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Assessing places' liveability: informational entropy for the construction of a set of criteria and indicators

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Assessing places' liveability: informational entropy for the construction of a set of criteria and indicators

The growing interest in well-being as a quality-of-life paradigm has led to a critical revision of its traditional conception. It is no longer limited to indicators of material prosperity and physical health (objective well-being indicators) but also individual perceptions of quality of life and happiness (subjective well-being indicators). In this new conception, the living environment plays a key role. The definition of well-being indicators based on the perceptual assessments of an urban environment crucially requires interdisciplinary skills. Using an investigative approach based on informational entropy, the objective of this paper is to construct a taxonomy that allows for the assessment of the quality of an environment to achieve adequate well-being standards and thus the improvement of quality of life. In detail, in the article explains the methodological process to define a structured set of criteria, sub-criteria, and their associated indicators for evaluating the characteristics of an urban environment and the physical and functional variables that contribute to achieving specific well-being thresholds. Through the involvement of a significant sample of 100 subjects, the results of the work consist of a set of 132 sub-criteria for the assessment of liveability.

1. Introduction

Some epochal changes and events have affected the world in recent years, such as globalization, the technological and digital revolution, increasing urbanization, pandemics, and climate uncertainties. This has led to rethinking the concept of well-being, no longer associated exclusively with indicators of material prosperity and physical health (objective well-being indicators), but rather related to individual perceptions of quality of life and happiness (subjective well-being indicators).

In Europe, over the past ten years and beyond, there has been a growing focus on the so-called "Economy of Wellbeing". In this framework, well-being and quality of life are no longer analyzed and evaluated through traditional, objective economic indicators, such as gross domestic product (GDP) or the level of infrastructure of an area (services). Instead, holistic, subjective well-being indicators, linked to personal perceptions, aimed at better incorporating the dimensions that influence citizens' quality of life (Varotto, 2019; Battisti, 2023), are adopted. Thus, in the most recent EU guidelines (see Personal and Social Well-Being from ESS Round 6) (European Social Survey, 2018), the concept of well-being is now unstructured and multidimensional (Bartolini and Bilancini, 2010); among the components affecting well-being, the community in which one lives, and thus the place, takes a key role. The idea that economic growth was the best way to maximize well-being is now surpassed (Layard, 2005a; Bartolini and Bilancini, 2010; Easterlin, 2013; European Commission, 2018). Instead, it is now recognized that the well-being of individuals is linked to the ability to create, or choose, an environment that allows them to realize their full potential and enjoy their fundamental rights (Āzena and Keiss, 2009; International Labour Organization, 2019; United Nations, 2015; World Bank Group, 2019). Particular emphasis is therefore placed on the liveability of territories.

In the scientific literature, liveability refers to similar concepts with different nuances: it can be defined as "suitability to human life" (Webster, 2018), "quality of life, well-being, and happiness" (Veenhoven, 2000), "quality of place and its synonyms" (Buton, 2014). The concept of liveability is thus closely interdependent with that of well-being, being summarized as perceived well-being within a place, dependent on objective factors (characterizing the place) but also subjective factors (related to individuals' perception).

Hence, the relationship between individuals' well-being and place becomes a subject of scientific interest, not least in light of the momentous changes that have had a relevant impact on human life in recent years, among which is the digital revolution that has led to the digital transition, in particular.

The digital transition can be described as an overhaul of administrative, work, business, and even recreational practices, using digital technologies to make them more efficient while achieving easier and more accessible data collection and evaluation. Indeed, in this society undergoing a digital transition, more and more functions and services are being performed through computer networks and computers. This has changed habits, ways of working, and the use of leisure time (OECD, 2019).

The repercussions of the digital transition on the territory have begun to be studied, mainly focusing on the immaterial transfer of services that were historically delivered physically, and the impact of this change on mobility (traffic) and the reuse of buildings that have lost their original use. There are almost no studies on the impacts of the digital transition on residential mobility, well-being, and liveability of places. Online citizen services, e-commerce, social networks, and new modes of social relations, but especially "smart working", can indeed significantly affect the type and quality of people's lives and affect "residential mobility".

Especially smart working, which potentially affects more than 15 million workers in Italy (employed in the service sector, ISTAT data) (ISTAT, 2021), accelerated between 2020 and 2021 by the health emergency due to the COVID-19 pandemic, which has demonstrated non-negligible merits, such as reduced management costs for employers, reduced time and costs dedicated to home-to-work commuting, and thus reduced environmental pollution. In some cases, this has even triggered repopulation phenomena in previously underpopulated or abandoned areas (Acampa and Pino, 2024).

This change is epochal, considering that it is taking place for the first time in modern human history; traditional "home-to-work" distance constraints, which have profoundly influenced people's choice of living places since at least the 18th century onward, are superseded. This is even more significant, considering that they have not been effectively overcome even by the technological advancement of means of transportation, and represents a relevant factor in the study of mobility (Acampa et al., 2024).

While considering that the choice of where to live depends on various and heterogeneous factors (home ownership, social relationships, family history, and personal preferences), the opportunities offered by the digital transition can still expand the opportunities for choosing the place (i.e., the social, economic, and environmental context) where to spend one's life, seeking liveability to increase one's well-being.

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Next, the literature review in Section 2 focused on the multi-dimensional analysis of the change in the concept of well-being, proposing an in-depth look into the concept of liveability and how it is measured at the international level, analyzing the 4 main reports worldwide (Global Liveability index; Global power city index; Innovation city index; Smart city index); Section 2 also illustrates the method of informational entropy, which aims to ensure proper weighting of criteria and sub-criteria.

Following the literature review, Section 3 defines the set of criteria, sub-criteria, and indicators for liveability assessment, proposing a hybrid approach based on the interaction between informational entropy and the detection of preferences stated through traditional social research tools. Informational entropy, first proposed by Shannon in 1948 and gradually introduced into many scientific fields, is used to explore the degree of order of a system, here initially represented by the items in the abovementioned indices. Thus, this hybrid approach consists of 3 consequential steps: *i*) de-structuring of the 4 international indices; *ii*) taxonomic re-aggregation of the liveability factors; *iii*) weighting of the taxonomy through informational entropy.

This procedure allowed defining and weighting a set of 200 items (sub-criteria and indicators, subdivided into 8 thematic categories or criteria), using a sample of 80 interviews. The results are discussed in Section 4; in Section 5, the conclusions of the present work are drawn, and limitations and future improvements are identified.

2. Materials and methods

It is now generally acknowledged that GDP alone does not provide a complete picture of people's well-being (Layard, 2005b; Bartolini and Bilancini, 2010; Easterlin, 2013). In the past, economic growth has been considered a priority for maximizing societal well-being; however, to date, the direct correlation between economic growth and perceived well-being of citizens is low and/or negligible, even at average levels of wealth. Indeed, there is evidence that in developed countries, increased economic prosperity may even be associated with increased rates of depression, divorce, and suicide (Helliwell, 2007). Following these deductions, it is clear that well-being is closely related to contextual conditions (place), and thus to the objective and subjective factors that characterize it (liveability). Based on the above, a literature review on the multidimensional concept of well-being and liveability is proposed to respond to the first objective of this article. This is followed by an analysis of the main indices for measuring liveability in the international arena to construct a taxonomy on the liveability conditions of a territory. Finally, the hybrid-type approach based on the interaction between informational entropy and preferences stated through traditional social research tools for the construction and weighing of the taxonomy is illustrated.

2.1 Well-being and liveability (or residential well-being)

The concept of well-being has been a hot topic in the analysis of quality of life throughout the world's territories since the second half of the 20th century (Larson, 1978; Veenhoven and Ehrhardt, 1995). After a long time, when it was believed that the well-being of a population was linked to income and therefore to the GDP of its country (Blanchard et al., 2016), the economist Easterlin developed the "happiness paradox" in 1974. He argued that the increase in income and material well-being of a society produces no directly proportional increase in people's happiness (Easterlin, 1974).

This theory was later confirmed by Inglehart and Klingemann (2000): they compared a plurality of countries at a defined point in time, as a function of their respective per capita income. This showed a positive correlation for the happiness index up to an income threshold of about $15,000; then, the values appear more dispersed, and the relationship between income and happiness stabilizes, as evidenced by the flat regression line (Fig. 1) (Inglehart and Klingemann, 2000).

However, the results of such studies were not new; psychologist Maslow, as early as the 1950s, had intuited the nondependence between wealth and well-being. A founder of humanistic psychology, he is known for his "hierarchy of needs" theory (Maslow, 1954), which analyzes the factors affecting individuals in their pursuit of happiness and subjective well-being. According to this theory, human needs are hierarchized on five levels of a pyramid, such as (from bottom to top): physiological, safety, love, esteem, and self-actualization (Fig. 2).

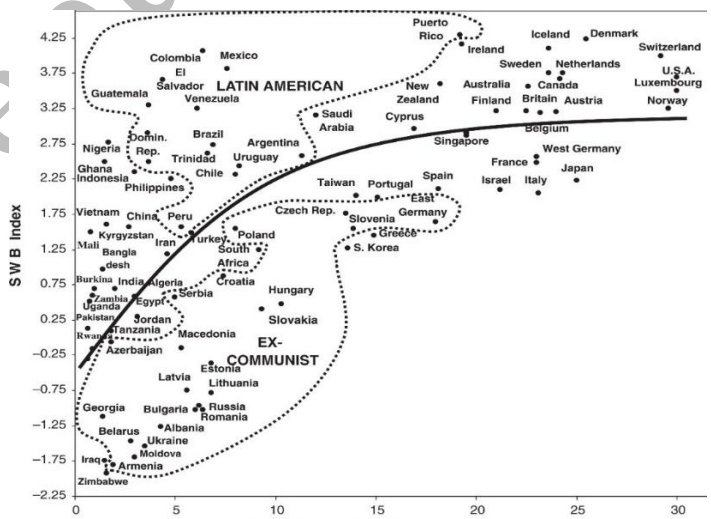

Figure 1. Inglehart and Klingemann (2000). Subjective well-being (SWB), per capita gross domestic product (GDP), and different types of societies.

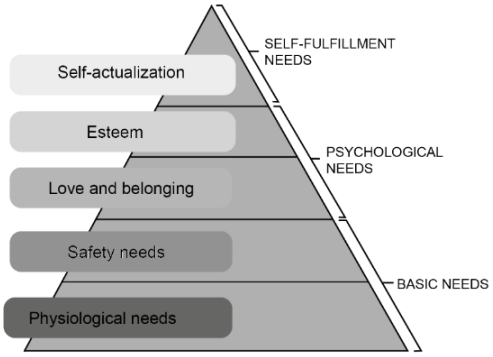

Figure 2. Maslow (1954). Motivation and personality (Authors' elaboration).

The theory exposes the limitations inherent in the use of money: the latter allows for the complete satisfaction of basic needs, while it fulfills social or self-related needs to a limited or even null extent. It follows that, regarding high standards of living, money will take an increasingly marginal role in one's definition of well-being and happiness.
These reflections show that well-being depends on heterogeneous and complex factors and cannot be separated from its context, i.e., from liveability (Cummins, 2000; Jeffrey et al., 2018; Sen, 1999).

The liveability of an area is defined as a function that correlates environmental characteristics (objective and intrinsic) and personal characteristics (subjective, social, and place attachment) (Pacione, 1990; Ahmed et al., 2019). To date, the concept of "liveability" is widely debated and difficult to understand, as there can be multiple interpretations of it. To express the concept of "liveability", the field of urban planning often uses the terms "quality of life" and "well-being", which are sometimes substituted for each other. Although they are interrelated, liveability directly refers to a place and its conditions: it indicates the presence and quality of services in built and natural environments (Ahmed et al., 2019). It is highly dependent on the prevailing context and values within the community, whether they are economic, social, or cultural (Okulicz-Kozaryn and Valente, 2018; Viviani, 2016). Consequently, it can be said that a resident's desire for a place determines the degree of liveability of that place (Chazal, 2010; Lyndhurst, 2004).

Liveability, and thus residential well-being, can thus be positively and negatively affected by numerous factors, which we attempt to summarize below: spatial characteristics (architectural and urban design); human and social characteristics (population and type of social relations); functional characteristics (available services); contextual characteristics (lifestyle, pollution/health, maintenance, and care) (Bonaiuto et. al, 2015; Bonaiuto and Alves, 2012). Citizens' experience within their neighborhood appears to be influenced by its physical characteristics (Amérigo and Aragones, 1990). When analyzing spatial characteristics, housing type, for example, appears to significantly affect housing well-being: the presence of single-family houses is associated with a higher level of well-being than townhouses or condominiums (Evans et al., 2003; Freeman, 1984). Spatial distances within the neighborhood have a direct impact on social interactions as well as safety (Abass and Tucker, 2018; Abu-Ghazzeh, 1999). In addition, people who live in well-designed environments that provide comfort, safety, and good air quality tend to have higher life satisfaction and lower levels of psychological stress (Evans, 2003). Moreover, the availability of shared public services (social characteristics) facilitates social connectedness, particularly if they have good location and visibility. (Francis et al., 2012). The presence of urban green spaces (contextual characteristics) is relevant to residential well-being, too. This term covers heterogeneous places, such as parks, community gardens, cemeteries, roof gardens, vertical gardens, lawns, street trees, and small green structures designed as green infrastructure. A growing body of research highlights the relationship between UGS (Urban Green Spaces) and various dimensions of well-being (Syamili et al., 2023; Maas et al., 2006). These are just a few of the factors that contribute to the liveability of a place; field studies show that the correspondence between characteristics of the environment and the activities of people must be studied through a holistic and integrated system to obtain practical indications and guidelines for improvement interventions (Battisti et al., 2017; Bonaiuto et al., 2009).

In the European context, the assessment of residential well-being to date is a widely debated topic due to changing habits and lifestyles (ISTAT, 2024; United Nation, 2015; Gössling et al., 2012). For example, the Covid-19 pandemic accelerated the digitization process by several years, placing digital technologies in a central role in daily life and giving rise to a new era of digital transition (Melluso et al., 2020). Traditional processes of innovation and development have been enhanced, and new forms of innovation have been created, concerning every segment of society. The detachment from the workplace and the online availability of many services (e-commerce, online citizen services, etc.) have enabled users to improve their lifestyles by decreasing their time schedules and thus fostering self-care. Moreover, these factors have set the stage for potential decentralization from urban city centers, where most workplaces, businesses, services, etc., are located (Felici et al., 2022). In this context, measuring liveability becomes a matter of scientific interest and requires an approach that is as shared and objective as possible.

2.2 The measurement of liveability at the international level

In the early 2000s, various studies and analyses were already being conducted regarding liveability in various urban settings. These have generated international initiatives involving leading bodies, such as the Organization for Economic Cooperation and Development (OECD) and the United Nations (UN). The latter has actively participated in the debate on the measurement of well-being by presenting concrete proposals, such as, respectively, the "Better Life Index" and the "17 Sustainable Development Goals", defined by the UN and applied by all member countries (Speroni, 2019). To monitor well-being, various experiments have been developed in recent years, including the Global Liveability Index, the Global Power City Index, the Innovation City Index, and the Smart City Index. These analyses, which are summarized in annual reports, use concrete, reliable, and measurable indicators and also consider several factors that comprehensively describe the multi-dimensionality of urban liveability and well-being. Therefore, these approaches, of recognized relevance and validity in the international arena, are useful for the taxonomic definition of criteria and indicators for assessing liveability.

Global Liveability Index

The Global Liveability Index is an annual ranking published by the Economist Intelligence Unit (EIU, a division of "The Economist" group), which evaluates the quality of life in 173 global cities. The methodology adopted for this evaluation is based on the integration of qualitative and quantitative indicators for a detailed and complex analysis focused on critical elements such as the quality of public services, personal safety, and the resilience of urban infrastructure (Economist Intelligence Unit, 2023). Data collected annually show how political stability and social security are determinants of a city's quality of life, followed by factors such as the quality of infrastructure and access to educational services (OECD, 2021).

Global Power City index

The Global Power City index (GPCI) is an index developed by The Mori Memorial Foundation's Institute for Urban Strategies. It rates and ranks the world's major cities based on their "magnetism", or ability to attract international people, capital, and businesses (The Mori Memorial Foundation, 2023). The index is coordinated by an Executive Committee, which includes a diverse group of experts from various disciplinary backgrounds, and an Operating Committee dedicated to detailed and meticulous analysis of the collected data. To ensure the objectivity and credibility of the classifications, the GPCI is also supported by external auditors. These professionals verify the accuracy and integrity of the data collected and provide advice and recommendations for possible improvements to the index. The GPCI's aim is not limited to simply ranking cities: it provides an in-depth analysis of their strengths and areas of vulnerability and identifies emerging challenges facing global cities.

This index measures urban magnetism across six key functions: Economy, Research and Development, Cultural Interaction, Liveability, Environment, and Accessibility, offering a multidimensional and comprehensive view of urban competitiveness.

Innovation City Index

The Innovation City Index is an index developed by 3DReid in collaboration with The Innovation Cities Program to rank cities based on their ability to foster innovation and competitiveness through technological, economic, and cultural factors. This index focuses mainly on aspects of digital connectivity, the presence of innovation infrastructure, the quality of education, and the ability to attract talent to measure how well cities can stimulate and host innovative initiatives. It aims to provide a solid and comparable basis for analyzing cities' innovative capabilities, enabling analysts and decision makers to identify strengths, areas for improvement, and opportunities for targeted interventions.

Smart City Index

The Smart City Index, created by the World Competitiveness Center in association with WeGO (World Smart Sustainable Cities Organization), an international consortium involving local government entities, is designed to act as a practical tool in the field of urban planning and management, emphasizing the importance of city perceptions through targeted surveys (IMD, 2023). Surveys are essential to understanding specific cities; therefore, questions are carefully worded to reflect the unique context of each city analyzed. For editions through 2021, the index relied on national Human Development Index (HDI) data provided by the United Nations Development Program (UNDP) to integrate the perceptions collected with objective development indicators. Then, in 2022, the adoption of ISU data collected at the city level was experimented with to obtain a finer and more accurate understanding of city-specific socioeconomic conditions. This transition to more localized data aims to strengthen the accuracy of the index, enabling a more direct and meaningful assessment of the effectiveness of smart city policies and urban quality of life.

2.3 Informational entropy and detection of stated preferences

As already anticipated, the proposed study involves the definition of a set of criteria, sub-criteria and indicators to assess the liveability of a place. Following an analytical analysis of the above-mentioned international measurement methods and then their de-structuring (Section 3.1) and subsequent taxonomic recomposition (Section 3.2), the selected sub-criteria are weighed through a hybrid approach, based on stated preferences obtained through social research methods and the application of the "informational entropy" method.

This "entropic" method is particularly useful for the proposed experimentation, as it allows for efficient management of the complexity arising from multiple indicators. The following is a summary of the method's origin and structure.
Information theory was formulated by Shannon in 1948 in his paper "A Mathematical Theory of Communication", in which he addressed the problem of optimizing a communication network. The system for quantifying information identified by Shannon turns out to be formally identical in form and properties to entropy, a quantity known in thermodynamics. Let *H* be an entropy function. The only variables on which H can depend are the probabilities of the different possible events. The original definition is given as $H(p_1, p_2, \ldots, p_n)$, as a function of a generic discrete random variable *X*, which can be realized in *n* different possible events with respective probabilities. $\sum_{i=n}^{n} p_i = 1$. Entropy allows us to measure how close or far the probability distribution is from the uniform case. In other words, if a system has high entropy, its state is shrouded in as much uncertainty as possible. Instead, low entropy corresponds to less freedom of change and thus preferential configurations among its options, making it less unknown. Uncertainty about a system state is interpreted as a quantity of the system itself, rather than as a cognitive limitation of the observer.

The properties that characterize the theory are 3:

1. $H(\ldots)$ is a continuous function of each of the p_i probabilities;
2. If the p_i probabilities are all equal $(p_i = 1/n)$, *H* takes its maximum value, since it represents the condition of maximum uncertainty about the result of variable *X*. This maximum value must be a monotonically increasing function of the number *n* of possible states;
3. If the possible events of variable *X* are separated into n disjoint subsets, the total entropy *H* must be a weighted composition of the H_i entropies of the individual subsystems. This property is called consistency.

Given these three properties, Shannon verifies that there is only one proper function and that it must have the following form:

$$H(X) = -\sum_{i=1}^{n} P(x_i)\, log_b P(x_i) \quad (1)$$

Let p_i be the probability of event x_i.

The methodological application process is divided as follows:

1. Identify the random variable *X*, i.e., the set of possible states of the analyzed system. This may represent, for example, a series of experimental measurements, discrete events in a decision-making process, or frequency distributions of observed data (Cover and Thomas, 2006);
2. Define the probability distribution associated with the random variable. If the system has n distinct states $\{x_1, x_2, \ldots, x_n\}$, the probability of each state is calculated as:

$$p_i = \frac{frequency\ of\ x_i}{\sum_{j=1}^{n} frequence\ of\ x_j} \quad (2)$$

Let p_i be the normalized probability of each state. The above formula allows the calculation of entropy.

This method requires information directly collected from a significant sample of subjects. To this end, social research uses various methodologies to analyze behaviors, opinions, and dynamics within a society. Among them is the Survey method, a fundamental tool for collecting data (quantitative or qualitative) from many individuals. It is widely recognized for its ability to provide structured and comparable information regarding a large number of individuals (Zotti, 2020). The method generally involves the use of standardized questionnaires, which allow the systematic collection of quantitative data, facilitating results processing (Babbie, 2021).

One of the key aspects in the use of Surveys is the design of the questionnaire, which must ensure the validity and reliability of responses (Groves et al., 2009). Questionnaires can be administered through many channels, including face-to-face, telephone, or online interviews, with varying implications for the quality and representativeness of the sample (Couper, 2008). The wording of questions, choice of measurement scales, and response format significantly affect the quality of the collected data (De Leeuw et al., 2012). In addition, according to some studies, the use of structured questionnaire interviews is particularly effective when the research objective is to assign scores to certain criteria (Fowler, 2014).

3. Methodological proposal

The proposed method consists of two stages; the first stage involves the taxonomic analysis of the 4 liveability indices selected in the previous Section (Section 2.2) and thus the de-structuring of the sub-criteria that constitute them; The second phase involves the recomposition of a set of criteria, sub-criteria, and indicators inherent to the theme of liveability and residential well-being. First, it involves the definition of a questionnaire to be submitted to a substantial and heterogeneous number of individuals, and, secondly, the weighting of the results obtained through informational entropy.

3.1 De-structuring of the 4 international indices

The index under study focuses on four multidimensional approaches that collect data and define indicative parameters on the Global Liveability Index, Global Power City Index, Innovation City Index, and Smart City Index. Data and results of each report analyzed below refer to the year 2024, the latest available as of this article's writing date.

EIU: The Global Liveability index

The methodology adopted for this assessment is based on the integration of qualitative and quantitative indicators that allow for a detailed and complex analysis focused on critical elements such as the quality of public services, personal safety, and the resilience of urban infrastructure. Specifically, for ranking urban liveability, the EIU employs more than 30 criteria, distributed into five main categories (criteria): *i*) stability, *ii*) health care, *iii*) culture and environment, *iv*) education, and *v*) infrastructure (Table 1). Each criterion for a given city is rated on a scale ranging from "acceptable" to "intolerable" (acceptable, tolerable, uncomfortable, undesirable, or intolerable).

This evaluation system enables precise identification of strengths and opportunities for each urban context analyzed, providing a clear and structured framework for urban policy decisions. For qualitative indicators, a score is assigned based on the judgment of internal analysts and local collaborators, while for quantitative indicators, a score is calculated based on performance relative to an external data set. The scores are then compiled and weighted to provide a score from 1 to 100, where 1 is considered intolerable and 100 is considered ideal. The liveability rating is provided both as an overall score and as a score for each category.

Table 1. EIU macro-indicators - Global Liveability Index (authors' synthetic graphic elaboration).

EIU - Global Liveability Index	
Stability	(a) Prevalence of petty crime; (b) Prevalence of violent crime; (c) Threat of terror; (d) Threat of military conflict; (e)Threat of civil unrest/conflict
Healthcare	(a) Availability of private healthcare; (b) Quality of private healthcare; (c) Availability of public healthcare; (d) Quality of public healthcare; (e) Availability of over-the-counter drugs; (f) General healthcare indicators
Culture and environment	(a) Humidity/temperature rating; (b) Discomfort of climate to travelers; (c) Level of corruption; (d) Social or religious restrictions; (e) Level of censorship; (f) Sporting availability; (g) Cultural availability; (h) Food & drink; (i) Consumer goods & services
Education	(a) Availability of private education; (b) Quality of private education; (c) Public education indicators
Infrastructures	(a) Quality of road network; (b) Quality of public transport; (c) Quality of international links; (d) Availability of good quality housing; (e) Quality of energy provision; (f) Quality of water provision; (g) Quality of telecommunications

GPCI: Global Power City Index

The Global Power City Index (GPCI) developed by the Institute for Urban Strategies, owned by The Mori Memorial Foundation, measures "urban magnetism" through six key criteria: *i*) economy, *ii*) research and development, *iii*) cultural interaction, *iv*) liveability, *v*) environment, and *vi*) accessibility (Table 2), offering a multi-dimensional and comprehensive view of urban competitiveness. Each of these functions is divided into various groups of sub-criteria, for a total of 26 groups. These contain a total of 70 specific indicators used to analyze the characteristics and performance of cities in detail. For each indicator, a score is calculated and aggregated at the sub-criterion level, and then further combined to obtain a score for each urban function. The sum of the scores for all urban functions determines the city's overall ranking in the GPCI, and the maximum score for a city is 2,600 points. The structure of the indicators and their weighting provide a balanced measure of the liveability, sustainability, and effectiveness of urban policies, which are crucial for land-use planning and evaluation in estimation.

Table 2. Global Power City Index-indicators of urban well-being (authors' elaboration).

GPCI - Global Power City Index	
Economy	(a) Market size: *i*) Nominal GDP; *ii*) GDP pre capita. (b) Market Attractiveness: *i*) GDP growth rate; *ii*) Economic freedom. (c) Economy Vitality: *i*) Stock Market Capitalization: *ii*) World's Top 500 Companies. (d) Human Capital: *i*) Total Employment; *ii*) Employees in Business Support Services. (e) Business Environment: *i*) Wage Level; *ii*) Availability of Skilled Human Resources; *iii*) Variety of Workplace Options. (f) Ease of doing Business: *i*) Corporate Tax Rate; *ii*) Political, Economic and Business Risk.
R&D	(a) Academic resources: *i*) Number of Researchers; *ii*) World's Top Universities. (b) Research Environment: *i*) Research and Development Expenditure; *ii*) Number of International Students; *iii*) Academic Performance. (c) Innovation: *i*) Number of Patents; *ii*) Winners of Prizes in Science; *iii*) Number of Startups.
Cultural interaction	(a) Trendsetting Potential: *i*) Number of International Conferences; *ii*) Number of Cultural Events; *iii*) Cultural Content Export Value; *iv*) Art Market Environment. (b) Tourism resources: *i*) Tourist Attractions; *ii*) Proximity to World Heritage Sites; *iii*) Nightlife Options. (c) Cultural facilities: *i*) Number of Theaters; *ii*) Number of Museums; *iii*) Number of Stadiums. (d) Visitor amenities: *i*) Number of Hotel Rooms; *ii*) Number of Luxury Hotel Rooms; *iii*) Attractiveness of Shopping Options; *iv*) Attractiveness of Dining Options. (e) International interaction: *i*) Number of Foreign Residents; *ii*) Number of Foreign Visitors.
Liveability	(a) Working Environment: *i*) Total Unemployment Rate; *ii*) Total Working Hours per capita; *iii*) Workstyle flexibility. (b) Cost of living: *i*) housing rent; *ii*) Price level. (c) Security and safety: *i*) number of murders; *ii*) Economic Risk of Natural Disaster. (d) Well-being: *i*) Life Expectancy; *ii*) Social Freedom and Equality; *iii*) Risk to Mental Health. (e) Ease of living: *i*) Number of Medical Doctors; *ii*) ICT Readiness; *iii*) Number of Retail Shops: *iv*) Number of Restaurants.
Accessibility	(a) International Network: *i*) Cities with Direct International Flights; *ii*) International Freight Flows. (b) Air Transport Capacity: *i*) Number of Air Passengers; *ii*) Number of Arrivals and Departures at Airports; *iii*) Station Density; *iv*) Public Transportation Use; *v*) Travel Time to Airports. (c) Transport comfortability: *i*) Commuting Time; *ii*) Average Driving Speed; *iii*) Ease of Mobility by Taxi or Bicycle.

IMD: Smart city index

The IMD Smart City Index quantifies residents' perceptions of urban infrastructure and available technologies in their cities. This index includes a comparative assessment of 141 cities globally, based on the responses of 120 residents from each city. The final score assigned to each city is the result of a weighted average of the perceptions collected over the past three years, following a weight distribution of 3:2:1 for the years 2023, 2021, and 2020, respectively.

The Smart City Index methodology consists of two main evaluation pillars: Structures, i.e., the physical infrastructure of cities, and Technology, based on the technological development and digital services available to citizens. Each pillar is examined under five crieria: *i*) health and safety, *ii*) mobility, *iii*) activities, *iv*) opportunities, and *v*) governance (Fig.3). To ensure a fair comparison, cities are categorized into four groups based on their score in the Global Data Lab's Human Development Index (HDI). Thus, cities in a higher HDI group are not compared with those in lower HDI groups. Each city within these groups is assigned a ranking that varies according to their relative perception score. These classifications are organized as follows:

1. Group 1 (highest quartile of the ISU): classifications AAA to BB (AAA-AA-A-BBB-BB)
2. Group 2 (second quartile of the ISU): classifications A to CCC. (A-BBB-BB-B-CCC)
3. Group 3 (third quartile of the ISU): classifications BB to C. (BB-B-CCC-CC-C)
4. Group 4 (lowest quartile of ISU): classifications CCC to D. (CCC-CC-C-D)

The results are presented both as an overall ranking, placing cities from 1 to 141, and as detailed ratings for each pillar and overall. This evaluation framework facilitates an in-depth understanding of a city's ability to meet the needs of its residents through infrastructure and technology, providing essential data for urban analysis and planning in spatial and estimative assessment. An example of the evaluation structure is presented below.

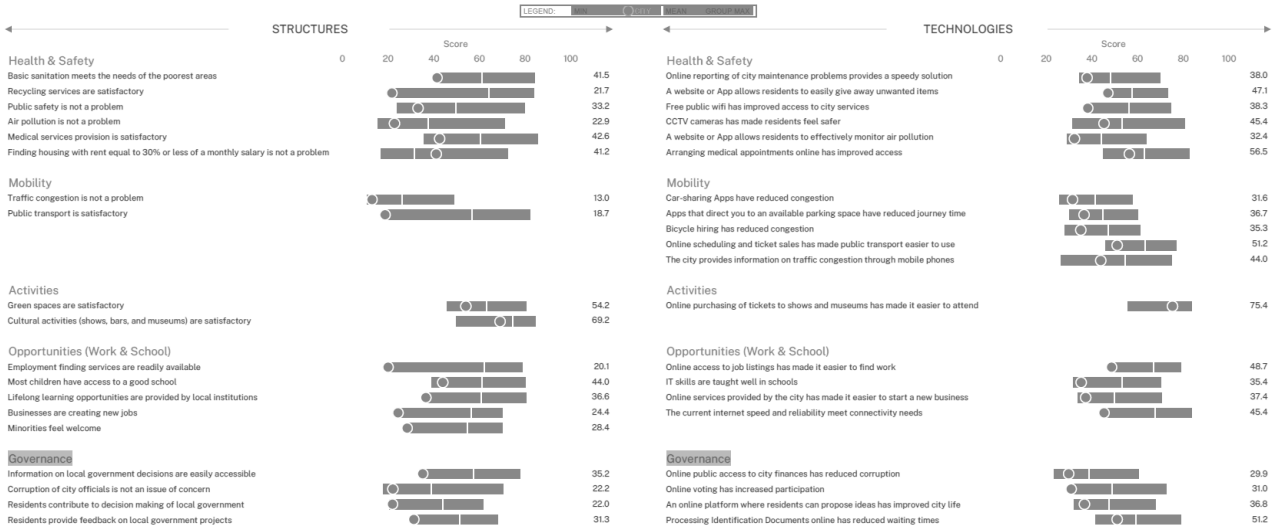

Figure 3. IMD, (2023). Extract of the Smart City Index assessment of the city of Rome.

Innovation Cities Index

This index allows a broad and detailed comparison between different cities globally, based on a reference dataset consisting of 500 essential data points (2Thinknow, 2023). The indicators are carefully designed to collect all variables relevant to urban innovation, thus ensuring comprehensive coverage of the dynamics and conditions that influence city development (Fig. 4). In this way, the methodology is useful both for assessments and to support the continuous improvement of urban development strategies. Again, the process goes through several steps. First, criteria that reflect key aspects of innovation are chosen; they include *i*) quality of education, *ii*) availability of human capital, *iii*) technological infrastructure, *iv*) access to services, and *v*) impact on public policy. Following data collection through government reports and field surveys, the indicators are standardized to enable comparisons between different cities worldwide.

SECTORS COVERED

Outlined for your convenience.

Updated Sept 2023 (v4.1)

Available 2thinknow® Innovation Agency

Sector	Industries & Clusters	Government Policy Areas	2012-2022 Label
Architecture, Planning & Heritage	Construction	Architecture, Heritage, Construction, Property, Urban Planning, Building	Architecture
Arts & Culture	Culture	Arts, Culture (excluding Music)	Arts
Banking, Tax & Finance	Financial Services	Banking, Tax, Finance, Insurance, Capital Markets	Commerce
Business & Commerce	Business (B2B)	Business, Commerce, Trade, Private Enterprises	Business
Communications & Technology	High Tech	Technology, IT, Communications, Automation, Robotics, Multimedia, eCommerce	Technology & Communications
Consumer & Small Business	Consumer & Retail	Retail, Shopping, Wholesale, eCommerce	Retail
Diplomacy & Foreign Affairs	Foreign Affairs	Diplomacy, Foreign Affairs	Diplomacy & Trade
Economics & Policy	Economics & Policy	Economics, Policy	Economics
Education & Science	Education, Science & Technical	Education, Science, Engineering, Colleges, Universities, STEM	Education
Environment, Sustainability & Nature	Sustainability	Environment, Sustainability, Nature	Environment & Nature
Fashion, Clothing & Textiles	Fashion	Fashion, Clothing, Textiles	Fashion
Food, Leisure & Hospitality	Hospitality	Food, Leisure, Hospitality	Food
Geography	Geo-spatial	Geography	Geography
Government & Politics	Government & Public Services	Government, Politics	Government
Health & Medicine	Health & Life Sciences	Health, Medicine, Life Sciences, Biotech, Healthcare	Health
Industry & Manufacturing	Industrial	Industry, Manufacturing, Circular Economy	Industry
Information, News & Publishing	Communications & Media	Information, Media, News, Publishing, Books, Entertainment	Information
Labour, Employment & Workforce	Recruitment	Labour, Employment, Workforce	Labor
Law & Governance	Law	Law, Governance	Law
Logistics & Ports	Logistics	Logistics, Freight, Ports	Logistics
Military, Defence & Aviation	Defence & Aerospace	Military, Defence, Aviation, Aerospace	Military
Music & Performance	Music	Music, Performance	Music
People, Rights & Families	Community Services	People, Population, Rights, Families	People
Police, Fire & Emergency Response	Emergency Services	Public Safety, Police, Fire, Emergency Response	Public Safety
Primary Industries, Services & Energy	Agriculture, Sanitation, Water & Energy	Electricity, Gas, Agriculture, Forestry, Renewables, Farming, Food, Water Supply, Aquaculture, Horticulture	Basic Services
Religion, Multi-Culturalism & Charities	NFPs	Spirituality, Religion, Charities, Not-for-Profits, Multi-Cultural	Spirituality
Resources, Mining, Oil and Gas	Resources	Resources, Mining, Oil, Gas	Resources
Sports, Wellbeing & Fitness	Sports	Sports, Wellbeing, Fitness, Gyms	Sports
Start-Ups & Enterprise	Start-Ups & Enterprise	Start-Ups, Entrepreneurs	Start-Ups
Tourism & Travel	Travel	Tourism, Travel, Conferences, Airports	Cultural Exchange
Transport, Roads & Mobility	Transport & Automotive	Transport, Rail, Automobiles, Cycling, Personal Mobility	Mobility

Figure 4. Extract of the Innovation Cities Index

3.1 The recomposition of the set of criteria, sub-criteria and indicators

After analyzing the index above, a set of criteria, sub-criteria and indicators for urban liveability has been developed. An exhaustive list of all the sub-criteria in the above indices, totaling 183 sub-criteria, was defined in the first stage. As they outline heterogeneous aspects of life, they have been grouped according to their area of interest, defining thirteen criteria, such as 1) Safety; 2) Government and Politics; 3) Market; 4) Health; 5) Environment; 6) Culture; 7) Services; 8) Education; 9) Tourism; 10) Communication and Technology; 11) Infrastructure; 12) Architecture; 13) Economy and Finance.

Since some aspects mentioned throughout the sub-criteria refer to similar concepts, a taxonomic recomposition of these has been carried out. Accordingly, the table (Tab. 3) has been further rationalised by aggregating similar sub-criteria under one sub-criterion. This reorganisation process allows the definition of a structured list of 132 sub-criteria (well-being indicators). Finally, a specific unit of measurement is assigned to each of them, allowing the multiple dimensions of urban liveability to be quantified and assessed. Through this multi-criteria approach, it is possible to interrelate the many dimensions that define liveability in relation to the place. This facilitates the identification of areas for intervention and improvement, supporting decision-making for urban planning and sustainable development projects.

Table 3. Well-being indicators: criteria, sub-criteria, indicators and reference reports.

Well-being Indicators			
Criterion	**Sub-criterion**	**Indicator**	**Reference report**
1. Safety	1.1 Micro-crime	%	EIU Indicator
	1.2 Violent crime	%	EIU Indicator, GPCI 2023
	1.3 Military conflicts	qualitative	EIU Indicator
	1.4 Protests and activism	%	EIU Indicator, Innovation Cities Index
	1.5 Threat of natural disasters	qualitative	Innovation Cities Index
	1.6 Health emergency locations	n.	Innovation Cities Index
2. Government and Politics	2.1 Government responsiveness	qualitative	Innovation Cities Index
	2.2 Government stability	years	Innovation Cities Index
	2.3 Political transparency	%	Innovation Cities Index
	2.4 Professionalism of public employees	qualitative	Innovation Cities Index
	2.5 Level of corruption	qualitative	EIU Indicator
3. Market	3.1 Total unemployment rate	%	GPCI 2023
	3.2 Working hours per capita	h	GPCI 2023
	3.3 Work style flexibility	%	GPCI 2023
	3.4 Average housing prices	€/m²	GPCI 2023, revisited
	3.5 Handicrafts	%	Innovation Cities Index
4. Healthcare	4.1 Private healthcare	%	EIU Indicator, Innovation Cities Index
	4.2 Public healthcare	%	EIU Indicator, Innovation Cities Index
	4.3 Over-the-counter drugs	d	EIU Indicator
	4.4 Healthcare staff	n.	Innovation Cities Index
	4.5 Health emergencies	%	Innovation Cities Index
	4.6 Population well-being	%	Innovation Cities Index
	4.7 Life expectancy	years	GPCI 2023, Innovation cities index
	4.8 Mental health	MH	GPCI 2023
5. Environment	5.1 Relative humidity	%	EIU Indicator, Innovation Cities Index
	5.2 CO2 emissions per capita	CO2/eq	GPCI 2023, Innovation Cities Index
	5.3 Thermal comfort	°C	GPCI 2023
	5.4 Noise pollution	dBA	Innovation Cities Index
	5.5 Water quality	service area	GPCI 2023, Innovation Cities Index
	5.6 Air quality	qualitative	GPCI 2023, Innovation Cities Index
	5.7 Nature	service area	Innovation Cities Index
	5.8 Urban green space	%	GPCI 2023, Innovation Cities Index
	5.9 Green Business	n.	Innovation Cities Index
	5.10 Renewable energy tariff	-	GPCI 2023
	5.11 Waste recycling rate	%	GPCI 2023
	5.12 Urban cleanliness	%	GPCI 2023
6. Culture	6.1 Cultural activities	n.	GPCI 2023, EIU Indicator.

	6.2 Religious freedom	%	EIU Indicator, GPCI 2023
	6.3 Gender Equality	%	Innovation Cities Index
	6.4 Citizen Rights	qualitative	Innovation Cities Index
	6.5 Press Freedom	qualitative	EIU Indicator
7. Services	7.1 Sports facilities availability	n./%	EIU Indicator, GPCI 2023
	7.2 Business activities	n./%	EIU Indicator, GPCI2023 Innovation Cities Index.
	7.3 Youth activities	n./%	Innovation Cities Index, GPCI 2023
	7.4 Cultural Assets	%	GPCI 2023
	7.5 Number of Hotels	n./%	Innovation Cities Index
	7.6 Postal services	n./%	Innovation Cities Index
	7.7 Department stores	n./%	Innovation Cities Index
8. Education	8.1 Private education	n.	EIU Indicator
	8.2 Public education	n.	EIU Indicator
	8.3 Quality of private education	qualitative	EIU Indicator
	8.4 Quality of public education	qualitative	EIU Indicator
	8.5 Academic performance	%	GPCI 2023
	8.6 Number of researchers	n.	GPCI 2023
	8.7 Number of international students	n.	GPCI 2023, Innovation Cities Index
	8.8 University supply	n.	Innovation Cities Index
	8.9 Research and development funds	€	GPCI 2023
	8.10 Global ranking of universities	qualitative	GPCI 2023
	8.11 Number of patents	n.	GPCI 2023
	8.12 Award winners in science and technology	n.	GPCI 2023
9. Tourism	9.1 Availability of tourist information	-	Innovation Cities Index
	9.2 Number of tourists	n.	Innovation Cities Index
	9.3 Multilingual city/language	n.	Innovation Cities Index
	9.4 Tourist attractions	%	GPCI 2023
10. Communication and Technology	10.1 Adoption of new technologies	%	Innovation Cities Index
	10.2 Broadband Internet	service area	Innovation Cities Index
	10.3 Landline telephone network	service area	Innovation Cities Index
	10.4 Mobile phone network	n.	Innovation Cities Index
	10.5 Public internet wireless	%	Innovation Cities Index
	10.6 Smart working	%	Innovation Cities Index
	10.7 E-commerce sales	%	Innovation Cities Index
	10.8 Internet Users	%	Innovation Cities Index
	10.9 ICT Readiness	%	GPCI 2023
	10.10 Government IT policy/digital infrastructure	qualitative	Innovation Cities Index, EIU Indicator
	10.11 Metaverse	%	Innovation Cities Index
	10.12 Mass transportation automation	%	Innovation Cities Index
	10.13 Smart devices	qualitative	Innovation Cities Index
11. Infrastructure	11.1 Quality of the road network	qualitative	Innovation Cities Index, EIU Indicator
	11.2 Car sharing	n.	Innovation Cities Index
	11.3 Traffic accidents	%	GPCI 2023
	11.4 Road signs	qualitative	Innovation Cities Index
	11.5 Number of stations	n.	GPCI 2023
	11.6 Use of public transportation	%	GPCI 2023
	11.7 Commuting time	Min.	GPCI 2023
	11.8 Travel time to airports	Min.	GPCI 2023
	11.9 Availability/frequency of public services	served area	Innovation Cities Index
	11.10 Quality of public transportation	% satisfaction	Innovation Cities Index, EIU Indicator
	11.11 Ease of cab mobility	n.	GPCI 2023, Innovation Cities Index
	11.12 Presence of International Airports	n.	Innovation Cities Index
	11.13 Cities with direct international flights	n.	GPCI 2023
	11.14 Number of arrivals and departures at airports.	n.	GPCI 2023
	11.15 Airport transfers	n.	Innovation Cities Index
	11.16 Transportation accessibility	%	Innovation Cities Index
	11.17 Walkable city	route density	Innovation Cities Index

	11.18 Bikeable city	route density	Innovation Cities Index
	11.19 Quality of energy supply	service area	EIU Indicator
12. Architecture	12.1 Architectural stratification	%	Innovation Cities Index
	12.2 Decorative characteristics of buildings	qualitative	Innovation Cities Index
	12.3 Green architecture	%	Innovation Cities Index
	12.4 Historical architecture	n.	Innovation Cities Index
	12.5 Quality of neighborhoods	%	Innovation Cities Index
	12.6 Vertical constructions	n.	Innovation Cities Index
	12.7 Public meeting spaces	n.	Innovation Cities Index
	12.8 Good-quality accommodation	qualitative	EIU Indicator
	12.9 New construction technologies	qualitative	Innovation Cities Index
13. Economy	13.1 Nominal GDP	€	GPCI 2023
	13.2 GDP per capita	€	GPCI 2023
	13.3 GDP growth rate	%	GPCI 2023
	13.4 Stock market capitalization	€	GPCI 2023
	13.5 Employment rate	%	GPCI 2023
	13.6 Salary level	€	GPCI 2023
	13.7 Professional Services	%	Innovation Cities Index
	13.8 Economic freedom	qualitative	GPCI 2023
	13.9 Banking stability	CAR/LCR/ ROA	Innovation Cities Index
	13.10 Corporation income tax	%	Innovation Cities Index
	13.11 Accessibility to finance for growing businesses	%	Innovation Cities Index
	13.12 Acceptance of major credit cards	%	Innovation Cities Index
	13.13 Start-up	n.	Innovation Cities Index, GPCI 2023
	13.14 Economic risk of natural disasters	risk	GPCI 2023
	13.15 Employees in business support services	n.	GPCI 2023
	13.16 Availability of qualified human resources	%	GPCI 2023
	13.17 Variety of options in the workplace	%/n.	GPCI 2023
	13.18 Political, economic and business risk	risk	GPCI 2023
	13. 19 Cryptocurrency	%	Innovation Cities Index
	13.20 Currency exchange	TCR	Innovation Cities Index
	13.21 Headquarters of multinational corporations	%	Innovation Cities Index
	13.22 Sales tax	VAT	Innovation Cities Index
	13.23 Advertising in the media	%	Innovation Cities Index
	13.24 Business approach	qualitative	Innovation Cities Index
	13.25 Designers	%	Innovation Cities Index
	13.26 Industrial diversity	%	Innovation Cities Index
	13.27 Professional services	%	Innovation Cities Index

The definition of the residential well-being criteria proposed in the table required a process of data selection and systematization. In particular, 56 sub-criteria were eliminated from the original table of all the criteria drawn from the previously mentioned international reports, as they were repeated two or more times and therefore not relevant to the research.

The table is organised into four parts: *i*) Criteria (thematic dimensions) *ii*) Sub-criteria (specific well-being factors); *iii*) Indicators (units of measurement); *iv*) Reference reports (source documents). This structure allows for a rigorous systematization of the evaluation process, providing a solid basis for measuring residential well-being. However, it must be noted that although much data is readily available through official sources or standardized tools, for others, the availability of information may be more limited. Some sub-criteria would require further studies regarding data collection, as for subjective aspects related to the individual's perceptions.

4. Experimentation and results

4.1 Weighting by informational entropy (applied to surveys)

To identify the most relevant well-being indicators on liveability, a systematic review of the indices underlying the experiment has been conducted. 129 sub-criteria belonging to different criteria (thematic dimensions of well-being) have been defined; social categories with a direct interest in residential well-being (students, workers, immigrants, senior

citizens, etc.) have been identified. Then, questionnaires were administered regarding the perceived relevance of the indicators with a numerical scale from 1 to 10 to weigh the criteria according to their importance. The attribution of different weights to each sub-criterion by the survey sample generates informational entropy; that is, given the variability of the data obtained, a situation of informational uncertainty occurs, possibly leading to unclear and unmanageable results. The decision matrix $A = (a_{ij})_{nxm}$ generated from the collected data is defined and normalized into the matrix $R = (r_{ij})_{nxm}$ through appropriate formulas. The R matrix is converted to the matrix $R = (r_{ij})_{nxm}$ using the normalized values, and the entropy attributed to the equivalent indicators is calculated. Finally, attribute weighting takes place. Since the entropic method attaches more importance to sub-criteria with more variability in respondents' responses (high entropy) and less importance to sub-criteria with less variability (low entropy), the theoretical method based on entropic information is supplemented with the simple weighted and normalized mean of the scores for each sub-criteria. This is because, if all (or most) respondents attribute the highest score to a specific sub-criteria, it must have a high final weight since it reflects an important aspect for the social groups surveyed (Guarini et al., 2014; Guarini and Battisti, 2014).

Surveys

The experimentation surveyed a sample of 100 individuals from heterogeneous social groups by employment and educational status. Therefore, the following groups of respondents are considered: *i*) on-campus students, *ii*) off-campus students, *iii*) smart workers, iv) non-smart workers, v) NEETs (Not in Education, Employment, or Training), and vi) retirees. To assign a weight to each well-being sub-criterion, questionnaires are administered to respondents regarding the evaluation by importance of the sub-criteria; the importance scale consists of Irrelevant; Unimportant; Slightly important; Moderately important; Neither important nor unimportant (neutral); Somewhat important; Important; Very important; Fundamental; Essential. Next, the interview results will be converted into numerical values from 1 to 10.
Figure 5 summarizes the average scores attributed to each of the 13 thematic categories. Environmental quality, market-related factors, and healthcare emerge as the most valued dimensions, reflecting the priority attributed to sustainability, economic vitality, and health infrastructure in determining residential well-being. Conversely, criteria such as tourism and governance are perceived as having a more marginal impact on daily life.

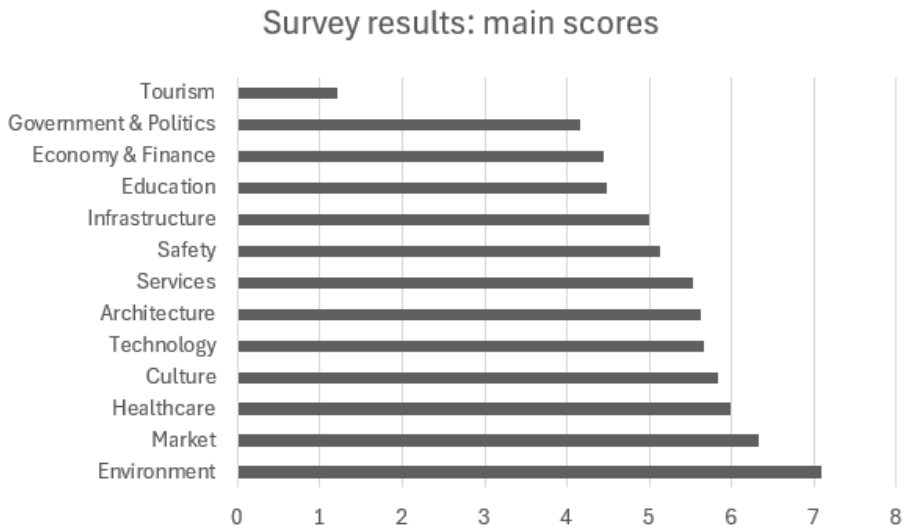

Figure 5. Survey results: main scores.

Entropy calculation

As a result of the data collected through the questionnaires referring to the various categories of selected individuals, some sub-criteria with heterogeneous opinions, which must be focused on, are highlighted. Thus, weights are pondered by considering: *i*) the variability of the answers given by the respondents; *ii*) the importance that respondents give to each indicator.

The procedure proposed and explained in Section 2.3 is applied to weight the various sub-criteria optimally and minimize error with the following assumptions:

- High entropy (≥0.6) and high mean (≥0.6) → High weight;
- Low entropy (< 0.6) and high mean (≥ 0.6) → High weight;
- High entropy (≥ 0.6) and low mean (< 0.6) → Moderate weight;
- Low entropy (< 0.6) and low mean (< 0.6) → Low weight.

First, each indicator was normalized to standardize the data in the decision matrix. The following formula was used:

$$\beta_i = \frac{x_i - min\ (x_i)}{(x_i) - min\ (x_i)} + \pi \quad (3)$$

where:

- x_i represents the response given by unit i for the indicator
- $(x_i)\ e\ min\ (x_i)$ are the minimum and maximum values (1 to 10), respectively
- π is a constant to ensure that β_i is always different from zero

Then, the entropy for each indicator is calculated as:

$$H(X) = -\sum_{i=1}^{n} P(x_i)\ log_b P(x_i) \quad (4)$$

Below is the table of standardized well-being indices (Table 4).

Table 4. Data standardisation and results processing for information entropy.

Results and Weighting					
Indicator no.	Entropy	Means (min/max)	Weight (0-1)	Weight (%)	Weight (qualitative)
Ind. 1.1	0.87	0.61	0.865	1.51	High
Ind. 1.2	1.00	0.55	0.573	1.00	Moderate
Ind. 1.3	0.25	0.14	0.088	0.15	Low
Ind. 1.4	0.36	0.18	0.132	0.23	Low
Ind. 1.5	0.69	0.71	0.819	1.43	High
Ind. 1.6	0.69	0.71	0.819	1.43	High
Ind. 2.1	0.87	0.31	0.495	0.87	Moderate
Ind. 2.2	0.87	0.43	0.495	0.87	Moderate
Ind. 2.3	0.48	0.43	0.245	0.43	Low
Ind. 2.4	0.56	0.24	0.213	0.37	Low
Ind. 2.5	0.69	0.43	0.388	0.68	Moderate
Ind. 3.1	0.69	0.73	0.831	1.46	High
Ind. 3.2	0.74	0.47	0.417	0.73	Moderate
Ind. 3.3	0.87	0.84	1.000	1.75	High
Ind. 3.4	0.56	0.82	0.462	0.81	High
Ind. 3.5	0.36	0.31	0.169	0.30	Low
Ind. 4.1	0.74	0.39	0.417	0.73	Moderate
Ind. 4.2	0.69	0.86	0.905	1.58	High
Ind. 4.3	0.48	0.78	0.437	0.77	High
Ind. 4.4	0.56	0.57	0.312	0.55	Low
Ind. 4.5	0.74	0.49	0.417	0.73	Moderate
Ind. 4.6	0.56	0.39	0.257	0.45	Low
Ind. 4.7	0.74	0.57	0.417	0.73	Moderate
Ind. 4.8	0.74	0.67	0.824	1.44	High
Ind. 5.1	0.56	0.80	0.450	0.79	High
Ind. 5.2	0.74	0.67	0.824	1.44	High
Ind. 5.3	0.56	0.80	0.450	0.79	High
Ind. 5.4	0.48	0.84	0.474	0.83	High
Ind. 5.5	0.48	0.67	0.376	0.66	High
Ind. 5.6	0.74	0.67	0.824	1.44	High
Ind. 5.7	0.56	0.71	0.400	0.70	High
Ind. 5.8	0.74	0.86	0.934	1.64	High
Ind. 5.9	0.56	0.57	0.312	0.55	Low
Ind. 5.10	0.56	0.55	0.306	0.54	Low
Ind. 5.11	0.69	0.80	0.868	1.52	High
Ind. 5.12	0.69	0.76	0.844	1.48	High
Ind. 6.1	0.69	0.53	0.388	0.68	Moderate
Ind. 6.2	0.69	0.43	0.388	0.68	Moderate
Ind. 6.3	0.74	0.67	0.824	1.44	High
Ind. 6.4	0.74	0.61	0.787	1.38	High
Ind. 6.5	0.25	0.61	0.339	0.59	High
Ind. 7.1	0.74	0.78	0.885	1.55	High
Ind. 7.2	0.25	0.73	0.413	0.72	High
Ind. 7.3	0.69	0.63	0.770	1.35	High

Ind. 7.4	0.56	0.37	0.250	0.44	Low
Ind. 7.5	0.48	0.10	0.146	0.26	Low
Ind. 7.6	0.69	0.41	0.388	0.68	Moderate
Ind. 7.7	0.48	0.71	0.400	0.70	High
Ind. 8.1	0.56	0.14	0.183	0.32	Low
Ind. 8.2	0.61	0.84	0.844	1.48	High
Ind. 8.3	0.36	0.14	0.120	0.21	Low
Ind. 8.4	0.25	0.80	0.450	0.79	High
Ind. 8.5	0.69	0.57	0.388	0.68	Moderate
Ind. 8.6	0.69	0.31	0.388	0.68	Moderate
Ind. 8.7	0.87	0.29	0.495	0.87	Moderate
Ind. 8.8	0.74	0.69	0.836	1.46	High
Ind. 8.9	0.87	0.43	0.495	0.87	Moderate
Ind. 8.10	0.36	0.22	0.144	0.25	Low
Ind. 8.11	0.36	0.22	0.144	0.25	Low
Ind. 8.12	0.36	0.22	0.144	0.25	Low
Ind. 9.1	0.25	0.00	0.045	0.08	Low
Ind. 9.2	0.25	0.00	0.045	0.08	Low
Ind. 9.3	0.25	0.02	0.051	0.09	Low
Ind. 9.4	0.25	0.00	0.045	0.08	Low
Ind. 10.1	0.56	0.67	0.376	0.66	High
Ind. 10.2	0.56	0.67	0.376	0.66	High
Ind. 10.3	0.48	0.14	0.158	0.28	Low
Ind. 10.4	0.48	0.84	0.474	0.83	High
Ind. 10.5	0.48	0.94	0.536	0.94	High
Ind. 10.6	0.69	0.69	0.807	1.41	High
Ind. 10.7	0.87	0.29	0.495	0.87	Moderate
Ind. 10.8	0.48	0.18	0.171	0.30	Low
Ind. 10.9	0.87	0.57	0.495	0.87	Moderate
Ind. 10.10	1.00	0.51	0.573	1.00	Moderate
Ind. 10.11	0.74	0.55	0.417	0.73	Moderate
Ind. 10.12	0.74	0.45	0.417	0.73	Moderate
Ind. 10.13	0.87	0.63	0.877	1.54	High
Ind. 11.1	0.69	0.41	0.388	0.68	Moderate
Ind. 11.2	0.87	0.33	0.495	0.87	Moderate
Ind. 11.3	0.36	0.76	0.425	0.74	High
Ind. 11.4	0.56	0.31	0.232	0.41	Low
Ind. 11.5	0.87	0.73	0.938	1.64	High
Ind. 11.6	0.69	0.59	0.388	0.68	Moderate
Ind. 11.7	0.74	0.43	0.417	0.73	Moderate
Ind. 11.8	0.00	0.10	0.000	0.00	Low
Ind. 11.9	0.56	0.73	0.413	0.72	High
Ind. 11.10	0.36	0.59	0.255	0.45	Low
Ind. 11.11	0.56	0.14	0.183	0.32	Low
Ind. 11.12	0.48	0.33	0.214	0.37	Low
Ind. 11.13	0.56	0.22	0.207	0.36	Low
Ind. 11.14	0.56	0.08	0.164	0.29	Low
Ind. 11.15	0.61	0.43	0.339	0.59	Moderate
Ind. 11.16	0.69	0.73	0.831	1.46	High
Ind. 11.17	0.48	0.84	0.474	0.83	High
Ind. 11.18	0.36	0.90	0.511	0.90	High
Ind. 11.19	0.87	0.27	0.495	0.87	Moderate
Ind. 12.1	0.36	0.06	0.095	0.17	Low
Ind. 12.2	0.87	0.63	0.877	1.54	High
Ind. 12.3	0.87	0.55	0.495	0.87	Moderate
Ind. 12.4	0.48	0.43	0.245	0.43	Low
Ind. 12.5	0.48	1.00	0.573	1.00	High
Ind. 12.6	0.48	0.12	0.152	0.27	Low
Ind. 12.7	0.56	0.80	0.450	0.79	High
Ind. 12.8	0.48	0.90	0.511	0.90	High
Ind. 12.9	0.87	0.43	0.495	0.87	Moderate
Ind. 13.1	0.39	0.65	0.363	0.64	High

Ind. 13.2	0.56	0.31	0.232	0.41	Low
Ind. 13.3	0.56	0.31	0.232	0.41	Low
Ind. 13.4	0.69	0.29	0.388	0.68	Moderate
Ind. 13.5	0.74	0.78	0.885	1.55	High
Ind. 13.6	0.56	0.67	0.376	0.66	High
Ind. 13.7	0.69	0.37	0.388	0.68	Moderate
Ind. 13.8	0.36	0.80	0.450	0.79	High
Ind. 13.9	0.74	0.73	0.861	1.51	High
Ind. 13.10	0.25	0.00	0.045	0.08	Low
Ind. 13.11	0.56	0.20	0.201	0.35	Low
Ind. 13.12	0.69	0.43	0.388	0.68	Moderate
Ind. 13.13	0.56	0.69	0.388	0.68	High
Ind. 13.14	0.87	0.53	0.495	0.87	Moderate
Ind. 13.15	0.25	0.00	0.045	0.08	Low
Ind. 13.16	0.56	0.14	0.183	0.32	Low
Ind. 13.17	0.87	0.71	0.926	1.62	High
Ind. 13.18	0.74	0.27	0.417	0.73	Moderate
Ind. 13.19	0.87	0.33	0.495	0.87	Moderate
Ind. 13.20	0.48	0.22	0.183	0.32	Low
Ind. 13.21	0.74	0.55	0.417	0.73	Moderate
Ind. 13.22	0.74	0.37	0.417	0.73	Moderate
Ind. 13.23	0.36	0.02	0.083	0.14	Low
Ind. 13.24	0.56	0.41	0.263	0.46	Low
Ind. 13.25	0.48	0.41	0.239	0.42	Low
Ind. 13.26	0.69	0.53	0.388	0.68	Moderate
Ind. 13.27	0.25	0.12	0.082	0.14	Low

The percentages obtained are a determinant for defining liveability criteria because they provide a quantitative measure of the survey participants' perceived relevance.

Through the interpolation of arithmetic averages and the variability of the scores assigned by the individuals surveyed, urban liveability indicators are weighted (see below, Figure 1). The Table 4 shows both the percentage weights of each indicator and a qualitative assessment of the sub-criteria, ranked according to their significance as previously specified: high, moderate, or low. High-importance sub-criteria total 54 and are mainly concentrated in the environmental and labor market areas. Sub-criteria with more variability in responses (entropy of 1) included violent crime (sub-criteria 1.2) and government IT policy (sub-criteria 10.10). Instead, sub-criteria such as travel time to airports (sub-criteria 11.8) and tourist attractions (sub-criteria 9.4) generated low entropy.

5. Discussions and conclusions

The results obtained in the analysis phase, involving the categories of respondents defined before, show a clear hierarchy among well-being sub-criteria. The results bring out the importance of factors such as environment, public health, and employment/unemployment agreed upon by all. This means that environmental quality, access to facilitated and quality public health care, and employment opportunities are generally recognized as crucial elements of quality life. In the environmental criterion, almost all indicators scored high, well above 0.8 per cent; in particular, good design of green and natural areas is considered crucial in the urban context. Healthcare, too, is a major factor, as it achieved very high results. Regardless of their income range, people believe that access to high-quality public health facilities is essential, especially in a post-pandemic context.

Another sub-criterion of considerable interest is smart or flexible working. This factor is considered important mainly because of the variability of the responses; in the middle-income categories, working remotely is found to be an indicator with increasing relevance compared to the others. This reflects a global trend, accelerated by the Covid-19 pandemic, in which smart working has been seen as an advantageous solution to balancing work and personal life. Although not all participants attached the same degree of importance to this factor, the general perception is that work flexibility can contribute significantly to improving personal well-being, and the indicator is important precisely because it elicits different opinions and thus deserves more debate and attention.

In contrast to the positive sub-criteria, factors such as tourism, the presence of facilities such as airports, or services such as hotels scored much lower. They have been considered marginal or even deleterious factors for residential well-being, especially for people in the low, low-middle, and upper-middle income categories. This could be due, for example, to the increase in prices for house rentals and sales caused precisely by the strong tourist attractiveness of the place. Similarly, the presence of large facilities such as international airports also negatively affects residential well-being.

Although access to global infrastructure may be perceived as important in terms of economic development and mobility, its direct impact on individual well-being was found to be less significant than other factors more related to everyday life, such as access to healthcare or environmental protection. To ensure a fair assessment of the importance of the various criteria, each criterion was assigned a weight, expressed as a percentage. The methodological process included the following steps: *i*) sum of the weights assigned to the individual sub-criteria for each criterion, so that each criterion is given an overall score; *ii*) definition of each criterion's mean weight, to avoid distortions due to the different numbers of sub-criteria contained in each criterion; *iii*) conversion of the mean scores of each criterion into percentage weights. Table 5 summarizes the process.

Table 5. Elaboration of criteria's weights.

Determination of percentage points for each criterion				
Criteria	**Sum of subcriteria weights**	**n. of subcriteria by category**	**Mean weight by category**	**Percentage weight**
Safety	5.76972	6	0.96	9.7
Government and politics	3.21448	5	0.64	6.5
Market	5.04121	5	1.01	10.1
Healthcare	6.97945	8	0.87	8.8
Environment	12.36337	12	1.03	10.4
Culture	4.77064	5	0.95	9.6
Services	5.69443	7	0.81	8.2
Education	8.10709	12	0.68	6.8
Tourism	0.32663	4	0.08	0.8
Communication and technology	10.80545	13	0.83	8.4
Infrastructure	12.90403	19	0.68	6.8
Architecture	6.81520	9	0.76	7.6
Economy	17.20831	27	0.64	6.4

The synthetic graph below provides a better visualization of the discussed data (Fig. 6).

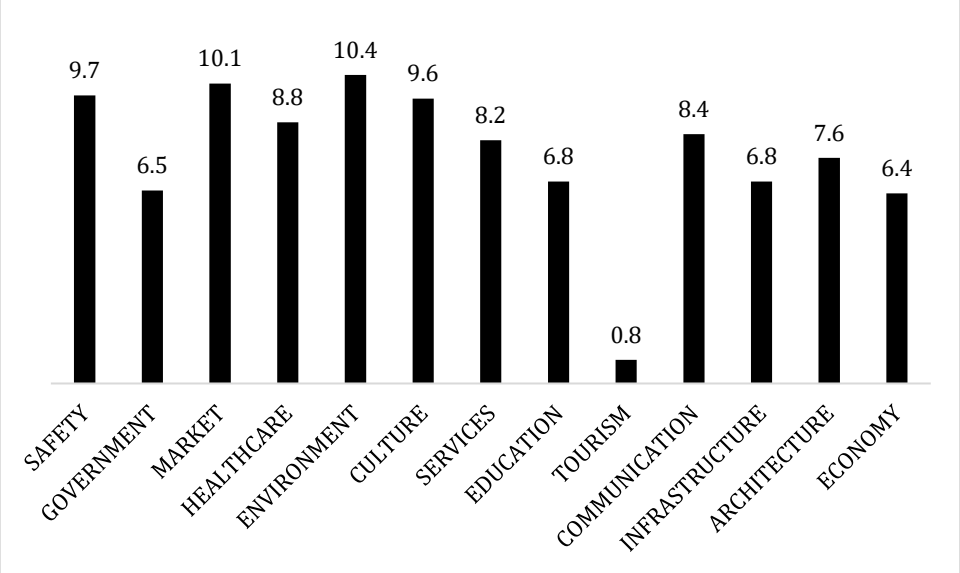

Figure 6. Percentage weights of well-being dimensions (macrocategories).

The results suggest that public policies should focus on criteria that are most relevant to well-being, such as environment, health, and employment. In a perspective of optimization of resource allocation to achieve the highest urban benefits (Acampa and Pino, 2023), policies should be focused on improving these criteria, which are perceived as fundamental by citizens. Ecological policies, universal access to health care, and job creation are, therefore, the key areas to invest to increase collective well-being. Moreover, housing accessibility also appears as one of the key sub-criteria for residential well-being.

In addition, the fact that smart work is emerging as an important sub-criterion also suggests that future policies may encourage the adoption of more flexible work patterns that allow workers to better balance professional and personal needs.

The analysis of indicators of residential well-being identified the most relevant aspects for citizens' perceived quality of life. The results obtained confirm the importance of criteria such as environment, health, and market, with weights above 8.5 percent compared to the total of thirteen dimensions. These results align with the literature suggesting that environmental quality, access to healthcare, and job stability are among the main determinants of well-being. In particular, the importance attached to the environment and health reflects the growing awareness of global ecological and health challenges, while employment is perceived as a key factor in ensuring economic and psychological well-being. In terms of policy implications, the results indicate that public policies should focus on interventions that improve environmental quality, access to health services, and employment opportunities, as these factors are perceived as essential to the population's well-being. In addition, the growing relevance of remote work suggests the need to promote more flexible and inclusive work solutions that can meet the needs of an evolving world of work.

However, it is important to recognise the limitations of this study: for example, in the study, a sample of 100 persons diversified by status (e.g. students, workers and pensioners) was considered. This sample size is relatively small compared er capitto the complexity of the phenomenon under investigation. A small sample size reduces the statistical power of the analysis and increases the margin of error, potentially obscuring significant trends or correlations. Furthermore, it may not accurately reflect the diversity of urban populations, which limits the generalisability of the results to larger or different socio-spatial context. Moreover, the methodology relies almost exclusively on quantitative data, yet this information could be supplemented with qualitative data, capturing the subjective nuances of how individuals perceive well-being and liveability. This could be developed through open-ended surveys, focus groups or interviews that would provide a more perceptive and emotional version of the results obtained. Finally, the timing of the survey—possibly influenced by post-pandemic perceptions—may have skewed responses on topics such as healthcare, green spaces, or remote work. In conclusion, this study has provided valuable information on how various criteria influence well-being perception for different socioeconomic categories, with important implications for the formulation of public policies geared toward improving the population's quality of life.

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