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Urban environment quality assessment using a methodology and set of indicators for medium-density neighbourhoods: a comparative case study of Lodi and Genoa

Metodologia e indicadores para avaliação da qualidade do ambiente urbano de bairros de média densidade: um estudo de caso comparativo entre Lodi e Gênova

Ioanni Delsante

Abstract

One of the main issues in urban sustainability and environmental assessment relates to the selection of indicators (SOCCO, 2000), as there are already many international and recognised core sets (DELSANTE, 2007; LEE; CHAN 2009). Nevertheless, specific local contexts are still in need of appropriate, original indicators and indices (MALCEVSCHI, 2004). This paper deals with the urban quality assessment of medium-density neighbourhoods, which typically include dwellings but also public functions, public spaces and urban infrastructure. The evaluation method is based on a set of 74 indicators used within a specific computational method that is based on scores and defined through pairwise comparison matrices (SOCCO, 2003) to convert qualitative and quantitative evaluations into scores (0 to +100). The assessment involved two different urban contexts in the cities of Lodi and Genoa (Italy). It tests if the set can be used in other sites and cities; the results show significant findings and potentialities, but also some limitations. As significant connections have already been found between urban quality and well-being surveys of inhabitants (ORLANDO, 2007), the possibility to act comparatively in different contexts increases overall research potentiality.

Keywords: Urban quality assessment. Neighbourhood scale. Qualitative and quantitative urban indicators. Medium-density neighbourhoods.

Resumo

Um dos principais temas nas áreas de sustentabilidade urbana e avaliação ambiental está relacionado à seleção de indicadores (SOCCO, 2000), tendo em vista os diversos sistemas internacionais já existentes e consagrados (DELSANTE, 2007; LEE, 2009). No entanto, há ainda contextos locais específicos que requerem indicadores e índices apropriados e originais (MALCEVSCHI, 2004). Este artigo aborda a avaliação da qualidade urbana de bairros de densidade média, que incluem, tipicamente, as residências, mas também serviços e espaços públicos e infraestrutura urbana. O método de avaliação é baseado em um conjunto de 74 indicadores usados em um método computacional específico baseado em pontos e definido por meio de uma matriz de comparação pareada (SOCCO, 2003) para converter avaliações qualitativas e quantitativas em pontos (0 to +100). A avaliação envolveu dois contextos urbanos diferentes nas cidades de Lodi e Gênova – Itália. O método verifica se o conjunto pode ser usado em outras cidades e localidades; os resultados mostram resultados significativos e potencialidades, assim como algumas limitações. Considerando que já foram identificadas relações significativas entre qualidade urbana e saúde da população (ORLANDO, 2007), a possibilidade de desenvolver estudos comparativos em diferentes contextos aumenta a potencialidade deste método.

Palavras-Chaves: Avaliação da qualidade urbana. Escala de vizinhança. Indicadores urbanos. Bairros de média densidade.

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Introduction

One of the main issues in terms of assessing urban sustainability, where scientific research and political action often intersect, is represented by indicators (SOCCO, 2000). There are different ways to define an indicator as it could deal with measurable and non-measurable phenomena. While CO₂ emissions are measurable and a meaningful indicator of environmental sustainability, “landscape value” is more difficult to measure¹, and its evaluation depends partly on subjective experience. Nevertheless, it is still possible to assign landscape a numerical value. In general terms, every phenomenon dealing with sustainability is quantifiable and can be expressed directly or converted through a weighting process into a numerical value (GISOTTI, BRUSCHI, 1992).

An indicator is a parameter or value that is derived from other parameters (ORGANIZATION..., 1993). It selects, provides information or describes a phenomenon, environment or area. Its meaning goes beyond what is directly associated with the parameter, as it is a measured or observed property (BEZZI, 2001). Each indicator reflects the relationship between an action and its consequences, serving as a conceptual tool that is expressed in clear and precise terms to measure the progress towards a goal. An indicator can thus be defined as a variable that is useful to describe complex realities in relationship to individual features or to an entire environmental system². Indicators can also be classified as absolute or relative; the former express absolute levels of individual variables that are considered meaningful, while the latter are based on relationships between absolute indicators. There are different and meaningful applications of both kinds of indicators in planning and environmental assessment procedures. In terms of sustainability, indicators are useful for evaluating performances in order to adopt the best political actions.

The choice of indicators is generally not left to the individual; core sets of indicators are shared between international stakeholders and institutions. In recent years, international core sets have been progressively developed. Some of the most commonly used are:

- (a) the “Core set of indicators for environmental performance reviews” by the OECD (ORGANIZATION..., 1993), a basic group of indicators that is meaningful for their relationships with the Pressure, State, Response (PSR) model;
- (b) the “Monitoring human settlements with urban indicators” by the United Nations Centre for Human Settlements known as Habitat (UN HABITAT, 1997), which are very heavily used in international contexts;
- (c) the “Indicators of sustainable development” by the United Nations (UNITED..., 2007), which are among the most systematic and complete works on sustainability indicators; they were inspired by the Agenda 21 process; and
- (d) the Agenda 21 process (UNITED..., 1992), which began after 1992 and has local implementations; it involves five different domains or categories of indicators, including urban and building structure, urban green, landscape, risk factors and infrastructure.

In the last few years, the difficulty in the management of an excessive amount of data led to the identification of core sets of indicators, each with a smaller number of indicators. Sustainability at different scales (e.g., local to national) is monitored through synthetic indicators or indexes. For example, Common European Indicators, Environmental Sustainability Index (ESI), Environmental Performance Index (EPI), European Green Cities Index and Genuine Savings by The World Bank all refer to ecological carrying capacity. Others like Human Development Index (HDI), Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI) and Well-Being Index by IUCN (The World Conservation Union) take an economic approach and use data to measure well-being from a sustainable perspective (CACCIOTTI, 2010).

As there are a large number of indicators, one of the most pressing issues is how to select an appropriate number that is limited, effectively populated with data and easily comparable between different places or nations. However, the need to provide specific indicators for particular circumstances or activities with precise focuses or needs is evident, in line with the goal of “[...] operating an estimate (not a direct measure) of complex realities in time and in space [...]” (MALCEVSCHI, 2004, p. 28). This applies for example in the case of evaluating overall “urban quality” achievements before and after urban regeneration programmes.

¹In terms of qualitative approaches, there are important references in terms of landscape evaluation, according to relevant research and case studied carried out in the UK since the 1960s (e.g., Hampshire County Council, 1968). These experiences are based mainly on direct observation and perceptions of sites made by experts.

² Even though in the literature and practice there is no longer any real distinction, an “index” could be defined as a number of parameters or indicators that are aggregated or weighted.

The more complex an investigation, the more indicators are needed. Regardless of scale or complexity, the use of indicators should be efficient and without semantic overlap or redundancy. Integration between indicators from multiple disciplines should be encouraged, as should the sharing of indicators between different sets. The process of defining new indicators should always start from the nature of the object to be investigated by defining its basic elements and meanings.

The term “neighbourhood”³ represents an intermediate urban scale, larger than a single building and its immediate surroundings but smaller than an entire town or city. It usually includes dwellings, infrastructure and community services. It is a scale in which multiple disciplines are involved, including environmental, mobility, accessibility, and infrastructure studies and their goals for optimisation, such as the call for smart cities in the Horizon 2020 European research programme⁴.

Concerning neighbourhood scale, Sharifi and Murayama (2013) identify seven neighbourhood sustainability assessment (NSA) tools that are fully developed, readily available and encompass all three pillars of social, economic and environmental sustainability. The seven tools are: LEED-ND, EarthCraft Communities (ECC), BREEAM Communities, CASBEE-UD, HQE2R, Ecocity and SCR.

It must, however, be kept in mind that most of these tools have been developed to assist in large-scale redevelopments rather than the assessment of existing settlements (NGUYEN, ALTAN, 2011). For example, BREEAM Communities was specifically designed to assess medium- to large-scale development and redevelopment projects, but covers only the design and planning stages of any development.

The CRISP⁵ (Construction and City-Related Sustainability Indicators) database consists of 510 indicators (BOURDEAUX, 2003; HAKKINEN, 2002) from a number of different core sets, the aim of which is to share knowledge, organise indicators by topics and goals and allow for comparisons between them. The database includes 40 sets from different countries, sometimes locally specified or targeted to specific issues such as social housing. It includes, for example,

“Demolition or renovation in a social housing neighbourhood” (France, 48 indicators), “Sustainable development monitoring indicators at the city scale for the Land Use Plan of Montauban” (France, 15 indicators), “Monitor Urban Renewal—Dwelling density within the urban area” (the Netherlands, 26 indicators) and the “Green Building Challenge” (GBC) (Canada, 77 indicators).

The “Index for environmental quality in residential space” in Reggio Emilia (Italy) (OSSERVATORIO... et al., 2002) is a tool for supporting planning at the neighbourhood scale and refers to existing urban settlements. The overall quality index is composed of two macro-indexes, four base indexes and 19 indicators (Figure 1). The indicators deal with housing quality (4), quality of housing context (5), quality of basic social services (5) and quality of house-services connections (5). Ideally, urban analysis would have been based on each plot unit; however, due to high costs it was finally delivered by considering homogenous plot units together.

Even though there are some meaningful sets of indicators corresponding to neighbourhoods, there remains substantial opportunity for further research and experimentation (DAMEN, 2014; SOCCO et al., 2003), especially in relation to various densities (LEE; CHAN, 2009). This paper aims to verify an accurate and flexible procedure for evaluating the urban quality of medium-density neighbourhoods in different cities. The use of the same methodology and a comparison of results might reveal significant findings and shortcomings.

Research methodology

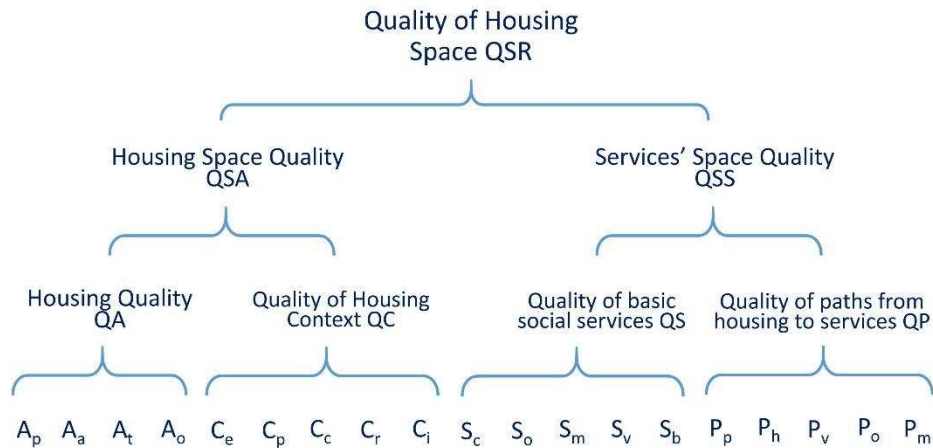
This paper is based on previous research developed at the University of Pavia within the PRIN 2004 Research Project (2004–2007), and coordinated by Paolo Orlando at the University of Genoa. Different scholars (BATTISTELLA, 2006; DELSANTE, 2007; GHIA, 2006; ORLANDO, 2007) have published the scientific outcomes of this research project. The adoption of the indicator set in one city council’s environmental assessment policy (COMUNE..., 2010) showed further research impacts. Further investigations have been conducted to check whether the indicator set could fit different sites in similar European contexts (DELSANTE et al., 2014), including comparative tests in Lodi and Genoa in Italy. Data collection, surveys and direct observation were also conducted on site.

³The concept of “district” does not fit this purpose, as it could refer to administrative areas of large districts between towns and regions, as in the UK.

⁴<<http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2148-scc-01-2015.html>>.

⁵2000-2003 FP-5 EU funded project.

Figure 1 - Tree structure to represent the Quality of Housing Space, based on 19 indicators



Source: translated from Socco *et al.* (2003).

Assessment and computation methodology

Indicators are organised within an organised tree structure, from single indicators to macro-indicators and indexes (OSSERVATORIO... *et al.*, 2002; SCUSSEL, 2007).

Four main domains have been defined (Architecture and Urban Design, Uses and Accessibility, Landscape and Environment and Social and Community) (DELSANTE, 2007), and 18 macro-indicators have been used to refer to these domains. The 74 indicators are each assigned to only one macro-indicator and one domain (Figure 2).

The indicators are grouped into four main categories, defined as domains, using a multi-disciplinary approach (GHIA, 2006; DELSANTE, 2007):

- (a) the Architectural and Urban Design domain group is related to architectural values, identity and other recognisable features;
- (b) the Uses and Accessibility domain is related to the presence and quality of services, infrastructure and mobility;
- (c) the Landscape and Environment domain is linked to the quality and presence of landscape, environmental systems and visual and perception issues; and
- (d) the Social and Community domain is related to public and collective functions and services.

The overall index of Urban Environment Quality (Q_{glob}) is defined as follows (Eq. 1):

$$Q_{glob} = f(Q_{arch}, Q_{acc}, Q_{env}, Q_{soc}) \quad \text{Eq. 1}$$

Where:

Q_{arch} = Architectural and Urban Design domain quality index;

Q_{acc} = Uses and Accessibility quality index;

Q_{env} = Landscape and Environmental quality index; and

Q_{soc} = Social and Community quality index.

In more detail, regarding Q_{glob} , the following formula is valid (Eq. 2):

$$Q_{glob} = k_{arch} Q_{arch} + k_{acc} Q_{acc} + k_{env} Q_{env} + k_{soc} Q_{soc} \quad \text{Eq. 2}$$

Where:

k_{arch} = weighted coefficient for Architectural and Urban design domain;

k_{acc} = weighted coefficient for Uses and Accessibility domain;

k_{env} = weighted coefficient for Landscape and Environment domain; and

k_{soc} = weighted coefficient for Social and Community domain.

Each domain quality index (Q_{arch} , Q_{acc} , Q_{env} , Q_{soc}) is the result of the weighted sum of its macro-indicators, as follows (Eq. 3, 4, 5 and 6) (Figure 5):

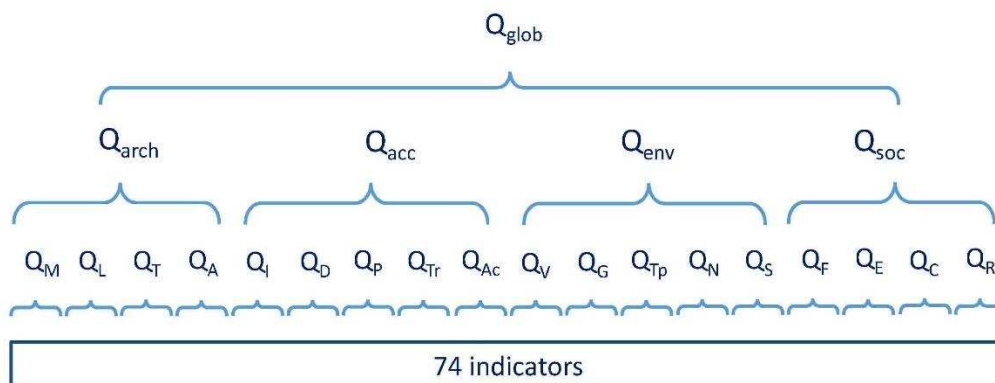
$$Q_{arch} = (k_M Q_M + k_L Q_L + k_T Q_T + k_A Q_A) \quad \text{Eq. 3}$$

$$Q_{acc} = (K_I Q_I + k_D Q_D + k_P Q_P + k_{Tr} Q_{Tr} + K_{Ac} Q_{Ac}) \quad \text{Eq. 4}$$

$$Q_{env} = (k_V Q_V + k_G Q_G + k_{To} Q_{To} + k_N Q_N + k_S Q_S) \quad \text{Eq. 5}$$

$$Q_{soc} = (k_F Q_F + k_E Q_E + k_C Q_C + k_R Q_R) \quad \text{Eq. 6}$$

Figure 2 - Tree structure of indicators, macro-indicators and domains



In the same way, each macro-indicator, such as Q_M (Urban Morphology), is defined by the weighted sum of the related indicators (for Q_M , these are M_s , M_r , M_d and M_v ; see Fig. 6). For the overall Urban Environment Quality Index (Q_{glob}), each of the four domains and the macro-indicators are functions of the weighted sum of other variables, starting from indicators (GHIA, 2006, OSSERVATORIO... et al., 2002; SCUSSEL, 2007). Each should be expressed with a numerical value; when the evaluation of single indicators is complete, the weighted sum of values results in the Urban Environment Quality Index.

The methodology is independent of the total number of indicators, macro-indicators and domains used. The accuracy of the evaluation depends on the overall number of indicators employed. In this case, the overall number of indicators, macro-indicators and domains has been specified according to the object of the investigation, with each indicator differentiated to avoid redundancy of information (DELSANTE, 2007; DELSANTE et al., 2014).

From qualitative to quantitative scores: matrices, indicators and weighted coefficients

The assessment procedure uses a score typology, with scores ranging from 0 to +100 and +60 considered sufficient. To convert a qualitative evaluation - Excellent, Good, Sufficient, Not Sufficient - into quantitative scores (SOCCO et al., 2003), a pairwise comparison technique is used. Values are compared by dividing 100 points between them (e.g., 80/20, 60/40, etc.). A pairwise comparison based matrix is generated, on which the diagonal of the numerical value is always 50 (Figure 3). By using pairwise comparison, the information is redundant to define the difference between different variables such as values. This redundancy allows the indirect control of the

coherence and cohesion of the evaluation (OSSERVATORIO... et al., 2002).

Starting from the numerical values in the matrix cells, final numerical values can be obtained based on a normalised scale from 0 to 1. A pairwise comparison matrix method allows us to reduce the risk of subjectivity during the evaluation process and increase coherence and efficiency (GHIA, 2006).

Each indicator is ultimately expressed in a table, with the relationship between qualitative evaluation and final score expressed in numerical values (OSSERVATORIO... et al., 2002). In fact, the numerical value changes according to the base matrix: for example, Not Sufficient scores 27. This score reflects real conditions of urban settlements where for example there is not a complete lack of infrastructure or public transport or other public services (Figure 4).

Weighted coefficients of macro-indicators and the four main domains (k_{arch} , k_{acc} , k_{env} and k_{soc}) are defined using the same methodology.

The final output involves the computation of a number of scores corresponding to each indicator, macro-indicator and domain. The overall Urban Environment Quality is expressed between 0 to +100. The significant feature of this method is to embed the possibility of adaptation, such as changes to the number of indicators or their specific weights, while maintaining the computational structure (GHIA, 2006; SOCCO et al., 2003)⁶.

⁶This adaptation is not considered in this paper, but could be applied to the computation methodology according to our findings and/or further investigations.

Figure 3 - Pairwise comparison matrix to convert qualitative into numerical values (0 to +100)

Base Matrix					
	Excellent	Good	Sufficient	Not Sufficient	
Excellent	50	52	70	80	100
Good	48	50	65	75	84
Sufficient	30	35	50	60	43
Not Sufficient	20	25	40	50	27

Source: Delsante (2007).

Figure 4 - Indicators: from qualitative evaluation to quantitative scores

Indicator name			
Grade	Description	Score	XX
Excellent	<i>(description according to specific features and references, see also Fig. 6)</i>	100	
Good	<i>(description according to specific features and references, see also Fig. 6)</i>	84	
Sufficient	<i>(description according to specific features and references, see also Fig. 6)</i>	43	
Not Sufficient	<i>(description according to specific features and references, see also Fig. 6)</i>	27	

Source: adapted from Delsante (2007).

Figure 5 - Landscape and Environmental Quality value as a result of the weighted sum of its macro-indicators - sample from Lodi pilot study

Landscape and Environmental Quality (Q_{env})						
$Q_{env} = (kV QV + kG QG + kT QT + kN QN + kS QS)$						
	Visual and perception	Green spaces and vegetation	Topography	Natural and landscape sites	Perceptions, senses and other environmental risks	
	V	G	T	N	S	Q AMB
k	kV	kG	kT	kN	kS	65
Weighting coefficient	0.28	0.22	0.09	0.13	0.28	
Indicator Score	QV	QG	QT	QN	QS	
	52	69	84	27	87	

Source: adapted from Delsante (2007).

A specific set of indicators for medium-density neighbourhoods

The Urban Environment Quality assessment is based on a specific set of 74 indicators (DELSANTE, 2007), described through quantitative and qualitative variables. This set has been matched with other international databases (BATTISTELLA, 2006; DELSANTE et al., 2014; GHIA, 2006). The hypothesis is that this set fits

not only the pilot site of Lodi, but can also be applied to similar urban contexts with medium density⁷. For example, it could be used in historical centres and consolidated urban districts, twentieth-

⁷Approx. 2.500 (Rotterdam, Turin) to 7.500 (Milan) inhabitants/km² in terms of European cities. The set and description of indicators should be updated if dealing with different urban structures such as suburban sprawl, low-density settlements or high-density cities.

century urban extensions or post-industrial districts undergoing urban regeneration.

As shown in Table 1, indicators have been defined, starting with indirect reference to those already present in the literature. However, in some cases

indicators are newly established (14) (DELSANTE, 2007). Referencing is always indirect as quantitative or qualitative features were adapted and specified differently; however, some of the variables are the same.

Table 1 - Complete list of indicators and their codes; macro-indicators and domains refer to the tree structure based on the computational methodology

Domain	Macro indicators	Indicators	Code	Sources and references
Q_{arch} - Architecture and Urban Design	Q _M - Urban morphology	1. Historical urban forms and heritage buildings	Ms	N/A
		2. Skyline/roof-scape: recognisability and symbolic value	Mr	Carmona et al. (2004) and Regione Lombardia (2016)
		3. Urban decay and un-used areas	Md	Comune di Milano (2003)
		4. Unused spaces (housing or offices)	Mv	Comune di Milano (2003)
	Q _L - Architectural expression and language	5. Places with high levels of coherence	Lc	Regione Lombardia (2016)
		6. Buildings with distinctive architectural features or which affect the urban context	La	Construction and City Related Sustainability Indicators (2000)
		7. Buildings with architectural features that are not appropriate to the context (negative elements in terms of architectural expression)	Lm	N/A
		8. General state of housing, maintenance of housing estates and of historical heritage	Lg	Construction and City Related Sustainability Indicators (2000) and Legambiente (2014)
		9. Colour identification and harmony, visual appearance (e.g. facades), in relationship with local tradition and overall harmony (materials, pavement, openings)	Li	Construction and City Related Sustainability Indicators (2000) and Carmona et al. (2004)
	Q _T - Typology	10. Site with high coherence, in terms of building typology	Tc	Regione Lombardia (2016)
		11. Architectural features and their adaptations to local climate	Tt	N/A
	Q _A - Urban design and furniture	12. Safety in urban networks (pedestrian and slow mobility)	As	Legambiente (2014)
		13. Urban quality and maintenance of pedestrian and bike pathways	Ap	Construction and City Related Sustainability Indicators (2000) and Socco (2000)
		14. Open spaces and building lighting quality (daily and nightly)	Ai	N/A
		15. Urban design quality (urban furniture, art installations) and public space maintenance	Aa	Carmona et al. (2004)

Table 1 - Complete list of indicators and their codes; macro-indicators and domains refer to the tree structure based on the computational methodology

Q_{acc} - Uses and accessibility	Q_I - Infrastructures and logistic	16. Main road (urban form and structure) in the heart of the neighbourhood	La	Construction and City Related Sustainability Indicators (2000)
		17. Quality of the link between the road network and the structuring axis	Lc	Construction and City Related Sustainability Indicators (2000)
		18. Site accessibility at urban scale	Lu	N/A
		19. Bike pathway density (length/site area)	Ld	Socco (2003) and Italian National Institute For Statistics (2016)
		20. Safety of road networks (vehicle traffic)	Ls	Italian National Institute For Statistics (2016)
	Q_D - Density	21. Dwelling density within the urban area	Da	Construction and City Related Sustainability Indicators (2000)
		22. Winter sun and daylight provision of dwelling units	Di	Construction and City Related Sustainability Indicators (2000)
		23. Ventilation effectiveness, in relation to building organisation (e.g. absence of obstructions)	Dv	Construction and City Related Sustainability Indicators (2000)
		24. Average height of buildings	Dh	N/A
		25. Average distance between buildings	Dd	N/A
		26. Visual privacy (from the exterior in principal areas of dwelling units)	Dp	Socco (2002) e Construction and City Related Sustainability Indicators(2000)
	Q_P - Parking	27. Quality and maintenance of parking areas	Pg	Comune di Milano (2003)
		28. Presence and distribution of irregular parking	Pi	Comune di Milano (2003)
		29. Parking spaces in high-pressure streets/areas	Pd	Comune di Milano (2003)
		30. Parking slots per inhabitant on public land	Ps	Italian National Institute For Statistics (2016)
		31. Parking slots per inhabitant on private property	Pp	Italian National Institute For Statistics (2016)
	Q_{Tr} - Public transport	32. Urban transport network density and typology (length/site area)	Tu	Italian National Institute For Statistics (2016)
		33. Efficiency and quality of urban transport	Te	Construction and City Related Sustainability Indicators (2000)
		34. Percentage of seats on public transport (urban and suburban/population)	Tp	Legambiente (2014)
	Q_{Ac} - Local and pedestrian accessibility	35. Percentage of residents with pedestrian access to public/green spaces (or public transport stops connecting to such spaces), within 300 metres	Ap	Comune di Milano (2003)
		36. Availability and dimensions of pedestrian priority areas or limited traffic zones	Ai	Legambiente (2014)
		37. Maximum pedestrian distance from and to primary schools	Ab	Socco (2000)
		38. Public space accessibility for handicapped or elderly people	Ah	Socco (2000)
		39. Barriers to urban mobility (e.g. dismissed infrastructures, railways, etc.)	Am	Comune di Milano (2003)

Table 1 - Complete list of indicators and their codes; macro-indicators and domains refer to the tree structure based on the computational methodology

Q_{env} - Landscape and environment	Q_v - Visual and perception	40. Visual access to the exterior in principal areas of dwelling units	Ve	Construction and City Related Sustainability Indicators (2000)
		41. Sites with panoramic or scenic views, sites with privileged topographical positions (e.g. visibility)	Vp	Construction and City Related Sustainability Indicators (2000), Regione Lombardia (2016)
		42. Elements with negative impacts on the visual quality of the site (affecting perceptions of the site)	Vi	Construction and City Related Sustainability Indicators (2003)
		43. Negative elements, in terms of visual relationships (obstructions, visual impacts on the site)	Vd	N/A
		44. Pathways and roads with environmental or landscape functions	Vf	Regione Lombardia (2016)
		45. Site perception from high-speed infrastructures	Vt	Regione Lombardia (2016)
	Q_G - Green spaces and vegetation	46. Public local green areas and alleys	Gp	European Common Indicators (2003)
		47. Maintenance and quality of public green spaces	Gq	N/A
		48. Vegetation and tree species with effects on living quality	Ge	Construction and City Related Sustainability Indicators (2000)
		49. Ecological areas (agricultural, permeable green)	Ga	Comune di Milano (2003)
		50. Maintenance and quality of green areas around social housing	Gc	Construction and City Related Sustainability Indicators (2000)
	Q_{To} - Topography	51. Ground and topographical structures with influence on landscape configuration (e.g. terraces, river banks)	Tm	Regione Lombardia (2016)
	Q_N - Natural and landscape sites	52. Sites of natural or landscape-related interest	Nn	N/A
		53. Pedestrian priority and low impact zones (e.g. areas with 30 km/hr speed limits)	Ni	Comune di Milano (2003)
	Q_s - Perceptions, senses and other environmental risks	54. Urban traffic nodes that impact city centre and environmental quality	St	Comune di Milano (2003) and Construction and City Related Sustainability Indicators (2003)
		55. Deficits in drainage systems with potential effects on olfactory perceptions	Sf	Comune di Milano (2000)
		56. Activities with environmental risk	Sr	Comune di Milano (2003)
		57. Sites of flood danger and potential risk	Se	Comune di Milano (2003)
		58. Density of municipal waste and recycling bins per inhabitant and quality/frequency of waste/recycling services	Sd	Italian National Institute For Statistics (2016)
		59. Innovative solutions for smart mobility	Sg	Italian National Institute For Statistics (2016)
		60. Light pollution	Sl	Carmona et al. (2004), Regione Lombardia (2016)

Table 1 - Complete list of indicators and their codes; macro-indicators and domains refer to the tree structure based on the computational methodology

Q_{soc} - Social and community	Q _F - Community and public functions	61. Presence and accessibility of public facilities	Ff	Construction and City Related Sustainability Indicators (2000)
		62. Presence and accessibility of community functions	Fc	N/A
		63. Presence and accessibility of health-related services	Fs	N/A
	Q _E - Buildings with social role or interest	64. Presence and accessibility of functions of social interest	Ef	N/A
		65. Percentage of social housing / total housing stock	Ep	N/A
		66. Quality of common areas in social housing	Ec	Construction and City Related Sustainability Indicators (2000)
		67. Mixed uses and functions	Em	N/A
		68. Quality and maintenance of social housing buildings	Ee	Regione Lombardia (2016)
	Q _C - Trade and retails	69. Retail surface per inhabitant and proximity to it	Cs	Construction and City Related Sustainability Indicators (2000)
		70. Shopfronts in urban landscape	Cf	Carmona et al. (2004)
		71. High streets	Ca	Comune di Milano (2003)
	Q _R - Leisure and open air public spaces	72. Leisure areas, entertainment spaces and places to meet	Rr	Construction and City Related Sustainability Indicators (2000)
		73. Public open-air areas used daily by inhabitants	Ra	Construction and City Related Sustainability Indicators (2000)
		74. Places with historical and symbolic value (e.g. festival spaces)	Rs	Legambiente (2014)

These indicators do not correspond to those used in the planning process, as they refer not only to quantitative but also to qualitative dimensions. Even if the overall number of indicators is greater than in other core sets, the set describes dense urban contexts with completeness and without redundancy. A significant tool for assessment is represented by forms (one for each indicator) filled with general descriptions, and a textual and visual description of each grade (Excellent to Not Sufficient)⁸ (Figure 6) (DELSANTE, 2007; DELSANTE et al., 2014). These forms aim to reduce subjectivity during the evaluation process (GHIA, 2006); through the creation of a precise description with international references, misunderstanding of meaning and ambiguity in use is reduced.

⁸Please note that there are some indicators which have a negative impact on Urban Quality (e.g., V_i Elements with negative impact on the visual quality of the site (perception of the site)). In this case the grades are as follows: Excellent: lack of elements with negative visual impact [...]. Not sufficient: Presence of detrimental elements; high impact on visual quality in relationship to their dimension, architectural quality or decay.

Comparative case study of Lodi and Genoa

The set of indicators and description of each indicator have been refined through various trials and iterative processes, after which a pilot case study in Lodi was successfully completed (DELSANTE, 2007). However, is the context tested in Lodi applicable to other urban contexts? Even though the methodology is meaningful to obtain an overall urban environment quality index (DELSANTE, 2007), what is of the utmost importance is not the numerical value in absolute terms, but its progress over time and its comparison with other locations.

Moreover, as urban environment quality is expressed through numerical values, it can be compared and monitored along with other quantitative data such as environmental indexes like air quality and health-related data. For example, urban quality of life is usually measured by either subjective indicators using surveys of resident perceptions, evaluations and satisfaction with urban living, or by objective indicators using secondary data and relative weights for objective measures of the urban environment (MCCREA; SHYY; STIMSON, 2006).

The results of recent studies show meaningful relationships between urban and environmental quality and perception of health status and personal well-being. These reductions or improvements in health status perception are discrete and, most of all, measurable (ORLANDO, 2007). In Lodi, some indices of urban quality showed statistically significant links with the subjective perceptions of well-being by the resident population (ORLANDO, 2007).

Assessment of a central neighbourhood in Lodi (Italy)

A site in the central area of Lodi was considered, also drawing on previous investigations (DELSANTE, 2007). It is a medium-high density area, with important city infrastructures and community services, dwellings and a resident population of approximately 4,000. After an urban analysis phase, the site was divided into three

smaller areas that are homogenous in terms of urban morphology and features. Infrastructure and accessibility were also set according to these features.

The evaluation process shows that the overall urban quality index differs between the three sub-areas: 62/100 for sub-area 1 (northern part), 61/100 for sub-area 2 (central part) and 65/100 for sub-area 3 (southern part). Even though the overall scores are similar, that does not mean that scores are equally close to each other for each indicator, some of which scored very differently due to specific local features. However, the evaluation process shows that the evaluation of the overall area is higher than those of the sub-areas, due to the lack of specific features in some sub-areas: Architectural Quality in sub-area 2, Social Quality in sub-area 3, etc. (see Figure 7 and Table 2).

Figure 6 - Skyline/Roofscape indicator: recognisability and symbolic value

Name - Skyline/Roof scape: Recognisability and Symbolic Value (code: Mr)
 Source: CARMONA et al., 2004. Living Places: Caring for Quality (indirect)


This indicator deals with the quality of a place in relationship with the recognisability of its formal structure. The artificial nature of an urban environment addresses the issue of the overall recognisability of a context that, through the harmony and balance of its parts, could evoke a memory of places. Figurability and Legibility (LYNCH, 1960) are also important references for understanding this qualitative indicator.

Values:


- Excellent: Very high or high quality in individual architectural buildings and elements and of the overall built environment that creates a very clear and formally recognisable image of the settlement. Example: the historical centre of Ferrara, Italy.
- Good: High quality in individual architectural buildings and elements with formal or symbolic character, but no consistent value in terms of quality. Examples: Pisa, Italy and Lyon, France.
- Sufficient: Architectural quality and visual relationships present in individual buildings or elements, with overall recognisability of the urban landscape, but no meaningful formal or symbolic identity. Example: Rotterdam, the Netherlands.
- Not sufficient: Urban landscape and views suffer from loss of visual references and a lack of architectural quality in individual buildings and elements. Example: Essen, Germany.

CARMONA, M., de MAGALHAES, C., BLUM, R., & HAMMOND, L. (2004). Living Places: Caring for Quality. London: RIBA Enterprises.

LYNCH, K. (1960). The Image of the City. Cambridge, MA: MIT Press.

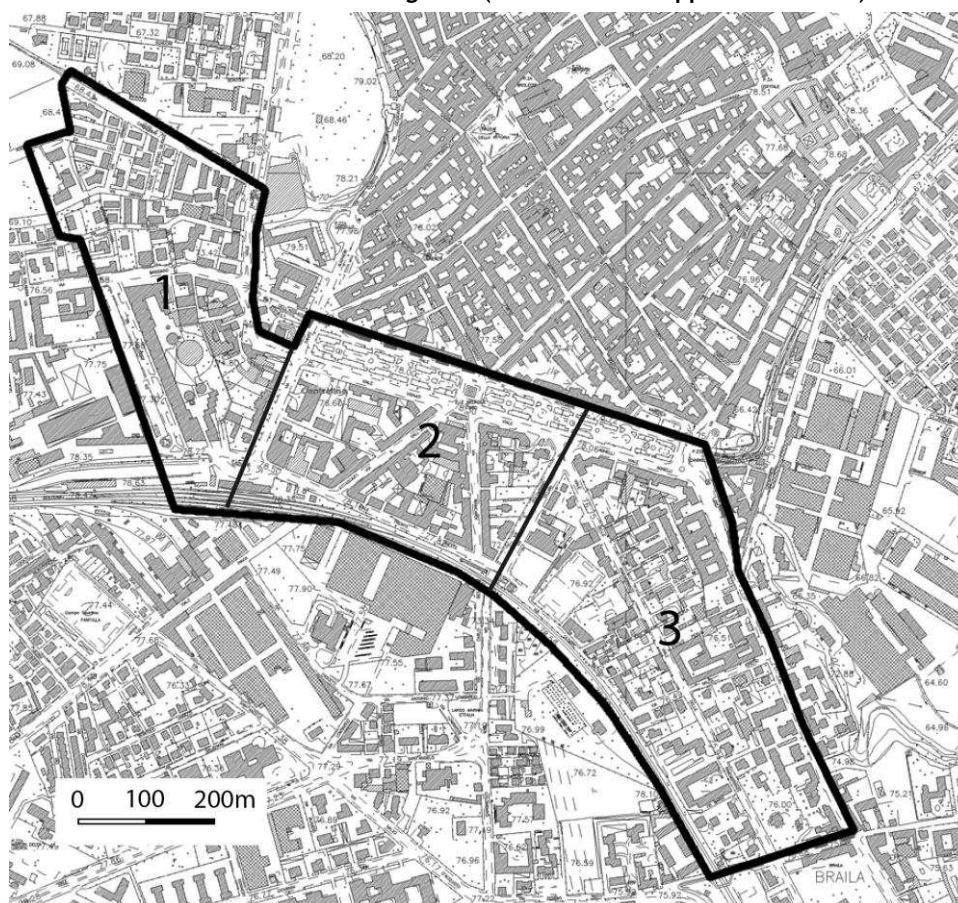


Excellent: Ferrara historical city centre (Italy)



Good: Lyon (France)

Source: Delsante (2014).

Figure 7 - Lodi: area and sub-areas of investigation (overall area of approx. 0.31 km²)

Source: adapted from Delsante (2007).

Table 2 - Urban Environment Quality Assessment in Lodi - Synthesis

Lodi	Q arch	Q acc	Q env	Q soc	Q glob
Sub-area 1	63	60	64	60	62
Sub-area 2	51	70	53	67	61
Sub-area 3	82	59	70	41	65
Area (approx. 0,3 Sq. Km)	77	58	72	67	67

Source: Delsante (2007).

Assessment of a central neighbourhood in Genoa

A site in Genoa's town centre was selected for this study. The site is close to the historic core of the town, and its perimeter coincides almost exactly with the boundaries of the combined Carignano and San Vincenzo neighbourhoods. As a core area of the city, it includes a hospital, an urban park, the city theatre and a relevant high-street (XX Settembre) that links one of the train stations (Genova Brignole) with the city council square (Piazza De Ferrari). Three underground rapid transit stops are in the area or its immediate vicinity. The Carignano neighbourhood is set on a small hill, and was urbanised largely during the

nineteenth century, while the San Vincenzo neighbourhood has a more articulated urban history with a strong emphasis on the nineteenth-century master plan under which its main roads and squares were constructed.

The entire area was organised into 11 sub-areas, mainly according to architectural, urban and landscape morphology features (Figure 8). An urban quality assessment was conducted for all of the sub-area sites, showing that for eight of the 11 sites, two indicators were not applicable - E_p : Percentage of social housing and E_c : Quality of common areas in social housing - due to the complete lack of social housing in these sub-areas. The selected areas are too small to accomplish

such an indicator reasonably and one macro-indicator (Q_E) is largely affected by those two indicators.

Given these findings, an evaluation was carried out in which the computational methodology was adapted, using only 72 indicators instead of 74. However, changing the number of indicators involved reformulating all of the weights and the matrices referring to macro-indicator Q_E , so it was decided to change the two indicators' weights (K_p and K_c) to 0 instead. It must be noted that, due to the presence of weighted macro-indicators, the overall weight of "Q_E: Buildings with social role or interest" in the domain is not affected by the number of indicators assessed.

Overall urban quality varied from 57 to 74 in those areas with no E_p and E_c indicators, while it varied from 69 to 73 in the others. It was not possible to compare the areas that were evaluated with different weights and sets of indicators. Consequently, an urban quality assessment was also conducted for the overall area, with no issues

found in terms of indicators (74). The overall urban quality score was 70, which is included in the range of sub-area scores (see Table 3).

Findings

The proposed set of indicators for urban quality evaluation allows for comparison between different sites under specific conditions. A comparison between the Lodi and Genoa case studies indicates both the potential and the limitations of this methodology.

In medium-density urban contexts (approx. in between 2,500 and 7,500 inhabitants/Sq.Km.), the set of indicators is suitable for areas with an overall dimension up to 1 Sq.km. When the area under investigation is too small, some meaningful indicators become non-applicable. In such cases, it is not possible to use the evaluation score to compare different sites.

Figure 8 - Genoa: area and sub-areas of investigation (overall area of approx. 0.97 km²)

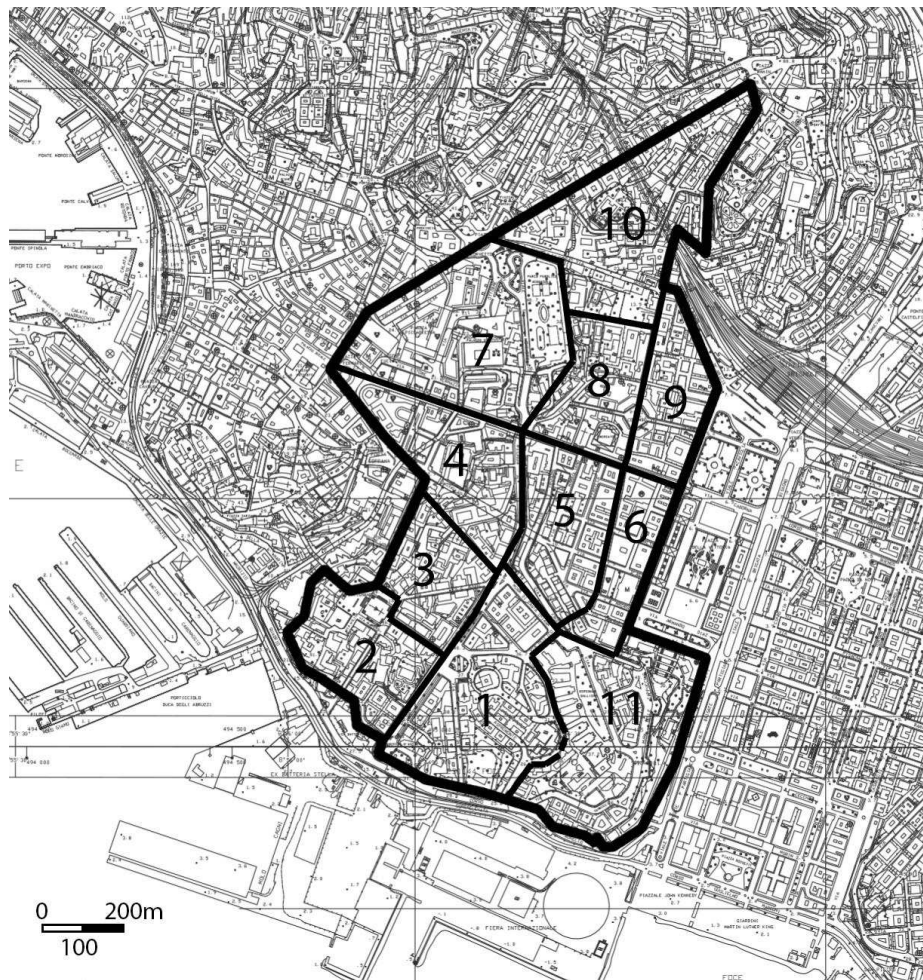


Table 3 - Urban Environment Quality Assessment in Genoa - Synthesis

Genoa	Q arch	Q acc	Q env	Q soc	Q glob
Sub-area 1	54	56	63	60*	57**
Sub-area 2	56	69	56	55*	61**
Sub-area 3	56	73	58	60*	64**
Sub-area 4	64	74	65	63*	68**
Sub-area 5	79	71	53	66	69
Sub-area 6	79	72	53	66	70
Sub-area 7	66	78	68	84*	74**
Sub-area 8	73	76	52	67*	70**
Sub-area 9	78	80	52	67*	73**
Sub-area 10	65	77	61	57*	69**
Sub-area 11	66	79	72	69	73
Area (1 Sq.Km.)	74	71	60	70	70

Note: *two indicators were not applicable **assessment based on 74 indicators, with 2 weighted 0.

Testing the set of indicators with various case studies makes it easier to determine site perimeters, as the evaluation depends heavily on the perimeter itself. The investigation site is not a given; it should be chosen according to specific local conditions. However, the perimeter should also be considered in relation to existing administrative borders and relevant data available (social, economic, mobility, etc.). The area for urban environment quality assessment should thus be defined after a reasonable amount of data and other information have been obtained.

Moreover, different sets of indicators could be created according to specific research aims, such as targeting different densities like high-density neighbourhoods or urban sprawl. In such cases, each indicator's description (textual and visual) might need some adaptation.

Overall, the proposed methodology is a meaningful tool for concisely evaluating urban environment quality as it is expressed with numeric values. It reduces subjectivity in the evaluation process and, most importantly, can be related to other data (e.g., environmental, health and well-being related). The index can also be monitored over periods of time (pre-post transformation assessment).

The final outcome of the assessment procedure is meaningful for the disciplines of architecture and urban design. If scores are monitored over time and/or compared with other sites, proper actions/transformations can be planned by public authorities and other relevant stakeholders.

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