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Computational Science and Its Applications – ICCSA 2024 Workshops

Hanoi, Vietnam, July 1–4, 2024
Proceedings, Part VIII

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Preface

These 11 volumes (LNCS volumes 14815–14825) consist of the peer-reviewed papers from the 55 Workshops of the 2024 International Conference on Computational Science and Its Applications (ICCSA 2024) which took place during July 1–4, 2024 in Hanoi (Vietnam). The peer-reviewed papers of the main conference tracks are published in a separate set consisting of two volumes (LNCS 14813–14814).

The conference was held in a hybrid form, with some participants present in person, hosted in Hanoi, Vietnam, by the Thuy Loi University. We enabled virtual participation for those who were unable to attend the event, due to logistical, political and economic problems, by adopting a technological infrastructure based on open source software (jitsi + riot), and a commercial Cloud infrastructure.

ICCSA 2024 was another successful event in the International Conference on Computational Science and Its Applications (ICCSA) conference series, previously held in Athens, Greece (2023), Malaga, Spain (2022), Cagliari, Italy (hybrid with few participants in presence in 2021 and completely online in 2020), whilst earlier editions took place in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing. China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational Science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies, and the ICCSA conference series have been providing a venue to researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in Computational Science. As the conference mirrors society from a scientific point of view, this year's undoubtedly dominant theme was the machine learning and artificial intelligence and their applications in the most diverse economic and industrial fields.

The ICCSA 2024 conference is structured in 6 general tracks covering the fields of computational science and its applications: Computational Methods, Algorithms and Scientific Applications – High Performance Computing and Networks – Geometric Modeling, Graphics and Visualization – Advanced and Emerging Applications – Information Systems and Technologies – Urban and Regional Planning. In addition, the conference consisted of 55 workshops, focusing on very topical issues of importance to science, technology and society: from new mathematical approaches for solving complex computational systems, to information and knowledge in the Internet of Things, new statistical and optimization methods, several Artificial Intelligence approaches, sustainability issues, smart cities and related technologies.

In the Workshops proceedings we accepted 281 full papers, 17 short papers and 2 PhD Showcase papers. In the Main Conference Proceedings we accepted 53 full papers, 6 short papers and 3 PhD Showcase papers from 207 submissions to the General Tracks of the conference (acceptance rate 30%). We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2024 in particular, vitally depends on the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, organizing committee members, student volunteers, Program Committee members, Advisory Committee members, International Liaison chairs, reviewers and others in various roles. We take this opportunity to wholehartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the best papers awards and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website https://iccsa.org where you can find all the relevant information about this interesting and exciting event.

July 2024

Osvaldo Gervasi
Beniamino Murgante
Chiara Garau

Welcome Message from Organizers

After the very hard times of COVID, ICCSA continues its successful scientific endeavors in 2024, hosted in Hanoi, Vietnam. This time, ICCSA moved from the Mediterranean Region to Southeast Asia and was held in the metropolitan city of Hanoi, the capital of Vietnam. Hanoi is a vibrant urban environment known for the hospitality of its citizens, its rich history, vibrant culture, and dynamic urban life. Located in the northern part of the country, Hanoi is a bustling metropolis that combines the old with the new, offering a unique blend of ancient traditions and modern development.

ICCSA 2024 took place in a secure environment, allowing for safe and vibrant in-person participation. Combined with the active engagement of the ICCSA 2024 scientific community, this set the stage for highly motivating discussions and interactions regarding the latest developments in computer science and its applications in the real world for improving communities' quality of life.

Thuyloi University, also known as the Water Resources University, is a prominent institution in Hanoi, Vietnam, with a strong reputation in engineering and technical education, particularly in water resources and environmental engineering. In recent years, the University has expanded its academic offerings to include computer science, reflecting the growing importance of technology and digital skills in all sectors. This year, Thuyloi University had the honor of hosting ICCSA 2024. The Local Organizing Committee felt the burden and responsibility of such a demanding task and put all necessary energy into meeting participants' expectations and establishing a friendly, creative, and inspiring scientific and social/cultural environment that allowed for new ideas and perspectives to flourish.

Since all ICCSA participants, whether informatics-oriented or application-driven, realize the tremendous advancements in computer science over the last few decades and the huge potential these advancements offer in coping with the enormous challenges of humanity in a globalized, 'wired,' and highly competitive world, the expectations for ICCSA 2024 were high. The goal was to successfully match computer science progress with communities' aspirations, achieving progress that serves real, place- and people-based needs and paves the way towards a visionary, smart, sustainable, resilient, and inclusive future for both current and future generations.

On behalf of the Local Organizing Committee, I would like to sincerely thank all of you who contributed to ICCSA 2024.

Nguyen Canh Thai

Organization

ICCSA 2024 was organized by Thuyloi University (Vietnam), the University of Perugia (Italy), the University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), the University of Minho (Portugal), and the University of Cagliari (Italy).

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Econometrics and Multidimensional Evaluation of Urban Environment (EMEUE 2024)

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Environmental, Social, Governance of Energy Planning (ESGEP 2024)

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Ecosystem Services in Spatial Planning for Resilient Urban and Rural Areas (ESSP 2024)

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Ethical AI Applications for a Human-Centered Cyber Society (EthicAI 2024)

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14th International Workshop on Future Computing System Technologies and Applications (FiSTA 2024)

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Geographical Analysis, Urban Modeling, Spatial Statistics (Geog-An-Mod 2024)

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Andreas Fricke	Hasso-Plattner-Institut für Digital Engineering, Germany
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Geomatics for Resource Monitoring and Management (GRMM 2024)

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International Workshop on Information and Knowledge in the Internet of Things (IKIT 2024)

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Regenerating Brownfields Enhancing Urban Resilience Appeal (INFERENCE 2024)

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International Workshop on Territorial Planning to Integrate Risk and Urban Ontologies (IWPRO 2024)

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MaaS Solutions for Airports, Cities and Regional Connectivity (MaaS 2024)

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Martina Sinatra	University of Cagliari, Italy
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Development of Urban Mobility Management and Risk Assessment (MAINTAIN 2024)

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Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2024)

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Building Multi-dimensional Models for Assessing Complex Environmental Systems (MES 2024)

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Models and Indicators for Assessing and Measuring the Urban Settlement Development in the View of Zero Net Land Take by 2050 (MOVEto0 2024)

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Carmen Guida	University of Naples Federico II, Italy
Chiara Di Dato	University of L'Aquila, Italy

4th Workshop on Privacy in the Cloud/Edge/IoT World (PCEIoT 2024)

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Scientific Computing Infrastructure (SCI 2024)

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Alexander Degtyarev	St. Petersburg State University, Russia
Alexander Bogdanov	St. Petersburg State University, Russia
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Downscale Agenda 2030 (SDGscale 2024)

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Socio-Economic and Environmental Models for Land Use Management (SEMLUM 2024)

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Paola Amoruso	LUM, Italy

Ports of the Future - Smartness and Sustainability (SmartPorts 2024)

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Marco Petrelli	Roma Tre University, Italy

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Massimiliano Bencardino	University of Salerno, Italy

Smart Transport and Logistics - Smart Supply Chains (SmarTransLog 2024)

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Smart Tourism (SmartTourism 2024)

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Brunella Brundu	University of Sassari, Italy
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Sustainable Evolution of Long-Distance Freight Passenger Transport (SOLIDEST 2024)

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Luigi Dall'Olio	University of Cantabria, Spain
Antonio Russo	University of Enna Kore, Italy

Sustainability Performance Assessment: Models, Approaches, and Applications Toward Interdisciplinary and Integrated Solutions (SPA 2024)

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Francesca Perrone	Sapienza University of Rome, Italy
Angela Pilogallo	Italian National Research Council, Italy
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Specifics of Smart Cities Development in Europe (SPEED 2024)

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ICCSA 2024 took place on the main campus of Thuyloi University in Hanoi, Vietnam.

Plenary Lectures

Harnessing Artificial Intelligence for Enhanced Spatial Analysis of Natural Hazard Assessments

Prof. Dr. Biswajeet Pradhan

Director - Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), School of Civil and Environmental Engineering, Faculty of Engineering and IT, University of Technology Sydney, Australia

Abstract. In the realm of natural hazard assessments within spatial domains, the advent of Artificial Intelligence (AI) represents a paradigm shift, revolutionizing the way we conceptualize, model, and interpret environmental risks. This keynote address illuminates the profound impact of AI technologies, particularly machine learning algorithms and data-driven approaches, in reshaping our understanding and prediction capabilities concerning natural disasters.

By assimilating and scrutinizing vast spatial datasets, AI-driven models offer unparalleled accuracy and efficiency, facilitating timely and precise hazard assessments. Real-time processing of geospatial information not only enables rapid predictions but also forms the cornerstone of proactive disaster management strategies. Furthermore, AI's capacity lies in its adeptness at deciphering intricate spatial patterns inherent to natural hazards, unraveling subtle cues and previously unnoticed correlations within the data fabric.

This keynote delves into how AI's nuanced interpretation, coupled with advanced algorithms, elevates hazard modeling, providing deeper insights into the spatial dynamics of environmental risks. By augmenting traditional methodologies and revealing hidden patterns, AI fosters comprehensive risk assessments, fostering informed decision-making processes. The fusion of AI and natural hazard assessments in spatial domains heralds a more resilient approach to disaster preparedness and response.

Join us in embracing this transformative era, where AI's sophisticated modeling techniques and precise spatial interpretations converge, heralding proactive and effective mitigation strategies amidst the ever-evolving landscape of environmental challenges.

Short Bio. Distinguished Professor Dr. Biswajeet Pradhan is an internationally established scientist in the field of Geospatial Information Systems (GIS), remote sensing and image processing, complex modelling/geo-computing, machine learning and soft-computing applications, natural hazards and environmental modelling. He is the Director of the Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS) at the Faculty of Engineering and IT at the University of Technology, Sydney (Australia). He was listed as the World's Most Highly Cited Researcher by the Clarivate Analytics Report for five consecutive years, 2016–2020, as one of the world's most influential minds.

He ranked number one (1) in the field of "Geological & Geomatics Engineering" during the calendar year 2021–2023, according to the list published by Stanford University Researchers, USA. This list ranks the world's top 2% most highly cited researchers based on Scopus data. In 2018–2020, he was awarded as World Class Professor by the Ministry of Research, Technology and Higher Education, Indonesia. He is a recipient of the Alexander von Humboldt Research Fellowship from Germany. Between 2015–2021, he served as "Ambassador Scientist" for the Alexander Humboldt Foundation, Germany.

Professor Pradhan has received 58 awards since 2006 in recognition of his excellence in teaching, service and research. Out of his more than 850 articles (Google Scholar citation: 70,000, H-index: 129), more than 750 have been published in science citation index (SCI/SCIE) technical journals. He has authored/co-authored ten books and thirteen book chapters.

Software Engineering Research in a New Situation

Prof. Carl K. Chang

Professor Emeritus, Iowa State University, USA

Abstract. With the rise of Generative Artificial Intelligence (GAI), epitomized by Large Language Models (LLMs), a profound shift has unfolded in software engineering research. In this presentation, I will traverse my four-decade journey in software engineering research, focusing on situational awareness in the era of the Internet of Things (IoT). I have witnessed the turbulence brought forth by the AI community that demands changes in our approaches. Meanwhile, owing to the pervasiveness of services computing, services became the first-class citizen in modern-day software engineering methodologies.

I argue that situational awareness must permeate the entire lifecycle to consistently deliver software services that align with the dynamic needs of users and the ever-evolving environments. I will elucidate this argument by reviewing the Situ framework, offering a comprehensive illustration of my perspective. Furthermore, I will outline my vision regarding the formidable research challenges considering the rapidly shifting landscape dominated by an irresistible and profoundly disruptive generative AI tsunami.

Short Bio. Carl K. Chang is a former department chair and Professor Emeritus of Computer Science at Iowa State University. His research interests include requirements engineering, net-centric computing, situational software engineering and digital health. Chang was the 2004 President of the IEEE Computer Society. Previously he served as the Editor-in-Chief for IEEE Software (1991–1994), and as the Editor-in-Chief of IEEE Computer (2007–2010). He was the 2012 recipient of the Richard E. Merwin Medal from the IEEE Computer Society. Chang is a Life Fellow of IEEE, a Fellow of AAAS, and a Life Member of the European Academy of Sciences (EurASc).

Interpretability and Privacy Preservation in Large Language Models (LLMs)

Prof. My Thai

University of Florida (UF) Research Foundation Professor
Associate Director of UF Nelms Institute for the Connected World

Abstract. Large Language Models (LLMs) have transformed the AI landscape, captivating researchers and practitioners with their remarkable ability to generate human-like text and perform complex tasks. However, this transformative power comes with a set of critical challenges, particularly in the realms of interpretability and privacy preservation. In this keynote, we embark on an exploration of these pressing issues, shedding light on how LLMs operate, their limitations, and the strategies we can employ to mitigate risks. We begin by examining the interpretability in LLMs, which often function as enigmatic "black boxes." Their complex neural architectures make it challenging to understand how they arrive at specific outputs. This lack of transparency raises questions of trust and accountability. When deploying LLMs in real-world applications—whether for chatbots, content generation, or decision-making—it becomes crucial to demystify their decision paths.

We will use explainable AI (XAI) to offer faithful explanations, from the black-box to white-box models, and from feature-based [1, 2] to neuron circuits-based [3, 4] explanations. By visualizing attention mechanisms, feature importance, and saliency maps, we empower users to comprehend LLM predictions. XAI not only fosters trust but also encourages responsible utilization of LLMs.

We next turn our attention to one of the utmost concerns and challenges: data privacy. LLMs process vast amounts of data, raising risks of data leakage, model inversion, the right to be forgotten, and inadvertent exposure of sensitive information. Furthermore, the integration of LLMs into diverse applications also significantly brings these challenges to the next level [5]. This talk explores strategies to protect privacy, including differential privacy, federated learning, and data encryption.

Short Bio. My T. Thai is a University of Florida (UF) Research Foundation Professor, Associate Director of UF Nelms Institute for the Connected World, and a Fellow of IEEE and AAIA. Dr. Thai is a leading authority who has done transformative research in Trustworthy AI and Optimization, especially for complex systems with applications to healthcare, social media, critical networking infrastructure, and cybersecurity. The results of her work have led to 7 books and 350+ publications in highly ranked international journals and conferences, including several best paper awards from the IEEE, ACM, and AAAI.

In responding to a world-wide call for responsible and safe AI, Dr. Thai is a pioneer in designing deep explanations for black-box ML models, while defending against explanation-guided attacks, evident by her Distinguished Papers Award at the Association for the Advancement of Artificial Intelligence (AAAI) conference in 2023. At the same year, she was also awarded an ACM Web Science Trust Test-of-Time award, for her landmark work on combating misinformation in social media. In 2022, she received an IEEE Big Data Security Women of Achievement Award. In 2009, she was awarded the Young Investigator (YIP) from the Defense Threat Reduction Agency (DTRA), and in 2010 she won the NSF CAREER Award. She is presently the Editor-in-Chief of the Springer Journal of Combinatorial Optimization and the IET Blockchain Journal, and editor of the Springer book series Optimization and Its Applications.

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Contents – Part VIII

A Selection of Sustainability Parameters for a Comprehensive Assessment of Urban Transformations

Sara Bianchi[1,2](✉), Anna Richiedei[2], and Maurizio Tira[2]

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Abstract. Urban planning is commonly recognized as strategic to tackle the global challenge of sustainable development. However, the implementation of sustainability in the urban practice is complex, and the existing tools in support of sustainable urban transformations are often incomplete and fragmented: e.g., the compliance with the land-use containment parameters, the ecological balance computation, and the economic and financial evaluation, are only partial regulation tools introduced at the local scale for ensuring an "adequate" sustainability character to land-development projects. Such a fragmentation of efforts is also traceable in the research approaches: a great variety of perspectives and diversity of domains animate the academic debates on the sustainability performance assessment. As a consequence, we wonder about the possible definition of new synthetic frameworks: a comprehensive protocol in support of the sustainability assessment of urban renewal scenarios, at the disposal of Public Administrations. Aware of the many and specific assessment frameworks traceable in the literature, we propose an attempt to analyse and select existing indicators, starting from the collection of those already investigated by scholars over the years (i.e., during the last two decades of the 21st century). Therefore, the analysis has been performed on an extensive database consisting of over 600 items.

Keywords: Urban Regeneration · Sustainability Assessment · Indicators

1 Introduction

Cities are places where the greatest amount of GHG is emitted and, at the same time, they are the front line places to face the challenge of climate change. Their potential of reducing GHG emissions by simply applying sustainable urban planning models is around 23–26% by 2050, compared to the business-as-usual scenario [1]. The IPCC-AR6-WGIII recognized models of sustainable urban planning in compact, resource efficient, and walkable urban forms, which adopt mixed land use and transit-oriented development (TOD). Therefore, if well planned cities can be considered "the source of solutions to, rather that the cause of, the challenges our world is facing today" and

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urbanization itself can be "a powerful tool for sustainable development" [2]. In this view, urban spatial frameworks and planning and design instruments assume pivotal roles in managing the use of land and resources within cities, as already highlighted by the transformative commitments of the New Urban Agenda (adopted at the United Nations Conference on Housing and Sustainable Urban Development - Habitat III - in Quito, Ecuador, on 20 October 2016). Despite this high commitment, the promotion of new planning and design tools should be even more emphasized to overcome the theoretical-practical gap, which has already been observed between the strategic planning and design phases of sustainable development interventions [3–5]. As [4] reported, there is a general operational difficulty in implementing sustainability criteria to be applied in the evaluation of urban transformation projects.

Moreover, existing tools are often characterized by a high level of fragmentation, with very sectorial procedures, approaches and required competences. At the local level, cities and municipalities, such as in the Italian context of the present study, set their own procedures and monitoring tools in the attempt to pursue the objectives of sustainability in the implementation of urban projects. For example, referring to the case of the Lombardy Region (since legislations change from region to region), the land-use containment parameters (refers, e.g., to the Lombardy Region Law n.31/2014), the ecological balance computation (refers, e.g., to the STRAIN methodology approved by the DDG n.4517/2007 of the Lombardy Region) and the hydraulic invariance regulation (refers, e.g., to the Lombardy Region Regulation n.7/2017) are some examples of sectoral tools put in place by Italian territories for monitoring the environmental sustainability of urban interventions. On the other hand, if the economic and financial evaluation (refers, e.g., to the DGR n.7729/2022 of the Lombardy Region) may assure an adequate level of economic sustainability, there are no or few tools to monitor aspects of social sustainability. Only in some recent cases, evaluation forms (mostly qualitative) or technical reports have been introduced to verify the sustainability performance of projects during their implementation phase.

This overlap of different regulatory requirements and methodological frameworks increases the complexity: for Public Administrations to holistically assess and monitor the sustainability performance of urban transformations; and for the scientific community to develop new tools aimed at this purpose (closing the theoretical-practical gap already mentioned). Due to the high variety of knowledge involved, such a fragmentation of efforts is also traceable in the research approaches. As emerged also in the 17th Edition of the International Conference on Computational Science and Its Applications [6] (held in Trieste, Italy), a great variety of perspectives animates the academic debates on the theme of sustainability performance assessments, such as the domains of: energy saving and building renovation; sustainable mobility, ecosystem services and biodiversity preservation; mitigation and adaptation solutions; circular economy, risk management; etc. As a result, specific indicators are often proposed by experts to investigate different and important aspects of sustainability, such as the key performance indicators (KPIs) to assess: the ecological value of urban settlements, e.g., [7]; the renewable energy communities (REC), e.g., [8]; the level of circularity of interventions at the different urban scales, e.g., [9]; the accessibility and walkability of urban areas, e.g., [10, 11]; the liveability indicator of urban spaces, e.g., [12]; etc.

Therefore, for speaking of a comprehensive sustainability assessment, able of providing an ex-ante holistic evaluation of potential project scenarios, a unanimous effort in terms of contamination and interconnection of disciplines is required [4]. In the perspective of a greater integration of knowledge and frameworks, in a previous study (refer to [5]) we analysed the main research trends and progresses, (occurred in the last two decades of the 21st century) on the topic of sustainability assessment of urban transformations, with a focus on the existing evaluation tools suitable for the urban regeneration scale. Since many authors focused on developing specific evaluation systems, by means of multiple methodologies, criteria and sets of indicators (among which, [13–16] to mention a few), in this contribution we aim at studying, in more detail, their measurement systems. In particular, we collected, classified, analysed and selected all the indicators already investigated and proposed by scholars, through the creation of an extensive database. Among the research questions we posed, there are: "Are the sustainability dimensions equally investigated by the evaluation frameworks? Are the proposed indicators more qualitative or quantitative? Are there standardized and comparable measures?". The structure of this contribution will lead the reader through the description of the chosen methodological approach and materials (Sect. 2), the main findings on the proposed analysis (Sect. 3), as well as their discussion in the conclusions (Sect. 4).

2 Material and Methods

The methodological approach we selected to: (i) create an extensive database of existing set of indicators, coming from the literature, and (ii) analyse its main features, can be described through the following four steps (see Fig. 1).

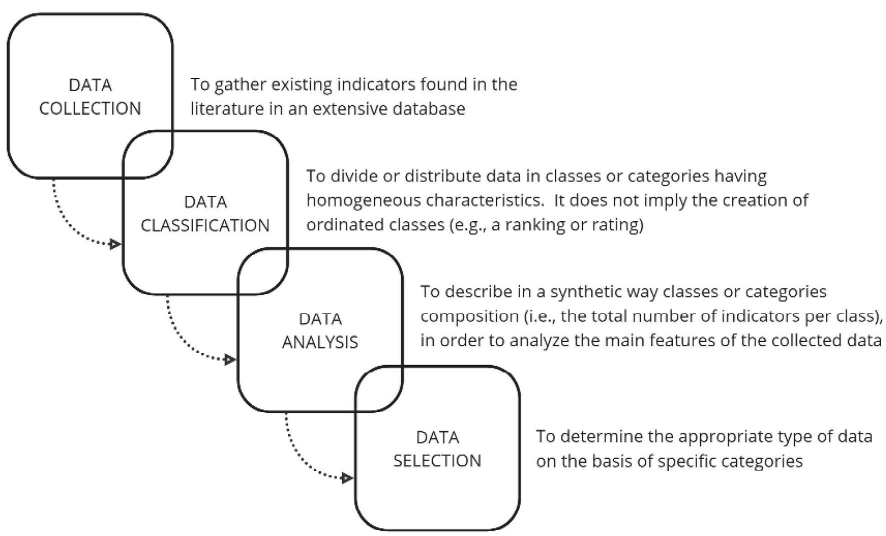

Fig. 1. The four-step methodological approach for the database creation and elaboration (i.e., classification, analysis and selection of data).

Data Collection. The preliminary phase concerned the collection of all the existing measures already investigated and used by scholars in the last two decades (published between January 2000 and February 2023). In particular, the collected indicators were part of multiple assessment frameworks elaborated within the urban planning discipline for the sustainable development of neighbourhoods. Starting from a previous literature review of 99 publications (refer to [5]), more than 600 indicators were gathered and composed the initial database. The following basic information fields have been filled in, as reported in the publications of origin:

- Bibliographic reference;
- Year of the study;
- Country of the study;
- Case study of application (if applicable);
- Applied methodology for the evaluation model;
- Spatial scale of application (i.e., city scale, regeneration scale)
- Temporal phase of the application (i.e., ex-ante, in itinere, ex-post compared to the processes of urban planning and building realization);
- Criteria and sub-criteria;
- Indicators and their description;
- Measurement units;
- Data source (if applicable).

Data Classification. Having defined a first rough database, the main question we faced is "how to select measures from this long list of items in a reasonable way?". To answer this question, the following three attributes were considered necessary in order to start classifying data with homogeneous characteristics:

1. The sustainability dimension;
2. The type of data;
3. The feasibility of data collection.

The sustainability dimensions have been set according to the "quadruple bottom line" perspective [17]: the environmental, social and economic dimensions, as well as the governance. The allocation of indicators to each dimension has been carried out on the basis of predominant themes: each indicator has been classified according to its major effects on one or more dimensions. A maximum of two dimensions has been considered in the case of multiple effects; for this reason, intra-dimensions have been defined (e.g., socio-environmental, eco-environmental, etc.). Some indicators, however, do not have a precise scope and, since they could have general benefits suitable for all dimensions, they have been classified as "neutral". Table 1 shows the main topics that could be investigated in the assessment of each sustainability dimension.

Table 1. Sustainability Dimensions

Dimensions	Main topics included
Environmental	Types of intervention (new expansion or urban regeneration), reclamation of contaminated land, reclamation of building materials, waste production and management, energy building efficiency, production of renewable energy, bioclimatic design, compatibility with the urban context, natural element characteristics, green areas, degree of soil sealing, water use and drainage characteristics, presence of natural protected areas
Socio-Environmental	Types of land uses (residential, commercial, industrial, etc.), preservation and renovation of heritage buildings, utilities for basic housing, provision of public services, public transports and sharing mobility services, road safety and accessibility, active mobility services, quality of the outdoor spaces, landscape preservation, type of environmental pollution and climate change consequences with direct impacts on the well-being
Social	Housing affordability, public spaces accessibility, functional mix, social services, social attractiveness, meeting spaces, community involvement, healthiness of houses and places, social security
Socio-Economic	Job opportunities, fight against poverty, balance in income levels, population trends, level of users' satisfaction, touristic attractiveness
Economic	Total costs of the project, profitability of the intervention, economic and financial information, house occupancy, provisions for establishment of different businesses, partnership and collaboration
Eco-Environmental	Economic activities aiming at improving the environment, share of environmental protection investments
Governance	Data driven decision making, integration and coordination of administrative sectors, management measures, communication plans, restrictions and statutory requirements
Socio-Governance	Participatory processes, community and stakeholder engagement, partnership and collaboration
Env-Governance	Integration of environmental data in the site development plan, adoption of management plans or measures for environmental components, degree of ecosystem considerations
Eco-Governance	Resource allocation, coordination to promote the economic development of areas, reinforced coordination of fiscal and economic policies, management of financial aspects
Neutral	Density, flexibility, ability to be transformed, preservation of existing urban configurations, duration of the transformation, temporary uses, reduction of the risk exposure

As regards the type of data, indicators have been classified as "quantitative" if they express information that can be quantified (with numerical values), counted or measured, and used for mathematical calculations or statistical analyses. On the other hand, indicators have been classified as "qualitative" if they are descriptive in nature, that means they are expressed in terms of language, ordinal values or scores, rather than numerical values. Since the main distinction can be made by observing the measurement units, in some cases of non-traceability of the unit of measurement itself, it has been impossible to establish a priori the typology of data. In these non-specified cases, the nature of the indicators has been classified as "unknown".

Finally, the feasibility of data collection has been questioned according to the local specific context and spatial scale of urban regeneration. Table 2 lists the criteria used to define the feasibility of data collection.

Table 2. Feasibility of data collection

Feasibility	Description of the main cases
Yes	Data immediately available or measurable
Yes, redefining the measurement unit	Data available or potentially available, with not specified unit of measurement; data with unit of measurement to be modified (e.g., due to scale adaptability)
Potentially yes	Data not directly available; data collection and measurement require extra operations to be finalized (math calculations)
No	Data not measurable in the initial stages of urban transformation (ex-ante); data measurable only through questionnaires; data not well defined (too general or incomprehensible); data not available at the urban project scale; poor utility of the data for the sustainability evaluation

Before moving to the next phase, we could not forget some further specifications relating to the main "reference" framework for sustainability indicators, that is the United Nations' 2030 Agenda. In order to deal with the increasing heterogeneity in the indicator systems, the fourth of The Bellagio Sustainability Assessment and Measurement Principles (BellagioSTAMP) [18, 19] on "Framework and Indicators" recalled the importance of consider "standardized measurement methods, wherever possible, in the interest of comparability". For this reason, two additional attributes were considered for the data classification (reaching a total of five attributes considered, see page 4):

4. The relevance of indicators to the Sustainable Development Goals (SDGs) of the UNs' 2030 Agenda;
5. The correspondence between indicators and the framework for the SDGs official statistical monitoring at the national level.

As regards the relevance of indicators to the SDGs of the UNs' 2030 Agenda, we detected all the potential connections between the collected indicators and the 17 SDGs. Each connection indicator-SDG has been counted as one link and, on the whole, the percentage of indicators tied to each SDG may be estimated.

The correspondence between indicators and the framework for the SDGs official statistical monitoring at the national level has been studied by analysing the similarity in: the phenomena measured by indicators, their measurement units, and their spatial scales of application. Respectively, three categories have been defined: "no connection" (in the case of no links found between the collected indicators and the ones of the official statistical framework for SDGs); "similar indicators" (in the case of similar phenomena monitored, but different measurement units); and "indicators to be downscaled" (if the measurement units are the same, but not the applied spatial scale).

The potential benefit of considering these additional attributes in the classification consists in the comparison of the collected measures with both (i) the globally defined SDGs and (ii) the frameworks for their official statistical monitoring. Since the statistical measures for the SDGs official monitoring are generally available at the national scale (i.e., the country level) and, only partially, at the local scale (i.e., the city level) [20], it would be interesting to verify their potential use or implementation at the urban scale.

Data Analysis. The third phase consisted in the synthetic description of the database main features, according to the attributes presented above. The results of this analysis are going to be widely illustrated in the Sect. 2.

Data Selection. At this point, in order to determine the appropriate type of measurements to be taken into consideration for the sustainability assessment of urban transformations, we expressed some preferences upon specific data attributes. In particular, these categories have been excluded to perform a first data selection: the non-feasibility of data collection, and the "unknown" type of data. Additionally, all the duplicated data (i.e., identical indicators traceable in multiple existing frameworks, or similar indicators aimed at measuring the same phenomenon) have been excluded from the database. The results of the data selection phase, as well as of the data analysis, are going to be shown in the following Section.

3 Results

The results of the present research are illustrated in this Section according to the four-step methodological approach: after a brief depiction of the data collection phase, a synthetic description of the database main features (i.e., the data analysis) is reported in accordance with the five attributes defined in the previous phase (i.e., the data classification); finally, similar analyses have been repeated for the selected indicators (i.e., after the data selection phase).

As previously mentioned, starting from the literature review of 99 publications (refer to [5]), 28 contributions have proven to be of interest in the collection of different set of indicators. In total, 661 indicators composed the initial rough database, with an average of 34,3 indicators per each evaluation framework analysed. Regarding the year of publication, the higher research production on this topic have been observed in the period 2011–2015. By considering the geographic context of the reference revision of the literature, that concerns developed countries (as defined by the UNs' Report "World Economic Situation and Prospects 2023" [21]), the majority of studies came from the United Kingdom.

An interesting feature to report here, is the temporal phase of application of the analysed evaluation frameworks (see Fig. 2). Compared to the processes of urban planning and building realisation, they could be applied: ex-ante, in itinere, ex-post, in two-phases (i.e., ex-ante and in itinere, in itinere and ex-post), or in a dynamic way (if the monitoring activity is intended to be dynamically repeated throughout whole process).

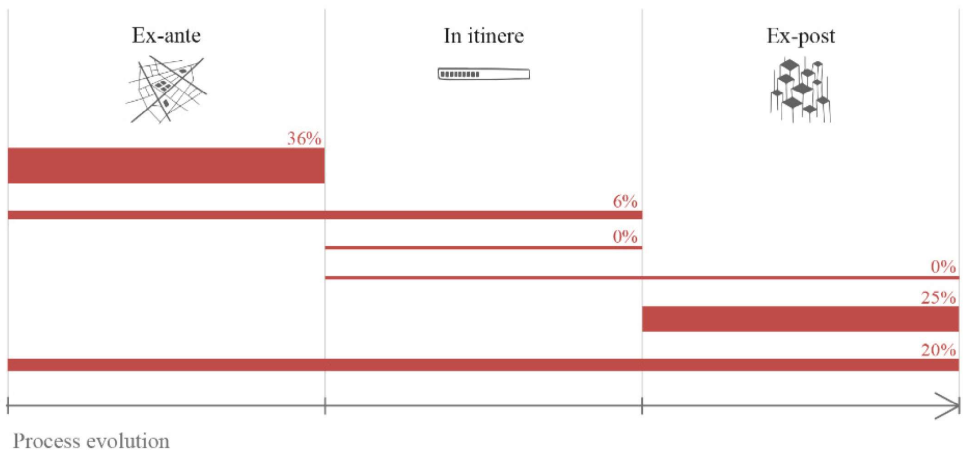

Fig. 2. The temporal phase of application of different indicators compared to the processes of urban planning and building realisation.

In the majority of cases, indicators are expected to be applied in the initial phases (around the 36% ex-ante) or in the final ones (around the 25% ex-post); and a smaller quantity (around the 20%) is designed to be adopted in a dynamic way. For the remaining 19% of indicators, this information was missing.

Data Analysis. As regards the results of the analysis, first of all, the main features of the 661 data collected are here reported in accordance with the sustainability dimensions and the quali-quantitative type of data (see Fig. 3).

The graph shows a great majority of social and environmental data (233 and 167 indicators respectively), compared to the others dimensions. However, such a high number of social indicators is justified by the presence (in the considered literature review) of studies specifically focused on measuring the social sustainability [22, 23] (that proposed 85 indicators in total). By considering the type of data, there are 147 total qualitative indicators, 165 quantitative indicators, and 349 unclassifiable or "unknown" data.

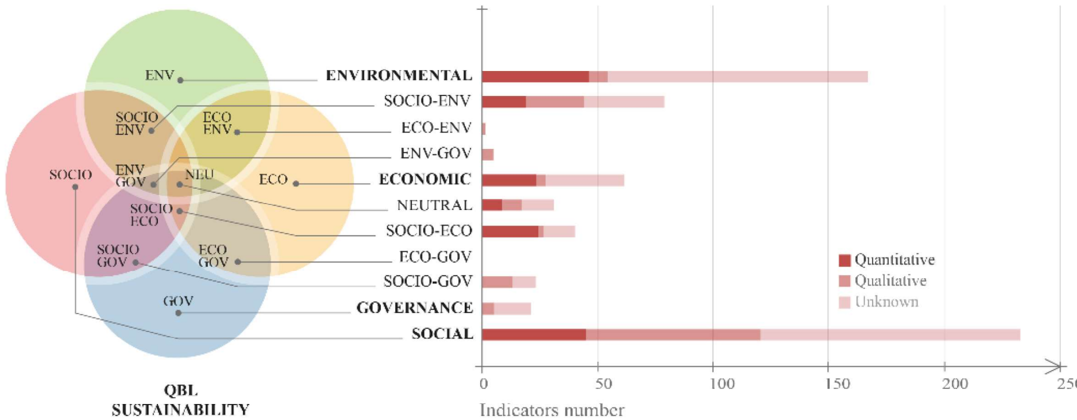

Fig. 3. The number of total indicators per each sustainability dimension and intra-dimension (according to the Quadruple Bottom Line – QBL), and per type of data (i.e., qualitative, quantitative or unknown).

Speaking about the feasibility of data collection, as a matter of fact, we predominantly considered the Italian local context of the present study. Results show that almost half of the indicators (306 out of 661) requires data that are not measurable, not available or useless for our scope (see Table 3).

Table 3. Number of feasible data to be collected

Feasibility	Number of indicators
Yes	102
Yes, redefining the measurement unit	214
Potentially yes	39
No	306

Data Selection. The exclusion of (i) the non-feasible data to be collected, the (ii) "unknown" type of data, and (iii) the duplicated data, has led to the selection of 134 indicators of synthesis. Figure 4 illustrates the same analysis proposed in Fig. 3, but performed only for the 134 selected indicators (please, play attention to the different interval scale on the horizontal axis). Results do not demonstrate relevant changes in the relative composition of sustainability dimensions (with the greatest classes represented by social and environmental indicators), and in the type of data (with 91 quantitative measures and 43 qualitative ones). In more details, the selected indicators per sustainability dimensions amount for: 43 social, 31 environmental, 11 economic, 4 governance, 22 socio-environmental, 9 socio-economic, 2 socio-governance, 5 env-governance, and 7 neutral (see the Appendix for the entire list of selected indicators).

Finally, the following Figs. 5 and 6 respectively illustrate the relevance of indicators to the SDGs of the UNs' 2030 Agenda, and their correspondence with the framework for the SDGs official statistical monitoring at the national level.

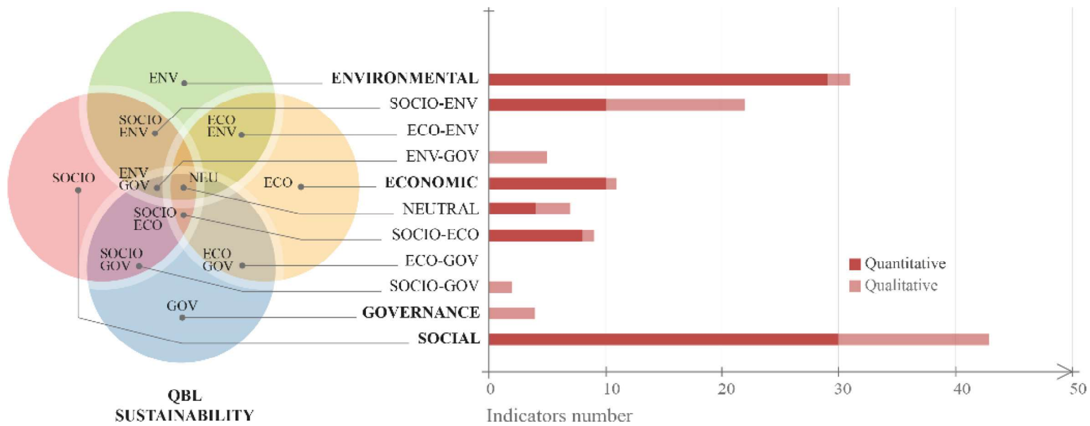

Fig. 4. The number of selected indicators per each sustainability dimension and intra-dimension (according to the Quadruple Bottom Line – QBL), and per type of data (i.e., qualitative or quantitative).

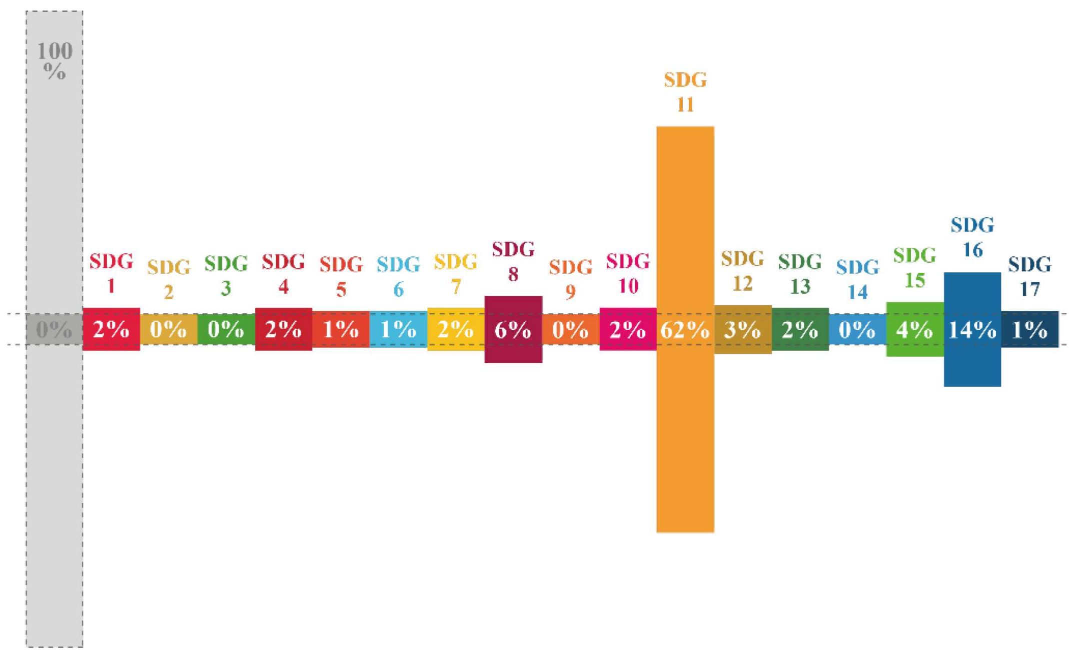

Fig. 5. The relevance of indicators to the SDGs of the UNs' 2030 Agenda (in percentage).

The potential connections identified between the 134 selected indicators and the 17 SDGs show: a predominant and high number of indicators linked to the SDG11 on "Sustainable cities and communities" (around the 62% of measures could be related or have an impact on this goal); at the second position, a relatively small amount of indicators tied to the SDG16 on "Peace, justice and strong institutions" (around the 14%); and a very small number of indicators connected to the others SDGs (less than the 6%).

As regard the official statistical frameworks for monitoring SDGs, they were initially defined by the United Nations Statistics Division (UNSTAT) at the international level, and were subsequently declined by different Member States' statistics institutes at the national level. Since the latter are based on the same foundations of UNSTAT, here we studied the correspondence with the official national framework in the context of the present study (i.e., Italy). As previously mentioned, the benefit would be to analyse the potential application of official statistical measures at the urban scale (currently absent). Therefore, we considered the ISTAT-SDGs official framework developed by the Italian Institute of Statistics (ISTAT) [24]. The results of the indicators' correspondence with the ISTAT-SDGs official framework are shown in Fig. 6.

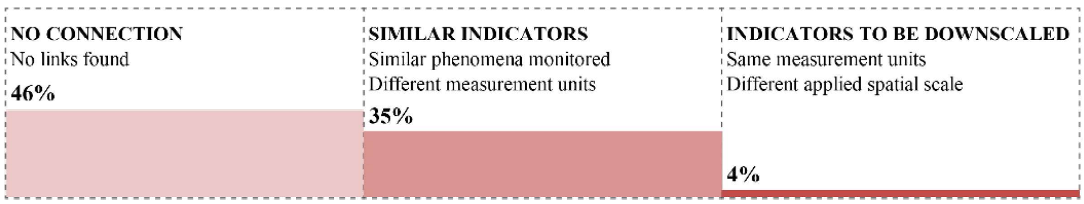

Fig. 6. The correspondence between indicators and the ISTAT-SDGs official framework of the Italian Institute of Statistic (in percentage).

The three observed categories (in Fig. 6) show a low presence of official ISTAT-SDGs indicators that could be used in place of the selected indicators, in order to monitor the selected phenomena (around the 46% of selected indicators has no connections with the ISTAT-SDGs framework). Similar ISTAT-SDGs indicators could be used for monitoring around the 35% of selected indicators; while the category "indicators to be downscaled" riches only the 4% of selected indicators. The Appendix reports the entire list of selected indicators with reference to the relevance to the UNs' SDGs, and to the correspondence with the ISTAT-SDGs statistical measures (when present).

4 Conclusions

The promotion of new urban planning and design tools can certainly be depicted as an essential instrument to support the sustainable transformation of our cities. However, the high level of fragmentation and complexity in the regulatory framework often leads to face operational difficulties in the planning practice. For this reason, the implementation of sustainability criteria and of holistic assessment procedures may support the decision-making process on urban projects.

In this contribution, we have proposed a general four-step methodology to collect, classify, analyse and select indicators, that aims at assessing the sustainability of urban transformations, and we have shown the main features of these measurement systems. Taking advantage of the previous literature review we have conducted on the topic of existing sustainability evaluation tools at the urban regeneration scale, 134 out of 661 indicators have been selected. The main attributes considered for the data classification (not to be intended as ordinated classes) and for the data analysis are: the sustainability dimension; the type of data; the feasibility of data collection; the relevance of indicators to the Sustainable Development Goals (SDGs) of the UNs' 2030 Agenda; and the correspondence between indicators and the framework for the SDGs official statistical monitoring at the national level.

In response to our initial questions, the results of our analysis have shown that:

- Sustainability dimensions are not equally monitored by the measurement systems proposed in the scientific literature, with a preponderance of environmental and social indicators;
- Quantitative data slightly exceed the qualitative ones in both the situations (before and after the selection of feasible indicators);
- A relative small amount of data could be directly linked to or substituted by official statistics already in use in the national context; however, it is important to encourage comparability of measures collected at the different scales also using redundancy.

Our contribution is far from being exhaustive, due to the fragmentation and numerosity of assessment frameworks and procedures already developed by the scientific community. Moreover, the present database does not include other frameworks developed by third parties, such as the numerous sustainability certification systems that mostly belong to the private sector (e.g., BREEM Communities, LEED Neighborhoods, CASBEE Urban Development, GREEN STAR Communities, DGNB Urban District, etc.). Nevertheless, the abundance of possible data to be considered to holistically assess the sustainability of urban projects, as well as the site-specific characteristics of places, decision-makers and their decision habits, lead us to focus on methodologies to explore this theme, rather than on specific and well defined tools.

Further prospectives on this topic will include a deepen reflection on the meaningfulness of inferences that potentially derived from the use of indicators and evaluation systems, and that can guide important decisions on urban development.

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Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

Appendix

(See Table 4)

Table 4. Selected indicators with reference to: the sustainability dimension, the relevance to the UNs' SDGs, and the correspondence with the ISTAT-SDGs statistical measures (see [24] for reference codes of metadata).

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Environmental	Global warming potential (kgeqCO2/m^2CAy)	SDG 11	SDG 13 13.2.2.4	
Environmental	Average annual emissions of NO2 (µgNO2/m^3; mgNO2/m^3)	SDG 11 11.6.2.7	SDG 13 13.2.2.7	
Environmental	Acidification potential (kgeqSO2/m^2CAy)	SDG 13 13.2.2.6		
Environmental	Change in volume of storm water run-off post-development	SDG 11 11.3.1.1	SDG 15 15.3.1.1	
Environmental	Construction and demolition waste recycled (%)	SDG 12 12.5.1.5		
Environmental	Floor area ratio (m^2/m^2)	SDG 11 11.3.1.1		
Environmental	Green public areas (%)	SDG 11 11.7.1.1	SDG 15	
Environmental	Green surfaces (%)	SDG 11 11.7.1.1	SDG 15	
Environmental	Increase of mixed land uses (m^2/m^2)	SDG 11		
Environmental	Infiltration surface and stormwater use (%)	SDG 11 11.3.1.1		
Environmental	Harmonization with the context (qualitative scale)	SDG 11		
Environmental	Land devoted to roads (%)	SDG 11		
Environmental	Number of parking spaces (n. spaces)	SDG 11		
Environmental	Percent of building(s) shell and non-shell reused (%)	SDG 11		
Environmental	Permeable surface / Territorial surface (m^2/m^2)	SDG 11 11.3.1.1		
Environmental	Ratio of open spaces to built form (%)	SDG 11 11.7.1.1	SDG 15	
Environmental	Ratio of redeveloped buildings to new build (%)	SDG 11		

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Environmental	Reclamation of building materials (%)	SDG 12 12.5.1.5		
Environmental	Reclamation of contaminated land (%)	SDG 11	SDG 15	
Environmental	Residential car-parking provision (n. spaces)	SDG 11		
Environmental	Retention of environmental features (%)	SDG 11 11.3.1.1		
Environmental	Territorial index (m^3/m)	SDG 11 11.3.1.1		
Environmental	Waste production (kg; tons)	SDG 11 11.6.1.2	SDG 12 12.5.1.4	
Environmental	Waste disposal (%)	SDG 11 11.6.1.1	SDG 12 12.5.1.1	
Environmental	Urban gardens (m^2)	SDG 11 11.7.1.1	SDG 15	
Environmental	Working car-parking provision (n. spaces/m^2)	SDG 11		
Environmental	Energetic quality (qualitative scale)	SDG 7 7.2.1.2		
Environmental	Energy consumption (kWh/m^2; $CO2/m^2$)	SDG 7 7.2.1.1/7.2.1.2/ 7.2.1.5/7.3.1.4		
Environmental	Reduction in energy use	SDG 7 7.2.1.1/7.2.1.2/ 7.2.1.5/7.3.1.4		
Environmental	Per capita water use (l/inhabitant/day)	SDG 6 6.1.1.1		
Environmental	Reduction in water use	SDG 6 6.1.1.1		
Socio-Env	Acoustic emission (dBA)	SDG 11 11.1.1.3		
Socio-Env	Average distance to a public transport stop (m)	SDG 1 1.4.1.4	SDG 11 11.2.1.1	
Socio-Env	Quality of service in public transport (qualitative scale)	SDG 11		

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Socio-Env	Tying status with "soft" mobility networks (qualitative scale)	SDG 11		
Socio-Env	Street layout: integration with existing streets, paths and surrounding development (qualitative scale)	SDG 11		
Socio-Env	Street layout: friendly streets for pedestrian, cycle and vehicle (qualitative scale)	SDG 11		
Socio-Env	Street layout: support to people with limited physical mobility (qualitative scale)	SDG 4 4.a.1.1	SDG 10	SDG 11
Socio-Env	Integration of land use and public transport (qualitative scale)	SDG 11		
Socio-Env	Work travelling habits (qualitative scale)	SDG 11 11.2.1.2/11.2.1.3		
Socio-Env	Leisure travelling habits (qualitative scale)	SDG 11 11.2.1.5		
Socio-Env	Average emissions of noise during the day (dBA)	SDG 11 11.1.1.3		
Socio-Env	Average emissions of noise during the night (dBA)	SDG 11 11.1.1.3		
Socio-Env	Car sharing / Bike sharing (n. car/bike sharing points)	SDG 11		
Socio-Env	Degree of prevention of light emissions (qualitative scale)	SDG 7	SDG 11	
Socio-Env	Conservation of built heritage resources (%)	SDG 11		
Socio-Env	Quality of outdoor spaces (qualitative scale)	SDG 11		
Socio-Env	Community space (qualitative scale)	SDG 11		
Socio-Env	Enhancement of cultural heritage (qualitative scale)	SDG 11		
Socio-Env	Land dedicated to pedestrians (%)	SDG 11		
Socio-Env	Occupancy levels (%)	SDG 11		

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Socio-Env	Public transport links (m)	SDG 11 11.2.1.1/11.2.1.4		
Socio-Env	Slow mobility (m^2)	SDG 11		
Social	Access to aggregation spaces (qualitative scale)	SDG 11	SDG 16 16.6.2.3	
Social	Access to cultural facilities (min)	SDG 11	SDG 16 16.6.2.3	
Social	Access to educational needs (min)	SDG 11	SDG 16 16.6.2.3	
Social	Access to leisure and entertainment facilities (min)	SDG 11	SDG 16 16.6.2.3	
Social	Access to medical facilities (min)	SDG 11	SDG 16 16.6.2.3	
Social	Access to open space (min)	SDG 11	SDG 16 16.6.2.3	
Social	Access to retail facilities (min)	SDG 11	SDG 16 16.6.2.3	
Social	Accessibility and public transport (qualitative scale)	SDG 1 1.4.1.4	SDG 11 11.2.1.1	SDG 16 16.6.2.3
Social	Affordable housing as percent of total residential stock (%)	SDG 1 1.4.1.1	SDG 11	
Social	Average distance to a commercial zone (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a cultural centre (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a high school (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a junior high/middle school (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a kindergarten (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a nursery (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to a public park (m)	SDG 11	SDG 16 16.6.2.3	

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Social	Average distance to a recreational green/natural area (m)	SDG 11 11.7.1.1	SDG 16 16.6.2.3	
Social	Universal access (qualitative scale)	SDG 4 4.a.1.1	SDG 10	SDG 11
Social	Average distance to a sport centre (m)	SDG 11	SDG 16 16.6.2.3	
Social	Average distance to an elementary school (m)	SDG 11	SDG 16 16.6.2.3	
Social	Buffer and common space (qualitative scale)	SDG 11		
Social	Co-housing inhabitants (n. residents)	SDG 11		
Social	Co-working spaces ($mm^2 2$)	SDG 8		
Social	Increase of accessibility to urban functions (n. functions within a distance; n. served residents)	SDG 11	SDG 16 16.6.2.3	
Social	Number of uses of green space (n. uses)	SDG 11		
Social	Number of uses of the site (n. uses)	SDG 11		
Social	Percent of occupants with views to outside (%)	SDG 11 11.1.1.1		
Social	Retail facilities located on site (qualitative scale)	SDG 11	SDG 16 16.6.2.3	
Social	Public / Private spaces (m^2/m^2)	SDG 11		
Social	Residential areas (m^2)	SDG 11		
Social	Residential development (%)	SDG 11		
Social	Retail areas (m^2)	SDG 11		
Social	Functional mix (qualitative scale)	SDG 11		
Social	Social mixing (qualitative scale)	SDG 11		
Social	Social attractiveness (qualitative scale)	SDG 11		
Social	Diversity (qualitative scale)	SDG 1 1.2.2.1/1.2.2.2	SDG 10	SDG 11
Social	Acceptability to stakeholders (%)	SDG 11	SDG 17	
Social	Degree of security (qualitative scale)	SDG 5	SDG 11	SDG 16 16.1.4.1

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Social	Resilience (qualitative scale)	SDG 11		
Social	Services for the population (m^2)	SDG 11		
Social	Sport and leisure areas (m^2)	SDG 11		
Social	Walking distance to green space (min)	SDG 11 11.7.1.1	SDG 16 16.6.2.3	
Social	Art and culture (qualitative scale)	SDG 4		
Socio-Eco	Net employment density (job/ha)	SDG 8		
Socio-Eco	New jobs (n. new jobs)	SDG 8		
Socio-Eco	Number of jobs created per 1000 square meters (n. jobs/1000m^2)	SDG 8		
Socio-Eco	Number of new enterprises created (n. new enterprises)	SDG 8		
Socio-Eco	Net jobs created (%)	SDG 8		
Socio-Eco	Number of new enterprises created (%)	SDG 8		
Socio-Eco	Quality of jobs created (%)	SDG 8		
Socio-Eco	Incorporation of training programmes (qualitative scale)	SDG 4 4.3.1.1	SDG 8	
Socio-Eco	Knowledge-based economy (n. jobs)			
Economic	Construction cost (euro/m^2)			
Economic	Investment cost (euro)			
Economic	Investment cost (euro/m^2)			
Economic	Level of occupancy (%)			
Economic	Annual operating costs (euro/m^2)			
Economic	Maintenance cost (qualitative scale)			
Economic	Percent increase in site property value (%)			
Economic	Internal rate of return			
Economic	Total economic value (euro)			
Economic	Rent premium (i.e., vs. comparable site)			
Economic	Gross rental yield (%)			

(*continued*)

Table 4. (*continued*)

Sustainability Dimensions	Indicators (Measurement Units)	Relevance to the UNs' SDGs ISTAT-SDGs measures (if present)		
Governance	Degree of access to information (qualitative scale)			
Governance	Degree of collaboration of professionals (qualitative scale)	SDG 11	SDG 17	
Governance	Degree of integration of an evaluation process (qualitative scale)			
Governance	Consistency with constraints (qualitative scale)			
Socio-Gov	Active community organizations (qualitative scale)	SDG 11		
Socio-Gov	Degree of participation of population (qualitative scale)	SDG 11		
Env-Gov	Logic of project footprint (qualitative scale)	SDG 11		
Env-Gov	Degree of residual contamination (qualitative scale)	SDG 11		
Env-Gov	Management of construction disturbances (qualitative scale)	SDG 11		
Env-Gov	Degree of ecosystem considerations (qualitative scale)	SDG 11 11.4.1.1	SDG 15	
Env-Gov	Management of construction waste (qualitative scale)	SDG 12 12.5.1.5		
Neutral	Flexibility (qualitative scale)	SDG 11		
Neutral	Transformability index (qualitative scale)	SDG 11		
Neutral	Degree of site remediation (qualitative scale)	SDG 11		
Neutral	Net population density (inhabitants/ha; inhabitants/m^2)	SDG 11		
Neutral	Reduction of seismic risk exposure (inhabitants/inhabitants)	SDG 11 11.1.1.1	SDG 13 13.1.1.11	
Neutral	Regeneration (m^2/m^2)	SDG 11		
Neutral	Population retention (n. population)			

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