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Urban typologies and urban sustainability: A comparative and landscape-based study in the city of Valencia

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ABSTRACT

The heterogeneous structure of cities generates critical challenges in the definition and implementation of sustainable urban transitions. This difficulty is intensified by an insufficient understanding of how different urban types perform for distinct sustainability dimensions and indicators. In this study, this knowledge gap is investigated in a highly representative Euro-Mediterranean city (Valencia) through: (1) a landscape-based approach leading to the characterization of urban-landscape types via the combination of three geospatial layers, and (2) the assessment of those urban-landscape types with a comprehensive sustainability index deducted from several international, national, and local indices. Results reveal firstly that urban-landscape types can help us identify areas with common morpho-functional patterns that differ from conventional districts or quarters. Secondly, a comparative analysis of these urban-landscape types reveal that they partially display different sustainability profiles and, consequently, might accommodate distinct policies and plans. Thirdly, the incorporation of spatial, metabolic, and mobility dimensions in the proposed index permits addressing transversal issues affecting environmental, social, and economic sustainability. By linking the form and functioning of the city with its sustainability profiles through a landscape-approach, this study is expected to assist planners and policymakers in the design of sustainability transitions adjusted to the specificities of different urban configurations.

1. Introduction

The key role of cities in the design, implementation, and management of sustainability transitions has been widely recognized and has revealed the necessity of approaching cities in a more systemic, integrative, and crosscutting way (Acuto et al., 2018; McPhearson et al., 2016). As a result of the increased understanding of the city as an open and complex socio-ecological-spatial system, we have witnessed over the last decades and at different scales, the formulation of new conceptual and operational frameworks, the generation of new assessment methods, or the definition of new types of policies or governance models under the common aspiration of creating more sustainable, resilient, lively, equitable and participatory cities (Childers et al., 2014; Dickey et al., 2022). However, the operationalization of urban sustainability transitions has posed new challenges especially regarding the multidimensional character of the sustainability concept, its consistent assessment through manageable sets of indicators, the definition of development paths in unpredictable contexts, and the design of policies and actions adapted to the specificities and heterogeneities of each city (EC., 2011; Stokes & Seto, 2019).

Based on existing epistemological and departmental divisions in academia and in public administrations, the triple bottom line ('social', 'economic', and 'environmental') has become a generalized way of dividing the sustainability concept into different dimensions although contrasting opinions exist on how they should be interrelated or prioritized (Fu & Zhang, 2017; Mori & Christodoulou, 2012). In addition, the 'spatial' dimension has been increasingly incorporated to address the implications that different spatial configurations might have in other sustainability dimensions, especially in cities, where the availability of space and the pressure for its intensive or unfair use can be particularly critical (UN, 2016). Moreover, in contrast to the triple bottom line approach, other models have been also proposed, such as the morpho-functional dimensions proposed by Rueda (2012), or the metabolic approaches based on the analysis and management of different urban flows (Galan & Perrotti, 2019; EC, 2015; Rueda, 2012).

Several indicators and indices have been defined over the last decades by public administrations, research institutions, and professional agencies to objectively support decision-making processes and guide the design, management and certification of more sustainable cities and neighborhoods (Holden, 2006; Pedro et al., 2019; Verma &

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Raghubanshi, 2018). These indices may place a different emphasis on distinct sustainability dimensions, but the interconnection between those dimensions should always be considered (Wu & Wu, 2012). Existing indices can be classified into two major groups: single-unit indices (e.g., the ecological footprint of a nation, city, or an individual) and composite indices comprising several indicators (Mori & Christodoulou, 2012). The proliferation of indices has been accompanied by the development of comparative studies aimed at detecting patterns of convergence between them and at defining more operational and balanced sets of indicators (Braulio-Gonzalo et al., 2015; Feleki et al., 2018). Overall, assessing sustainable urban development involves measuring a wide range of variables and remains a critical challenge, especially concerning the selection of indicators, the availability of data, the definition of conceptual frameworks and targets, the clustering and weighting of different indicators within composite indices, and the definition of city-specific variables (Verma & Raghubanshi, 2018).

Shen and Zhou (2014) identify five criteria for defining a set of urban sustainability indicators: balanced coverage of different sustainability dimensions, connection with urban challenges and strategies, public participation, focus on sustainable development goals, and consistency in the combination of different indicators. Similarly, Tanguay et al. (2010) recommend using a reduced and manageable number of indicators as long as this reduction does not imply an oversimplification. Ultimately, indicators should help us to understand and manage the city in an integrated manner rather than as a combination of disconnected variables. This integrative approach would imply considering how spatial and programmatic patterns generate distinct urban types and how these types relate to different sustainability profiles (Weber et al., 2014). Urban types or typologies can be defined as distinct urban configurations whose definition can be based on the multidimensional and systematic analysis of different urban factors or attributes (Gil et al., 2012).

According to Storch and Schmidt (2006, p. 149), "*the main purpose of urban typologies is to ensure that assessment of planning policies can be clarified and simplified by grouping neighborhoods with common characteristics and [that] could therefore have similar sustainability problems and environmental impacts*". In this line of thought, it has been claimed that different urban types display distinctive ecological footprints and sustainability profiles (Dong et al., 2019; Forman, 2014; Wu, 2021). However, the link between urban patterns or types and sustainability is not so straightforward and socio-economic, locational, cultural, climatic, or other contextual factors can also have a strong influence. Thus, Nielsen and Jensen (2010) observed that, in addition to urban density or structure, lifestyles or levels of income could clearly affect the levels of environmental sustainability in different districts of Copenhagen. Similarly, Buzási and Jäger (2020) found that the contrasting levels of environmental, social, and economic sustainability in different districts of Budapest could be explained by formal factors (like the presence of extensive green areas), but also by the concentration of economic power. Likewise, Baabou et al. (2017) detected that the location of Mediterranean cities on high-income or low-income countries led to significant differences on their ecological footprints (regardless of their internal structure).

Concerning the definition of urban types, conventional administrative units, such as districts or quarters, might fail to provide adequate spatial units for sustainability planning, especially when they internally display high levels of morphological and social heterogeneity (Jabareen, 2006; Ronchi et al., 2018). In some cases, this heterogeneity can be diminished when the small neighborhood scale is used for sustainability assessment (Sharifi et al., 2021). Similarly, Stokes & Seto (2019, p.1) claim that understanding heterogeneity in urban landscapes is essential to promoting urban sustainability and that new characterization methods based on structural differences (e.g., relationships between the built and unbuilt) are needed to "*monitor and manage urban systems towards sustainability, targeting spatial planning strategies to the micro-geographies where they would be more relevant*".

In this regard, as claimed by different authors, a landscape approach can provide an adequate lens for urban characterization and for the subsequent definition of urban types by integrating morphological variables, ecological and socio-cultural values, identities, and senses of place (Hersperger et al., 2020; Pinto-Correia et al., 2018). The connection between landscape structure and sustainability has been mainly studied at a regional scale under the assumption that some landscape patterns might be more sustainable than others for different sustainability dimensions (Wu, 2021). Moreover, as indicated by Wu (2012), there is a clear need to link landscape pattern metrics and sustainable development indicators. Nonetheless, this connection needs to be further investigated, especially in cities, which are often perceived as places of 'no landscape' rather than highly anthropized and constructed landscapes (Dobson, 2018; Peng et al., 2021). The key question in cities would be what kind of characterization method and landscape layers or properties would be needed to define spatial units which could help us achieve a particular goal or knowledge (e.g., urban sustainability). Landscape characterization in British urban/metropolitan areas has provided since the late 1960s new insights into town planning by addressing aspects such as urban morphology, landform, built fabric, historical topography, or streetscape (Dobson, 2018). Moreover, a consistent characterization of urban landscapes can provide new and synthetic insights into the links between the physical components of the city (e.g., buildings, infrastructures, open and green areas, etc.); the urban processes that these components sustain; and the socio-cultural, productive, experiential, and perceptual values that they provide (Wu, 2010).

From a spatial or landscape planning perspective, consolidated and holistic methodologies for landscape characterization usually involve the definition of generic 'landscape (character) types' that, in a second step, get concretized in specific spatial units known as 'landscape character areas' or 'landscape units' (Tudor, 2014; Nogue et al., 2016; Galan Vivas, 2011; Swanwick, 2002). Following the same logic, urban landscape characterization can approach the city as a "*collage of different landscape types*" formed "*by particular combinations of green types, building types, and land-uses.*" These types would support the identification of 'urban-landscape units' that, subsequently, could become functional areas for the design and implementation of more sustainable and synergic interactions between people and the environment (Galan, 2020).

Based on the detected knowledge gaps and in the hypothesis that a landscape approach may provide a more integrative lens to define urban types, two instrumental and independent research questions (RQ1 and RQ2) and one central research question (RQ3) linking RQ1 and RQ2 are proposed:

- RQ1: Which sustainability dimensions and indicators can better inform an integrative approach to urban sustainability planning?
- RQ2: Which processes could help us define urban-landscape types and units, and how would they relate to conventional spatial units in cities such as districts or quarters?
- RQ3: Can we detect different sustainability profiles (for the dimensions and indicators deducted in RQ1) in distinct urban-landscape types (for the types deducted in RQ2)? And if so, can those differences help us improve urban sustainability by linking more clearly assessment and decision-making processes?

By answering these questions, the conducted research is expected to provide urban planners and policy makers with a diagnostic framework helping them to analyze and improve urban sustainability in different urban types in a wide range of international contexts.

2. Materials and methods

The potential connection between urban types and sustainability profiles is investigated in this paper through the definition of a set of urban sustainability dimensions and indicators which are assessed in different urban-landscape types within a highly representative Euro-Mediterranean city: Valencia.

2.1. Terminology

For this study, urban sustainability is understood as a systemic property of urban areas or cities combining different dimensions. Based on the definitions provided by the New Urban Agenda of the United Nations (UN, 2016), the social dimension is associated with the '*rights of all people to the benefits that cities can offer*' and to the right to participate in the management and evolution of cities. The economic dimension is linked with the "*sustained and inclusive economic growth with decent employment for all,*" whereas the environmental dimension relates to the capacity of cities to "*protect, conserve, restore and promote their ecosystems, water, natural habitats and biodiversity, minimize their environmental impact and change to sustainable consumption and production patterns*." The spatial dimension is approached as a crosscutting dimension facilitating the adequate form and use of the urban space for the achievement of environmental, social, and economic sustainability (UN, 2016). In addition, a metabolic dimension is proposed to address the efficient and circular use of physical resources like water, energy, matter, and waste (EC, 2015), whereas the mobility dimension is introduced as a framework to analyze and improve the flows of people and goods in cities.

These dimensions can be measured through indicators. The use of indicators and indices usually requires the definition of scoring systems based on predefined standards or in the % of deviation from minimum objectives (Feleki et al., 2020).

Finally, an 'urban-landscape type' is understood in this paper as a distinct configuration of urban landscape including built and unbuilt components that is homogeneous in character, and that differs from other types. Each type represents a generic combination of physical, spatial, perceptual, and functional factors and can get concretized in different and discrete 'urban-landscape units' sharing the main characteristics of the generic type (Tudor, 2014). From a planning perspective, similar urban-landscape types (in similar social, cultural, and biophysical contexts) might present analogous problems and potentials and can therefore incorporate comparable solutions and policies (Storch & Schmidt, 2006). For instance, urban-landscape types associated to dense urban grids in Europe can share problems of transport congestion and explore the generation of superblocks. Similarly, old and compact city centers can incorporate similar solutions to increase the provision of green areas per capita. To be accepted, urban-landscape types are expected to be defined by using explicitly stated methods and repeatable procedures (Simensen et al., 2018).

2.2. Research methods

Fig. 1 illustrates the research methods applied in this paper. The proposed research questions are investigated in Valencia, which can be considered a highly representative Euro-Mediterranean city and a relevant international case study due to its population, density, compactness, and demographic evolution (Apreda et al., 2020; Baabou et al., 2017; EUROSTAT, 2022; Munoz, 2003; Prytherch & Boira Maiques, 2009; Salat & Nowacki, 2011).

Regarding RQ1, the definition of sustainability dimensions and indicators is implemented by analyzing existing indices and available data in the city of Valencia. The identification, selection and analysis of existing urban sustainability indices was based on the following criteria.

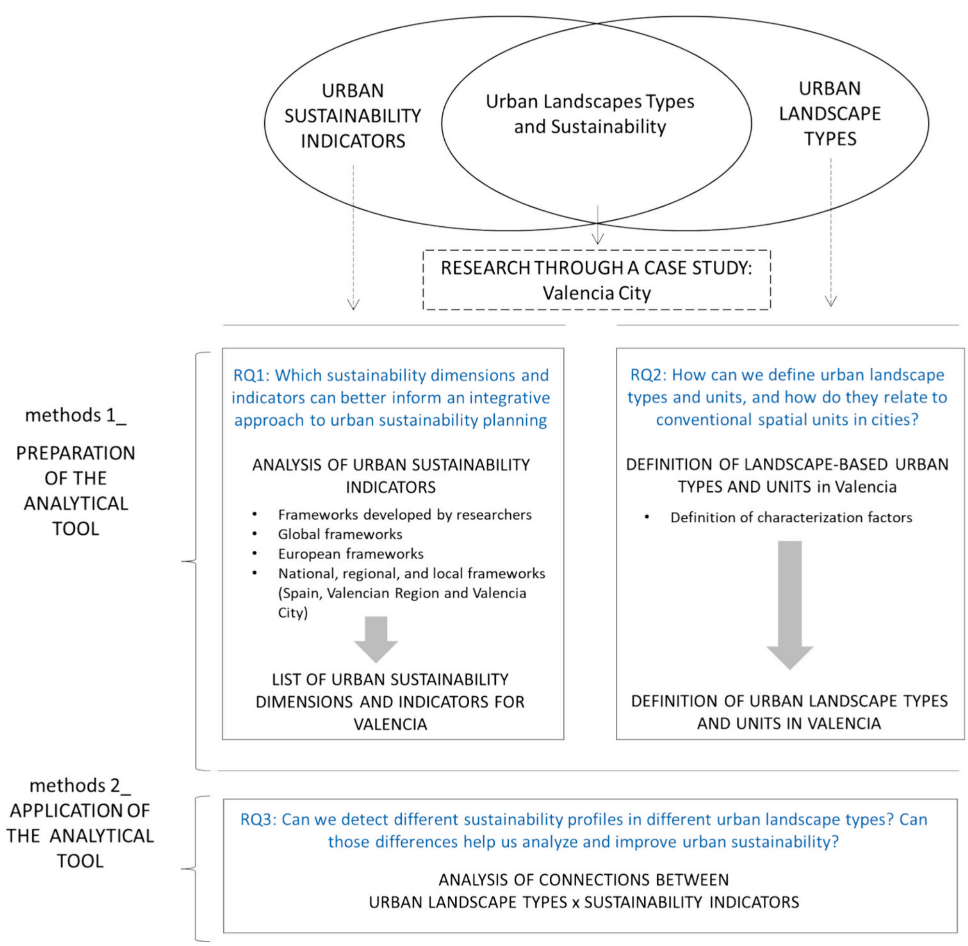

Fig. 1. Research questions and research methods.

(1) Incorporation of different geographical scopes, from global to European, Spanish, and Valencian. (2) Coverage of different chronological periods to detect evolutionary trends in sustainability dimensions and indicators. (3) Inclusion of indices developed or promoted by governmental administrations. (4) Incorporation of indices developed by professional groups to assess and certify urban schemes or projects. (5) Inclusion of highly cited research works comparing different urban sustainability indices.

As presented in Appendix A, 15 indices or frameworks are selected and analyzed: 3 comparative research works (Feleki et al., 2018; Feleki et al., 2020; Merino-Saum et al., 2020); 2 frameworks developed by the United Nations (UN, 2016); 3 indices or methods promoted by the European Union (EC, 2015); one agenda developed by the European Union (EC, 2018); 3 indices developed or promoted by the Spanish government; 1 framework defined by the City of Valencia (Valencia Urban Strategy 2030, 2022); and 2 professional assessment and certification indices (BREEAM, 2012; DGNB, 2020).

The analysis is conducted according to the following steps:

1. Identification of dimensions or topics used to assess urban sustainability in each index (see column 4 in Appendix A).
2. Definition of a new set of sustainability dimensions linking all the dimensions detected in step 1, and reclassification of the indicators included in the studied indices according to the proposed new set of sustainability dimensions (see columns 6–12 in Appendix A)
3. Selection of the most recurrent indicators within each new sustainability dimension
4. Analysis of sustainability indicators available in the city of Valencia and the scale for which they are available (city, district, functional area, quarter, other). See list of sources at the end of Appendix A)
5. Final selection of sustainability indicators based primarily on the indicators selected on step3 and complemented by additional indicators detected in step 4.

Concerning RQ2, a spatial and visual approach is used in this study to characterize the urban landscape of Valencia. Three main morphological factors were considered:

- (1) **Geometry of the urban fabric:** This factor reflects the pattern of masses and voids in the city (Dobson, 2018) and includes in Valencia 4 categories: (i) organic fabric; (ii) orthogonal grid with closed blocks, (iii) irregular grid with closed blocks, (iv) free standing buildings and open or linear blocks in free layouts.
- (2) **Building types:** This factor reflects the type of buildings and their role in the delimitation of the public space (streets, squares, parks). Following the study from Hernández Aja et al. (2022), the factor includes 3 categories: (i) multifamily buildings defining the frontage of the street; (ii) multifamily buildings with a free position in the plot, and (iii), row single-family houses.
- (3) **Age of urban fabrics and buildings**: This factor reflects the design principles and visual appearance of buildings and open spaces from different periods. It could be linked with the 'historical' and 'human-aesthetic' landscape properties identified by Groom (2005) and includes 4 categories in Valencia: (i) areas with a prevalence of buildings constructed before 1900; (ii) between 1900 and 1950, (iii) between 1951 and 1980, (iv) after 1980.

As shown in Fig. 2, the three morphological factors listed above were combined in GIS to define and locate the main urban-landscape types and subtypes in Valencia. These types were later described according to their main morphological, perceptual (visual), and functional factors (see Results and Appendix B). The 4 categories included in the 'geometry of the urban fabric' layer were identified in the cartography of the city (IDEV, 2023). The 3 categories included in 'building types' were imported from the study conducted by Hernández Aja et al. (2022). Finally, the 4 categories included in the 'age of urban fabrics and buildings' were determined by grouping the buildings according to their age (Catastro, 2023).

As presented in the results, 5 out of the 12 possible combinations between 'geometry of the urban fabric' and 'building types' were found in Valencia. Those 5 combinations became the main urban-landscape types considered in this study since they represent the main morpho-functional types in the city. The map displaying the location of those types was then overlayed in GIS with the chronological factor/map to define different urban-landscape subtypes that represent formal variations within the same type (see results and Appendix C).

Thirdly, concerning RQ3, the sustainability dimensions and indicators proposed in this paper are assessed in the urban-landscape types identified in Valencia. As existing data are available in official spatial areas (districts, functional areas, or quarters) and are measured with different metrics, the following steps are followed:

1. Since 'functional areas' are the spatial units for which most of the sustainability data are available, they are intersected with the map of urban-landscape types and subtypes. Only 'functional areas' with a dominating urban-landscape type (>70 % of its overall area) are selected for the study. When this overlapping occurs it is assumed that data from the 'functional area' can be linked to the predominant urban-landscape type that it contains.
2. The sustainability profile of each urban-landscape type is analyzed using the dimensions and indicators defined in this study. To represent all the indicators in a single graph, their values are rescaled based on international or local standards (1 (worst), 3 (average or minimum desirable value) and 5 (best). See column Scoring and Normalization Criteria in Appendix D.
3. A comparative analysis is conducted of the sustainability profiles in different urban-landscape types of Valencia.

3. Results

3.1. *Definition of a synthetic set of sustainability dimensions and indicators*

3.1.1. *Dimensions*

Following the comparative analysis of sustainability dimensions in different indices (Appendix A), the model displayed in Fig. 3 is proposed in this research to assess urban sustainability. This model includes the triple bottom line of sustainability (environmental, social, and economic) and incorporates a spatial dimension to specifically address the space as a resource and dimension critically affecting the triple bottom line. Similarly, metabolic flows (energy, water, waste), mobility flows (people, goods), or even information flows, are used in some indices as transversal dimensions to analyze urban sustainability and are specifically incorporated in the proposed model.

3.1.2. *Indicators*

Apart from classical environmental, social, and economic indicators, the literature (Appendix A) reveals the relevance in many indices of indicators associated with flows (metabolism of energy, water, and waste), although they are normally included within the 'environmental' dimension. Transport or mobility indicators have indistinctly been associated with environmental or social dimensions. In addition, spatial indicators are crucial in some indices due to the importance of compactness and density in urban sustainability. In addition, indicators about information flows and the level of implementation of integrative sustainability planning have gained importance in recent indices.

Based on the proposed sustainability model (Fig. 3) and the indicators included in the analyzed indices, a synthetic list of 67 urban sustainability indicators clustered in six sustainability dimensions (environmental, metabolic, mobility, social, economic, and spatial) is proposed in Table 1. As displayed in Appendix D, the proposed indicators are available in Valencia at a district or 'functional-area scale'

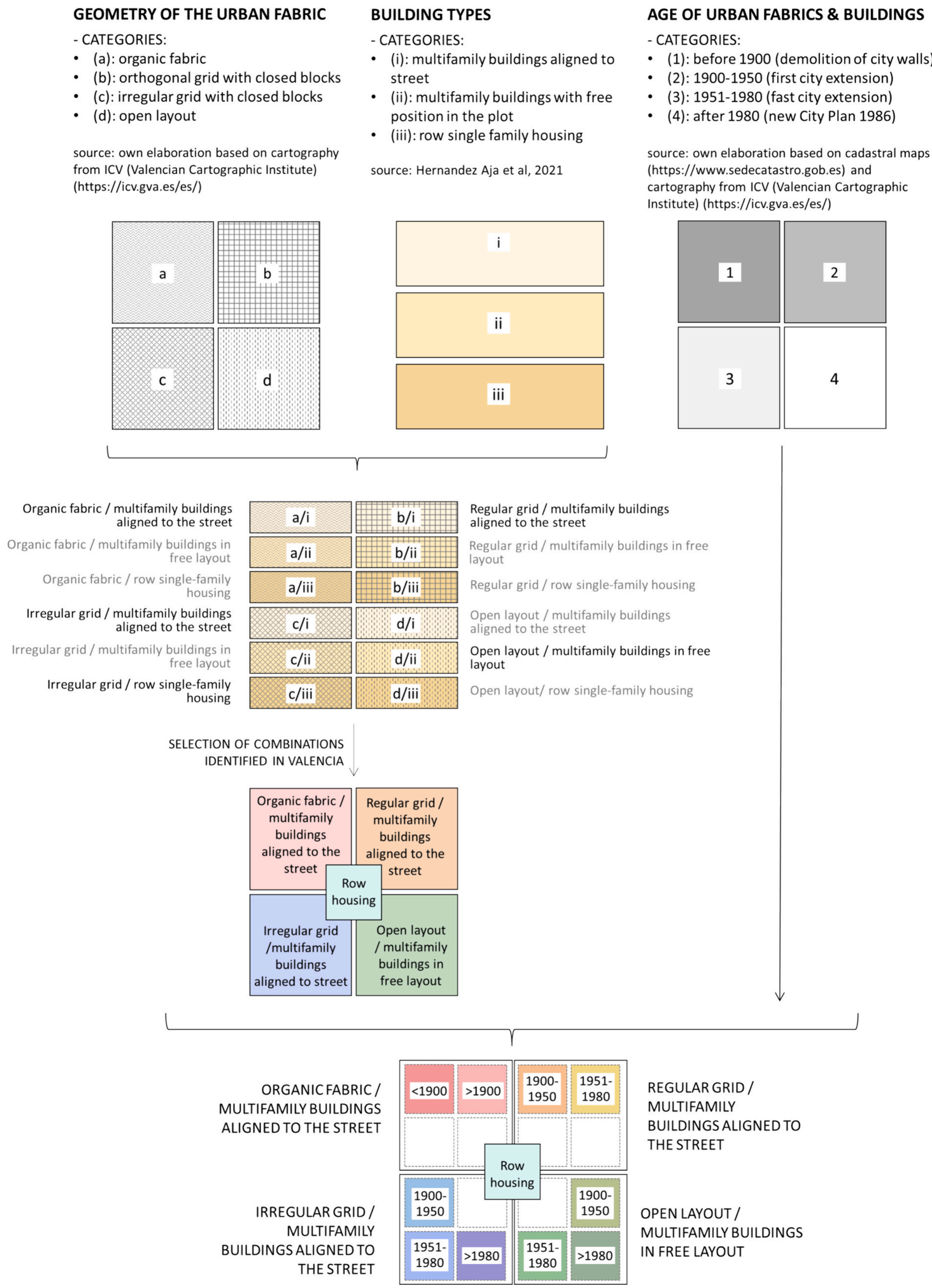

Fig. 2. Cartographic process followed for the definition of urban-landscape types and subtypes in Valencia.

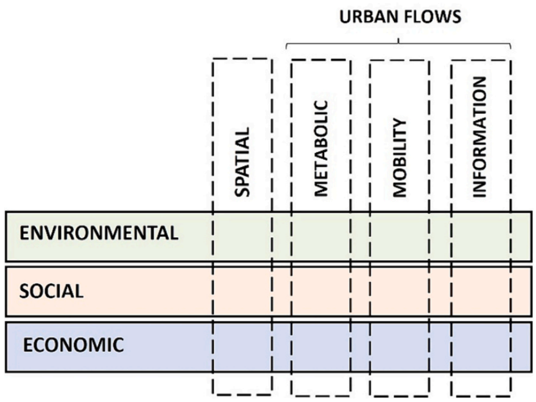

Fig. 3. Conceptual model linking different sustainability dimensions.

and, in some specific cases, in monitoring stations located in various parts of the city.

3.2. Definition of URBAN-LANDSCAPE TYPES, SUBTYPES AND UNITS

Following the urban-landscape characterization process described in section 2.2, five urban-landscape types (see Fig. 4) were identified in the city of Valencia: (A) ORGANIC TOWN (organic fabric with multifamily buildings defining the frontage of the street); (B) REGULAR GRID (orthogonal grid with closed blocks composed by multifamily buildings defining the frontage of the street); (C) IRREGULAR GRID (irregular and trapezoidal grid with closed blocks composed by multifamily buildings defining the frontage of the street); (D) FREE LAYOUTS (open layouts with multifamily buildings with a free position in the plot); and (E) ROW HOUSING (terraced single-family houses). For these types, different chronological subtypes were detected. These types and their respective subtypes are fully described in Appendix B.

As displayed in Fig. 5, and following the cartographic process described in Fig. 2 and illustrated in Appendix C, these urban-landscape types and subtypes can be found in urban-landscape units. When compared with the most recent administrative units defined by the City of Valencia (functional areas), it can be detected that the following four functional areas are highly homogeneous since >70 % of their area is covered by a single urban-landscape type: CIUTAT VELLA (72 % Organic Town Type), ENSANCHE (85 % Regular Grid Type), OLIVERETA (86 % Irregular Grid Type), and CAMPANAR (83 % Free Layout Type). In consequence, the analysis of the sustainability indicators available for those homogeneous functional areas can be associated with the 'urban-landscape types' they contain. The urban-landscape type 'E' (row housing) could not be associated with any functional area due to its small and dispersed presence in the city.

3.3. Comparative analysis of sustainability indicators in the selected urban-landscape types

Fig. 6 displays the performance of the four analyzed urban-landscape types for the proposed sustainability dimensions and indicators (see Table 1). A common scoring system ranging from 1 (worst) to 5 (best) was used to show in the same radar graph indicators with different metrics (see detailed scores and normalization/conversion method in Appendix D). The scoring system was based on local standards except for indicators with globally accepted standards (e.g., square meters of green space per inhabitant).

Regarding **environmental sustainability**, free layouts with a substantial proportion of green areas and moderately high densities show a superior performance for all the environmental indicators except those affecting CO2 emissions in transport and housing. Conversely, many indicators are negatively affected by the lack of green areas in dense regular grids, irregular grids, and old city fabrics that, nevertheless, display low CO2 emissions due to their compact and multifunctional character. Irregular grids from the 60s and 70s benefit from the zoning principles that led to the presence of district parks whereas the presence of boulevards in regular grids from the first half of the 20th century partially explains the good provision of street trees. Overall, the influence of urban form on environmental factors is confirmed (Pan, 2021).

Metabolic sustainability indicators reveal that denser urban-landscape types perform better in energy and water consumption in Valencia, whereas free layouts -with more extensive, unsealed, and interconnected green areas- score higher in water retention or waste composting potential. Waste recycling can be properly managed in all types if sufficient recycling points are provided.

In terms of **sustainable mobility**, the high density of all the studied urban-landscape types (150 inhabitants/ha in the free layout, 190 in the old town, 313 in the regular grid, and 462 in the irregular grid), together with the effective introduction of public transport and cycling lanes, and the proximity, multifunctionality, and lifestyles that characterize the analyzed neighborhoods explain the good performance for all mobility indicators (Weber et al., 2014). However, the lower density and multifunctionality of the free layout type and the more suburban lifestyle of their inhabitants might explain the higher use of the private car and the increase in daily travel distances.

Regarding **social sustainability**, no clear differences can be found between urban-landscape types. Most indicators seem to depend more on how the urban type is provisioned and managed or the socioeconomic profiles of their inhabitants rather than on its morphological structure. In general, all types accommodate a complete and close range of public facilities and services, mainly on the ground floors, but display a lack of social housing and an aging population.

Concerning **economic sustainability,** the old city center and, to a lesser degree, the regular grid, with their central location in the city and their intense commercial and administrative functions, display good performance for most of the indicators whereas, the other types show a more fluctuating pattern. Thus, the level of income and the availability of space for economic activities is respectively lower in irregular grids and free layouts, due to the socioeconomic profile of the residents in the former and the looser structure and residential character of the latter.

The effect of the urban form in **spatial sustainability indicators** such as density or compactness/compacity has been widely reported (Li et al., 2016). Free or open layouts provide more space for green areas, public and private facilities, and, in general, for public space. This occurs in Valencia at the expense of lower densities, compactness, and levels of multifunctionality. The situation is reversed in the irregular grid and regular grid types. For many indicators, the traditional old town is situated in a middle position but displays the highest level of multifunctionality. Regarding accessibility and proximity to facilities and green areas, all the urban-landscape types scored quite high. This suggests that even when the quantity of available public space is limited in some types, its adequate distribution can make it easily accessible for most of the population (e.g., small green areas, facilities integrated into residential buildings, etc.).

4. Discussion

The central hypothesis behind the conducted research was that different urban-landscape types may have different sustainability profiles. This hypothesis and its implications for planning are discussed in the following paragraphs based on the proposed research questions and the obtained results.

In relation to existing literature and knowledge gaps, this study proposes an expanded and needed framework to assess urban sustainability by incorporating crosscutting dimensions to the triple bottom line of sustainability. Secondly, in response to the heterogeneous character of the city and the need of defining more functional and homogeneous urban areas for the design and implementation of urban

Table 1
Urban sustainability indicators organized according to the proposed sustainability dimensions. (*not assessed in Valencia).

Dimension	Topic	Code	Effect	Indicator
Environmental sustainability	Air quality	E1	–	**AIR (concentration PM10)**
		E2	–	**AIR (concentration NO2)**
		E3	–	**AIR (concentration PM2,5)**
	Climate change	E4	–	**CO2 emissions (domestic)**
		E5	–	**CO2 emissions (transport)**
	Comfort	E6	+	**THERMAL COMFORT (tree shade)**
		E7	+	**ACOUSTIC COMFORT**
	Nature and biodiversity	E8	+	**GREEN AREAS**
		E9	+	**STREET TREES**
		E10	+	**BIODIVERSITY**
		E11	+	**ECOLOGICAL CONNECTIVITY**
		E12	+	**ECOSYSTEMS SERVICES (CULTURAL)**
Metabolic sustainability	Energy cycle	M1	–	**ENERGY CONSUMPTION (domestic)**
		M2	–	**ENERGY CONSUMPTION (transport)**
		M3	+	**ENERGY PRODUCTION (solar potential on roofs)**
	Water cycle	M4	–	**WATER CONSUMPTION**
		M5	+	**WATER RETENTION (potential retention on roofs)**
		M6	+	**WATER INFILTRATION (permeable soils)**
	Waste cycle	M7	+	**WASTE (Recycling points)**
		M8	+	**WASTE (composting potential)**
Sustainable mobility	Travel patterns	MO1	–	**TRAVEL DISTANCE (daily trips)**
		MO2	–	**TRAVEL SCOPE (in relation to residence)**
	Urban fabric and modal split	MO3	+	**VIABILITY OF SUSTAINABLE MOBILITY**
		MO4	+	**FLEXIBLE MOBILITY (MODAL SPLIT)**
	Walkability	MO5	+	**WALKABILITY**
	Cyclability	MO6	+	**CYCLABILITY (network)**
		MO7	+	**CYCLABILITY (access)**
	Parking	MO8	+	**REGULATED PUBLIC PARKING**
Social sustainability	Health	S1	+	**LIFE EXPECTANCY**
	Demographics	S2	–	**AGING INDEX**
	Equity and social inclusion	S3 (*)	–	POVERTY RISK
	Labour	S4	–	**UNEMPLOYMENT RATE**
	Education	S5	+	**LEVEL OF EDUCATION**
	Governance	S6	+	**PUBLIC PARTICIPATION**
	Wellbeing	S7	+	**SATISFACTION WITH THE NEIGHBORHOOD**
		S8	+	**PERCEPTION OF SAFETY**
		S9	+	**NEIGHBORS SUPPORT**
		S10	+	**INTEGRATION**
	Social diversity	S11	+	**CULTURAL DIVERSITY (FOREIGN POPULATION)**
		S12 (*)	+	**INCOME DIVERSITY**
	Identity	S13	+	**LOCAL LANDMARKS**
	Housing	S14	+	**SOCIAL HOUSING (available)**
		S15	–	**VACANT HOUSES**
		S16	+	**HOMES IN GOOD CONDITIONS**
	Facilities and services	S17	+	**FACILITIES & SERVICES (ratio public/private)**
		S18	+	**FACILITIES & SERVICES (full coverage)**
	Information	S19	+	**INFORMATION FLOWS**
Economic sustainability	Wealth	EC1	+	**GDP (per capita)**
		EC2	+	**REAL ESTATE VALUE**
	Entrepreneurship	EC3	+	**DIRECTORS & ENTREPRENEURS**
	Local businesses	EC4	+	**NEW BUSINESSES**
		EC5	+	**TOURIST FLATS**
	Space for economic activities	EC6	+	**SPACE FOR ECONOMIC ACTIVITIES**
	Commerce	EC7	+	**SHOPS AND COMMERCE**
		EC8	+	**LOCAL MARKETS**
		EC9	+	**TEMPORARY MARKETS**
	Investment	EC10 (*)	+	**DIRECT INVESTMENT**
Spatial sustainability	Density	SP1	+	**DENSITY (people)**
		SP2	+	**DENSITY (Floor Area Ratio)**
	Compactness	SP3	+	**COMPACTNESS (Efficiency)**
	Multifunctionality	SP4	+	**SPATIAL MULTIFUNCTIONALITY**
	Spatial availability	SP5	+	**PUBLIC SPACE (per inhabitant)**
		SP6	+	**GREEN SPACE (per inhabitant)**
		SP7	+	**PERMEABLE SOIL (%)**
		SP8	+	**SPACE FOR FACILITIES & SERVICES (per inhabitant)**
	Accessibility and proximity	SP9	+	**ACCESSIBILITY TO GREEN SPACES**
		SP10	+	**ACCESSIBILITY TO FACILITIES & SERVICES**

sustainability transitions, this study confirms that a landscape approach based on the use of morpho-functional characteristics leads to the definition of new urban types that might differ from traditional administrative units such as districts or quarters. Thirdly, in answer to the need of understanding potential connections between urban types and sustainability profiles, this study reveals that the urban-landscape types analyzed in Valencia display clear differences for some sustainability dimensions and indicators.

Fig. 4. Main Urban-Landscape Types in the city of Valencia (A): Organic Town (subtype A1: Old organic town); (B): Regular grid (subtype B1: first half of the 20th Century); (C): Irregular grid (subtype C2: 1950–1980); (D): Free layout (subtype D3: 1980–2023); (D′): Free layout (subtype D2: 1950–1980); (E): Row Housing.

4.1. RQ1: sustainability dimensions and indicators

Concerning RQ1 and the debated definition of urban sustainability dimensions and indicators, the proposed list includes 67 indicators organized in six dimensions (Table 1). In addition to the triple bottom line of sustainability, the inclusion in this study of the *spatial dimension* addresses holistically fundamental issues that intersect the environmental, social, and economic dimensions of the city, such as urban density, compactness/compacity, land use relationships, or multifunctionality (Feleki et al., 2018; UN, 2016). Moreover, the spatial dimension allows for the analysis of other dimensions from the perspective of the space allocated for them (e.g., square meters for environmental, social, or economic functions). Besides, the incorporation of a *metabolic dimension* provides a framework to analyze and manage crosscutting flows (e.g., water, energy, or waste) that affect the environmental, social, and economic dimensions of the city and that occur in different ways in distinct urban-landscape types or cities. Finally, the *mobility dimension* defines a specific platform to analyze and manage the movement of people and goods in the city.

These findings align with the existing literature and with the need of addressing other sustainability dimensions and of defining manageable and comprehensive sets of indicators based both on international studies and in local conditions (Tanguay et al., 2010; Verma & Raghubanshi, 2018; Wu & Wu, 2012). In this regard and based on the multiscale process that was followed for their definition, the dimensions and indicators proposed in this paper, have the potential to be transferred or adapted to a wide range of cities.

4.2. RQ2: landscape-based spatial types in cities for sustainability planning

Regarding the definition of more suitable and operational areas for

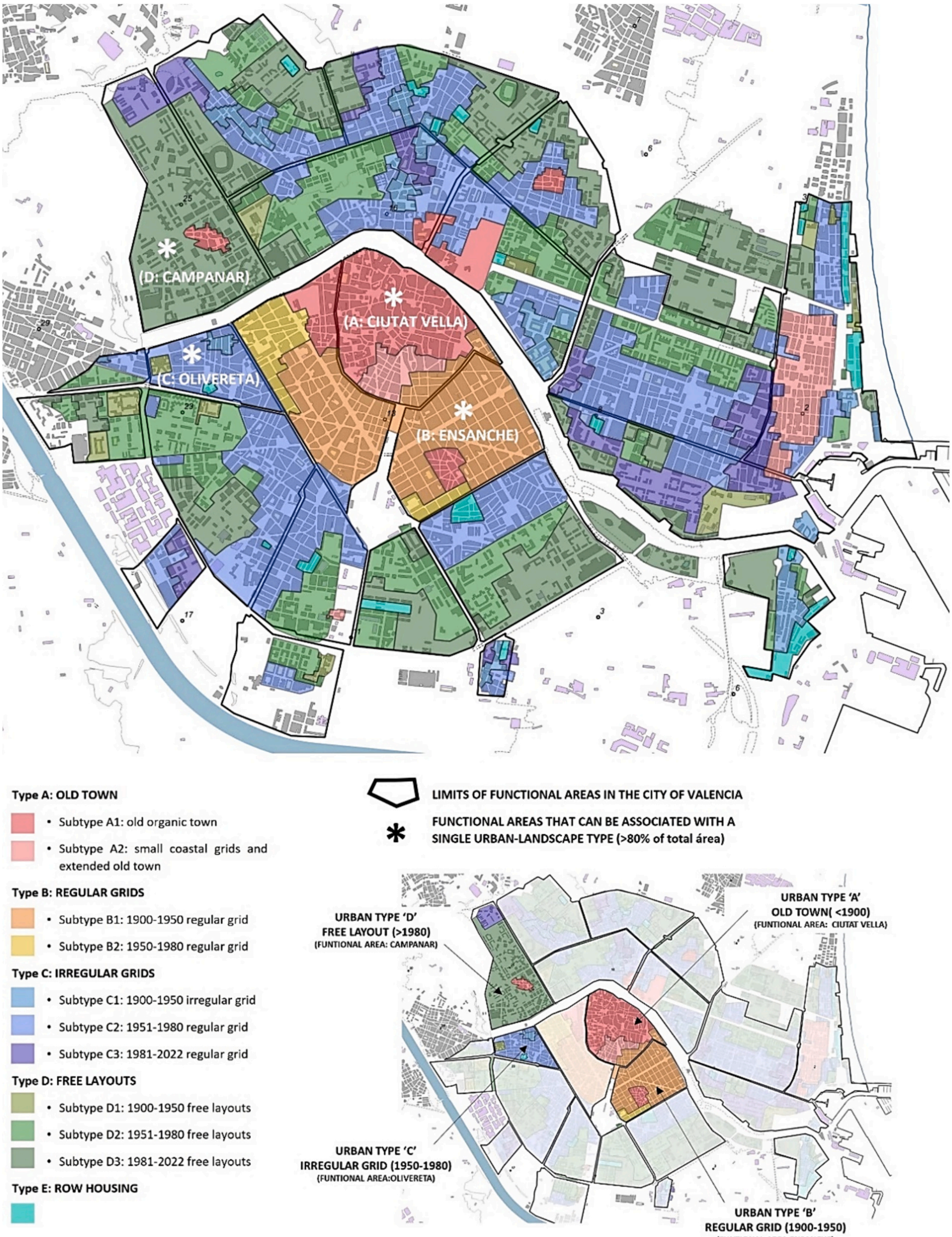

Fig. 5. Urban-landscape types and subtypes in the city of Valencia and identification of four city functional areas that can be associated with a single urban-landscape type.

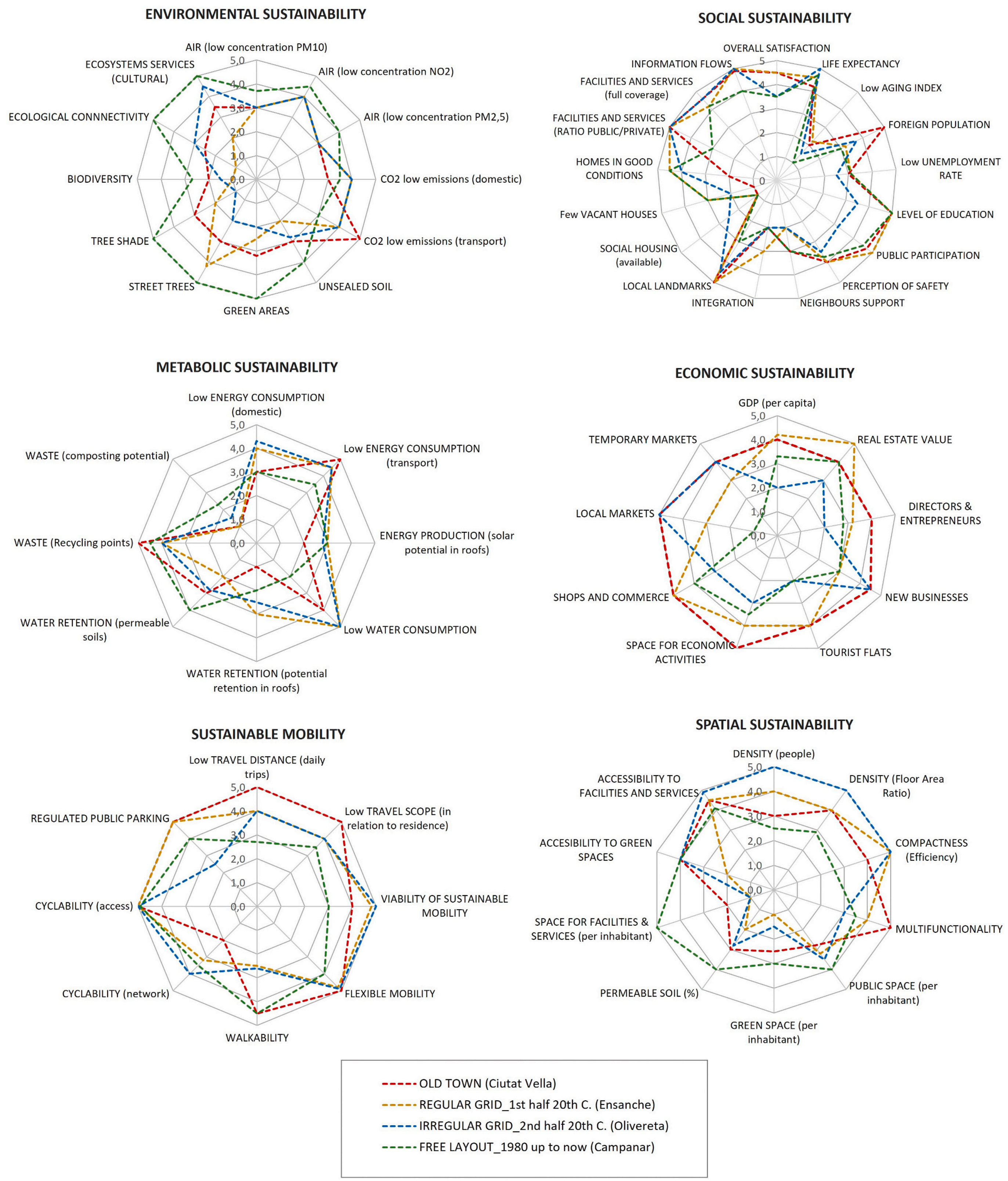

Fig. 6. Performance of Urban-landscape types for environmental, metabolic, sustainable mobility, social, economic, and spatial sustainability indicators (1 worst, 5 best).

the diagnosis and improvement of urban sustainability, results suggest that a landscape approach can facilitate the definition (through the urban-landscape type concept) of more coherent spatial units based on the integrated combination of spatial patterns, urban processes, and functions. These urban-landscape types and units capture nuances and differences that cannot be appreciated if extensive and heterogenous areas (e.g., some districts) are considered, or if only a single factor (e.g. urban density) is taken into account (Buzási & Jäger, 2020; Nielsen &

Jensen, 2010). The three main morphological factors used in this study to characterize the urban landscape of Valencia were in accordance with the factors proposed by Dobson (2018), and were complemented by the introduction of additional morphological, perceptual, and functional factors (see Appendix B). Although the identified urban-landscape types could be associated with standard urban types or fabrics, the introduction of these additional factors provided a more holistic insight and helped to understand contrasting performances for some indicators. Overall, the generated results provide a new insight in the definition of urban types (Stokes & Seto, 2019; Weber et al., 2014). Firstly, the proposed landscape approach aligns with the integrative and holistic approach advocated by Liao et al. (2020) and searched by Dobson (2018). Secondly, the tested methodology for the definition of urban-landscape types can be easily applied or adjusted to other cities. Thirdly the urban-landscape types identified in Valencia (old city centers, regular grids, free layouts) are common in many cities worldwide, what increases the general interest and applicability of some of the presented findings.

4.3. RQ3: links between urban-landscape types and sustainability indicators

In answer to RQ3, previous studies often used full sets of sustainability indicators to compare different cities (Schwarz, 2010; Stokes & Seto, 2019) or to analyze a single city (Feleki et al., 2020). In both cases, cities were approached as homogeneous entities despite their internal heterogeneities. Alternatively, other studies have compared different urban types but only for few indicators (Li et al., 2016; Pan, 2021; Thomson & Newman, 2018). In contrast and in agreement with few other studies based on the comparison of city districts (Buzási & Jäger, 2020; Nielsen & Jensen, 2010), this paper presents a comparative study of different urban-landscape types for a full set of sustainability indicators and dimensions in one representative Euro Mediterranean city.

As displayed in Fig. 6, the comparative analysis of sustainability dimensions in different urban-landscape types of Valencia reveals divergences that are more evident and consistent in environmental, spatial, mobility, and economic sustainability. In addition, metabolic sustainability is affected by the kinds and intensity of flows of water, energy, and waste which are determined by the structure and functioning of each urban-landscape type. Finally, social sustainability cannot be clearly connected in this study to each urban-landscape type since distinct types obtained similar scores or swiped positions for many social indicators. This might be the consequence of socio-economic differences that could not be captured in a highly morphological approach like the one followed in this study. It must be noted that all the urban-landscape types considered in this study were quite compact, and the inclusion of looser types (e.g., low density suburbs) may have led to greater differences between them (Ronchi et al., 2018; Soltani et al., 2022).

Based on the indicators displayed in Fig. 6, Table 2 shows how the conducted analysis of sustainability indicators in different urban-landscape types might lead to the definition in Valencia of more tailored and site-based strategies, policies, plans, and actions. This aligns with existing studies claiming that sustainability assessment in coherent spatial units which share similar sustainability problems can support the identification and prioritization of urban policies (Ortiz-Fernandez et al., 2023; Storch & Schmidt, 2006). Similarly, other studies show how urban types can be effectively used to define strategies for densification or climate change adaptation (De Urbanisten, 2013; Tillie et al., 2012). As revealed in Table 2, the old city landscape of Valencia requires policies and actions to improve affordable housing, buildings renovation, and some metabolic flows (water and energy). In addition, site-specific solutions are needed in this type to improve the green infrastructure and the quality of the public space. Regular and irregular grids require in Valencia initiatives to improve the quality and quantity of public space and green infrastructure. In this regard, the generation of superblocks

Table 2
Examples of actions to address the most critical sustainability indicators in the studied urban-landscape types of Valencia (XXX: strongly recommended, XX: recommended, X: slightly recommended).

ACTIONS AND AFFECTED SUSTAINABILITY INDICATORS (E: environmental, M: metabolic; MO: mobility, S: social, EC: economic, SP: spatial)	**OLD CITY**	**REGULAR GRID (1900–1950)**	**IRREGULAR GRID (60–70s)**	**FREE LAYOUTS (1980s)**
Improve the green infrastructure (spaces, fair distribution, connectivity, generation of ecosystem services, more street trees) **(E6, E8, E9, E11 / M5, M6 / SP6, SP7)**	XX	XXX	XXX	X
Improve ecological biodiversity **(E10)**	XX	XXX	XXX	XX
Promote a more circular urban metabolism at different scales (especially regarding water retention and energy production in buildings, public space, quarters, districts, city) **(E6, E9 / MO5, MO6 / SP5)**	XX	XX	XX	XX
Promote soft mobility to decrease carbon emissions, traffic, and noise **(E5, E7 / M2)**	X	XX	XX	XXX
Promote the city of proximity: dense and multifunctional **(E5 / M2 / MO1, MO2 / SP1, SP2, SP4)**	X	X	X	XX
Improve the quality and walkability of the public space (e.g., wider sidewalks, more street trees) **(E6, E9 / MO5, MO6 / SP5)**	X	XXX	XXX	X
Increase the availability of space for facilities, services, and green areas **(SP8)**	XX	XXX	XXX	X
Keep and promote the commerce of proximity and the presence of a diversified range of economic activities, also regulating tourist flats (**EC6, EC8, ERC9 / MO1, MO2)**	X	XX	XX	XXX
Increase the availability of social/affordable housing, especially for young people **(S2, S14)**	XXX	XXX	XXX	XXX
Support buildings renovation **(S16)**	XXX	X	XX	X

offer a multitargeted solution that is already being tested in Barcelona and Valencia (Mueller et al., 2020). Finally, free layout landscapes in Valencia require policies and actions to improve their levels of multifunctionality, the availability of spaces for economic and commercial activity, and the use of public transport. These policies and actions are in line with the literature explaining the benefits of the 15 min city (Pozoukidou & Chatziyiannaki, 2021). As displayed in Table 2, the lack of social and affordable housing remains a critical challenge in all urban-landscape types in Valencia. Generally speaking, and as claimed by Nielsen and Jensen (2010), the detected sustainability profiles might help local communities and authorities to open processes for urban improvement and regeneration, in this case, highly linked to the specific characteristics of each urban-landscape type.

From a wider and global perspective, the presented research opens a possibility for a more comprehensive and multidimensional analysis of the levels of sustainability in distinct urban types through the identification of urban-landscape patterns and sustainability indicators (Wu, 2012). As exemplified in Table 2; by using the proposed method, cities can better understand their internal heterogeneities and define more tailored sustainability actions and policies for each urban type (Storch & Schmidt, 2006).

4.4. Additional reflections, limitations, and future research

Concerning limitations of the conducted research and future lines of theoretical and practical investigation, the proposed list of urban sustainability dimensions and indicators should be evaluated in different cities and urban-landscape types to confirm their general applicability. It should also be kept in mind that urban sustainability indicators and scorings systems must respond to the specificities of each city or neighborhood, and that local stakeholders might participate in their definition (Nielsen & Jensen, 2010).

In answer to the need of placed-based case studies testing the transdisciplinary and holistic potential of the landscape sustainability concept (Zhou et al., 2019), the presented case suggests that a landscape approach can facilitate a higher level of integration and contextualization (Liao et al., 2020), even in a highly anthropized landscape like a dense and compact city.

From a methodological perspective, the characterization of the urban landscape and the subsequent definition of urban-landscape types should incorporate in further studies additional internal and contextual factors. These factors could in fact explain why, in some cases, urban-landscape types with the same morpho-functional structure might display different ecological footprints or sustainability profiles, for instance due to divergences in their socioeconomic landscape. The focus of this paper on morphological and spatial characteristics of the urban landscape was justified in terms of their static or permanent quality. However, social, cultural, economic, managerial or governance factors are also crucial in a complete landscape characterization process. In fact, this wider approach would help to connect the sustainability assessment of urban-landscape types to critical urban challenges of a socioeconomic nature like gentrification, segregation, inadequate management, lack of community feelings, undemocratic governance, or deterioration of the urban image.

Regarding links between urban-landscape types and sustainability profiles, it should be assumed that we cannot establish a biunivocal and universal connection between urban-landscape types (as studied in this paper) and sustainability profiles due to the influence of factors which were not considered in this research. However, it must be noticed that the differences detected in Valencia for some environmental, spatial, metabolic and mobility dimensions or indicators are fully aligned with existing literature and attest a certain connection between the morpho functional characteristics of an urban area and some components of its sustainability profile (Dong et al., 2019; Stokes & Seto, 2019; Wu, 2021).

In addition, results (Fig. 6) unveil the critical importance of some structural characteristics of the urban landscape, such as the amount and distribution of green and permeable areas, the levels of multifunctionality and compactness, etc. Their key role in urban sustainability could be analyzed in further research through correlational studies investigating the level of connection of these indicators with other sustainability indicators in different cities.

From a practical perspective, the city of Valencia will be the European Green Capital 2024 and is included amongst the 100 European Cities in the Mission for Carbon Neutrality 2030. As displayed in Table 2, the produced results can help understand the internal heterogeneities of the city and, subsequently, support the definition of more site and landscape-based policies and actions.

Finally, in order to assess the transferability of the obtained results, it would be advisable to compare in future research, and in different cities, similar urban-landscape types (to confirm convergences with the Valencian case) and different urban-landscape types (to detect similar divergences). In this regard, the city of Valencia can be considered a highly representative example of a compact city, and so are the urban-landscape types studied in it. However, a replication of the study in other cities would be useful to reconfirm and adjust the presented findings, especially regarding social indicators, that in Valencia were not significantly different in distinct urban-landscape types but that can diverge in other cities. Overall, the main contribution of this paper to the international literature derives from the combination of new urban types (based on a holistic landscape approach), and the multidimensional assessment of urban sustainability in those types. The proposed methodology and the obtained findings expand and complement existing studies developed in other cities and suggest that some sustainability indicators are highly influenced by the morpho-functional structure of the city. Besides, the presented results open the possibility for the definition by planners and policy makers of more tailored sustainability policies and plans in different urban types and help to open new bridges between landscape studies and urban planning.

5. Conclusions

The detection of different sustainability profiles in distinct urban-landscape types of Valencia opens a potential way for the design of sustainability transitions adapted to the specificities of urban areas sharing a common landscape pattern. In contrast to most of the existing literature, which compares entire cities or which studies one or few sustainability indicators in different districts; this study assumes the internal heterogeneity of cities and the multiple dimensions of urban sustainability as preconditions for a broad and complete sustainability assessment of different urban types within the same city.

Following the definition of urban-landscape types in the city of Valencia and their comparative analysis with a new and comprehensive sustainability index, the conducted research suggests that different urban-landscape types might have distinct and recognizable performances for different sustainability dimensions and indicators, although these performances can be considerably affected by additional social and contextual factors. This conclusion opens the way for further research to assess the exportability of the obtained results and for the definition of more coherent, effective, and site-based policies and actions supporting urban sustainability planning and management. In addition, the incorporation of three transversal dimensions (spatial, metabolic, and mobility) to the triple bottom line of sustainability, provides a specific ground to address urban issues that intersect the environmental, social, and economic dimensions of the city and that are crucial in current urban agendas (for instance, spatial proximity and multifunctionality in the fifteen minutes city, or energy flows in carbon neutral cities). Besides, the produced results reveal that the use of a landscape approach in the definition of urban types might help to define more coherent spatial units that can differ from conventional administrative units such as districts, quarters, or neighborhoods. These urban-landscape types and units are embodied with a significant level of integration and can be identified through landscape characterization processes specially designed for urban areas like the one proposed and assessed in this paper. From an operational perspective, the conducted research shows how disconnected data from various sources can be effectively combined to generate a complete and holistic sustainability diagnosis of cities.

Overall, the produced results are expected to provide city planners and decision makers with an innovative approach and spatial framework based on the recognition of urban landscape patterns. This framework would permit the identification in each city of urban-landscape types and the subsequent design and implementation of integrative sustainability plans and policies highly adapted to the specific conditions of each urban configuration. The proposed framework can be applied in different geographical contexts as long as the specific characteristics and heterogeneities of each city are considered both regarding the definition of urban-landscape types and the selection and assessment of sustainability indicators. In this regard, the Valencian case presented in this paper can be considered an initial pilot opening a promising path for future replications and further theoretical, methodological, and practical research.

CRediT authorship contribution statement

Juanjo Galan: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared my data on the appendices. Additional data can be shared on request.

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2024.105344.

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