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Opportunity-spaces for self-regenerative processes: assessing the intrinsic value of complex peri-urban systems

The research aims at evaluating the ability of a peri-urban system to activate territorial self-regenerative processes, according to Circular Economy principles. The adopted methodology identifies *opportunity-spaces*, through indices of space heterogeneity and of the relational dynamics, established in collective spaces. Through a site-specific set of indicators, it evaluates opportunity-spaces intrinsic value, adopting Analytic Network Process (ANP) as Multi-Criteria Decision Aid method (MCDA). As a result, five categories of opportunity-spaces are defined and spatialised, within hill area of Naples, in the South of Italy.

1. Introduction

1.1 Theoretical background

Urban critical issues, related to territorial marginality and exclusion, often emerge within those in-between metropolitan areas, which can be referred to as *peri-urban spaces* (Brook and Davila, 2000; Iaquinta and Drescher, 2000; Allen, 2003; Marshall et al., 2009). These are conflicting and heterogeneous areas, made of a differential and fragmented reality, where intermediate and ambiguous zones are continuously being generated (Lefebvre, 1974). They are places of social and spatial negotiation, where polarities meet, keeping the urban relational dynamics alive (Stavrides, 2016). According to this perspective, the contribution investigates the possibility for these urban areas to activate complex dynamics, functioning as a territorial *residue* (Clément, 2004), where the urban metabolism (Wolman, 1965) is to be understood through an interdisciplinary perspective, combining natural and social sciences (Dijst et al., 2018) and interpreting cities as ecosystems, produced by different complex processes, which can develop into self-sufficient ones, if conceived according to an *autopoietic* thinking (Varela et al., 1974), deriving from the study of ecosystems mechanisms.

The Circular Economy (CE) concept, referring to natural ecosystems intrinsic capacities, as well, conceptualises the definition of urban metabolism within a wider framework of *urban circularity* (Marin and De Meulder, 2018), a model pro-

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moting the development of environmental, social and economic innovations, allowing urban self-regenerative processes. An interesting parallel can be traced between the elements of a CE cycle, happening in the city, and the territories deriving from urbanisation processes: indeed, CE proposes to introduce what is *residual* of a consumption chain into sustainable loop processes of reuse and renewability, for value creation, turning wastes into services (Ceschin, 2013; EMF, 2013). Berger's (2006) concept of *wasted places* refers to marginal and abandoned sites and is strongly related to Clément's (2004) definition of *residual landscape* as *third landscape*, which is connected to uncultivated areas, fragments of uncertain landscape, in a dynamic state of waiting, where hybrid and entropic spaces, being always in motion and transformation, can be understood as the complex product of a *social vitality* (Clément, 2006, p.128).

According to this interpretation, the research analyses the case-study periurban area as a complex territorial system, where the circularity strategy and the renewable closed-loop processes, at the base of CE (Stahel, 1982), could turn the concepts of residual and waste places into their understanding as vital areas: in recent times, for example, the CE strategies are being applied within urban critical, hybrid and underutilised areas (Lewin and Goodman, 2013; EEA, 2015; Hassan and Lee, 2015). In this sense, the paper refers to the widening of the concept of circularity towards the definition of its urban dimension (Marin and De Meulder, 2018), aiming at addressing urban circular processes as spatial practice (Prendeville et al., 2017).

The definition of cities as complex systems is shifted from the biological world. Biology defines the ecosystem as a natural system, made of biotic and abiotic factors, which synergistically interact, constituting the ecosystem self-sufficiency and dynamic balance. Social ecology, stressing social and urban systems ability to manifest social diversity, mutualism and connectivity, considers them as ecosystems, as well – also defines them as *eco-communities* – underlining their self-producing mechanisms (Boockchin, 1992). At the same time, urban ecology, considering the city as a living organism, studies the biodiversity of urban systems, as deriving from the synergistic coexistence of social ecosystems and natural ecosystems (Müller et al., 2013): an urban ecosystem is the product of the interaction among natural capital, manufactured capital and cultural identity of places (Magnaghi, 2010). An urban hybrid territory is, therefore, substantiated as a spatial ecosystem, composed of different complex subsystems, allowing the vital (environmental-economic-social) conditions for the system itself, hence its self-development: the marginal urban landscape provides the city with ecological, material and energy resources and works as environmental support (Haines-Young and Potschin, 2018), constituting the self-regulating and balancing capacities of the metropolitan system between the natural ecosystem sphere and the anthropic pressures that tend to modify it (Maes et al., 2018); creative enterprises, clusters of creative industries (Zheng and Chan, 2014), social enterprises and cooperatives are giving way to alternative economies (Boonstra, Boelens, 2011), based on collaborative and supportive community mechanisms; cooperative actions produce the territory itself, by aiming at self-governing it, through self-organising processes (Magnaghi, 2015).

Combining these different subsystems, the metropolitan heterogeneous territory synergistically links natural ecosystems and urban ecosystems (natural capital and manufactured capital), whose vitality depends on the capacity of a community (social capital and human capital) to be in solidarity, guaranteeing: integration and coevolution; the possibility to build a collective identity-based sense of recognition in a place or in a culture over time; the activation of cooperative and self-organising processes.

In ecology, self-producing ecosystems are defined as *autopoietic* and are organised through a network structure of mutual interactions among the elements that make up the system (Varela et al., 1974). A first attempt to abstract the concept of autopoiesis from the biological world theorises a trans-disciplinary concept, according to which not only living systems, but also physical systems and social systems can be defined as autopoietic (Luhmann, 1986; Seidl, 1992). Ecosystems can be considered as the realisation of the autopoietic organisation, as they produce themselves: if an ecosystem is autopoietic, it is necessarily a *social* system (the opposite is not necessarily true); a spontaneous social system (not defined by heteropoietic mechanisms, external to the system) that produces itself is *autopoietic* (Zeleny and Hufford, 1992; Zeleny, 2009). Autopoietic social systems have been studied through categories, which differ on the type of communication (reciprocal interactions in the social system), that links the system parts to each other (Luhmann, 1986; Schatten, Bača, 2010). The communication mechanism of autopoietic systems is at the base of their *structure* and *organisation*: the first one refers to the system composition, to the types of elements and interactions among the elements; the second one refers to the network of coordination rules among the system parts, which, within a social system, are the interactions among different personalities, their bonds and relationships, regulating people association (Zeleny and Hufford, 1992; Zeleny, 2009). Then, social interactions, allowing communication among the system parts, not only organise the system itself but, by transferring information, informatise it, retain and metabolise the information that makes the system able to compare the external environment and the changing needs of those who use it (Bača, 2007).

The first definition of an autopoietic social system, as a self-referential system – which defines itself distinguishing itself from the external environment (Luhmann, 1986), through a defined and closed perimeter (Varela et al. 1974; Zeleny, Hufford, 1992) – is reinterpreted through an information system model, reacting to environmental impulses and continuously adapting to them (Quick, 2003): this type of ecosystem can be considered as a complex adaptive system (Gunderson and Holling, 2002), whose development is linked to a limited degree of predictability (Costanza et al., 1997, p. 103). Therefore, an autopoietic ecosystem reproduces itself, through a structure and an organisation, based on the information transfer, through relationships and links; it is then social; the information transfer makes the system adaptable to the external environment, therefore resilient.

The notion of autopoiesis of ecosystems is linked to that of *land health*, defined by Leopold (1949) as the capacity of the land for self-renewal (Walck and Strong, 2001). Leopold evaluated it through the criteria of *integrity*, *stability*, *productivity* and *beauty* of the biotic community (Leopold, 1970; Walck and Strong, 2001): *integrity* represents the set of elements of the system/community, linked by interdependence relations (this definition can be easily associated with that of the ecosystem); *stability* (far from the concept of stasis) refers to the organisation through which the system/community develops; *productivity* is the capacity of the system/community to produce what it needs for its survival (this concept could be associated with that of self-support); *beauty* is connected to the system/community intrinsic value, which consists in the capacity for self-renewal.

Costanza (1992) associates the definition of *ecosystem health* to the concepts of *diversity or complexity*, and formulated three indicators, through which the ecosystem health and integrity can be evaluated: *stability or resilience* can be defined as the ability of the ecosystem to absorb external pressures and adapt to them creatively, rather than resisting to them, by maintaining its unchanged configuration; *vigor or scope for growth* refers to the ecosystem productivity, activity or metabolism; *balance* among the components of the ecosystem. This concept is synthetized by the expression $HI=VOR$, where: HI is the complex ecosystem health index and a measure of sustainability; V, the vigor; O, the ecosystem organisation; R, the resilience. The ecosystems capacity for self-renewal, or self-production – autopoiesis – constitutes the *ecosystem intrinsic value*, *EIV* (Zhang et al., 2015).

If the concept of intrinsic value is linked to that of system complexity, studying a complex territorial system implies the need to analyse its capacity to produce intrinsic value. Assuming an autopoietic and ecosystem approach, based on the definition of natural ecosystem integrity and health, the formation process of intrinsic values can be analysed within social and urban ecosystems as well (Fusco Girard and Nijkamp, 1997). Cerreta and De Toro (2001) propose the index $I=ORV$ to evaluate the integrity of urban systems and their capacity to self-organise over time, shifting the terms used by Costanza from the natural sphere to the social and anthropic one. In this expression, the terms *resilience* and *organisation* are related to that of *vitality*, that is to be understood as the capacity of the urban system to enable the social self-production of material and immaterial relationships, of common feeling and shared place identity, to produce that *primary value*, on which the formation process of the other values depend, the *intrinsic value*, *IV* (Pearce and Turner, 1990; Fusco Girard and Nijkamp, 1997). Turner (1992) defines this value as *glue value*, since it keeps different individualities of a community together, tying them within a structure. IV cannot be evaluated in monetary terms since it depends on social vitality and social capital: it is, also, referred to as *intangible* (Daniel at al., 2012) and *incommensurable* (D'Agostino, 2000). Non-monetary values can refer to: *cultural/historical values*, based on cultural heritage, and held by a distinguishable society and its institutions (Frey, 1994); *social* or *societal values*, based on civic engagement in decision-making, cultural and recreational shared activities, participation and inclusion (Dirksmeier, 2008; Pike at al., 2011; Sherrouse et al., 2011); *communal values*, shared by a local community, and based on place-based identity, spiritual connection to a land or place, symbolic and iconic identification (Gobster, P.H., 2001; Kato, 2006; Kanowski and Williams, 2009; Cerreta and Panaro, 2017). A community is realised within the physical space of a city, that supports its activity, its culture, the formation of social relationships and shared habits. Such a city can be defined as biopolitical (Hardt and Negri, 2011), being structured through a living dynamic of cultural practices, intellectual circuits, affective networks, and social institutions (Hardt and Negri, 2011, p. 154). In essence, it allows urban vitality formation, by strengthening the social productive power. This dynamic constitutes the immaterial drivers (Goonetilleke et al., 2011) catalysing the metabolic capacity of the city to activate urban regeneration processes, based on the local culture (Sacco et al. 2014) and the creative capacities of an urban community.

1.2 Research questions and aims

This research investigates a heterogeneous peri-urban system in Naples, in the South of Italy, identifying the *opportunities* deriving from the relational dynamics in collective spaces. The case study is selected, though a preliminary analysis of the city peri-urban spaces, according to which the two main spatial categories, studied in this research, heterogeneity and relational consistency, result to be considered as very much specific for the study area. The methodology aims at detecting the capacity of this territory to allow the catalysation of urban regeneration processes, based on self-production, self-organisation and place identity enhancement, through the development of a place-based model. This derives from the analysis and interpretation of uses and relationships in collective space and highlights how use and non-use values and the opportunities of a marginal urban area can depend on IV. According to an autopoietic thinking, based on the attempt to activate local cooperative processes, this study evaluates the IV of the analysed spatial-social system, through criteria of *organisation (cooperation), resilience* and *vitality*.

The contribution engages with the 2030 Agenda for Sustainable Development (United Nations General Assembly, 2015), deepening, in particular, the issues related to social self-development and inclusive urban spaces promotion, defining site-specific quantitative and qualitative indicators. These differently refer to the categories mentioned above and to types of possible local regeneration processes and social synergies among the inhabitants-stakeholders, that could enable the definition of a local social ecosystem.

The following questions address the methodological approach: How can opportunities, deriving from the use of space and the relational dynamics in collective spaces, be identified and spatialised? Can synergistic territorial processes be addressed, according to the different identified opportunities, and starting from the evaluation of social self-production capacity and IV?

In order to answer to the above issues, in Section 2 the methodological framework is described; in Section 3 the application to the selected case-study is presented; in Section 4 the results are analysed, and in Section 5 the discussion and conclusions are presented.

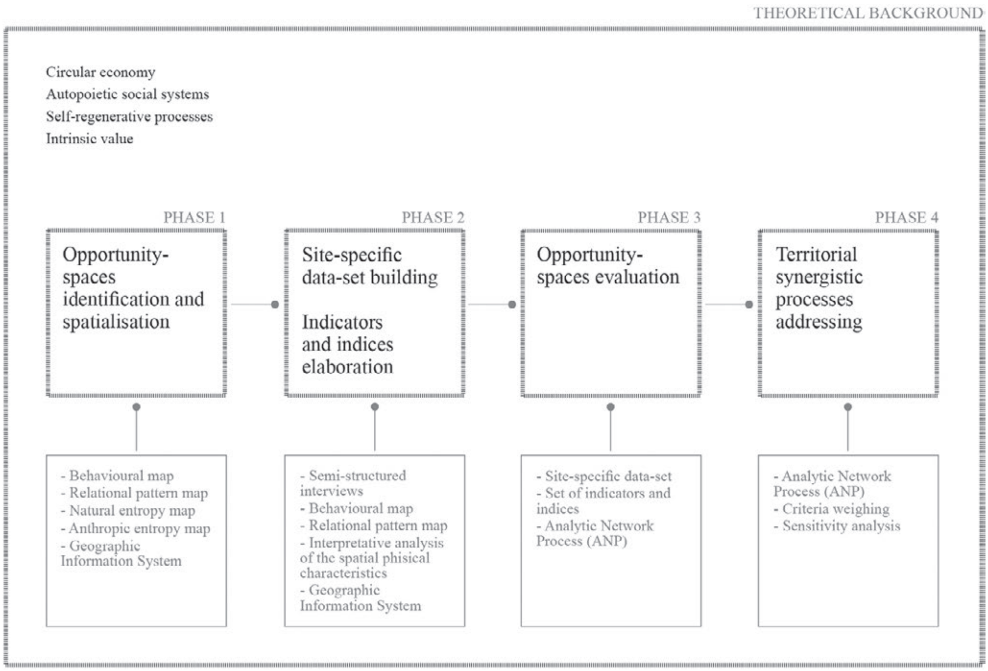
2. Materials and methods

Adopting an ecosystem approach to social systems analysis, the proposed methodology develops an evaluation framework, integrating different data elaboration methods, to catch the different dimensions of values, and, in particular, the immaterial one of the IV.

The methodological structure can be summarised through the following phases (Figure 1):

1. Identifying and spatialising opportunity-spaces, according to the use of space and to the relational dynamics in collective spaces (*2.1*; *4.1*);
2. Building a specific set of quantitative and qualitative indicators, defining the different characteristics and potentials related to each type of opportunity-space (*2.2*; *4.2*);
3. Evaluating the opportunity-spaces, through the categories of organisation, resilience and vitality, and the criteria, specifically defined for the case study, in order to understand the local dynamics depending on IV (*2.3*; *4.3*);
4. Addressing different synergistic processes, based on the identified opportunities (*2.4*; *4.4*).

Figure 1. The methodological framework for the opportunity-spaces evaluation.



2.1 Opportunity-spaces identification and spatialisation

Meaning by *opportunity* the possibility to start or catalyse a cooperative and synergistic process within a space, opportunity-spaces are identified according to the heterogeneous physical characteristics of a space, and to the relational dynamics detectable in this space. Four indices are structured, elaborating the data deriving from different interpretative analysis of the use of space and of people's activity and behaviour according to the use of space itself:

- Environmental entropy H_e;
- Anthropic entropy H_a;
- Complexity of relationships R_c;
- Density of relationships R_d.

These indices are measured through a spatial discretisation, corresponding to a 20x20 meters grid, that is the minimum spatial unit for the values to be assessed. This allows the spatialisation of the measured values within GIS software. For this contribution, *QGIS 3.4* software was used, implementing a GIS-based data-set, collecting the results of the interpretative analysis and the interviews. Below, the elaboration methods of the four indices are described.

The analysed area consists of a very hybrid and heterogeneous territory, with different – natural, rural and anthropic – fabrics and realities overlapping. The characteristic of *the disorder* is, here, considered as an indicator of the urban space metabolic capacity. Today, urban complex systems are interpreted through new categories, shifted from the biological world. Through the studies of landscape ecology (Vranken et al., 2015), the concept of *entropy* has emerged as an indicator of complexity in territorial systems: spatially, it can be interpreted as *heterogeneity*, complexity of the landscape pattern, according to the types of land occupation and their configuration (Fahrig at al., 2005); temporally, as *unpredictability*, instability in landscape evolution. The first one is an indicator of diversity concentration, combination and configuration; the second one of the landscape ability to be resilient, to respond to various types of external pressures, often caused by human activity (Zaccarelli et al., 2013; Zurlini et al., 2013). Shannon's entropy index (Shannon and Weaver, 1948) (Equation 1), having applications to many fields, is being used in territorial and landscape analysis as a measure of: marginal urban landscape complexity (Cerreta and Poli, 2013); urban growth dynamics (Cabral at al., 2013); spatial concentration of information and data (Batty at al., 2014); the built environment morphological structure (Boeing, 2018); informality in temporary spontaneous settlements (Lara-Hernandez et al., 2019).

$$H = -\sum_{i=1}^{n} pi \; ln\, pi \qquad (1)$$

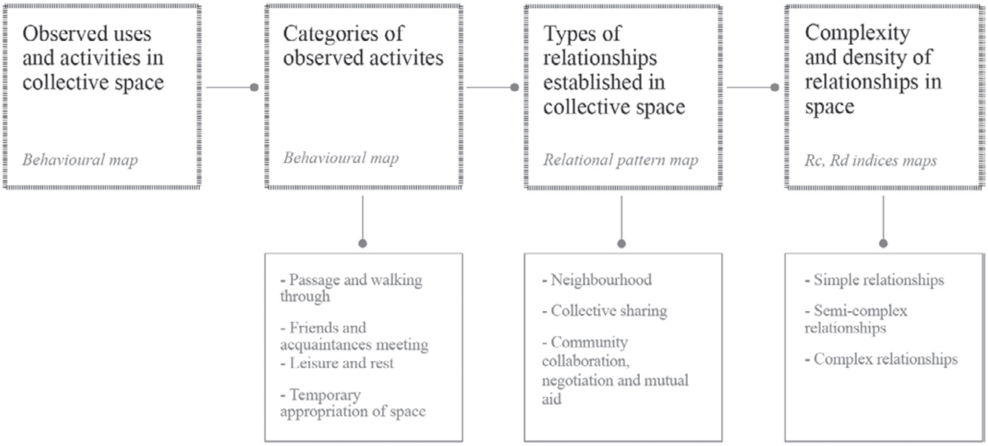
Where: i = considered features; n = number of different features; pi = frequency of the features within the considered area, that is, the probability of finding the features within the considered area, and it is calculated as a ratio between n and n_{max}. H varies from 0 to $ln\ n$. The higher its value, the greater the concentration of heterogeneity or disorder in the analysed space.

Here, two entropy indices are developed: one, expressing *environmental entropy* H_e, and measuring the types of different natural species; the other one, *anthropic entropy* H_a, measuring different characteristics of the built fabric. In particular, H_a takes into account: the presence of buildings, surrounding the analysed area; material alterations and anomalies of these buildings; informal structures; planned and unplanned street furniture; mobile objects of various types, insisting in collective space.

The other two indices derived from the attempt to detect the daily relational dynamics happening within collective space. The literature studying activity patterns in public space has developed the *behavioural mapping* methodology, to inquiry about spatial relations between occupancy and the physical structure of squares and parks in city centres (Goličnik, 2005). It registers the uses of spaces, through different repeated observations, on different days and time; it discusses the results, analysing the activity and behavioural patterns; it uses interactive GIS maps, building an empirical knowledge structure. The behavioural maps elaborated within this research were developed as it follows: observations were conducted on different days and time, over a period of one year; the points of observations were chosen according to the visibility of space; the different observed uses and activities were registered on-site while developing a legend of symbols corresponding the activities (Goličnik, 2005); photographic materials were also collected to support the description of the different activities; the results were then registered through GIS tool, according to the detected categories of uses. Three different maps resulted from this empirical process. The indices elaboration was conducted according to only one map, the one reporting the highest presence of people in space, to consider the highest observed level of spatial sociability. The observed activities were divided into four categories: passage and walking through; friends and acquaintances meeting; leisure and rest; temporary appropriation of space. Each category of activity has been related to a type of relationship, established by people in collective space - this step was possible, because of some short interviews made during the observations: to the first activity category, the relationships of *the neighbourhood*; to the second and the third ones, the relationships of *collective sharing*; to the fourth one, the relationships of *community collaboration*, *negotiation* and *mutual aid* (Figure 2). These types of relationships were classified as: *simple* (relationships of the *neighbourhood*), daily interactions, realised in collective spaces close to the private ones and involving a neighbourhood community; *semi-complex* (relationships of *collective sharing*), constituting potential bonds within a local community; *complex* (relationships of *community collaboration*, *negotiation* and *mutual aid*), generating community ties and common feeling (Figure 2). Through this empirical analysis, a spatial map of social relationships was defined, informing on *which types* of relationships have been realised *where*, and with *which level of frequency*. As a consequence, the two indices, measuring the relational consistency of space, were so defined: *complexity of relationships* R_c, according to the classification mentioned above; *density of relationships* R_d, according to the frequency of people in space, registered through the behavioural map (Figure 2).

According to the interpretative analysis, a first attempt to define the qualitative characteristics of the opportunity-spaces, through some categories, is made,

Figure 2. Behavioural map processing, relational consistency of space.



summarising the main features, that emerged within the different observed spaces, where the relational dynamics were mapped:

- *Relational* space, where the frequency in space, hence the relational density, are high, but these relationships are classified as *simple*;
- *Metabolic* space, where many heterogeneous dynamics seem to be happening in the hybrid space;
- *Residual* space, where the frequency in space is low, but the landscape quality and the presence of green spaces, enable people to establish spatial bonds;
- *Inclusive* space, where complex relationships pattern is very dynamic;
- *Natural-non-anthropised* area, where there is a strong presence of the natural ecosystem, and the frequency of people in space is very low.

In order to spatialise and evaluate them, these attributes are expressed through the *He*, *Ha*, R_c, R_d indices, associating to each type of opportunity-space four value ranges, corresponding to the assessed indices.

2.2 *Site-specific data-set building*

The data have been collected and produced according to four criteria of analysis: services and facilities; use of space and physical characteristics of space; people's behaviour according to the use of space; perception of space. The data production method was based, as already mentioned, on different types of integrated analysis: spatial interpretative analysis, according to the spatial physical characteristics and elements, and the use of space (Nijhuis et al., 2011; Lara-Hernandez et al., 2019); behavioural mapping and social-spatial relationships mapping (Goličnik, 2005; Müller-Eie et al., 2018); consultation with experts and actors; semi-structured interviews (Kallio et al., 2016). The latter were conducted at various levels of the methodological process: to link the activity pattern, detected in space, with the relational one; to integrate the data with information about the daily social habits and practices, happening in space; to measure the perception of space, inclusion and security, the shared sense of place belonging and identity.

The indicators and their domains, referring to the categories of organisation, resilience, vitality, and to the SDG's indicators, highlight the opportunity to activate local synergistic and cooperative processes, as well as the material and immaterial benefits, deriving from them.

2.3 Opportunity-spaces evaluation

The research adopts the Analytic Network Process (ANP) (Saaty, 2006) multicriteria method for the opportunity-spaces evaluation. The ANP is a Multi-Criteria Decision Aid method (MCDA) that overcomes the Analytic Hierarchy Process (AHP) hierarchical structure, allowing the decision problem to be structured through a network model, based on interactions and dependencies among elements, belonging to different hierarchical levels. These are interrelated clusters and nodes, contained within the clusters. ANP method develops a supermatrix, in which the priorities – established through pairwise comparisons, as well as in the AHP method – are integrated. The supermatrix expresses the influence of an element on another one, according to the selected criteria, hence the dependencies among the clusters and the nodes of the network. The ANP, has, indeed, been selected as MCDA method, because it is suitable to represent the decision problem characterised by many interrelations among the chosen criteria and indicators, selected in the evaluation process.

The ANP is able to capture different aspects of "tacit knowledge", and the different elements are grouped into clusters of related factors, and links are made from a parent factor in a cluster to several elements, for example, the alternatives of the decision in another cluster. They may influence the parent or be influenced by the parent with pairwise comparisons being made to establish their priorities. A network is comprised of the clusters, elements and links. According to Saaty (2006) the ANP is based on a descriptive theory that combines these measures to match what people actually do or guides them to do better than they were previously using only qualitative thinking and hunches, and not limited to the top-down thinking of the hierarchic models. A simple network can be extended to complex multi-level models of networks of benefits, opportunities, costs and risks. The software used in this research for the ANP evaluation is *SuperDecisions 3.2*.

2.4 Territorial synergistic processes addressing

In the ANP model of this research, the opportunity-spaces are considered as alternatives; the different processes, that could be activated according to the chosen criteria, are interpreted as clusters; and the indicators as nodes. However, the aim of this evaluation – instead of choosing among alternatives – is to define which type of synergistic process could be better activated within which type of opportunity-space, that is to recognise the territory aspirations and intrinsic features, enhancing them. This result is obtained by progressively attributing different priorities to the clusters and repeating the ranking elaboration for each priority.

When the distinction among some of the opportunity-spaces results to be not very definite, a sensitivity analysis is conducted. Sensitivity analysis allows balancing the uncertainties related to the evaluation output, according to the needs and interests of the actors involved in the decision process. The result can be very much affected by the different sources of involved interests.

3. The case study

3.1 Peri-urban space in Naples

The analysed area is a peri-urban region, located in-between the central urban districts of Naples (Italy) and the inland municipalities, surrounding the city. It is part of Piscinola district, being connected to the historical city centre and the districts on the northern hills through an urban tube line. The study area is very close to the northern part of Capodimonte park – one of the biggest urban park in Naples – and can be located between the limits of the districts of Colli Aminei and Scampia; it is largely included in the Regional Park of the Hills of Naples (Città Metropolitana di Napoli, 2004), being crossed from south-west to north by the northern part of San Rocco valley, a yellow tuff gorge, occupied by large wooded areas (Figure 3). In the 2004 Report of Naples General Master Plan (Comune di Napoli, 2004), the area description underlines the predominantly agricultural use of the territory and the heterogeneous composition of the urban fabric: illegal and

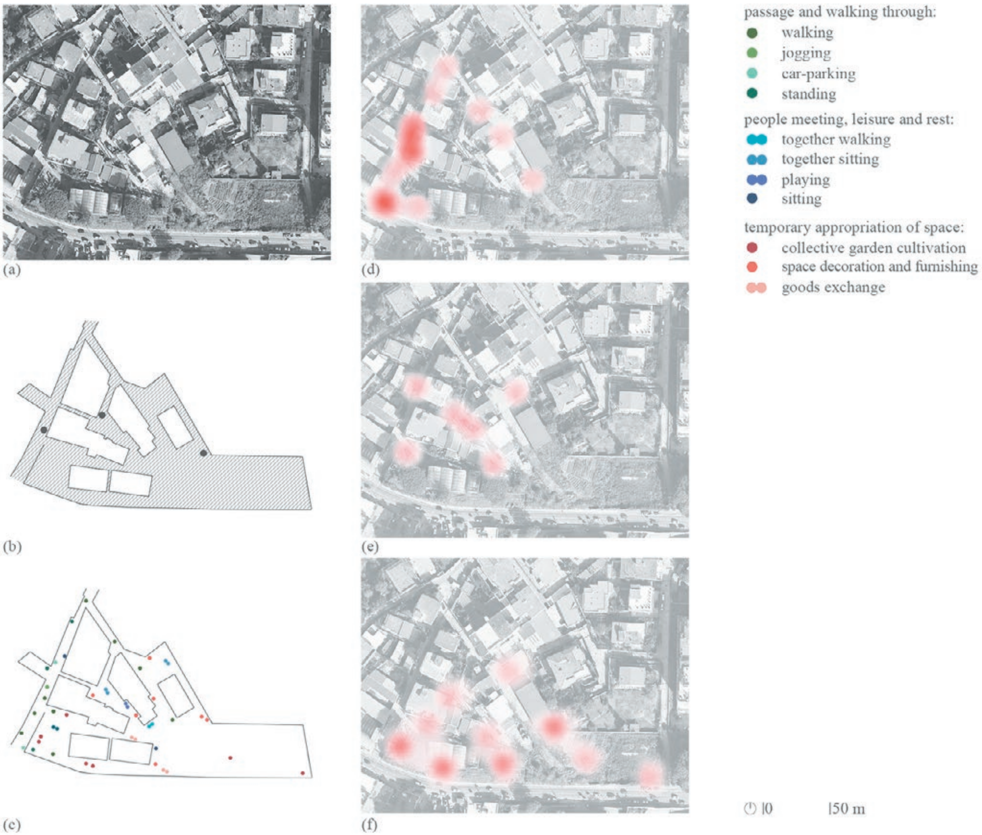
Figure 3. (a) Campania region, Italy; (b) Municipality of Naples, Metropolitan City of Naples; (c) study area, Municipality of Naples; (d) study area, built fabric and urban green areas.

non-normed buildings – constituting an actual new urban fabric – overlap with the cultivated areas, where the presence of farmhouses and rural buildings persists; peri-urban agriculture coexists seamlessly with the urban fragments of ancient and recent formations. San Rocco valley constitutes an extensive ecosystem resource for the city, crossing the urban built fabric and the rural areas. The uncultivated and unused green areas are widely distributed on this territory, resulting from different abandonment processes of rural and productive structures.

3.2 Behavioural mapping, social-spatial relationships

For the behavioural map elaboration, many observations were conducted on different days in ten months. Three of them resulted in being the most interesting, reporting the highest frequency in space: February 5th, 2018 – a Friday after-

Figure 4. (a) exemplificative focus area; (b) points of observation; (c) behavioural map; (d) heath-map for the category *passage and walking through*; (e) heath-map for the category *people meeting, leisure and rest*; (f) heath-map for the category *temporary appropriation of space.*



noon; May 1st, 2018 – a national holiday, celebrating workers' rights; November 17th, 2018 – a Saturday morning. The average observation time for each observation point lasted 30 minutes. In Figure 4, an exemplificative focus area – west of the study area – is shown, reporting the activity pattern registered on November 17th. Different observed uses and activities are represented according to the chosen categories of activities: *passage and walking through* refers to *simple* relationships; *people meeting, leisure and rest* to the *semi-complex* ones; *temporary appropriation of space* to the *complex* ones.

3.3 Spatialisation of He, Ha, R_c, R_d indices, with GIS support

In Figure 5, Environmental entropy (*He*), Anthropic entropy (*Ha*), Complexity of relationships (R_c), Density of relationships (R_d) indices are spatialised, according to the 20x20 meters grid. *Ha* values result higher where commercial and sports facilities are located, and, in particular, within informal and unplanned settlements. *He* values are quite high within agricultural areas and highest within San Rocco valley wooded area. The two indices of relational dynamics define the same areas, with different value intensity: within commercial areas, for example, R_d values result high. In contrast, R_c values are low, that is to say, that these areas are very frequented, but cannot be related to the realisation of spatial bonds among people, since the observed uses are connected to walking through activities. R_c and R_d are spatialised according to a 0-3 based scale, where: 0 stands for those areas in which the activity dynamics are very low; 1, for *simple* (R_c) and *less frequent* (R_d) relationships; 2, for *semi-complex* (R_c) and *frequent* (R_d) relationships; 3, for *complex* (R_c) and *very frequent* (R_d) relationships.

4. Results

4.1 Opportunity-spaces

Following the definitions of the opportunity-spaces (*2.1*), their attributes are expressed through the *He*, *Ha*, R_c, R_d indices, associating each type of opportunity-space to four value ranges, according to the four measured indices (Table 1). *He* varies from 0,00 to 2,00: three equal value ranges are chosen, representing low (0,00-0,67), intermediate (0,67-1,33) and high (1,33-2,00) values. *Ha* varies from 0,05 to 1,92: three equal value ranges are chosen, representing low (0,05-0,67), intermediate (0,67-1,30) and high (1,30-1,92) values. Opportunity-spaces are spatially identified, by matching the *He*, *Ha*, *Rc*, *Rd* values, measured within the 20x20 meters spatial unit grid (Figure 6).

Three clusters of opportunity-spaces result to be located at the three corners of the study area, surrounding the cultivated areas, at the centre of the area. *Natural-non-anthropised* area coincides with San Rocco valley area, crossing the study area, among the three opportunity-spaces clusters. *Relational* spaces are to be found

Figure 5. (a) *Anthropic entropy* H_a; (b) *Environmental entropy* H_e; (c) *Complexity of relationships* R_c; (d) *Density of relationships* R_d.

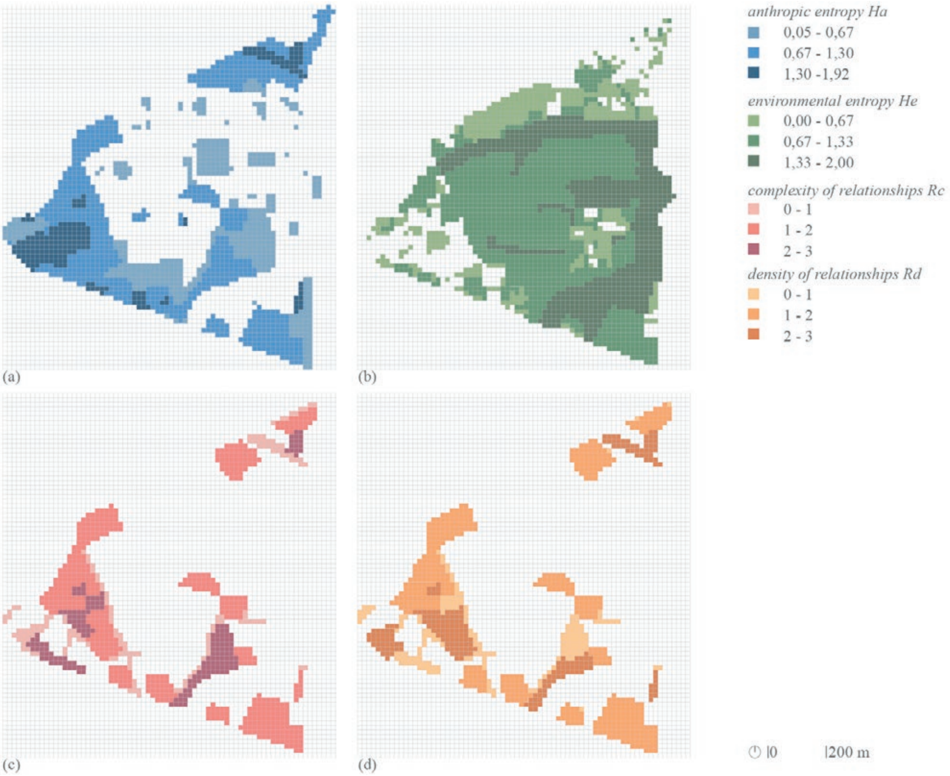


Table 1. Opportunity-spaces definition through value ranges of *He*, *Ha*, R_c, R_d indices.

	Relational	Metabolic	Residual	Inclusive	Natural-non-anthropised
He	0,00-0,67	0,67-1,33	0,67-1,33	0,00-0,67	1,33-2,00
Ha	0,67-1,92	0,67-1,30	0,67-1,30	1,30-1,92	0,05-0,67
Rc	1-2	2	3	3	0
Rd	3	2	1	3	0

near to the busy commercial streets or sports facilities. *Metabolic* spaces are very diffused and individuate those very hybrid areas, where the built fabric – often productive and storage buildings – and the rural one overlap, generating continuity zones among the mix-used areas. *Residual* spaces identify the various unused green areas, resulting from heterogeneous urbanisation processes: the inhabitants are now using these areas as collective gardens or unplanned parks, where to go

Figure 6. Opportunity-spaces spatialisation.

walking or jogging; they function as small green infrastructures within the urban fabric. *Inclusive* spaces are located in-between other zones, within more protected and inner areas, with indirect contact with the busy streets surrounding the study areas: these spaces include collective and shared semi-public-private threshold spaces among the housing buildings and the informal dwellings, shared courtyards and small neighbourhood streets.

4.2 Site-specific set of indicators

The selected set of 39 indicators and 13 domains is reported in Table 2. Each indicator refers to a specific SDG, while each domain to the categories of organisation, resilience and vitality, within the social-urban contexts. Quantitative and qualitative indicators values are reported in Appendix A, Table A1. With the exception for *Natural-non-anthropised area*s – being the area just a wide continuous one – indicators values are assessed within exemplificative opportunity-spaces, with a similar and comparable extension, for each type: in particular, the south-western identified spaces are considered. The relation among the domains, the possible synergistic processes and the different types of values is shown in Table 3.

Table 2. Site-specific set of indicators, for the opportunity-spaces evaluation.

Domain	Indicator	Indicator code	Data production method	Data source	Rel. to SDG's	Rel. to O-R-V
Local Attractiveness	Sights and landmarks	LA1	Spatial interpr. analysis	Authors' elaboration	11	Cultural and Economic Vitality
	Cultural facilities (cinemas, museums, theatres)	LA2	Open map consultation	OpenStreetMap	11	
	Commercial activities	LA3	Open map consultation	OpenStreetMap	8	
	Touristic facilities (hotels, b&b, renting rooms)	LA4	Open map consultation	OpenStreetMap	8	
Connectivity and Permeability	Public transport (near-by stops)	CP1	Open map consultation	OpenStreetMap	9	Urban Resilience
	Pedestrian paths, usable by people with disability	CP2	Open map consultation	OpenStreetMap	11	
	Cyclable paths	CP3	Open map consultation	OpenStreetMap	8	
	Parking lots	CP4	Open map consultation	OpenStreetMap	9	
Sociability	Density of relationships and people meeting in space	S1	Behavioural mapping	Authors' elaboration	11	Social Vitality
	Relational dynamics within the district	S2	Behavioural mapping	Authors' elaboration	11	
Common Green spaces	Accessible, non-fenced or privatized green spaces and parks	CG1	Open map consultation	OpenStreetMap	15	Urban Resilience
	Abandoned green areas of uncertain property	CG2	Spatial interpr. analysis	Authors' elaboration	15	
	Green spaces, used as community gardens	CG3	Spatial interpr. analysis	Authors' elaboration	15	
Negotiation	Informal spatial negotiation	N1	Semi-structured interviews	Authors' elaboration	11	Social Organisation and Cooperation
	Goods exchange	N2	Semi-structured interviews	Authors' elaboration	11	

Domain	Indicator	Indicator code	Data production method	Data source	Rel. to SDG's	Rel. to O-R-V
Mixed Use of space	Buildings uses and functions	MU1	Open map consultation	OpenStreetMap	11	Urban Resilience
	Public space uses and functions	MU2	Spatial interpr. analysis	Authors' elaboration	11	
Temporary Use of space	Daily/weekly uses and activity in public space	TU1	Behavioural mapping	Authors' elaboration	11	Urban Resilience
	Monthly uses and activity in space	TU2	Collection of news about public events	Websites of the Municipality and of the local associations	11	
Creativity	People's collective problem-solving capacity	C1	Semi-structured interviews	Authors' elaboration	11	Social Resilience
	Spontaneous actions and practices that could trigger new processes	C2	Semi-structured interviews	Authors' elaboration	11	
	Recycle and reuse processes	C3	Semi-structured interviews	Authors' elaboration	11	
Appropriation of Space	Public space occupied by people for daily practices	AS1	Semi-structured interviews	Authors' elaboration	11	Social Resilience
	Unplanned objects and furniture insisting on public space	AS2	Semi-structured interviews	Authors' elaboration	11	
	Threshold spaces of indoors-outdoors continuity	AS3	Semi-structured interviews	Authors' elaboration	11	
Communal Praxis and Networking	Neighbourhood informal initiatives and associations	CPN1	Semi-structured interviews	Authors' elaboration	11	Social Organisation and Cooperation
	Daily practices shared by people meeting in collective spaces	CPN2	Semi-structured interviews	Authors' elaboration	11	
	Complexity of relationships and bonds in space	CPN3	Semi-structured interviews	Authors' elaboration	11	

Domain	Indicator	Indicator code	Data production method	Data source	Rel. to SDG's	Rel. to O-R-V
Inclusion and Participation	Openness to externalities by a consolidated community	IP1	Semi-structured interviews	Authors' elaboration	11	Social Organisation and Cooperation
	Self-organized maintenance and cleaning of shared space	IP2	Semi-structured interviews	Authors' elaboration	11	
	People's involvement and interest in shared space defining	IP3	Semi-structured interviews	Authors' elaboration	11	
Place Identity	Space distinguishability and peculiar characteristics	PI1	Semi-structured interviews	Authors' elaboration	11	Social Vitality
	Sense of belonging to a neighbourhood/district	PI2	Semi-structured interviews	Authors' elaboration	11	
	Social habits derived from the specific local anthropisation	PI3	Semi-structured interviews	Authors' elaboration	11	
	Sense of security in public space	PI4	Semi-structured interviews	Authors' elaboration	11	
Urban Ecosystem	Wooded non-anhropised areas	UE1	Open map consultation	OpenStreetMap	15	Ecosystem Resilience
	Typical natural species	UE2	Local botanical expert consultation	OpenStreetMap	15	

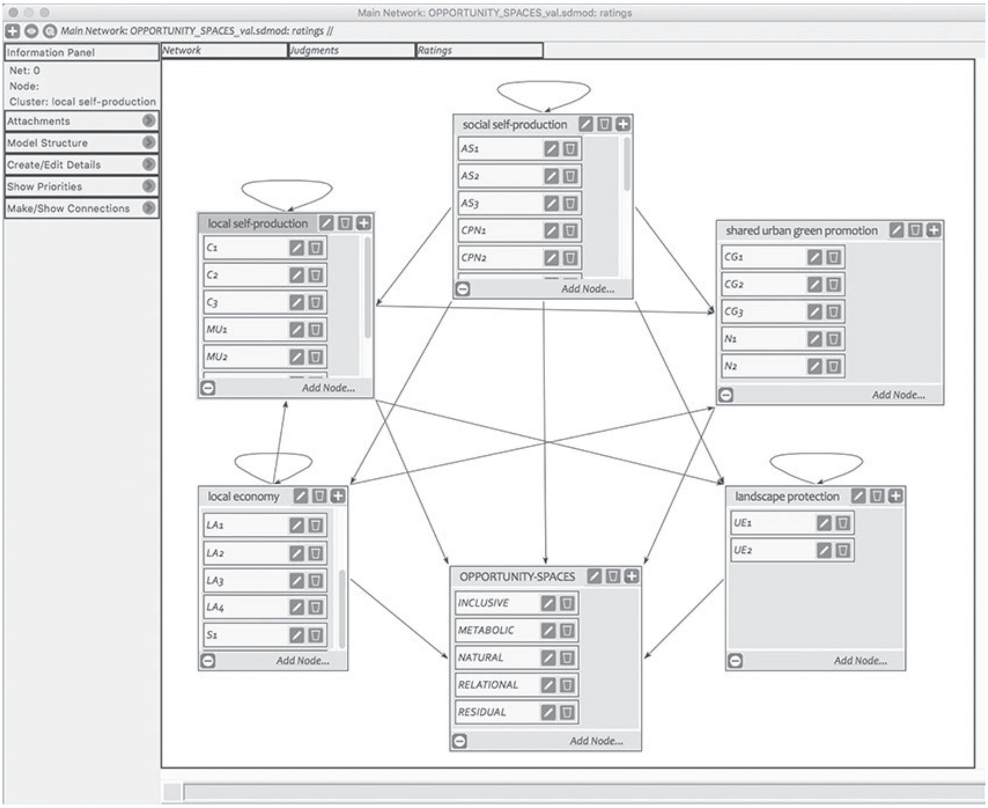
Table 3. Indicators domains, synergistic processes, benefits and values.

Process	Synergies	Benefit	Value	Domain
Local economy	Local enterprises and local administration	Local profits	Use value	Local Attractiveness
				Connectivity and Permeability
				Sociability
Shared urban green promotion	Cooperatives of inhabitants and local administration	Exchange of local products and social benefits	Use value and Intrinsic value	Common Green spaces
				Negotiation
Local self-production	Cooperatives of inhabitants	Exchange of local products and resources	Use value	Mixed Use of space
				Temporary Use of space
				Creativity
Social self-production	Open community of inhabitants	Mutual support and collective identity	Intrinsic value	Appropriation of Space
				Communal Praxis and Networking
				Inclusion and Participation
				Place Identity
Landscape enhancement and protection	Local associations and local administration	Ecosystem services	Non-use value	Urban Ecosystem

4.3 Opportunity-spaces evaluation with ANP method

The ANP network model is structured through 6 clusters (5 processes + 1 cluster for the opportunity-spaces) e 39 nodes, corresponding to the indicators. Connections and dependencies are established among elements of different clusters – network arrows – and of the same cluster – network loop arrows (Figure 7). The influence matrix shows these different dependencies among the elements (Figure 8). The opportunity spaces ratings, deriving from the overall ranking, result to be very similar, with the exception for the *Natural-non-anthropised area*, where – as it was, already evident, from the selected indicators and evaluation inputs – the only possible processes should be addressed towards the protection

Figure 7. ANP network model, screenshot from *SuperDecisions* software.



and maintenance of its integrity. The differences among the opportunity-spaces will emerge in the next phase, by attributing different priorities to the clusters.

4.4 Opportunities and processes

By progressively attributing different priorities to the clusters (Figure 9), each opportunity-space is related to the process that better responds to its features and relational dynamics. In particular: the *Natural-non-anthropised* area is connected to the mechanism of landscape protection and enhancement; *Relational* spaces result to better catalyse public and private initiatives of local economic development; within *Metabolic* spaces, cooperative processes of local production could be activated; *Inclusive* spaces are to be considered as a spatial realisation of those immaterial and intangible processes of social self-production; *Residual* spaces could be linked to cooperative processes, related to sharing mechanisms, as well. As regards the possibility to promote the collective sharing of urban green areas, all four spaces – *Relational, Metabolic, Inclusive, Residual* – seem to respond very well, having very

Figure 8. Influence matrix, derived from the ANP method application.

		Opportunity spaces					Local economy										Shared urban green promotion					Local self production							Social self production													Land. enh.	
		Rel.	Mrt.	Res.	Incl.	Nat.	LA1	LA2	LA3	LA4	CP1	CP2	CP3	CP4	S1	S2	CG1	CG2	CG3	N1	N2	MU1	MU2	TU1	TU2	C1	C2	C3	AS1	AS2	AS3	CPN1	CPN2	CPN3	IP1	IP2	IP3	PI1	PI2	PI3	PI4	UE1	UE2
Opportunity-spaces	Rel.						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Mrt.						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Res.						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Incl.						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Nat.						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Local economy	LA1	x	x	x	x	x																																					
	LA2	x	x	x	x	x									x	x																											
	LA3	x	x	x	x	x									x	x																											
	LA4	x	x	x	x	x									x	x																											
	CP1	x	x	x	x	x									x	x	x	x	x			x	x																				
	CP2	x	x	x	x	x									x	x	x	x	x			x	x																				
	CP3	x	x	x	x	x									x	x	x	x	x			x	x																				
	CP4	x	x	x	x	x																																					
	S1	x	x	x	x	x																																					
	S2	x	x	x	x	x																																					
Shared urban green promotion	CG1	x	x	x	x	x																																					
	CG2	x	x	x	x	x																																					
	CG3	x	x	x	x	x																																					
	N1	x	x	x	x	x																																					
	N2	x	x	x	x	x																																					
Local self production	MU1	x	x	x	x	x																																					
	MU2	x	x	x	x	x																																					
	TU1	x	x	x	x	x																																					
	TU2	x	x	x	x	x																																					
	C1	x	x	x	x	x											x	x	x					x	x																		
	C2	x	x	x	x	x											x	x	x					x	x																		
	C3	x	x	x	x	x											x	x	x																							x	
Social self-production	AS1	x	x	x	x	x														x	x																	x	x	x	x		
	AS2	x	x	x	x	x														x	x																	x	x	x	x		
	AS3	x	x	x	x	x														x	x																	x	x	x	x		
	CPN1	x	x	x	x	x																							x	x	x							x	x	x	x	x	
	CPN2	x	x	x	x	x																							x	x	x							x	x	x	x		
	CPN3	x	x	x	x	x																																					
	IP1	x	x	x	x	x									x	x				x	x													x				x	x	x	x		
	IP2	x	x	x	x	x									x	x				x	x													x				x	x	x	x		
	IP3	x	x	x	x	x									x	x				x	x													x				x	x	x	x		
	PI1	x	x	x	x	x																																					
	PI2	x	x	x	x	x																																					
	PI3	x	x	x	x	x																																					
	PI4	x	x	x	x	x																																					
Landscape enhancement	UE1	x	x	x	x	x																																					x
	UE2	x	x	x	x	x																																					

Figure 9. Different priorities attributed to the clusters, screenshots from *SuperDecisions* software: (a) Local economy; (b) Shared urban green promotion; (c) Local self-production; (d) Social self-production.

(a) (b) (c) (d)

close ranking values (Figure 10). For this last option, a sensitivity analysis is conducted, aiming at better addressing the result. The results are not very much influenced, when changing weights, that is, in ANP model, changing node for sen-

Figure 10. Different rankings according to the priorities, screenshots from *SuperDecisions* software: (a) Local economy; (b) Shared urban green promotion; (c) Local self-production; (d) Social self-production.

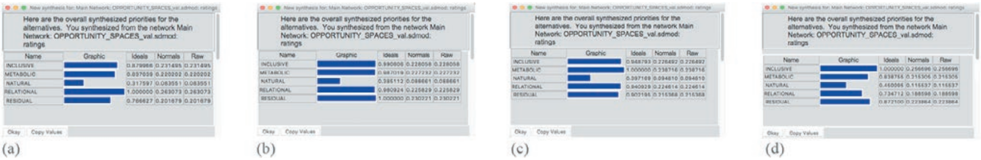


Table 4. Opportunity-spaces, processes and synergies.

	Relational	Metabolic	Residual	Inclusive	Natural-non-anthropised
Processes	Local economy; Shared urban green promotion	Local self-production; Shared urban green promotion	Social self-production; Shared urban green promotion	Social self-production; Shared urban green promotion	Landscape enhancement and protection
Synergies	Local enterprises, Local administration, Cooperatives of inhabitants	Cooperatives of inhabitants	Open community of inhabitants, Cooperatives of inhabitants	Open community of inhabitants, Cooperatives of inhabitants	Local associations and local administration

sitivity, with two exceptions: when choosing CG2 indicator – *Abandoned green areas of uncertain property* – as a node for sensitivity, *Metabolic, Inclusive, Residual* spaces have almost the same values, while *Residual* spaces have the lower one; on the contrary, when choosing S1 indicator – *Density of relationships and people meeting in space* – *Residual* spaces obtain the highest value. The evaluation results are synthesised in Table 4.

Furthermore, the obtained results highlight how processes of circularity can be addressed, by enhancing existing processes of self-organisation among people, individual and community actors, whose cooperation is fundamental for the activation of systemic self-regenerative mechanisms. Starting from the strong connection between collective spaces within peri-urban areas and the relational pattern, detectable in these spaces, the opportunity-spaces evaluation allows linking the socio-spatial dimension with circular and self-renewable processes, based on the implementation of social synergies. At a local scale, the activation of processes of shared urban green promotion and landscape protection could involve cooperatives of inhabitants in the collaborative maintenance of green areas, which, enabling social negotiation and cooperation, would result in the local managing of green resources and waste and in the implementation of a much more symbiotic relationship between urban space and green infrastructures. The formation of local enterprises could define new business models, building a constant conversation with the inhabitants, about their needs and habits, aiming at offering them missing or new services. Processes promoting the production of social and community bonds and spaces would reverse the development logic based on the maximisation of economic capital, allowing the production of social capital and new intrinsic values. At a territorial and urban scale, the activation of the mentioned processes could lead towards a synergic dialogue among cooperatives of inhabitants-stakeholders and the local administration, providing the base on which CE strategies could be implemented on a wider scale, through a bottom-up regulation of systems of rules and policies.

5. Discussion and Conclusion

The research aims at proposing a multi-methodological approach for the interpretation and evaluation of peri-urban hybrid territories, through an autopoietic thinking. The literature that studies and evaluates social ecosystems complexity – shifting its categories from the vital mechanisms of natural ecosystems – refers to their capacity to activate and self-regenerate processes, while establishing connections among the elements (Luhmann, 1986; Zeleny and Hufford, 1992; Quick, 2003; Bača, 2007; Zeleny, 2009; Schatten, Bača, 2010). The network of connections and relationships is what makes the system adaptive (Gunderson and Holling, 2002; Locurcio et al., 2019), the diversity of its components makes it resilient (Costanza, 1992), the dynamics of shared and interdependent activities and practices make it productive, alive (Hardt and Negri, 2011). The study interprets the spatial heterogeneity of the analysed area as a physical manifestation of an entropic and productive mechanism, whose functioning depends on the territory capacity to allow the establishment and growth of a systemic and adaptive network of relationships among people. As a consequence, reading and evaluating this territory through spatial opportunities means understanding and measuring its metabolic capacity to self-regenerate, strengthening the intangible connections, that people establish within a place and among themselves, by using collective spaces. In this sense, the concepts of natural ecosystem self-renewability and CE renewable closed-loop processes (Stahel, 1982) have driven the research towards the evaluation of self-regenerative territorial capacities and opportunities, based on social capital self-production (Cerreta, 2010).

The first methodological step identifies opportunities in space by measuring its entropic physical characteristics and detecting its relational dynamics. Entropy index constitutes a fundamental measure of territorial complexity: here, its application attempts to provide a measure not only of landscape complexity – as in the case of wooded and residual green areas – but of public and shared built spaces, as well. The effectiveness of the defined *Anthropic entropy index* depends on the categories and types of analysed characteristics: the empirical surveys collected just a few of the many spatial characteristics, aiming at making space informal and spontaneous uses evident. Choosing different categories of elements and characteristics could probably make the spatial interpretation vary. As regards the relational dynamics spatialization, it is based on empirical and subjective data, as well – activity and behavioural mapping and interviews – and its results are very sensitive to observations duration and days. However, this approach results to be useful to deeper understand the reinvented use of collective spaces and abandoned areas, and the role that these ambiguous hybrid spaces play in the peri-urban system and how they influence people's daily habits.

The second step aims at providing a site-specific declination of SDG's indicators categories, referring to social and community empowerment – in particular, Goal 11^{th} – through the production of inclusive and resilient spaces. The set of selected indicators draws a parallel among SDG's categories and those of organisation, resilience and vitality, deriving from the natural ecosystem literature. The O-R-V indicators are, here, referred to with a spatial-social meaning, and address the evaluation towards intangible values. This phase constitutes the methodological base for the intrinsic-value-based evaluation. O-R-V indicators refer to wide territorial issues but allow to think through ecosystems categories: the system structure and network of informative connections; the diversity and heterogeneity of the system components; the system self-production capacity. In terms of social and common urban systems, these categories can be understood as: cooperation and self-organisation; inclusion and acceptance of externalities, and social creativity; social self-production capacity. The criticalities emerging in this phase refer to the inconsistency of some of the data, collected through semi-structured-interviews: the qualitative indicators values result from the processing of reduced number of interviews, compared to the total number of conducted interviews. For this reason, in order to develop the research, it could be useful to integrate the proposed methodology with other evaluation methods, taking into account other types of measurement, such as linguistic and fuzzy judgements.

The application of ANP network model for the opportunity-spaces evaluation allows: taking into account the relative interdependences among the structure elements, underlining, for example, the close relationship among services, space uses and sociability, and participation in space definition processes; considering the dependences of many different indicators to the ones related to social practices and behaviour in space. The results are very sensitive to the network structure and to the chosen priorities and weights, suggesting how decisions, according to the identified opportunities, depend very much on the interests and possible synergies involved in the local processes catalysation: a collaborative table for the weights attribution would potentiate a so structured model. However, if on one hand, ANP method is very useful to grasp the complexity of the proposed issues related to peri-urban systems, on the other, its downsides emerge when it is applied through the direct involvement of stakeholders in the decision-making process: the decision problem modelling would become more difficult and the network more complex; the questionnaires filling could require more time and effort, to define the priorities among criteria and indicators; as a consequence, the decision problem results could become of much more problematic interpretation.

Finally, the chosen categories of opportunity-spaces are indicative of local mechanisms and depend on the specific detected characteristics: further researches could improve the definition of these categories, constituting a decision support system for peri-urban territories, and addressing processes of territorial heterogeneity enhancement and local communities empowerment, toward the establishment of local *eco-communities* consistent with CE processes.

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Appendix A

In Table A1 (Table A1), the indicators values are reported. As explained in (*4.2*), they have been measured within chosen example opportunity-spaces for each type.

Qualitative indicators are expressed through a 0-3 scale, with: 0 = non-present quality; 1 = modest quality; 2 = significant quality; 3 = very significant quality.

Table A1. Indicators values.

Indicator code	Measure unit	Relational	Metabolic	Residual	Inclusive	Natural-non-anthropised
LA1	number	3	1	0	0	2
LA2	number	2	0	0	0	0
LA3	number	6	1	0	0	0
LA4	number	4	1	0	1	2
CP1	number	4	2	2	1	2
CP2	m^2	3.026,22	1.285,39	587,68	651,29	0,00
CP3	m^2	1.738,93	193,29	206,36	464,28	0,00
CP4	m^2	188,23	99,27	0,00	0,00	0,00
S1	0-3	3	2	1	3	0
S2	0-3	3	1	1	2	1
CG1	m^2	184,28	3.268,27	4.233,58	199,73	0,00
CG2	m^2	53,29	2.495,39	8.239,37	0,00	0,00
CG3	m^2	1.235,64	2.465,78	3.760,39	0,00	0,00
N1	0-3	1	2	3	2	0
N2	0-3	2	1	3	2	0
MU1	number	3	5	1	1	1
MU2	number	2	4	3	2	1
TU1	number	1	3	2	1	1
TU2	number	2	4	2	1	1
C1	0-3	1	3	2	2	1
C2	0-3	1	3	3	2	1
C3	number	1	3	2	1	0

Indicator code	Measure unit	Relational	Metabolic	Residual	Inclusive	Natural-non-anthropised
AS1	m^2	0,00	331,28	125,39	942,34	0,00
AS2	number	2	8	3	12	0
AS3	m^2	52,30	0,00	0,00	218,29	0,00
CPN1	number	1	2	2	3	1
CPN2	0-3	1	1	2	3	0
CPN3	0-3	1	2	3	3	0
IP1	0-3	2	1	2	3	2
IP2	0-3	1	1	2	3	0
IP3	0-3	1	2	2	3	2
PI1	0-3	1	1	2	3	2
PI2	0-3	1	2	2	3	2
PI3	0-3	1	1	2	3	2
PI4	0-3	2	2	2	3	2
UE1	m^2	0,00	0,00	0,00	0,00	210.472,93
UE2	number	0	2	5	0	15