a territorial scale, and aims to assess their environmental impacts (i.e. the changes in status of the environmental components) normally linked to an authorization process.

These evaluations have a static character and do not consider the interaction of several variables or how they react to changes caused by external factors. Also, many developments, such as the re-functionalization of old industrial buildings, or the regeneration of degraded parts of the city, are considered interventions at a microscale, so no practical tools are available supporting the analysis of the consequences of the design of these activities.

As the design activity is affected by the lack of an integrated view (Malatras *et al.*, 2008), in the current practice the interventions are conducted by specialists and are the sum of specific contributions and not the best result of a real and effective integration of skills. A real integration can only be realized if we can systematize the process of assessing, checking and evaluating the results of the different contributions. Useful tools are increasingly being employed, especially at regional level, such as atmospheric models, that can now reliably reproduce the spatial distribution of concentrations of air pollutants and therefore are used extensively, for example in the preparation of the annual report on air quality or in the planning and evaluation of limitation measures.

The planning of measures for the remediation of ambient air quality has so far been carried out at regional level (e.g. incentives for markets of cleaner technologies) or urban scale (e.g. pollution charge for accessing low emission zones), but little is worked out at the finer scale of a district, also because of the supposed lack of operating analytical tools; the perception, on the part of authorities, planners and citizens, that the climate may be to some extent influenced by urban planning at district scale, is still weak. This theme is generally regarded as pertaining to a global scale – obviously the most appropriate – and operations such as a SEA of a neighbourhood tend to contribute to the theme with the quantification of the contributions to the global greenhouse gas budget (Roper and Beard, 2006).

However, assessment tools are now available to clarify the role of planning actions at the neighbourhood scale on local climate, such as the Leadership in Energy and Environmental Design (LEED, 2011) neighbourhood protocol, which is an American rating system for the design, construction and operation of high performance green buildings, homes and neighbourhoods. The main weakness of this protocol lies in the fact that it originates in a territorial context that is deeply different from the European one.

Understanding how the design of the neighbourhood affects the local microclimate is not an end to itself. Consider the increase in hospitalizations and deaths that usually occur at extreme temperatures. Summer heat-wave events which are more and more frequent at European latitudes, because of climate change. The introduction of urban design elements that reduce the air temperature even just a few degrees would improve not only the comfort state of the neighbourhood inhabitants but also their health (Chan and Lee, 2008). In this sense, the improvement of microclimate must also be considered within a protocol aimed at quantifying good practice in design and, as demonstrated by tests carried out by the working group on CityLife district of Milan, tools to quantify changes in the microclimate induced by different design solutions at the neighbourhood scale are now available.

2. Findings and methods

A new approach, which aims to simulate construction and development projects through specific modelling, could provide concrete suggestions to improve their quality and, above all, really contribute to an improvement in citizens' quality of life. This goal can be achieved only by identifying indicators that can be assessed in an integrated way and suggesting corrective actions/modification and/or integration of the projects to improve their environmental performance.

In 2012 the project team received a private commission, requiring the assessment of environmental performances of a large urban project in the city of Milan: the CityLife district.

The work focused on four main areas of research:

(1) three-dimensional rendering of the project area and its surroundings;

(2) determination of the quality of urban life, at the level of the urban district, based on international protocols;

(3) measurement of air quality and comfort of the microclimate in the finished district, through specific modelling; and

(4) measurement of acoustic comfort in the finished district, through specific modelling.

In particular, the parameters related to air quality, acoustic comfort and well-being of the microclimate were compared with an area similar to that of the project analysed. Before the works were carried out, in collaboration with the client, information and data were collected in relation to the project based on a checklist prepared by the work group, with particular reference to:

- technological solutions, plants and buildings that characterise the features of the urban district CityLife;
- the district's green spaces and parking system;
- the transport system and infrastructure within the urban district CityLife and the network to connect it with the city; and
- the services in the area.

3. CityLife

3.1 Three-dimensional rendering of the project area and its surroundings

In order to carry out the work, the project area and the area for comparison were rendered in three-dimensional using a shape file, a file containing a plan of building perimeters with their height as an associated attribute.

Thanks to the collaboration with the owners and the use of satellite and map image display tools, all necessary data for the three-dimensional rendering were collected, mainly in reference to building perimeters and heights, road networks and green areas, etc. (Figure 1).

3.2 Identification of indicators of urban and environmental quality for the urban district CityLife: the 2009 LEED protocol for neighbourhood development

In this phase the indicators of urban and environmental quality of the CityLife district were represented based on national-international protocols/standards: in particular,

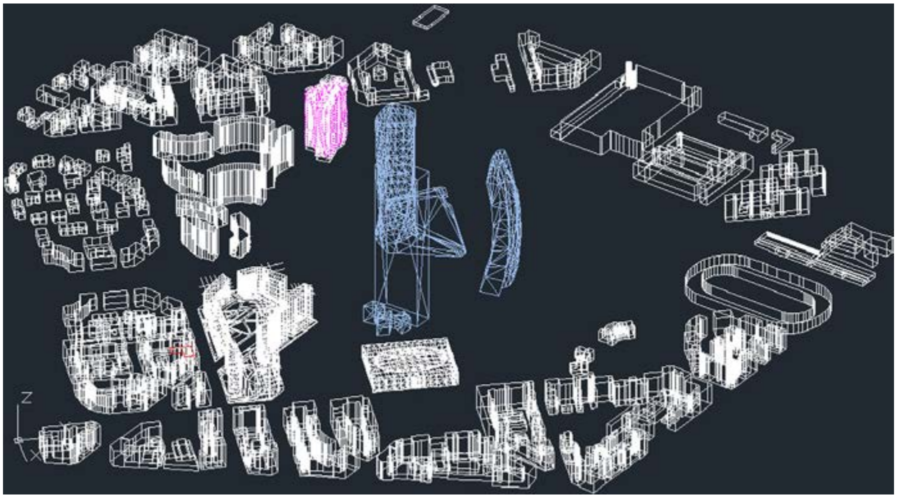


Figure 1.
The three-dimensional rendering of the project area and its surroundings

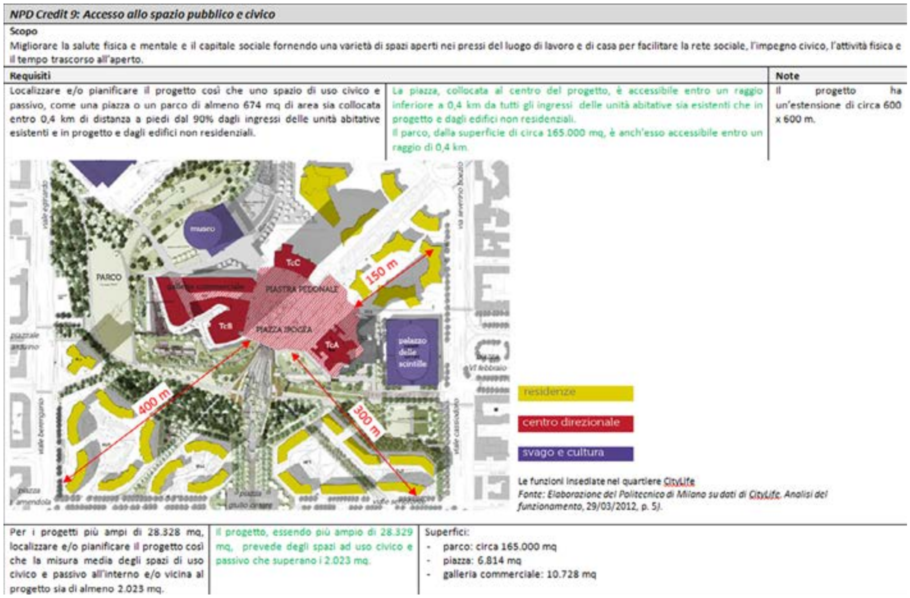
specific key performance indicators (KPIs) have been identified that are able to represent the quality of the CityLife district, verifying the compliance of the project with some of the indicators adopted by the 2009 LEED protocol for the neighbourhood development rating system (LEED-ND). These indicators may be, for example:

- availability of pedestrian streets;
- dependence on vehicular traffic;
- proximity to workplaces;
- cycle paths and pedestrian areas;
- parking systems;
- usability, etc.

The LEED-ND is a rating system developed for the planning and development of urban districts with the aim of setting a national standard for assessing and granting recognition to "green" neighbourhood development practices. It bases its approach on the dispersive use of land, typical of the US model, which provides for construction on isolated portions of land only accessible by highways. It is therefore appropriate to consider that such a protocol in Italy has never been applied and that only some of the indicators (those applicable in the context under analysis) were taken into account. The work done in this phase has allowed us to compare the characteristics of the CityLife project against the parameters covered in the international LEED neighbourhood protocol through the compilation of a series of report sheets that analyse in detail the data of each prerequisite and requisite forming part of the categories analysed (Figure 2).

3.3 Microscale assessment of microclimate comfort and air quality in the urban district CityLife for the purpose of comparison with average values

The objective of this phase is the development of specific micro-simulations to assess the benefits contributing to the comfort of the microclimate and air quality at a local level in the CityLife project. A number of parameters have been identified to represent



NPD Credit 9: Accesso allo spazio pubblico e civico

Scopo

Migliorare la salute fisica e mentale e il capitale sociale fornendo una varietà di spazi aperti nei pressi del luogo di lavoro e di casa per facilitare la rete sociale, l'impegno civico, l'attività fisica e il tempo trascorso all'aperto.

Requisiti		Note
Localizzare e/o pianificare il progetto così che uno spazio di uso civico e passivo, come una piazza o un parco di almeno 674 mq di area sia collocata entro 0,4 km di distanza a piedi dal 90% dagli ingressi delle unità abitative esistenti e in progetto e dagli edifici non residenziali.	La piazza, collocata al centro del progetto, è accessibile entro un raggio inferiore a 0,4 km da tutti gli ingressi delle unità abitative sia esistenti che in progetto e dagli edifici non residenziali. Il parco, dalla superficie di circa 165.000 mq, è anch'esso accessibile entro un raggio di 0,4 km.	Il progetto ha un'estensione di circa 600 x 600 m.
Per i progetti più ampi di 28.328 mq, localizzare e/o pianificare il progetto così che la misura media degli spazi di uso civico e passivo all'interno e/o vicina al progetto sia di almeno 2.023 mq.	Il progetto, essendo più ampio di 28.329 mq, prevede degli spazi ad uso civico e passivo che superano i 2.023 mq.	Superfici: - parco: circa 165.000 mq - piazza: 6.814 mq - galleria commerciale: 10.728 mq

Figure 2.
Example report sheet for the analysis of a LEED-ND protocol requisite

the district in terms of comfort and quality and compared with another district in Milan, which was urbanised in a more traditional way. These parameters refer to practices adopted by individuals and institutional sources for the representation of environmental/urban quality (i.e. *Report on the State of the Environment in Lombardy* ARPA Lombardy (2011), *Quality of the Urban Environment* ISPRA (2012), *Urban Ecosystem* Legambiente (2011), etc.) (Table I).

In particular, the calculations made allow us to:

- quantify the benefits, from the viewpoint of air quality, of the solutions adopted in the urban district project compared to those estimated within a more traditional urban context; and
- highlight the major/minor environmental critical points of the district (relative to air quality and microclimate) transmitting, if necessary, the design choices that are still works in progress (ideal location of cycle and pedestrian paths, play areas, public transport stops, etc.).

Table I.
Parameters analysed in reference to microclimate well-being and air quality

Air quality parameters	Meteorological parameters
Carbon monoxide – CO: maximum hourly concentration	Temperature: daily average and excursion
Nitrous oxides – NOx-NO_2: average daily and maximum hourly concentrations	
Dust particles – PM_{10} e $PM_{2.5}$: average daily concentration	Relative humidity: daily average and excursion
Benzene: average daily concentration	Wind speed: daily average and excursion
Polycyclic aromatic hydrocarbons (PAH): average daily concentration of total PAH or benzo(a)pyrene	Predicted mean vote (PMV): daily average and excursion

The steps of this phase are:

(a) Selection of the weather-dispersive episodes and weather simulations. Simulations were carried out considering two episodes lasting one to two days each, chosen from those typical and/or critical from a weather/dispersive viewpoint for the city of Milan. To select these episodes (winter and summer) one year of meteorological data obtained from a weather station of the regional network was analysed, significant with respect to the location of the project district. Taking the precise meteorological time series as the starting point, simulations were performed to reconstruct wind fields and turbulence for the area in question, in relation to the two selected episodes (Figure 3).

(b) Preparation of three-dimensional computational domains. Starting from the shape file previously developed, the three-dimensional topography was created at high resolution (approximately 1 m) of the land and buildings of the project area and of the area for comparison, nearby and not more than 1 km away (Figure 4).

(c) Definition of the pollution sources and calculation of emissions. Once the location and characteristics of the sources of air pollutants present were defined (roads, parking areas, power plants, etc.) the corresponding polluting emissions were calculated using standard methodologies at European level documented in "EPER/EEA air pollutant emission inventory guidebook". With regard to road traffic, emissions (CO, NOx, VOC, N_2O, NH_3, SO_2, CO_2, CH_4, Pb, PM, Pb, HM, NMVOC) were calculated using the program TREFIC, developed on the basis of the most up-to-date methodology COPERT (computer program to calculate emissions from road traffic). The working group has been involved in developing the distribution of vehicles in the COPERT categories on the basis of national data of registered vehicles and average distance travelled. The simulations, representing a winter situation and a summer situation, take into account the contributions of both the city's local and background emissions (Figures 5 and 6).

(d) Study of air quality in microscale. Through the use of the Model MSS – Micro-Swift-Spray, which allows the microscale reconstruction of diffusion of pollutants into the atmosphere, up to four simulations have been performed, varying the two domains and the two weather-dispersive episodes. In this way maps of the relevant concentration statistics were generated and comparisons made between

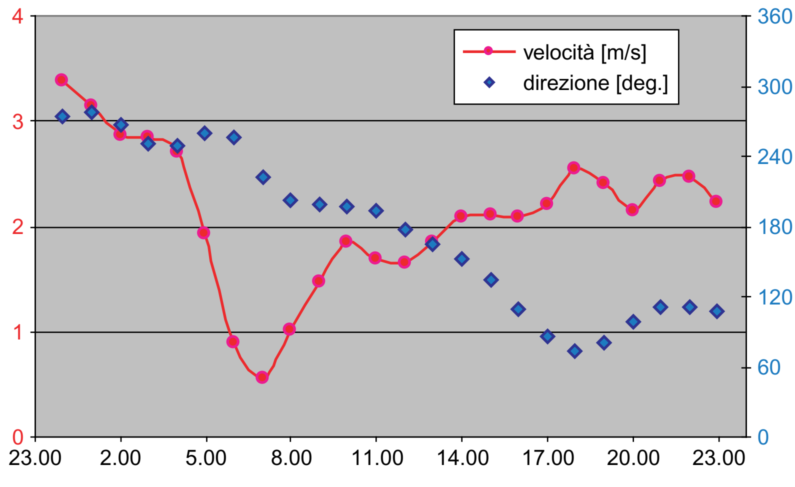


Figure 3.
Winter simulation period: 29 January 2010 (wind speed and direction)

Figure 4.
Three-dimensional rendering of the domain for the simulations on microclimate and air quality

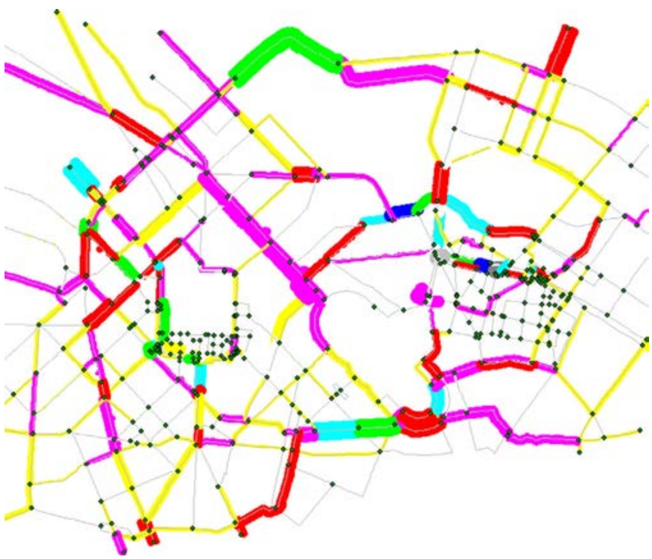
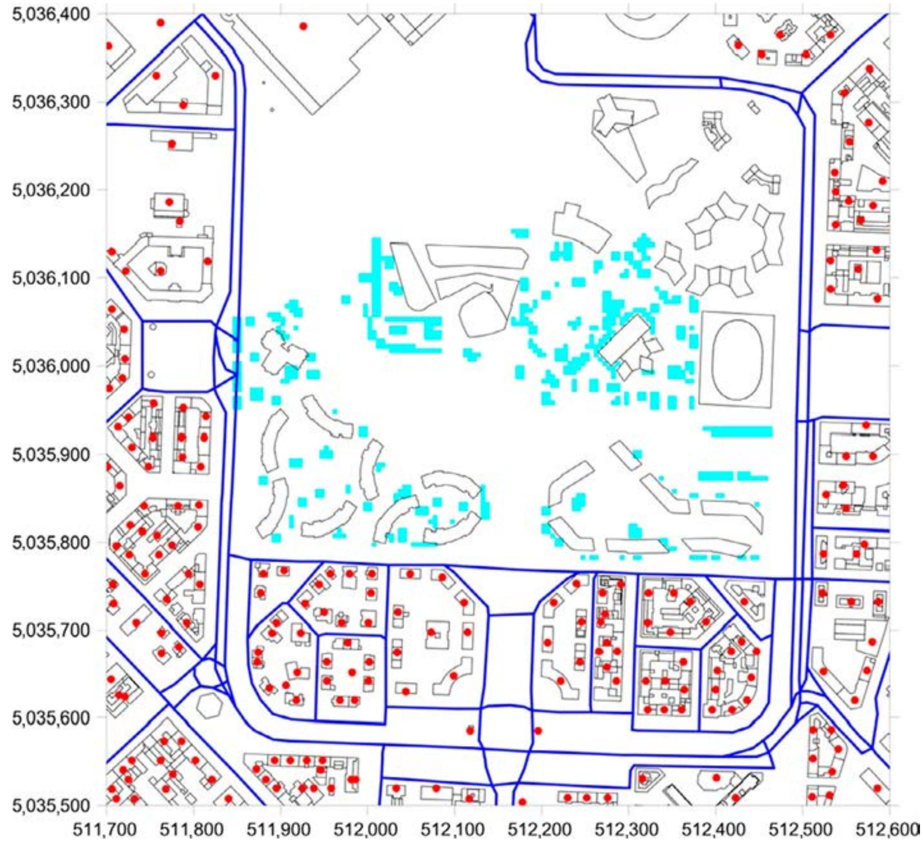


Figure 5.
A traffic allocation model

domains and between episodes. The simulations, representative of a winter situation and a summer situation, take into account both the contributions of both the city's local and background emissions (Figures 7 and 8).

(e) Study of the microclimate. Through the use of ENVI-met, a three-dimensional model of the microclimate designed to simulate the surface-plant-air interactions in an urban environment, modelling studies were conducted for the reconstruction of the



Notes: Blue lines – streets; blue areas – grates; red dots – fireplaces/chimney pots

Figure 6.
Location of emissions within the domain

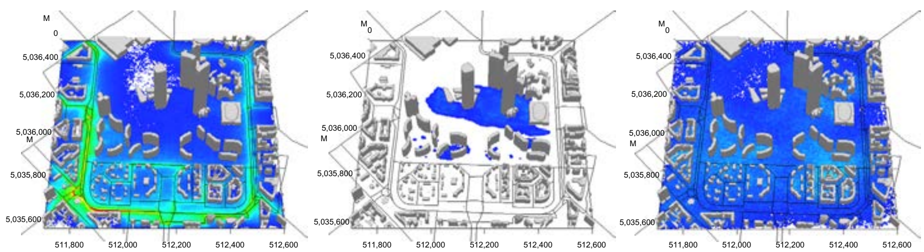


Figure 7.
Contributions from PM10 concentrations in winter coming from the following emission sources: traffic (left), grates (centre) and heating (right)

microclimate in the presence of the architectural elements characteristic of the urban intervention in question and of that used for comparison. The simulations conducted for the microclimate study take into account some initial parameters shown in the following table. These were chosen based on the series of climatic conditions measured at Linate (Milan) weather station and, with regard to the wind, on simulations of the national project QualeAria. The results were presented as three-dimensional maps

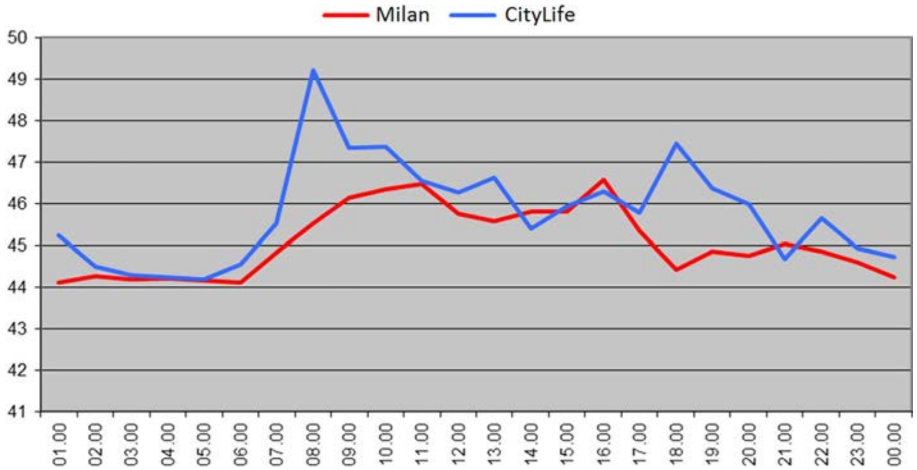


Figure 8.
Comparison between different domains and similar episodes of hourly PM10 concentrations in winter

(at different altitudes) of the meteorological parameters calculated, highlighting the presence of points of particular criticality or, vice versa, those that were particularly advantageous from a microclimate viewpoint (Table II and Figures 9 and 10).

(f) Comparison with the sampling area. The area for comparison, characterised by traditional urban solutions, has been considered as an area representative of Milan for comparison with the project area. The simulations were carried out in order to follow the temporal evolution of the main physical parameters over a span of 24 hours, and in order to compare the parameters that characterise the microclimatic comfort and local air quality of the two domains. They are, therefore, simulations of very specific episodes; although representative of typical winter and summer conditions, but have no statistical value. The average values were calculated on the basis of simulation results at 1 p.m., for both the winter and summer scenarios scenery, so as to maximize the effect of solar radiation (Table III).

3.4 Acoustic comfort evaluation of the CityLife urban district for the purposes of comparison with average values

The acoustic comfort evaluation aims to analyse potential acoustic dependence that could be generated in confined environments. Sounds and noises in confined environments must have low intelligibility, clarity and definition so they are not harmful and do not constitute a clear limitation of quality of life and a significant loss

Table II.
Initial meteorological parameters for the simulations with ENVI-met in two winter and summer episodes

Base parameters – city of Milan	Winter	Summer
Simulation start date	10 January 2010	10 July 2010
Potential temperature of initial air (K)	275.5	296.8
Wind speed at 10 m height (m/s)	3.15	2.80
Wind direction (°C)	247.5	337.5
Roughness length (z_0) (m)	0.4	0.4
Specific humidity at 2,500 m (g H_20/kg air)	4.0	7.0
Relative humidity at 2 m (%)	81	66

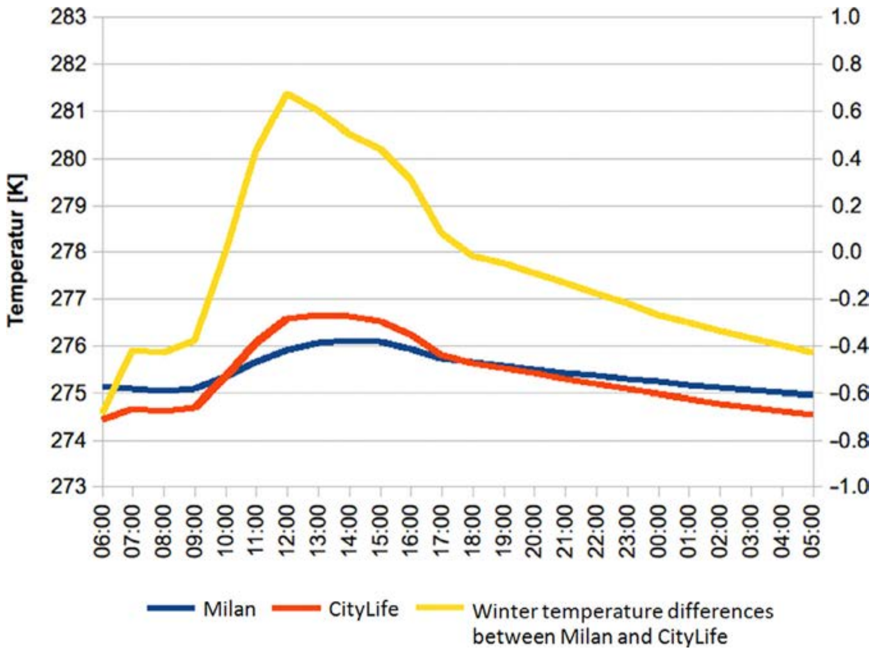


Figure 9.
Comparison of winter temperature

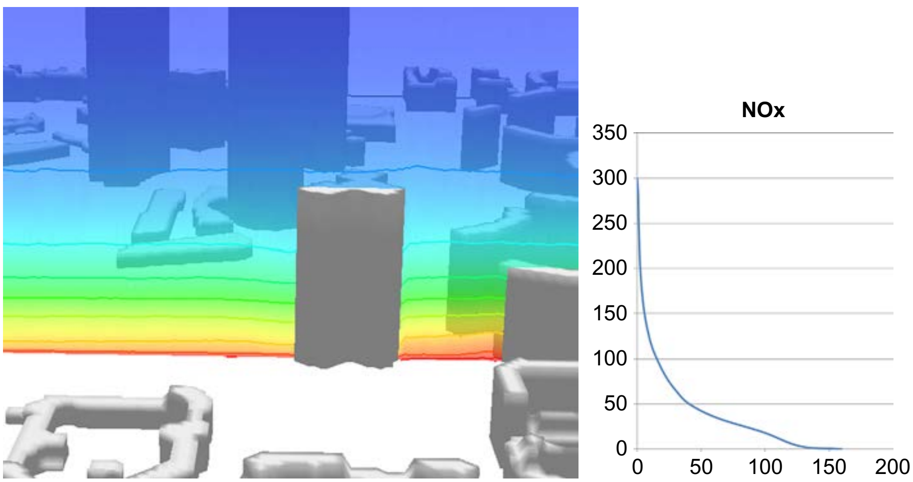


Figure 10.
Average NOx concentrations

of privacy. These parameters can be determined at the planning stage from the position of buildings in the territorial context, the form of each building and the materials used on the exteriors.

Quantifying acoustic descriptors for sound levels and intelligibility of speech has enabled the degree of privacy and comfort of the site to be established.

To achieve this objective a study was carried out consisting of separate sequential parts:

Simulation period	ARPA Lombardy findings[a]	CityLife	Milan	CityLife	Milan
	Air quality comparison			Microclimate comparison	
	Nitrous oxide: NOx ($\mu g/m^3$)			Temperature (°C)	
Winter	168	155.7	173.2	3.6	3.0
Summer	51	32.4	41.7	27.8	28.7
	Nitrous dioxide: NO_2 ($\mu g/m^3$)			Average radiant temperature (K)	
Winter	75.9	79.6	82.1	307.8	305.1
Summer	45	26.7	31.8	335.2	338.1
	Carbon monoxide: CO ($\mu g/m^3$)			PMV (K)	
Winter	1,300	1,236.3	1,281.6	−0.6	−0.7
Summer	800	700	731.9	3.8	4.2
	Dust particles: PM_{10} ($\mu g/m^3$)				
Winter	57.6	45.3	45.9		
Summer	25.5	11.4	12.2		

Note: [a]Measured data were obtained through the analysis of the year's time series, measured in regional network huts, on the quality of air within Milan's urban fabric and managed by ARPA Lombardy

Table III. Air quality and microclimate comparisons between CityLife and the municipality of Milan

- Virtual modelling designed using the customized proprietary software CATT Acoustic produced by CATT in Gothenburg (Sweden) and simulation of the whole representative built context. This phase of the simulation includes a section on the current scenario simulation, using a source of white noise with the same sound level across the entire frequency range.
- A series of measurements on site using the white noise source mentioned above, calibration of the model calculated by comparing experimental data with simulated data.
- Future scenario simulation conducted using a source with human voice characteristics.

Computerized acoustic simulation of indoor spaces has been conducted using special software based on principles of geometric acoustics.

The first step has been to reproduce the correct geometry of the environment to be modelled in the software. In a second stage, according to the type of material chosen, each surface has been assigned a coefficient of acoustic absorption (α), corresponding to the assumed technical characteristics.

Starting with a specific position of the sound source, which can be positioned at will, the computer has simulated the contemporaneous emission of many thousands of sound rays, using a technique called "raytracing":

- if the sound ray hits an absorbent material, the sound is reduced; and
- if the sound ray hits a reflecting material, the sound is transmitted into the environment.

In these types of studies, unlike in energy studies, the wall construction is not important, just the layer that comes into direct contact with the sound wave. The precision and value of the results obtained depend to a large extent on:

- surface modelling;
- absorption characteristics; and
- transmission characteristics.

As CATT Acoustic does not have a graphic interface and autonomous modelling system the graphic representation of a confined environment is produced in the form of three files in .TXT format:

(1) The .GEO file contains all the information needed to reconstruct the geometry of the model and the assignation of a material to every surface, identifying it by its absorption values (ABS) at different frequencies.

(2) The .SRC file provides information regarding the sound sources (positions and spectrum of sound pressure that the source produces for every frequency).

(3) The .REC file contains information regarding the positioning of the receptors using Cartesian coordinates.

These files can be produced manually or using special CAD plugins (for example ArchiCAD).

This software can also be used to check the influence of sound transmission on objective parameters such as: T60 (reverberation time), C80 (clarity index), D50 (definition index), STI (speech intelligibility) and SPL (sound pressure level), which form the basis of architectural acoustics. The sound pressure level in an environment is determined in dB(A).

Using this software it is possible to carry out mapping on confined environments in order to:

- identify areas with different degrees of reverberation in various scenarios;
- identify the intelligibility, clarity and definition of the sound from different positions in the room;
- design a graphic scale that assigns a colour to each value in relation to the objective criterion under evaluation;
- determine case by case the scale of values best suited to the criterion under evaluation; and
- adapt the geometry or materials to reach an optimal acoustic level.

With this kind of representation the results of the simulation will also be easily understood by the layman.

The study carried out showed that:

- Areas with Leq values of 45 dBA or less, the areas highlighted in yellow, mostly internal courtyards of the houses, are protected from road traffic noise.
- Areas with Leq values between 50 and 55 dBA, which are almost all pedestrian areas inside the settlement, correspond to especially protected areas. These pressure levels allow sound to be perceived but this perception is equivalent to a single source of road noise in an open field, located 250 m away. The settlement in question appears to be, instead, surrounded by noise sources road away from the receptor, in some cases, even less than 200 m (Figure 11 and Table IV).

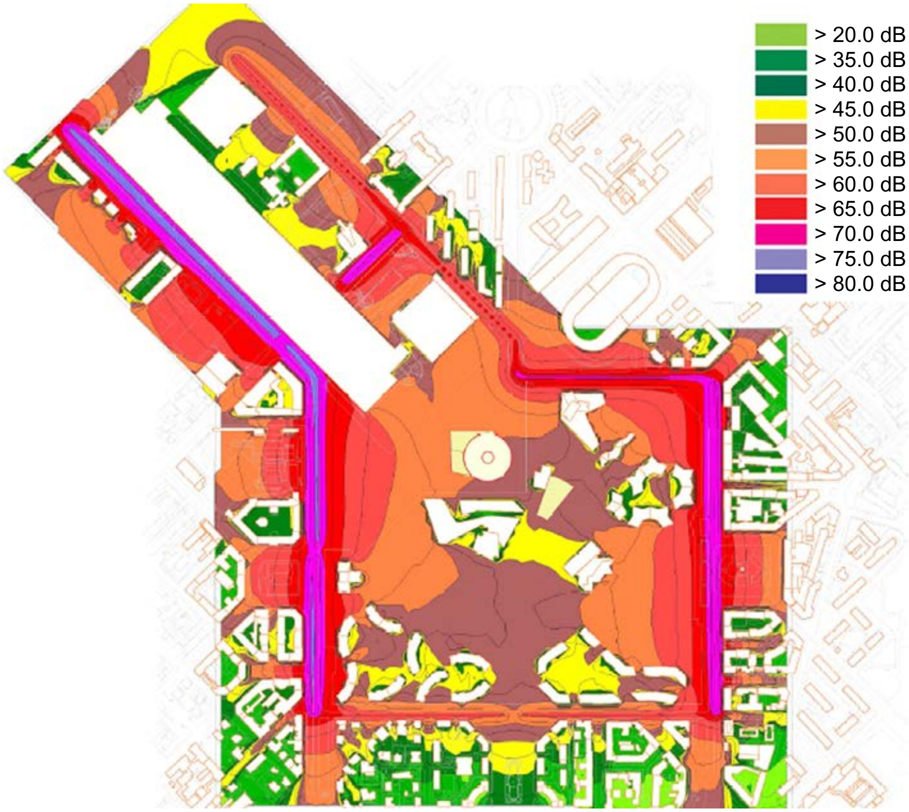


Figure 11.
Leq levels in the CityLife urban district

Table IV.

	Reference times			
	Emission threshold values Leq in dB(A) (art. 2)		Absolute emission threshold values Leq in dB(A) (art. 3)	
Classification for intended use of land	Day 6 a.m.-10 p.m.	Night 10 p.m.-6 a.m.	Day 6 a.m.-10 p.m.	Night 10 p.m.-6 a.m.
I. Specially protected areas	45	45	35	35
II. Mainly residential areas	50	50	40	40
III. Mixed type areas	55	55	45	45
IV. Areas of intense human activity	60	60	50	50
V. Mainly industrial areas	65	65	55	55
VI. Exclusively industrial areas	65	65	65	65

Source: DPCM 14 November 1997, "Determination of threshold values for sources of noise"

4. Conclusion

This is a project aimed at promoting innovative application of technologies and systems in support of the "urban environment" in order to assess the environmental quality at a microscale level in a dynamic way.

The model represented by a set of indicators, refers to the three main areas of activity:

(1) the measurement of microclimate comfort;
(2) the measurement of air quality; and
(3) the measurement of acoustic comfort.

A specific-oriented modelling will simulate the real conditions of the neighbourhood/district by considering all the internal and external factors.

The model is able to benefit both the local public administration, which may require this type of assessment on the occasion of complex projects and the promoters/developers, who could make changes to the initial project should the evaluation identify critical issues related to the design choices (orientation of buildings, quality and presence of green, traffic emissions inside the neighbourhood, etc.).

The main result of the project is the delivery of a protocol for environmental good practice in urban planning and design at the district scale. The project will also monitor the socio-economic impact under several points of view.

During the project, we will also measure how successful it has been:

- to attract and mix highly professional figures from several fields (architecture, city planning, engineering, environmental sciences, physics, etc.), in other words create a new consultancy market in the local territory of Milan metropolitan area where most of the partners are based;
- to play an active role in the planning and design process by guiding it towards virtuous interaction with the urban planning and design world; and
- to increase social awareness.

The protocol that will be developed inside the project is aimed at pointing out and encouraging the best design practice, at the district scale, for improving the protection of the environment and the quality of life of the citizens.

Activities will be performed to monitor the extent of the protocol's capability to drive the district design towards positive environmental consequences.

This experience highlighted the lack of appropriated integrated instruments – applying a general approach – for this scope and, above all, the total lack of validated protocols aimed at guiding both local administration and real estate operators throughout the combined assessment and designing process.

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