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Towards European Transitions: Indicators for the Development of Marginal Urban Regions

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Abstract: Urban transitions and urban-scape have been heavily impacted by the COVID-19 pandemic and will likely be affected by the current Ukrainian-Russian conflict. These two major events have affected European urban regions and especially marginal regions. Indeed, these regions are mostly struggling with inequality, lack of optionality, interoperability, and resilience due to their energy dependency and digital asymmetries. The continuous demand for a green and digital transition to strengthen social and economic resilience sought and targeted by the European Community has driven the policy of recent years to new European Guidelines. Nevertheless, the digital transition will require sustainability targets in the urban context, changing economic, social, and ecological relationships and balances. In this context, faced with these new transitions, marginal urban regions must plan, design, build, and manage future urban planning choices in a new digital-hybrid space. Therefore, it is crucial to support these transitions with a multi-dimensional sustainability concept through economic, environmental, social, and digital measurements. Urban sustainability indicators (USIs) play an essential role in supporting urban choices and planning. The current study analyzes recent literature and European standards to verify if and how they have changed in embracing the European Policy Pillar under a new and different sustainability profile, which needs to include digital sustainability. As a matter of fact, even if the concept of digitization has been recognized as a pillar of ongoing transitions, the literature and even European indicators struggle to recognize it as a tangible and measurable indicator of sustainability. Seeking to bridge the gap between European requirements and urban practice, the aim of this study is to identify and suggest new key indicators of digitalization to enable the digital sustainability of urban planning to be measured. These indicators can be used to implement a new valuation tool capable of supporting marginal regions by promoting sustainable urban investments in this new hybrid space.

Keywords: marginal areas; sustainable planning; urban sustainability; digital and green transitions; urban sustainability indicators

1. Introduction

In recent years, the COVID-19 pandemic has been one of the engines of European dual transition policies, despite its social and economic impacts. In addition to the pandemic situation, the current Ukrainian-Russian conflict heavily impacted and currently is affecting the urban scape and, in particular, marginal urban regions development. These two events have stressed out the existing disparities between urban regions and marginal regions. On the one hand, the pandemic has highlighted the digital discrepancies and delay of these areas in health, work, and administrative responses to digital demands dictated by these events. On the other hand, the Ukrainian conflict has highlighted the high European energy dependence, aggravated by unsustainable and highly under-digitized energy choices. As mentioned, the social–economic life has had to struggle, mostly addressing digital urban deficiencies in different sectors.

These challenges have been the opportunity and the boost to implement new policies seeking for a more environmentally sustainable, social, digital, and resilient Europe [1–3].

This ongoing request for green and digital transitions to strengthen social and economic resilience requested and targeted by the European Community has driven the policies of recent years, leading to new European Policy Guidelines. This Program focuses on six headline ambitions for Europe in the coming years: (1) A European Green Deal (EGD); (2) An economy that works for people; (3) A Europe fit for the digital age; (4) Protection for our European way of life; (5) A stronger Europe in the world; (6), and a new push for European democracy [4]. These are the six pillars and challenges that European Urban Regions will face and handle in the near future to strengthen European cohesion. Indeed, European countries are undergoing unprecedented transformations and transitions in the context of major uncertainties linked to the global and security outlook.

The first pillar (1) set by the European Green Deal, approved in 2019, leads to green and ecological transitions that may make it possible to achieve climate neutrality by 2050 through an intermediate transition step to 55% by 2030. This ambitious plan demands a drastic drop in greenhouse gas emissions to be implemented immediately by all European countries, leading to tangible improvements of urban and environmental living conditions [5]. Cities, urban developments, and regions have already started to confront ecological challenges and changes to achieve this goal through projects and plans that seek a circular economy and clean technologies.

The second (2), fourth (4), and sixth pillar (6) are tightly related to social transitions that Europe must handle. Social fairness, equity, resilience, and welfare are the targets under these pillars. To consolidate its social, economic, and regional cohesion, according to the Treaty on the Functioning of the European Union, the EU aims to reduce development disparities between European regions, the underdevelopment of peripheral regions and the rural areas suffering from production, demographic, and natural deficiencies. By including these three pillars, the EU introduced a new dimension that was previously barely considered the social aspect of sustainability and equality [6]. As pointed out by Newell and Simms, many transitions seeking green and ecological benefits have historically led to social regression, such as the shift from coal to gas in the 1980s in the UK. [7].

Literature and practice have already introduced and consolidated an environmental and social sustainability assessment of urban settlements through more or less traditional indicators and indexes [8–14]. There is a consistent and substantial background that fills the need for urban sustainability assessment of these two European macro-pillars as social and environmental transitions have been a part of European aims even before the European Green Deal approval. On the contrary, the third pillar, "Europe fit for the digital age" (3), is a more recent pillar that has been introduced and announced in 2020. This headline deals with digitalization through digital technologies, artificial intelligence, data, and metadata that are changing and interfering with social, ecological, and economic dimensions of our life [4,15]. On 9 March 2021, the European Commission (EC) presented a vision for European digital transformation to be achieved by 2030. This proposal seeks a Digital Compass involving four major cardinal goals: digital skills, digital transformation of businesses, secure and sustainable digital infrastructures, and digitalization of public services. Furthermore, the European Commission (EC) is currently working on a digital transformation that pursues three macro-pillars: technology that works for the people; a fair and competitive digital economy; an open, democratic, and sustainable society. However, even though the concept of digitization has been recognized as a pillar of ongoing transitions, the literature and even European indicators struggle to recognize it as a tangible and measurable indicator of sustainability. This lack is evident in the assessment of the urban sustainability sector, which hardly tends to value digitalization as a value-added tool able to account for sustainability achievements in the planning processes.

Assessing sustainable developments and measuring the achievements of required targets is a real challenge for urban regions pursuing European Goals [16]. This difficulty is primarily due to the combination of Urban Scale complexity with the challenge of sustainability measurement through indices and indicators. This complexity can be exponential if we need to introduce additional variables and indicators that are no more linked to the traditional physical urban scale and space but to a third hybrid dimension, which has been introduced by the digital space.

To systematically assess urban processes through all the different dimensions of sustainability, we first need to describe how sustainability has been addressed at an urban scale and then identify how the literature, practice, and policies assessed it through indexes and indicators.

Given the context described above, critical reviews and comparative analyses on existing indicators and indexes have been performed to analyze the current practices to value urban sustainability levels and to suggest possible future drivers in this field. Our analysis investigates the recent literature, following the new European Policy Guidelines publication in 2019. This short timeframe has been selected to capture whether the literature and practice started to implement urban assessment tools and indicators after Europe recognized digitalization as a fundamental pillar. Consequently, we inscribed our work in this incipient line of research by addressing the following research questions:

- Which sustainability dimensions do current indicators cover in urban assessment?
- Has the digital transition been taken into consideration in the assessment of urban sustainability?
- What lessons can be drawn from current practices to support the development of future indicator sets for urban sustainability assessment?

The findings of the current study lay the foundations for future research on defining new evaluation matrices for urban sustainability assessment. The results can assist policymakers in implementing valuation tools to support and justify sustainable urban programmatic choices. Further studies in this field need to focus on implementing indexes and indicator matrices to assess digital sustainability. This study may represent a starting point for completing the missing knowledge on digital sustainability in the urban sector.

There are five sections in this study. Following the introduction, Section 2 details the related literature review, and Section 3 details materials and methodology including the research design and search strategy. Section 4 elucidates the results of the study and presents the discussion focusing on the absence of digital indicators in the urban field. Finally, Section 5 discusses the conclusion, limitations, and future research directions.

2. Literature Review

Sustainability, and specifically sustainable urban planning is considered a mandatory strategy to improve livability, ensure self-sustaining communities, and reduce environmental impacts over the long-term [17]. Over the last decade, urban sustainability has become increasingly eminent both on political agendas and on scientific studies due to the recent European sustainability policies emission [18].

It is clear how difficult it is to measure such a volatile and aleatory concept as that of sustainability. However, the need to go through its measurement has become mandatory to ensure responsible and interoperable planning for policymakers. To help policymakers, municipalities, and public institutions to pragmatically measure, assess, and infer in the urban sustainable development field, the use of indicators and indexes can be a supportive and easily readable tool, if properly implemented [9,19–21]. Nowadays, the gap between theory and practice is evident. The literature and theory have developed various tools to measure urban sustainability that often discount the problem of an adequate interpretation of the concept of sustainability, which is vague and not unique [16].

The use of indicators has become increasingly important in recent years for two strictly related aspects:

1. Their nature and purposes.
2. Their outcomes.

Regarding the the first aspect, indicators can be seen not only as neutral and numerical instruments such as "data carriers" for measuring sustainability, but also considered as "messages carriers" [19,22–25]. As for this second aspect, indices and indicators are not only measurement tools that researchers and specialists use in their analysis, but are also political and normative tools used by policy makers and the public sector to set targets and funds [18,26].

To facilitate their application, Urban Sustainability Indicators (USIs) are used and classified according to different sustainable dimensions. The literature, studies, and practice have so far embraced the division of sustainability into three dimensions or pillars: economic, environmental or ecological, and social or governmental/ethical factors [9–11,17,27–31]. These three pillars are so widely accepted that this taxonomy is also known as the "Triple Bottom Line". Each pillar includes several indicators that can best represent and measure the state of the specific dimension. The sustainability concepts linked to these three dimensions focus primarily on improving long-term human well-being by balancing these three pillars. They provide for the reduction of resource consumption and environmental damage, maximizing efficiency in the use of resources and ensuring social equity and democracy [18,32–39].

In Table 1, we identified these three main urban sustainability dimensions including a brief description for each dimension, which summarizes the frameworks that the literature and practice link to each dimension. The descriptions are extracted from the related literature, attempting to describe urban sustainability divided into dimensions [9,40–44].

Table 1. Urban Sustainability Dimensions: definitions and covered SDGs.

Urban Sustainability Dimensions	Key Words (Literature Review)	Key Words (European Commission)	SDGs 2030 Agenda
Social & Governance/Institutional	Social values, Gender equality, Identities, Relationships and institutions, Health, education, Food, Water, Housing affordability, Social Cohesion, Inequalities and Justice, Welfare and Equity	Social: health life, work and inclusion, empowerment, free or non-remunerated time, equality, Governance: fundamental rights, security, transparency, sound public finances, education, wealth	
Economic	Human and social capital, Intergenerational equity for resources, Distributional equity, Optimal growth, Economic activity	Labour productivity and research and development intensity, industrial base, economic growth, Trickle down	
Environmental	Climate change, Natural resource management and thresholds, Resource and renewable energy consumption, Infrastructure and cities, Biodiversity and Ecosystem	Eco-system integrity, Carrying capacity, Greenhouse gas emissions reduction, biodiversity, material use, energy productivity	

According to the literature, Social Sustainability is achieved by fostering the capability of present and future generations to create fair, rightful, and sustainable communities. The mandatory key words of the pillar related to this are: identities, relationships, institutions, participation, health, education, food, water, housing affordability, social cohesion, inequalities, justice, welfare, and equity [17,45]. Economic Sustainability refers to utilizing, preserving, and maintaining resources in urban development and management, generating long-term value, which must be achieved through optimal use, recycling, and protection of scarce natural resources [17,46–48]. The literature associated with this pillar uses keywords such as human and social capital, intergenerational equity for resources, distributional equity, optimal growth, and economic activity. Finally, Ecological Sustainability on an urban scale is directly linked to vulnerability and increasing resilience of citizens at the environmental level [28]. Both sustainable urban policies and urban environmental planning are crucial tools, capable of monitoring and managing ecological resources and services, biodiversity and natural ecosystems [17].

The literature and best practices associated with this pillar are concepts such as climate change, natural resource management and thresholds, resource and renewable energy consumption, infrastructure and cities, biodiversity and ecosystem.

In the same table, we have included the Sustainable Development Goals of the 2030 Agenda for Sustainable Development (SDGs) to be associated with each urban dimension that better fits the goal targets. Seven goals are associated with the Social Dimension, while six goals are included in the environmental dimension, and four goals with the economic dimension.

Despite the three-macro dimensions recognized above, some authors usually divide the Social Dimension into two categories: the Social and the Governance/Institutional dimensions. A recent literature review study conducted in 2021 was performed to identify how the authors classify USIs by pillars [49]. This study showed that about 60% of the analyzed papers did not organize the frameworks in pillars, only 18% of the studies were organized within four pillars (Economic, Environmental, Social, and Institutional/Governance), and 22% of the papers were organized into three sustainability dimensions (Economic, Environmental, and Social). [50].

Also, according to the EU's 2022 Annual Sustainable Growth Strategy, sustainable transitions can be reach and need to be measured through four dimensions (Economic, Environmental, Social, and Governance) [50,51]. Composing a Transitions Performance Index (TPI), the EC monitors and ranks countries based on their progress towards fair and prosperous sustainability across the four mentioned transitions, focusing on resilience, inclusiveness, and sustainability. Each dimension is described as detailed in Table 1:

- Social: health life, work and inclusion, free or non-remunerated time, equality;
- Governance: fundamental rights, security, transparency, sound public finances;
- Economic: education, wealth, labor productivity and research and development intensity, industrial base;
- Environmental: reduction of greenhouse gas emissions, biodiversity, material use, energy productivity.

However, considering the recent update of the European Policy Guidelines, which includes digitalization as one of the main ambitions, we believe that it is mandatory to include this pillar as one of the sustainability dimensions mentioned above. This inclusion will lead to adequate recognition and assessment of the Digitalization Sustainability dimension as an independent pillar to be persecuted.

Digitalization has been defined in several ways in these recent years by the literature and sector studies [27,52–54]. However, the common thread of the definitions could be summarized as "the way many domains of social life are restructured around digital communication and media infrastructures" [55]. Digitalization is an effective and recognized tool that can improve effectiveness, interoperability, and transparency, reducing costs and wastefulness through automatization in many different fields and sectors. Many studies have been conducted to define whether and how digital technologies are really supporting

sustainable developments by helping to address the major challenges of tackling climate change [56].

It can be said that little has been studied about the effects of digitization on the urban system compared to other areas. However, today it is accepted worldwide that intangible investments, such as digitalization and R&D, information technology, artificial intelligence and 'big data' development and exploitation changed the accounting, financial, and enterprises world. In addition to this, a change in the accounting method is required [57,58]. Digitalization and intangible investments are recognized as non-assessed value capturing in the accounting field. Due to this lack, in 2019 Lev [58] proposed a reform in accounting approaches. This change, required by Lev for non-tangible assessment, is necessary not only in the accounting field, but in general in all sectors that include intangible investments, such as the urban field.

As mentioned, several fields could take advantages from digital sustainability, creating new opportunities for sustainable developments [15]. However, on the other hand, digitization also implies new challenges in balancing technological drive, energy consumption, and social imbalances. It is mandatory to balance the use of digital technology fairly and wisely in order to not penalize yield distribution nor increase inequalities [59–61].

Few studies have been performed on how digitalization can negatively affect both environmental and social sustainability [62]. However, despite the possible dual effects that digitization may have on the sustainability pillars, it can still be said that digitalization could be an effective tool in urban planning and building design if properly applied, through technology that improves efficiency, smartness, and reduction of emissions, waste of resources, and time [63].

In this perspective, we want to explore how digitalization can pave the way for sustainable development, even in the urban field. We propose Digitalization as a Sustainable Dimension in the urban field to be included in the existing three sustainable pillars, implementing a new Dimensions Classification that we are going to call from here onward the ESED Classification (Economic-Social-Environmental-Digital).

On the basis of this, in the next Section we will demonstrate that urban sustainable indicators and indexes are lacking in assessing the digital sphere both at the literature and the European Commission levels, underestimating the digital dimension.

3. Materials and Methods—Indicators for Urban Sustainability

In the urban context, the use of indexes and indicators to assess urban sustainability levels has become increasingly important in supporting urban regions' transitions [64,65]. This is due to the key role of urban assessment, which started to distinguish between sustainable and unsustainable investments. The impact of urban indicators is crucial in assessing urban development process. Indicators help policymakers, decision-makers, and more in general the public to better understand and map the status of a regional area, measuring and assessing its current strengths and weaknesses. By defining needs and opportunities policymakers can easier identify urban development priorities and strategies according to sustainable targets [17,66]. Indicators are used to improve urban assessment robustness of urban assessment and to secure the analysis. To assess different levels of sustainability often indicators are compounded together to create ad hoc indexes. Simple indicators, which assess individual phenomena, can be weighted together to compose indexes capable of describing complex scenarios [67]. Indicators and indexes are often used mainly for two reasons. First, they are quantitative measures easily readable by the involved stakeholders in the decision-making processes, who are often not technicians. Indeed, indicators can help them to implement informed decisions without ambiguity, which can be clearly reported to the community [68,69]. Furthermore, indicators can be used through all the stages of the urban process comparing expectations, results and impacts in sustainability targets [70]. Due to their impact on public decision policy, since the early 90′s many studies focused on the classification and selection of Urban Sustainability indicators. However, since then many aspects of urban developments have been changed

and even European Policy has been update trying to integrate these changes and new features in Sustainability concepts.

The approach applied in this study followed the three phases showed below and presented in Figure 1. A fourth phases will be conducted in future research as an application of the current results.
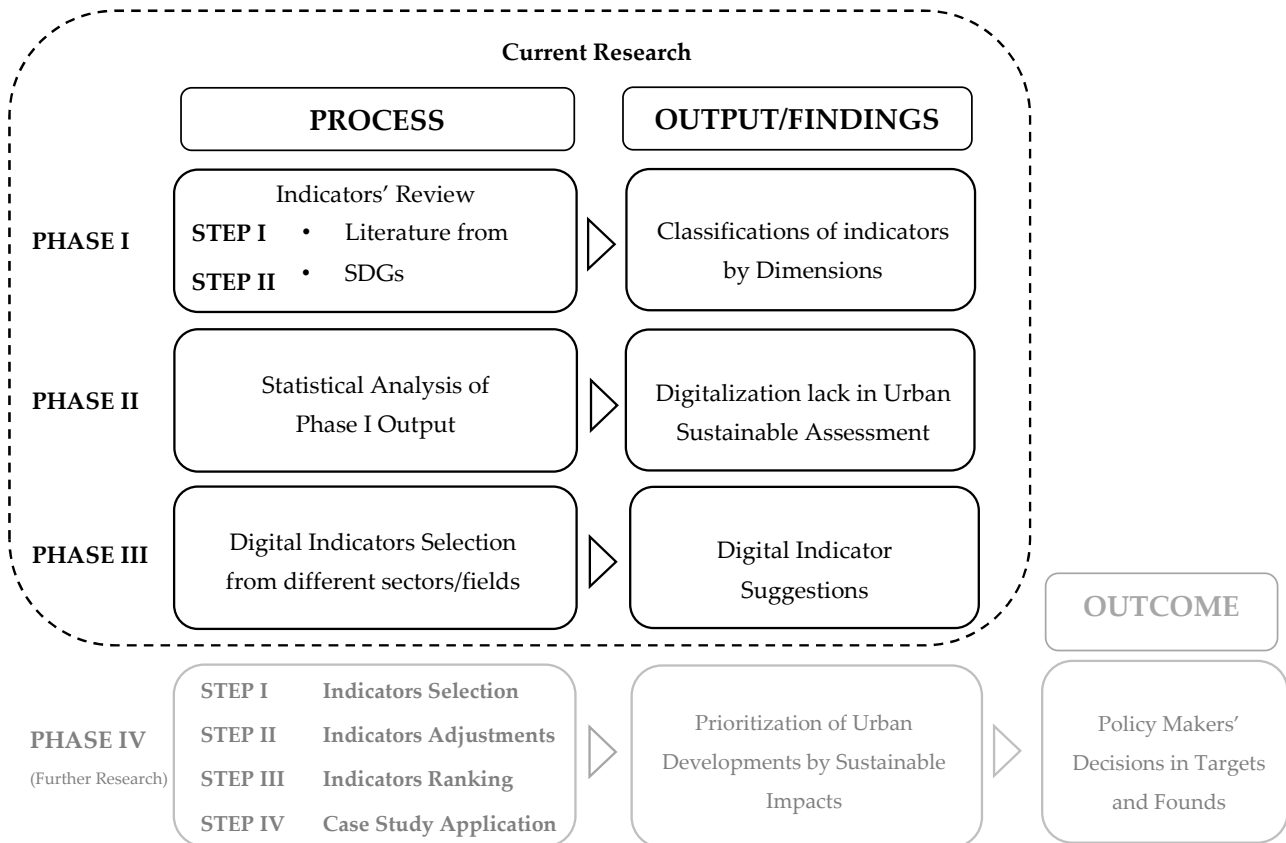
Figure 1. Detailed steps of the Research Process. Source: Authors.

Phase I provides for an extensive review of USIs both in Literature (Step I) and through the European SDGs (Step II). The 2019 Political Guidelines focused on six headline ambitions for Europe are considered as leverage steps toward sustainable programmatic choices in different fields. However, we investigated whether academic studies have internalized Digitalization Goals and Targets set off by the EC to respond to urgent sustainable needs in the urban field as well. To achieve this, we analyzed studies on the Urban Sustainable Assessment that occurred after Political Guidelines publications in Step1, from 2020 onwards. We want to respond to the following question: "has the digital transition been taken into account and internalized in the assessment of urban sustainability?"

There is an extensive literature review on USIs and an accurate classification of indicators that has been run by Verma and Raghubanshi in 2018 [9]. However, what happened next? We conducted a systematic ESED Classification of urban sustainability indicators by comparing existing studies in Urban Sector. In Step II, we organized Sustainable development goals Indicators (SDGIs) according to our ESED Classification.

Phase II provides a statistical analysis of the data collected in Phase I and presents these results. In Phase III, to recognize the importance and the impact that Digital Transition will have on Urban Filed, we proposed to implement the Digital Sustainable Dimension, introducing new digital indicators to be drawn from different fields.

3.1. Phase I—Indicators for Urban Sustainability

3.1.1. Academic Studies

In collecting the sets of indicators, the retrieval of measurement initiatives from academia was deemed necessary to verify whether and how literature has internalized digital transition in its approaches as one of the European new Pillar. Only documents published from 2020 onwards have been analyzed.

Academic measurement initiatives were identified through a systematic literature review, for which the Scopus search engine was selected due to its wide coverage of sustainability journals. This was then crossed with a Google Scholar search. The search was conducted using 'urban' AND 'sustain*' (to include both the terms "Sustainability" and "Sustainable") as keywords from 2020 onwards, with the following query: TITLE (urban AND sustainab*) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020)) AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "MATH") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "CENG") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PSYC") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NEUR")). In the first selection, all studies not strictly correlated and relevant to the current research topic were excluded. The remaining selection yielded 962 results as of July 20, 2022, which have been reduced to 150 including the 'inde*' query. We then crossed this search output with the search that was run in Google Scholar. The remaining studies were then filtered and included in the final sample according to the following criteria: (i) large-scale application, at least 30 indexes included in each study; (ii) clear and comprehensive focus on sustainability; (iii) urban scale field recognition; and (iv) list of indicators or indexes that can be clearly identified and accessible. The application of the filters mentioned above yielded a final sample of 1.112 indexes through 10 selected studies.

To determine how urban sustainability translates into metrics, a systematic analysis of the 1.112 collected indexes was carried out, assigning a Sustainability Dimension and a Sustainability Sub-Areas to each indicator. The Sustainability Dimensions selected as described in Section 2 can be classified as ESED, including Economic, Social/governance/institutional, Environmental, and Digital Dimensions.

We presented our results in Table 2, which classifies indexes and indicators of the different Authors by Dimensions and Sub-Areas.

3.1.2. Sustainable Development Goals Indicators

In Step 2 of Phase I, we analyzed the SDGIs as presented by EC. Established by the United Nations' 2030 Agenda for Sustainable Development, the Sustainable development goals Indicators (SDGIs) set up major principles and priorities, representing a combined goal- and issue-oriented framework [71]. The 17 SDGs covers a thematic area (Goal) and is further sub-devided in169 Targets and 231 unique indicators, However, we need to emphasize that the total actual number of SDGIs is 248, 13 of them have been used multiple times under different targets. The proposed SDGIs have been linked to the most applicable and pertinent categories within each. According to this classification, each indicator has been identified with a cross-typological characterization to standardize comparisons and statistical analysis. As said, each indicator is identified by a unique code that identifies the Goal and the Target, to whom the indicator belongs. For example, the Indicator "Ratio of land consumption rate to population growth rate" is identified by the code number 11.3.1, which means that this indicator is the first one (0.1) belonging to Goal 11 ("Make cities and human settlements inclusive, safe, resilient and sustainable") and to Target 3 ("By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries").

Table 2. The most popular USIs used in Literature after 2019, categorized by ESED Classification.

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezaei, 2021	Zeng et al., 2022	Amoushahi et al., 2022
Economic												
	Economic Employment											
		Unemployment rate/duration	1	1	1	1	1	2	28	2		3
		Qualified workers			1							
	Business Wellbeing											
		Active business/competitiveness				1			37			2
		Green business									2	
		Local Activities/Businesses				1						1
		Foreign direct investments	1									
	Poverty											
		Per capita annual expenditures					2		3			
		Poverty rate	1			1		1	12			1
		Engel coefficient									1	1
		Child labor rate										1
	Economic Wellbeing											
		Retirement security						1	13			1
		Average income	1		1		1	1	6	1		1
		Cost of Living								1		
		GDPs	3					1	10			1
		Inflation rate							13			1
		Households									1	
		Government debt				1	2		17	1		
		GINI coefficient			1			1				
	R&D											
		R&D costs							14			1
		High-tech industries/employability	1									
	Political Situation											
		War										1
		Economic downturn										1
		Health expenditure by government					1		3			
Social												
	Population											
		Demographic								3		1
		Family Size								2		
		Population growth rate								1		1
		Immigration Rate								1		
		Population density	1				1	1	13	1		1
	Education											
		The number of schools										1
		People Education Level/Years	1			1	4	1	33	2		2
	Medical care											
		Mortality rate				1						1
		Number of doctors/Health institutions					5	1	27	1		2
		Access to hospitals								4		
		Percentage of adults who exercise			1							1
		Addictions				1						2

Table 2. *Cont.*

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022
	Life expectancy											
		Medical coverage				1		1			1	
		Life expectancy	1					1				1
	Social security											
		Total crime rate	1				1	1		2		1
		The number of deaths due to suicide										1
		Police/Fire D. interventions				1	2			5	1	1
	Equality											
		Education equal rights				1			25			1
		Employment equal rights				2			11		1	1
	Culture											
		Number of recreational facilities			1	2		1	21	5	1	1
		Community garden									1	
		Number of NGOs										1
	Social capital											
		Social engagement (Voters/Volunteers)	1			1		2	21		1	2
		Number of homeless									1	1
		House price								1		1
		Social Housing	1		1				26			1
		Sustainability Policies		9	3				17	1	1	
		Number of traffic injuries						1				
Environmental	Water quality											
		Water consumption (per capita)	1	3	1	1	1	1	39	1	1	1
		Wastewater collected		1	1							
		Recycled water/Treatment systems		2	2							1
		Households with safe water		1	1			1				1
		Water quality									1	1
	Waste management											
		Waste production rate		5		1	3	1	34	2		1
		Waste recycling rate	1	4	1	1	1	1		1	1	1
		Hazardous waste management			1			1				1
		Sewage treatment capacity/rate					2					
	Air quality											
		Number of air pollution monitoring			1							1
		Number of polluted days			1				33			1
		Greenhouse gas emissions	5	8	2	1		4	21	1	1	1
	Energy resources											
		Non-RES consumption	1	13	1	1	3	1	31	2		1
		RES consumption	1	1	1						1	1
		RECs/Smart Grids		2								
	Urban noise											
		Noise pollution	1	1				1	16	1		2
	Transportation											
		Motor/non-motor vehicles	1	3	2	1		1				2
		Public transport rate/Proximity	1	1	3		1	2	39	2		1
		Travel time/ Traffic congestion		2	1	2						
		Modal split/Public Transport Use	1	1	1	1		1				1
		Road network density per person			2		2			1		2

Table 2. *Cont.*

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezaei, 2021	Zeng et al., 2022	Amoushahi et al., 2022
	Buildings											
		Use of local materials/resources		1	1						1	1
		Buildings age		1	1							1
		Conservation Projects			1					1		
		Buildings Energy Certificates			2							2
	Planning											
		Urbanization rate					1		19			2
		Housing density/Surface coverage	1	1	2	1			29		1	2
		Sidewalk route length	1		1							1
		Use of existing sites			1							
		Public spaces vs. Private spaces			1							
		Distance to basic services	1		3	5			25			1
		Green coverage rate of built-up areas	2		3	1		2	15	1	2	2
		Land use management Plan								1	1	1
	Biodiversity											
		Tree density	1						7	1	1	1
		Shannon-Wiener index	1						23	1		
	Hazards/Climate Change											
		Soil erodibility							3	1		2
		Natural disasters							6			4
		Vulnerability to climate change	1				1		21			2
Digital	Connections											
		Internet access/Digital services			2	1	1					1
		Mobile phone traffic			1							
		Energy used for web servers			2							
	Buildings											
		Domotic			1							

As we performed with academic studies, we then classified the 231 indicators, set by the UN, into the four Sustainable Dimensions (ESED) identified by the authors. After analyzing SDGs Indicators, we acknowledged that some of them were the combination of multi-index. Some indicators proposed by the SDGs are characterized by complex formulations and are a combination of several and different factors. For this reason, we had to classify them under multiple and non-univocal Sustainable Dimensions. As shown in the Venn Diagram (Figure 2), many indicators have been placed under two or more different dimensions.
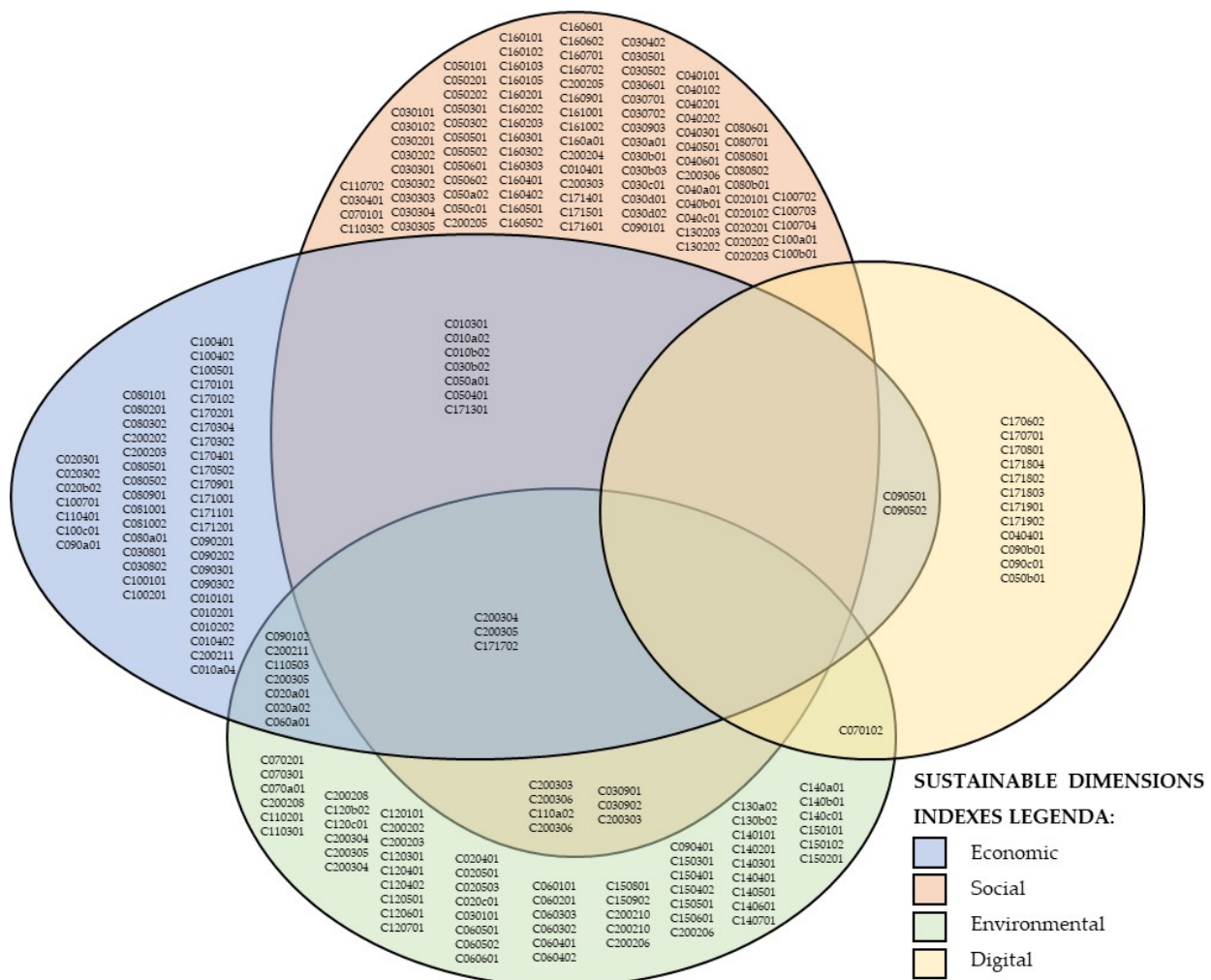
Figure 2. Venn diagram of SDGIs classified by ESED. Source: Authors.

4. Results and Discussion—Phase II and III

It is crucial to analyze the results of our classifications. This study identified and classified under each dimension over 1.390 indicators.

According to the summary of the descriptive analysis (Table 3), which combined the classification of both Academic Studies and SDGs Indicators, 20% of the Indexes (i.e., 277) have been classified in the Economic Dimension, 30% of the Indexes (i.e., 423) have been classified in the Social Dimension, 48% of the Indexes (i.e., 672) have been classified in the Environmental Dimension and only 2% of the Indexes (i.e., 22) have been classified in the Digital Dimension. According to our classification, the United Nations are the ones that mostly considered Digitalization Dimension in their indicators. The results of the SDGs Indicators show that 24% of the indexes were included in the Economic

Dimension, 41% in the Social Dimension, 31% in the Environmental Dimension, and 5% in the Digital Dimension.

Table 3. Sustainability Indicators categorized by ESED Classification-Results.

Sustainable Dimension	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022	SDGIs	AVERAGE	TOTAL
Economic	8	2	3	5	7	7	156	5	4	16	64	25	277
Social	6	9	6	11	13	10	194	29	8	25	112	38	423
Environmental	21	51	38	16	15	17	361	18	10	42	83	61	672
Digital	0	6	1	1	0	0	0	0	0	1	13	2	22
TOTAL	**35**	**68**	**48**	**33**	**35**	**34**	**711**	**52**	**22**	**84**	**272**	**127**	**1394**
Economic	23%	3%	6%	15%	20%	21%	22%	10%	18%	19%	24%	20%	
Social	17%	13%	13%	33%	37%	29%	27%	56%	36%	30%	41%	30%	
Environmental	60%	75%	79%	48%	43%	50%	51%	35%	45%	50%	31%	48%	
Digital	0%	9%	2%	3%	0%	0%	0%	0%	0%	1%	5%	2%	

If we exclude the source of SDGs and analyze only the Academic Studies (Figures 3 and 4), only four authors included at least one Digital indicator to account for Urban Digital Sustainability, with an average of only one digital indicator per study. According to Figure 4, 19% of the Indexes (i.e., 213) have been classified in the Economic Dimension, 31% of the Indexes (i.e., 311) have been classified in the Social Dimension, 59% of the Indexes (i.e., 589) have been classified in the Environmental Dimension and only 1% of the Indexes (i.e., 9) have been classified in the Digital Dimension.

Comparing Academic Studies with the classification of the European Goals (Table 4), it is clear that Academic Studies are decidedly more concerning and tend to pay more attention on the Environmental Dimension of Sustainability (52% vs. 31%), and they tend to underestimate the social (28% vs. 41%) and the digital dimension (1% vs. 5%) with respect to the UE Targets.

Table 4. SDGs vs. Academic Studies Indicator Classification.

	SDGIs		Academic Studies	
Sustainable Dimension	N. of Indexes	%	N. of Indexes *	%
Economic	64	24%	21	19%
Social	112	41%	31	28%
Environmental	83	31%	59	52%
Digital	13	5%	1	1%
TOTAL	**272**	**100%**	**112**	**100%**

* Average number per Study.

Analyzing the results of our ESED classification, as presented in Table 4, we can observe how the digital dimension at both UE and Academic Level is not adequately taken into account, with an overall average of only two digital indicators per study (Table 3), more precisely academic studies show an average of one digital indicator per study, with an average of 1% of the overall indicators, as shown in Table 4. At European level the number of digital indicators rises up to 13, with a 5% distribution, which is above the academic studies indications. These results stress out how academic research is still far behind the European requirements in terms of digital transition. The Digital Dimension, which is represented by the studies analyzed above, accounts for urban Sustainability by including the following indexes: Internet and digital access, services or skills, Mobile phone traffic or possession, Energy used for web servers, Domotica Percentage. Considering the strong emphasis that the EC is giving to the twin transition, these few indicators seem not to be exhaustive and seem to underestimate the sustainability measure of the digital dimension in the urban field, focusing mainly only on measuring digital sprawl rather than its sustainability.
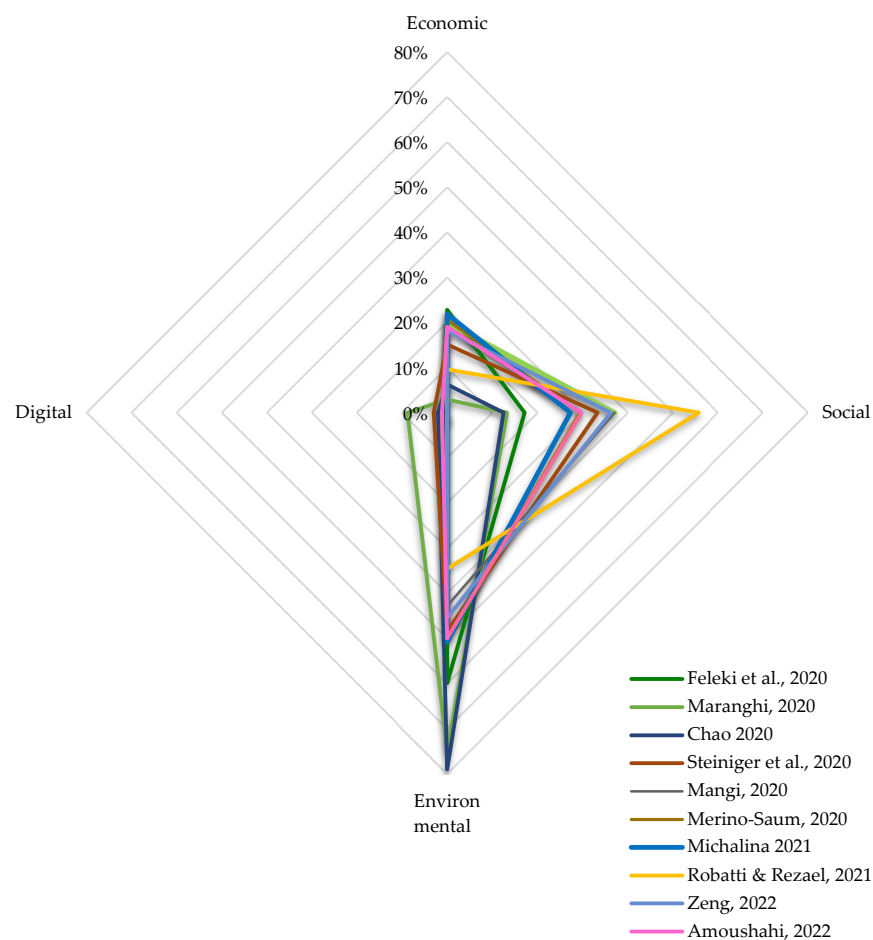
Figure 3. Academic Studies: radar chart of Sustainability Indicators Dimensions by Authors.

An extensive literature review on the digital sustainability definition was provided by Wut et al., which exanimated this concept in several research fields. They summarized their findings describing digital sustainability as digital preservation along its overall life cycle in the socio-cultural and organizational context [72]. However, the introduction of new additional digital indicators will have to address the awareness that digitalization also leads to various sustainability challenges. The increase in digitization processes could generate spillover effects both at an environmental and social level. As regards environmental externalities, the increase in energy consumption could be a concern. In terms of social effects, the main problems could be related to increasing social vulnerability, due to the disparity and inequality in the distribution of value capture, and due to the increasing gap in information and technology access. This effect is well known as the digital divide effect [73].

Despite many studies focusing on digital sustainability definition, the literature shows a profound lack of contextualization and presence in the urban sector. As a consequence, today the absence of an appropriate selection of indices and indicators capable of defining the Sustainable Dimension is relevant. An attempt to introduce digitalization indicators in urban contests was made by Dmitrieva and Guseva [74]. The authors proposed to take into account the digitalization factor as one of the keys to assessing territorial competitiveness. However, this study takes into account only the traditional concept of urban competitiveness from an economic point of view and does not seek global sustainability. Feroz et al. mentioned the impact that digitalization is having on urban sustainability, focusing on a literature review of studies on smart cities and sustainable cities [75]. Yet, they do not account for sustainable assessment and measure through indexes and indicators. In fact,

they limit their study to verifying whether it is well accepted, by current literature, that digitization contributes to resilience and sustainability of the urban sector.
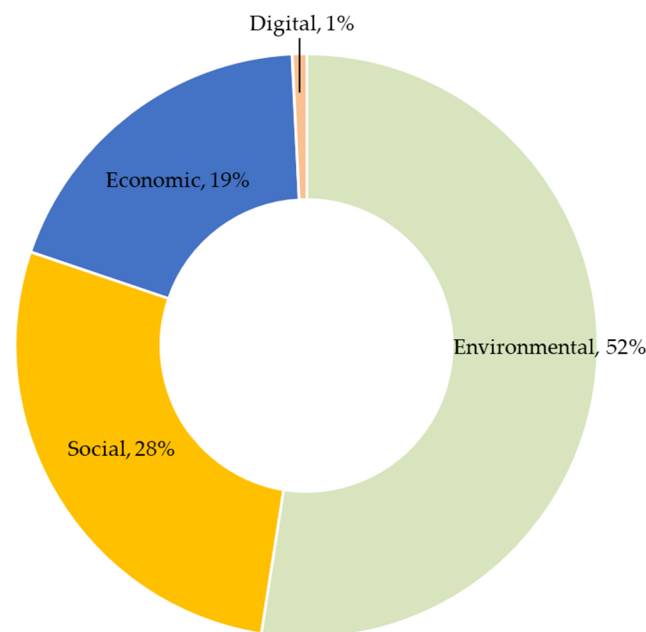

Figure 4. Academic Studies: pPie chart of Sustainability Indicators Dimensions.

Considering that urban studies lack consideration and therefore measurement of digital sustainability, our suggestion is to look for digital indexes and indicators in other fields, such as entrepreneurial, business financial, and industrial fields. These areas have a more consolidated and sensitive awareness of the impact and the effects that digitalization could have on the dimension of sustainability, given the longer contacts that they had with digital transformations. These fields already recognized digitalization impacts on costs, spaces, optionality, resilience, and information asymmetries in their systems. To verify which sectors are highly involved in the digital sustainability assessment, we first run a literature review on Scopus and exported in VOSviewer. The VOSviewer software was used to analyze the keywords "digital index" and "digital indicators" [76]. This software allows users to visualize data maps of bibliometric networks based on Visualization of Similarities (VOS) and it is ussually used to perform preliminary research litterature review [77–79]. The distance between the nodes (in our cases the names of the Journals) is proportional to the divergence that occurs between the topics of the journals [80].

Through this logic, our two-dimensional map (Figure 5) represents the existing network between journals that published papers and sudies between 2020 and 2022 that include the keywords mentioned above. In addition, the size of the nodes is weighted by the number of articles published in the quoted journal based on the selected query.

The analysis produced a total of five clusters which represent five different journal topics. According to the names of the journals, these are the main topics for each cluster:

- Cluster 1: social, communication, economic and business science.
- Cluster 2: natural and environmental science.
- Cluster 3: computer and technology science.
- Cluster 4: energy and engineering.
- Cluster 5: material and mechanical science.

This clustering can help identify the most relevant fields that study and suggest digital indicators to measure sustainable systems.
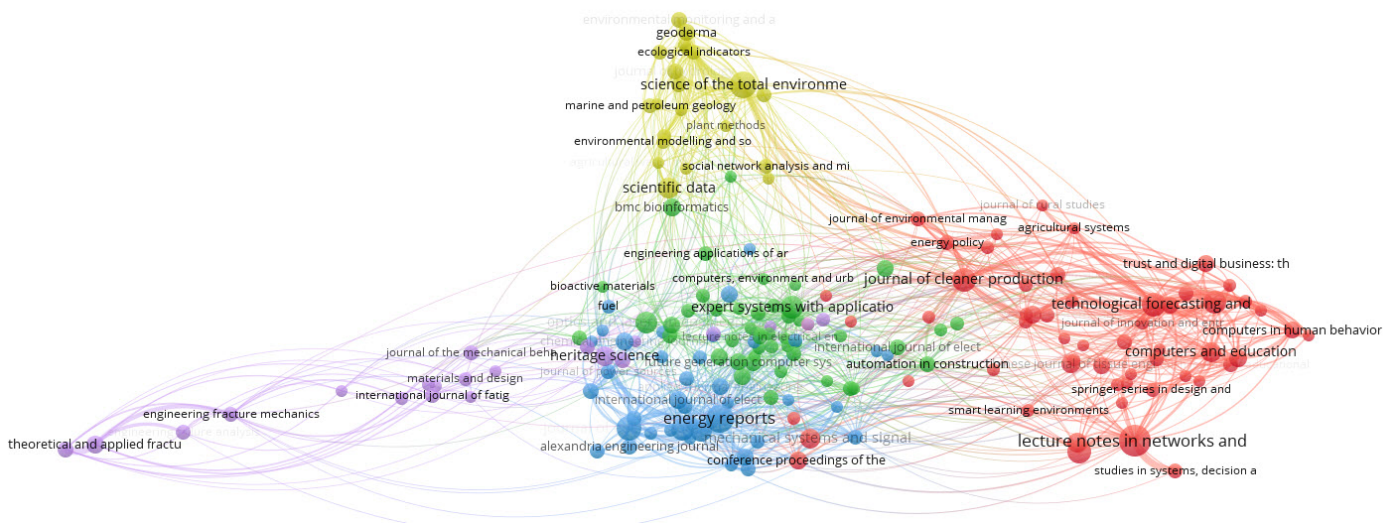
Figure 5. Source visualization 2-D map including "Digital" and "Index" and "Indicator" keywords. Source: authors' elaboration using VOSviewer.

We further analyzed, in depth, some of the papers mentioned above to search for digital indicators and indices that could encourage and be a sort of guideline to the urban sector in measuring digital sustainability. In Figure 6, we reported the results of this preliminary research, identifying the most recurrent digital indexes classified by the field of belonging. Most of the indexes detected belong to the social and economic and to information and technology fields. [27,81–84].
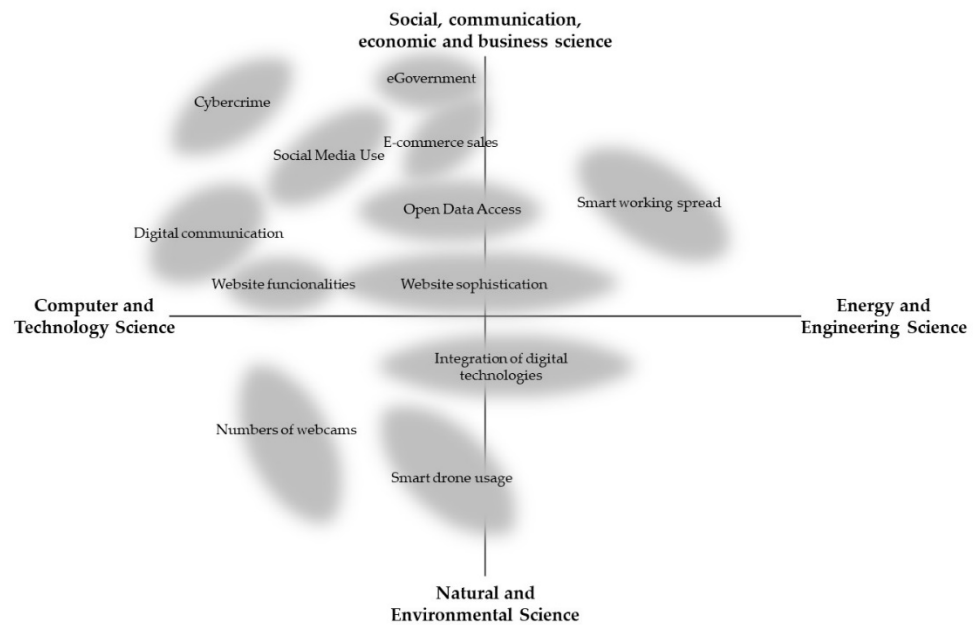
Figure 6. Digital Sustainability Indexes and Indicators suggested by different academic fields.

The indices and indicators examined are a possible driver for further research as a link between the urban field and the digital sustainability assesment. However, these indices need to be deeper analyzed to better interpret the urban dimension and its peculiarites. We believe that a systematic review of these indicators and indices could help urban studies to implement the assessment of the Digital Sustainable Dimension, which can be an engine for the development of marginal urban regions.

5. Conclusions

In the near future, new digital technologies will increasingly lead us to convert traditional activities and processes towards new forms of virtual actions. Digitization will therefore bring new challenges to be faced in a "hybrid" virtual space with countless benefits. However, we are still unprepared to properly and wisely assess the economic, environmental, and social risks and implications. In this uncertain and unexplored near future, marginal urban regions need to ensure programmatic choices for sustainable development. To support them in their decisions, we believe that it will be extremely important to correctly assess and measure the sustainability of their choices. In this global contest, sustainability includes four pillars: Economic, Social, Environmental, and Digital (ESED Classification).

By analyzing the scientific literature of the last three years in the urban sector, the lack of sensitivity and digital evaluation was highlighted. Furthermore, our study proposes new indicators to be transferred to the urban environment to measure digital sustainability. This report is the starting point for follow-up studies that have the potential to introduce the digital dimension into the urban sector. In particular, further studies will have to focus on the possible correlations between these four pillars (ESED). Indeed, the identification of new indicators and evaluation matrices capable of measuring the sustainability of urban development will be crucial to promote sustainable marginal regional investments.

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