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Ontological and formal analysis in representation of, and for, the spatial organization of the built environment:
examining assumptions and ambiguities across description and prescription in spatial planning

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Settore Scientifico Disciplinare CEAR-12/A

Dottoranda
Dott. Guadagnoli Giulia

(firma)

Tutor
Prof. Perrone Camilla

(firma)

Co-tutor
Borgo Stefano PhD, ISTC-CNR

(firma)

Coordinatore
PROF. PAOLA GALLO

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Abstract

Applied ontology, the study of a-priori distinctions structuring knowledge representation and modeling in a given domain, provides an explicit framework for semantics to unambiguously articulate and organize the meanings of concepts and language expressions. Spatial planning and planning behaviour, the multi-level decision-making processes engaging individuals, communities and institutions in the organization of the built environment, require shared frameworks and meanings, explicit assumptions and constrained ambiguities. This dissertation addresses this convergence with regard to the spatial representation of the built environment, understood as cutting across knowledge construction and normative action, across description of and prescription for the built environment spatial organization. As key constituents of spatial planning, description and prescription both work by designating attributes of areas of land or elevated ground, describing either a knowledge base on what these areas are, or a proposal regarding what these areas can or should be. The identification of areas for these designations depends on concepts of spatial information and on the models of spatial representation built with these concepts. Qualitative Spatial Representation and Geographic Information Science show that concepts of spatial information carry ontological assumptions about space and spatial organization. This dissertation inquires on the ontological assumptions carried by concepts used to represent, define, identify and visualize, parts of the built environment in spatial planning, and on the opportunities and constraints for knowledge and action created by these assumptions. The use of geometric concepts is taken-for-granted in geography and architecture, and therefore in spatial planning, because of a wide-spread assumption synecdochically conflating spatial representation with Euclidean geometry. This synecdoche enables a specific a-priori allowance of implicitness for certain concepts of spatial information. Therefore, the assumptions behind the use of these concepts and related models are left unchecked, generating ambiguities in their intended meanings. By drawing on scholarship in applied ontology and qualitative spatial representation, this research explores an approach to make these assumptions explicit, expanding the set of concepts and supporting distinctions among natural language expressions in spatial planning. It does so by tapping on mereology, the study of part-whole relations, and mereotopology, the intersection of mereology and topology as the study of the connection relation. By cross-referencing different sources, the research explains the association between the representation of spatial organization and the decisions by which spatial planning contributes to organize the built environment, assuming that diversifying options for the former diversifies options for the latter. Questioning this association between representation and planning behaviour is particularly relevant for concepts of spatial information, given their specific condition of implicitness. It allows to track more systematically the coherency between their meanings and both the intent and the paradigm of reference in the planning process at stake. Qualitative spatial representation offers a rich set of formal principles of spatial organization as partial ordering, principles considered in this research as building blocks of spatial imaginaries, providing the vocabulary for mental models of places and spatial organization. Along these lines, a case study from the city of Bologna, in Italy, examines the ontological assumptions behind the use of different concepts of spatial information to identify target areas of spatial planning regulations and spatially explicit policies. The case study provides one example of the practical applications of this approach in the context of heritage policy making. Finally, the discussion on the findings from the case study highlights the role of concepts of spatial information and related models of spatial representation, and therefore of semantics and applied ontology, bridging description and prescription towards the construction of spatial imaginaries sensitive to spatial relations of parthood and connection.

1. Introduction: representation, planning and the spatial organization of the built environment

"Intelligence organizes the world by organizing itself"
(Jean Piaget, cit. in von Glasersfeld, 2007)

This dissertation builds the case for taking inspiration from the domain of qualitative spatial representation (QSR) to increase and diversify options for the representation of the spatial organization of the built environment. It explains the relevance of such diversification to spatial planning by inquiring on the role of representation in knowledge construction and normative action, description and prescription, in spatial planning and planning behaviour (De Roo & Perrone, 2020). The definition of representation as a signifying practice (Hall, 1997) points to its descriptive and prescriptive role in the construction of meaning. In the domain of spatial planning, the spatial organization of the built environment constitutes a primary subject of representation, description and prescription. Semantics as the study of meanings conveyed through representation, articulates the meaning of any sort of conceptual representation based on ontological assumptions. Likewise, these assumptions lay the bedrock for the adoption of models of spatial representation in spatial planning and spatially explicit policy making. These models use spatial concepts to define, identify and visualize geographic entities such as parts of the built environment, or of the Earth crust more broadly. Definition, identification and visualization are all acts of spatial representation, enacted in spatial planning to assign descriptive and/or regulatory attributes to geographic entities, often carrying implicit ontological assumptions and semantic ambiguities. In statutory planning, such designations mainly work by the subdivision of land into discrete units typical of so called Euclidean land zoning (Savini, 2021; see also Friedmann, 1993, 1994; Alexander E. R., 1994). Moreover, representation of geographic entities in different types of planning, statutory or strategic, generally operates by spatial concepts corresponding to geometric shapes, georeferenced or not, regardless of the various graphic languages and mapping styles adopted for spatial visualization. Focusing on the built environment, standard heritage protection policies and plans provide a particularly stark example of this tendency, promoted through "authorized heritage discourse" as defined by Laurajane Smith (cit. in Bonfiglioli, 2024). According to this discourse, regulation for the preservation of tangible urban heritage assets relies on the identification of a bounded area including the assets of interest within its perimeter (UNESCO, 2017). In this light, this research stems from the observation that architecture, geography and spatial planning preferably conflate spatial representation and Euclidean geometry, leaving the assumptions behind the use of geometric representation implicit. An ontological approach to semantic interpretation in QSR formalism, the dissertation contends, makes the assumptions behind the choice of concepts and models of representation as much as possible explicit. Adopting this approach in spatial planning enables scrutiny and reflection on options for diversification. Adopting in this case requires a degree of adaptation, taking the results of the ontological formalization of natural language back to natural language, borrowing and adapting insights across domains belonging to different disciplines. This constitutes an experimental endeavour which makes of the case study for this research a pilot whose evaluation can provide criteria for standardization through further transdisciplinary engagement. The research questions attend to this aim by exploring:

- what are the ontological assumptions behind the different concepts of spatial information with which we represent and identify parts of the built environment in spatial planning?
- how do these assumptions translate into concrete opportunities and constraints for knowledge production and normative action on the spatial organization of the built environment in spatial planning?

The state-of-the-art corroborates the novelty of these questions by showing that models of spatial organization and its representation, regardless of the confirmation of their teleological nature in geographic information science, are not taken into consideration in the conversation about sense-making or problem-setting, nor in the one about spatial imaginaries. The novelty of these questions found further confirmation in the reactions of interlocutors regarding the scope of the research. Indeed, these reactions highlighted, in both fellow scholars and stakeholders in the case study, a lack of consideration for the very possibility that models of spatial representation alternative to Euclidean geometry may identify areas for planning designations.

This dissertation refers to spatial planning and planning behaviour as the multi-level (De Roo & Perrone, 2020) decision-making processes of individuals, communities and institutions aimed at organizing the built environment at the different scales relevant to human settlement processes, predominantly in geographical areas subject to statutory legislation and modern property law. This entails a primary focus on planning behaviour by public authorities but could as well apply to other types of decision-making bodies. In John Friedmann classic definition, these decision-making processes enact planning as the relation between knowledge and action (Friedmann, 1987). Organization, in turn, refers to the multi-agent and multi-level process of introducing a certain degree of order (Moroni et al., 2020) into a given context, and to the layout embodying such order as a result of this process. Furthermore, the focus on spatial organization entails that the context at stake has a spatial extension, such as the built environment. In relation to spatial planning, spatial organization stands as the layout subject of planning knowledge and the process resulting from planning action. In this sense, the intersection between spatial ontology and spatial planning lies in the fact that ontology and semantics contribute to organize the built environment through representation of knowledge about what is, and of the norms leading to what can or should be. This observation relies on a constructivist and normative (Davoudi, 2016) reading of the relation meaning-information-purpose, connecting semantics, knowledge and action.

The state-of-the-art provides the rationale behind the research questions and their relevance in the domain of spatial planning. By cross-referencing different sources, it explains the connection between the representation of spatial organization and the decisions by which spatial planning organizes the built environment, assuming that diversifying options for the former diversifies options for the latter. It does so in three steps corresponding to three sections of the chapter, 2.a, 2.b and 2.c. Section 2.a locates this dissertation in relation to shared intellectual traditions in planning and computer science, building the case for trans-disciplinary collaboration between scholars sharing a pluralist standpoint. Sections 2.b and 2.c explain the disciplinary relevance of applied ontology and semantics in the design disciplines in general, then zooming in on spatial planning in particular.

To further support the argument on the role of applied ontology, semantics and representation in spatial planning, the methodology chapter presents insights from applied ontology and QSR, explaining their aptitude to make the necessary distinctions to diversify spatial representation. Section 3.a in the methodology chapter introduces key aspects of diversification between geometric, mereological and mereotopological models of spatial representation to highlight concerns and questions regarding the representation of geographic entities in spatial planning. In so doing, it provides a repository of principles for the representation of spatiality. The second section focuses on the case study, presenting the approach, the key interlocutors and the research methods adopted with each group of interlocutors during the field work. Afterwards, the case study addresses the research questions in specific circumstances, dealing with a peculiar part of the built environment, the porticoes of Bologna in Italy, explaining how they elude geometric representation and the contested process of their representation as bounded vectorial objects in a concrete case of spatially explicit policy making. The problem of their elusiveness offers a fertile ground to answer the research questions, as it led to contestations and contradictions regarding the use of different concepts of spatial information to identify the porticoes in the context of their nomination as UNESCO World Heritage. The evidence compares the different solutions adopted within the reporting process for the UNESCO nomination and inscription in the World Heritage List and within municipal spatial planning, to represent and identify the porticoes as the target area of heritage protection regulations and policies. The debates occurred along this process, as observed by this dissertation's author during her internship at the Municipality, also demonstrate the nexus between description and prescription intrinsic in the representation of parts of the built environment, and possibly of space in general.

The chapter presenting the case study addresses the research questions incrementally. The first section provides a historical background on the emergence of the contemporary *ensemble*, or whole, evoked by the notion of "the porticoes of Bologna". The second section explains the multiple attempts to define it by conventional geometric concepts, along the reporting process for the nomination of the porticoes of Bologna to the UNESCO World Heritage List. It discusses these attempts in the light of the underlying references to parthood and connection relations raised by the research interlocutors. It also evokes ontological, mereological and mereotopological principles relevant to the problems of representation raised during the process. The heterogeneity of actors and functions featured in the history of the construction of porticoes in the city supports a reading of the "porticoed city" as the result of a mix of statutory and customary normativity, integrating enforced and spontaneous behavior (De Roo, 2020). This mix reflects the emergence of a spatial imaginary, together with the physical infrastructure which inspires it, by the repetition of a pattern sustained throughout the typically unstable history of Italian cities, from the Middle Ages to the national unification, through the world wars, the reconstruction and the rampant urbanization which prevailed ever since. Emergence by heterogeneity supports the observation of the porticoes of Bologna as an unfolding whole generating its own parts, like the embryo in a classic metaphor by Christopher Alexander (1979, 2002). It suggests looking at spatial organization as both a state, or result of a process, and an action engendering a process, displaying a kind of agency expressed in the interaction between parts of the (built) environment. It also explains its elusiveness to geometric representation in a multi-dimensional way. This multidimensionality includes at least three trajectories, plus another centripetal one, with the most common reading of the porticoes as interfaces between solid and void, public and private, accounting for only one among these. The third section takes the case study beyond the initial focus of the previous section on heritage preservation. It examines the spatial patterns in the emergence of the porticoed city and proposes a work in progress classification of spatial entities in the built environment inspired by ontology and QSR. This line of reasoning also inspires two appendixes including two research proposals for future follow up. These two proposals consist of: an assessment of the semantic and ontological implications of different models of spatial representation for identifying the porticoes of Bologna as a united and distinct whole within the urban fabric of the city; an inquiry into the agency of the built environment and the interactions it enacts. Prior to these appendixes, the two concluding chapters respectively describe the present stage of research results and the answers to the research questions, and discuss these results listing a number of possible topics for future research towards the generalization of the research findings, in addition to the two proposals in the appendixes. Now, before moving to the state-of-the-art chapter, the following paragraphs provide some preliminary terminological clarifications.

The process of developing the interdisciplinary research project behind this dissertation was characterized by the recurrent need to state, and restate, its topic, responding to feed backs from academic audiences struggling to fit it into categories of topics familiar to them. This problem indicates the originality of the research questions as a distinct asset of this research project, carrying significant risks regarding research outcomes and requiring extensive efforts in the problem definition stage of the research. The problem can be ascribed to at least three issues. The first, which will not be further discussed, is typical of research development in general, and particularly PhD research, itself dedicated to progressively carving out the specific problem and questions it wishes to address about a particular topic, ensuring clarity of communication. The second refers to interdisciplinary projects such as this, where mismatches in the interpretation of the terminology across disciplines create confusion on the identification of the research topic and scope of work. The third refers to the uneven competition between well-established categories of topics – those most people are familiar with in any given domain - and cognate yet distinct less ordinary ones, in audiences' attitudes in identifying the topic of any given content. Along the research development, such unevenness recurrently scattered efforts to clarify conceptual mismatches between design disciplines, computer science and social sciences, ultimately affecting the progress of research milestones. It led audiences to assume conventional definitions of topics from a given domain, ignoring prompts towards alternative interpretations from other domains. For this reason, the following paragraphs put meanings under the spotlight from the very onset of this dissertation, discussing key terms surfaced in the debates occurred so far on its topic. It addresses three main mismatches repeatedly faced in previous audiences' feedback, to actively support comprehension by a variety of audiences towards improved transdisciplinary exchange. Unpacking the following conceptual mismatches requires considering the different perspectives according to which they may be interpreted from different disciplinary perspectives.

The first mismatch refers to the notion of *representation*. In planning and design disciplines this notion is often conflated to visualization, and tied to graphic design, or more broadly framed as visual thinking, as in the classic interpretation of the role of visualization in urban planning through cartography and graphic representation (Söderström, 1996). This dissertation addresses representation as a broader notion, adopted in computer science by *knowledge representation*, a field of research intersecting logic, linguistics and cognitive sciences. This notion may include visual and graphic representation as one ramification, explaining why view and vision are often used synechdochically instead of representation in key references of this study (Couclelis, 1999; Decandia, 2008). Yet, representation refers more broadly to the overall dynamic relation between meaning and sign, and it is key to understanding the interest of this dissertation in semantics, as the study of this relation. In this sense, representation, unless otherwise explicitly or conventionally agreed, shall not be reduced to visualization, nor flattened onto the static graphic outputs resulting from mental processes of visual representation. Borrowing a definition from cultural studies, intersecting humanities and social sciences, representation as meant in this dissertation may otherwise be explained as a "signifying practice" (Hall, 1997), in other words, the practice of associating a sign, verbal, numerical, sonic or visual, and a meaning. Concepts, the subjective, yet shareable, mental representations (Margolis & Laurence, 1999) where this association materializes, are therefore the core focus of this dissertation, whether they feed into visualization or into other types of mental projections.

Once stated the dissertation's focus on representation and concepts, it is now time to specify which types of representation and concepts. This specification addresses the second mismatch affecting the identification of the topic. Since the concepts of interest in this dissertation are concepts of spatial information (Kuhn, 2012), it is consequential to clarify the meaning of *spatial* from different disciplinary perspectives to position this dissertation's use of the term. As defined in information science, concepts of *spatial* information cover a broader range of scales than those relevant to planning. Indeed, information scientists concerned with transdisciplinary research refer to *spatial* information as a wider category than geo-information, to include, for example, the scale of biological cells (Kuhn, 2012). Moreover, qualitative spatial representation and reasoning (QSRR, Cohn & Renz, 2008) effectively tackle any entity having a spatial extension, confirming the variety of scales and concerned scientific domains addressed by the attribute *spatial*. Instead, spatial planning refers to *spatial* as a qualification encompassing the different scales - for example global, regional, urban, neighbourhood, building, etc. – concerned by human settlement processes, collapsing the meaning of *space* with that of the terrestrial surface and its parts, or possibly of any other planet surface human settlements might occupy in the future. This dissertation sticks to the latter meaning of spatial, setting its focus on the suitability of concepts of spatial information for the representation of the built environment, keeping the other scales covered by spatial information science in the background. Beside this clarification on scale, the spatial focus also requires addressing two further elements of potential confusion. First, the attribute spatial may also be interpreted in opposition to place, flattening insights from human geography on the complexity of the space and place binomial (Tuan, 2001; Massey, 2005) into a sharp dichotomy. According to the dichotomic reading, *spatial* mainly refers to the abstract embedding field of entities or phenomena and to the metrics of their location in this field, whereas *platial* refers to the material and dynamic manifestation of the specific conditions of location for a social entity or phenomenon (Mocnik, 2022; see also Farinelli, 2009). In this context, this dissertation's reference to spatiality does not engage with this dichotomy, in order not to bind itself to the assumptions it entails on the ontology of space as opposed to that of place (Agnew, 2011). The spatial focus wishes to keep open the possibility of revisiting this kind of ontological assumptions regarding space and its representation, attending to some of the insights on spatiality proposed by critical geography (Soja, 1985; Massey, 2005). In so doing, the dissertation walks on a thin edge, facing the gap left by the lack of dialogue between the research areas of post-modern geography and geo-ontologies, notwithstanding their common themes (Tambassi, 2017, 2018a). Second, the focus on geographic scales and the wish not to reduce *space* to its *opposite-to-place* abstract metric interpretation further shed light on the first mismatch regarding representation and visualization. Given that the appeal of visualization in relation to spatiality corresponds to its status as the dominant form of representation in geometry, once *spatial* information is not limited to geometric attributes, a broader interpretation of representation may as well be required.

Finally, the third mismatch refers to the scope of the case study. This scope looks at porticoes, a typical element of the built environment in the city of Bologna, Italy, bearing a long historical tradition and continuously marking the history of the city since the Middle Ages till today, as acknowledged by the nomination of related sites to the UNESCO World Heritage List. This focus easily triggers assumptions ascribing the research to the domains of urban heritage or traditional urbanism. These assumptions divert attention from the actual interest of the case study as an exercise in representation and modeling of the built environment, and as a rich body of evidence on their ontological implications, for heritage conservation of the past and the old, as much as for urban design guidelines for the future and the new. On the one hand, these assumptions may overlook the fact that heritage and tradition also include contemporary works of art and culture and should not be conflated with legacies of the far past, but rather aimed at ushering old and new traditions towards the future. On the other, they also divert attention from the question of representation and modeling of the built environment as a topic in its own right in the domain of spatial planning, particularly in relation to the identification of areas across description and prescription. This diversion indicates a common logic behind the confusion on the topic of the case study and on the definition of representation of space. Any element of the built environment which eludes definitions by geometric concepts cannot but be classified as pertaining to heritage and tradition, opposed to a stereotyped idea of modernity. Likewise, representation is reduced to visualization precisely because the spatial concepts in use are considered as the only possible ones, and the only subject left for discussion is how to translate these concepts into drawing.

2. State of the Art: representation and spatial planning at the intersection of knowledge and action

“Spatial reasoning is no abstract business”
(Varzi, 2007)

Spatial planning, as defined in the introduction, designates areas of land with attributes describing either existing knowledge about what these areas are, or a proposal regarding what these areas can or should be. These descriptions adopt models of representation of space to designate the concerned areas of land, based on spatial concepts which define, identify and visualize geographic entities as parts of the built environment, and of the Earth crust more broadly. Definition, identification and visualization are all acts of spatial representation, enacted in spatial planning to assign descriptive and prescriptive attributes to geographic entities. In statutory planning, such attribution mainly works by the subdivision of land into discrete units typical of so called Euclidean land zoning (Savini, 2021). The attribute Euclidean here refers to the notion of Euclidean or Euclidian planning introduced by John Friedmann and further discussed by Enrst R. Alexander (Friedmann, 1993, 1994; Alexander E. R., 1994). This debate does not delve on questions of representation and spatial modeling, but tackles directly its procedural implications. It nonetheless indirectly puts description, and therefore representation, in the spot light, pointing to the possibility of describing “space as a complex nested hierarchy of spaces” (Alexander E. R., 1994, p. 373). This dissertation focuses on representation of geographic entities, which generally operates by spatial concepts corresponding to geometric shapes, georeferenced or not, regardless of the various graphic languages and mapping styles adopted for spatial visualization by different types of planning, statutory or strategic (Fig. 2.1). Focusing on the built environment, standard heritage protection policies and plans provide a particularly stark example of this tendency, promoted through “authorized heritage discourse” as defined by Laurajane Smith (cit. in Bonfiglioli, 2024). According to this discourse, regulation for the preservation of tangible urban heritage assets relies on the identification of a bounded area including the assets of interest within its perimeter (UNESCO, 2017). As put by Smith and Waterton specifically regarding authorized heritage discourse, it can be argued that geometric representation of geographic entities “has become so comfortable and commonplace within heritage management practices [read: planning practice] that wider debate over heritage [read: representation] is significantly constrained. Indeed, so pervasive is this air of inevitability that any new debates are ultimately unlikely to lead to changes in heritage management and planning practices.” (Smith & Waterton, 2012, Abstract).

In this perspective, this dissertation addresses the role of spatial ontology, representation and semantics in the adoption of a model of choice, placing this role at the intersection of knowledge and action, evoking John Friedmann's classic definition of planning as the relation between knowledge and action (Friedmann, 1987). The spatial focus of the dissertation narrows the broader meaning assigned to planning by Friedmann to focus on human settlement processes. Yet, it also broadens Friedmann’s focus on public planning to encompass a wider range of decision-making bodies, because of the shared character of models of spatial representation among public and private stakeholders. This shared character requires semantics to support a shared understanding of the intended meanings conveyed by a model. Yet, leaving this shared understanding implicit constrains the diversification of options for the representation of space, leading all stakeholders in spatial planning to consider a single model of representation of space, Euclidean geometry, as the only available option. According to Helen Couclelis, absolute Newtonian space and Euclidean geometry "became orthodoxy for three full centuries" (Couclelis, 1999, p. 32) following the triumph of classical mechanics in the XVIII c. Since then, the related

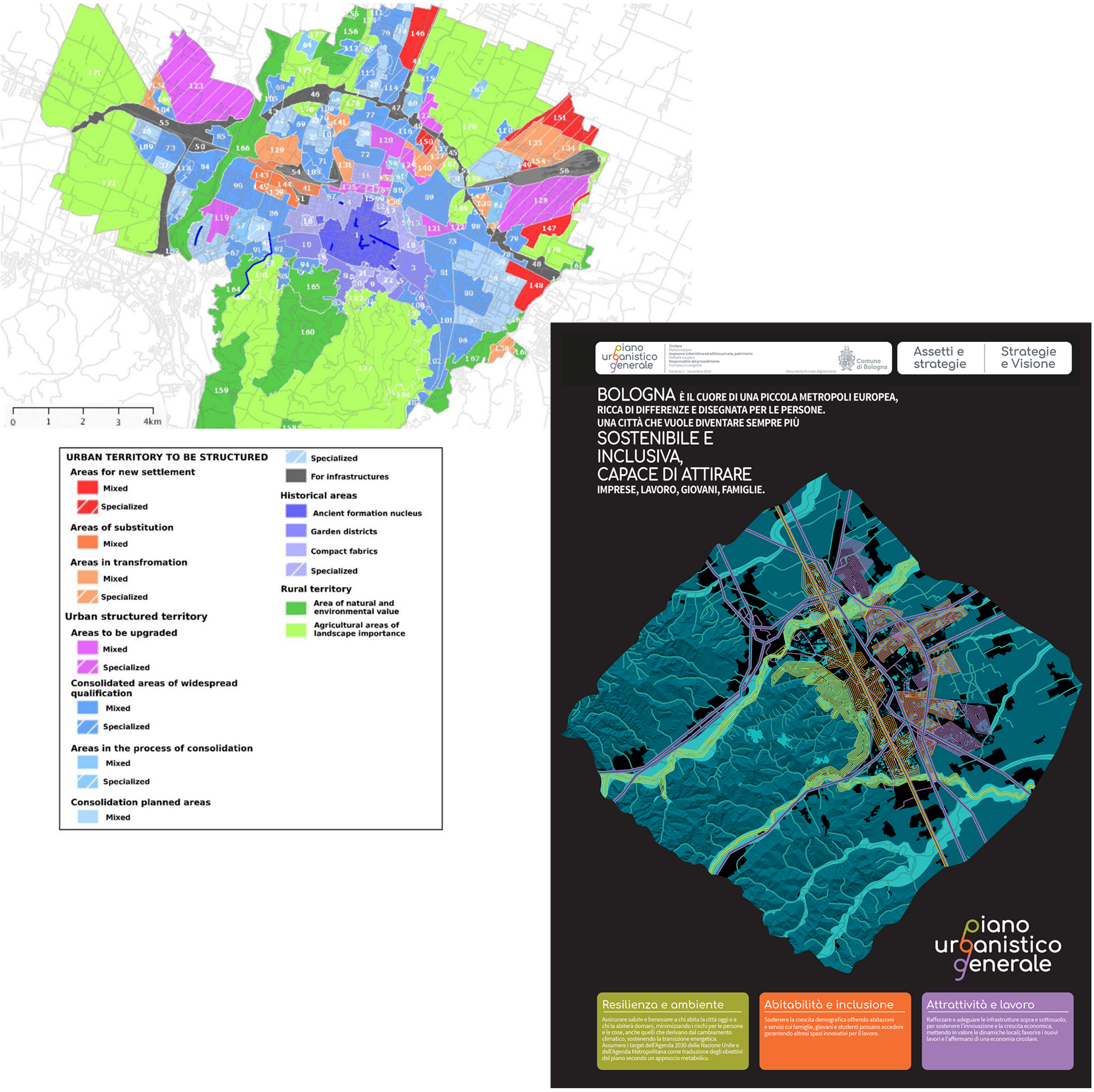

Fig. 2.1 Two examples of graphic languages and mapping styles in different types of planning instruments from the city of Bologna: the 2008 Municipal Structure Plan (Comune di Bologna, 2020a) and the 2021 General Urban Plan (Comune di Bologna, 2021c). In the public domain.

model of representation of space has been overwhelmingly taken-for-granted as the only possible choice for the representation of land, or any type of ground considered for human settlement. As a result, even the critics of Euclidean geometry implicit reductionism adopt what they identify as "non-spatial mathematical settings" to study complex spatial phenomena such as human movement, where non-Euclidean becomes a synonym of non-spatial (Calissano et al., 2020).

Ontology, as the study of being or what exists, and semantics, as the study of the meanings of representations, concepts and language expressions, are proposed here as a key to overcome this assumption of a single possible option for the representation of space in the domain of spatial planning. In recent years, planning scholars explicitly engaged with ontology as the identification of the defining characteristics of a given entity, such as the city as an hybrid entity (Amato Cameli, 2021), urban self-organization as a defining dynamic in the making of cities (Boonstra & Rauws, 2021), or the very conceptualization of planning as the co-existence and co-evolution of different planning perspectives and practices in the context of wider governance settings (Beunen et al., 2021). Yet such planning scholarship did not engage with the method of ontological analysis as applied in computer science, while other studies built on multi-disciplinary collaboration towards the definition of key notions such as cities and places (Borgo et al. 2021; Melone et al. 2017). Nonetheless, while all of these studies address ontology because of their focus on definitions of key concepts in spatial planning, they are not directly concerned with the representation of space. At the same time, various critiques of the ontological assumptions informing the modern metric representation of geographic space in spatial planning (Alexander, 2002; Davoudi, 2012; Decandia, 2008; Friedmann cit. in Savini, 2021; Lefebvre cit. in Schmid, 2022; Webber, cit. in Paba & Perrone, 2017) also do not refer to the method of ontological analysis as applied in computer science. Meanwhile current pioneering experimentation in planning oriented geo-spatial analysis based on non metric theories of space derived from QSR is still confined into experimental niches (Hahman & Gruninger, 2012). In this context, the following sections provide a conceptual framework for the definition of the research problem regarding spatial planning engagement with ontological analysis as a method developed in the service of computer science.

2.a Computer science and the engineering mind set in planning thought

The history of ideas and practices in any scientific domain gives way to traditions.[1] Traditions lay the ground for new contributions developing previous ones or critically searching for alternatives. They also work as moulds for mindsets, constraining intellectual innovation (Healey, 1997), steering motives and attitudes behind perceptions and understandings of new discoveries and inventions, especially those circulating across domains. The scrutiny of traditions cultivates awareness of the chain of inspiration informing a domain vocabularies, narratives and approaches, and the legacies shared across domains. Looking at planning traditions a couple of decades into the second millenium CE, their heterogeneity (Allmendinger, 2002) coexists with the persistence of the foundational positivist legacy in planning practice (Davoudi, 2012). This section's literature review recalls the engineering mindset positivist tradition in planning theory and its critique, comparing it to the last thirty years trends in computer science. The comparison sheds light on the

1 The content of this section contributes to an article submitted to the journal Contesti, Città, Territori, Progetti, FUP, Università di Firenze, and to a paper presented at the 2025 AESOP Congress in Istanbul.

commonalities between intellectual traditions in these two domains. These commonalities challenge both anxious and enthusiast reactions to the use of computing tools in planning practice, as these reactions mutually intensify in the wake of artificial intelligence applications.

In his classic review of intellectual traditions defining the relation of knowledge to action, John Friedmann (1987) provides a comprehensive overview of two centuries of planning theory. Here, he traces the origin of planning back to the emergence of the belief that society can be improved by the guidance of scientifically based knowledge, beginning with early positivist thought. Indeed, he wrote at the beginning of what can retrospectively be considered the spring of post-positivist (Allmendinger, 2002), interpretative or hermeneutic (Davoudi, 2012) approaches to planning. These approaches challenged positivist assumptions such as the supremacy of technocratic decision making, the objectivity of expert knowledge, and the validity of certainty. While separated for explanatory purposes, these assumptions are dependent on one another, taking certainty as a fundamental attribute of knowledge, of its objective translation into decisions, and of the linear causality between decisions and their outcomes. The corresponding post-positivist counter-assumptions rely on the endorsement, to different degrees, of three aspects of a pluralist understanding of reality. These aspects are: the necessity, or the plain fact, of distributed or dispersed[2] multi-criteria decision-making; the legitimacy of different sources and types of knowledge; and the inevitability of uncertainty. This article identifies these aspects as three dimensions of pluralism, as they altogether do away with the idea of the singularity of truth. The above-mentioned spring season also saw the parallel development of digital modeling applications intended as decision support systems in planning practice (Geertman and Stillwell, 2004). Since their onset, support systems developed within academia and the private sector keep facing the so-called implementation gap (Jiang et al., 2020). In fact, many public authorities, for example in the EU, lack the expertise required for the use of these systems, with few pioneer cases, such as the Amsterdam Institute for Advanced Metropolitan Solutions, proactively building partnerships across government, academia and the private sector to bridge these gaps. Yet, the development of digital decision support systems can also claim substantial achievements, first of all that of diversification including capabilities in data analytics, monitoring, scenario building and knowledge sharing. Next to data-driven applications centred on computational capabilities (Gil, 2020), other modeling applications adapted to suit different planning approaches. Significant efforts went into supporting participatory decision making and the integration of different sources of knowledge (Borri et al., 2006; Pelzer et al. 2015; Campagna, 2016). Others committed to adapting modeling techniques to shifts in system theory inspired by complexity science towards open-ended simulations (Batty & Torrens, 2001; Portugali, 2021). Moreover, looking beyond spatial planning applications, semantic cognitive approaches to computer science also contributed to new breakthroughs in digital modeling (Guarino, 1998; Borgo et al. 2022). While these distinctions often go overlooked in outsiders' perceptions of digital modeling, the latest experiments in artificial intelligence (AI) have revived expectations that computer science may ultimately be trusted to deliver technocratic solutions for planning problems. These expectations stir either

2 A clarification provided by Stefano Moroni at the 2025 AESOP Conference pointed to the distinction between these two adjectives.

anxiety or enthusiasm depending on whether one endorses the post-positivist critique of the singularity of truth and the limitations of expert knowledge, or whether they assume that these limitations rest on inadequate computing abilities. Comparing literary insights from specific sectors of planning and computer science scholarships, this article challenges flattening and polarized perceptions of digital applications in planning to building the case for trans-disciplinary collaboration between like-minded scholars by a pluralist approach. The methodological paragraph explains the criteria applied in the selection of sources. Afterwards, the literature review splits in two parts, the former focused on planning and the latter on computer science and digital modeling. The first looks at positivism and post-positivism in planning thought. The second covers two focuses among contemporary developments in the umbrella category labelled by John Friedmann (1987) as system engineering. It looks at pluralism in philosophical and semantic-cognitive approaches to computer science and at uncertainty in digital modeling of urban and environmental complexity. The findings encourage like-minded scholars to join forces to foster pluralist approaches across domains. Based on shared interests, such collaboration constitutes the most appropriate response to both enthusiasms and anxieties about the persistence and revival of positivist planning through AI applications.

The literature review does not provide a systematic account of the ongoing debates on its topics of interest in the domains of planning and computer science. It rather spots evidence of the relevance of these topics across domains, highlighting the thread or line of argument by which some authors address these topics, and tracking the matching of meanings behind terminological variety. Accordingly, the selection of sources prioritized authors whose citation rates and involvement in scholarly circles, joint events and publications suggest a fair degree of relevance in ongoing debates in each research area. Here, the prominence given to geographically and intellectually situated circles depends on the author's participation in these circles. Moreover, the selection cumulatively integrated two criteria for both domains. The first criterion was the use of one or few related starter key words. The second criterion added sources using one or few related follow-up key words, hand-picked from the texts selected by the first criterion to root the review in the terminology in use in the referenced literature. In a few cases, additional ad hoc references provided explanatory examples, evidence of shared interests across domains and/or insights on terminological matches and mismatches. The starter and follow up search key words for each domain are presented in Table 2.1.

Domain	Starter key word	Follow-up key word
Planning theory	tradition, typology	positivism
Computer science (philosophy, cognitive-semantic)	pluralism	ontology
Modeling urban and environmental complexity	uncertainty, prediction	open/closed systems, wholes

Tab. 2.1: Starter and follow up key words identified by the author to guide the search for references.

Introducing the intellectual traditions which shaped the domain of planning, John Friedmann (1987) points to the eve of the industrial revolution as the cradle of the very project of scientific planning. He stresses Saint-Simon's (1760-1825) influence on the foundation of sociology, through his disciple Auguste Comte, and other disciplines relevant to the domain of planning. According to Friedmann, Saint-Simon's social physiology assigned to scientists and engineers the task of serving humanity with "their ability to predict the future outcomes of present actions" (Friedmann, 1987, p. 52). He introduced the idea that scientific planning can guide social progress by the assumption that history is governed by objective laws, and that human freedom submits to these "immutable laws of human progress" (Friedmann, 1987, p. 73). Accordingly, planning can guide social progress by observation and measurement, focusing on functional fit and efficiency as stable absolute principles. Meanwhile, politics with its volatility could be made unnecessary by the consolidation of a consensual society, according to a supposedly neutral and value free system, "supposed to be obvious and therefore reasonable to all who were properly informed" (Friedmann, 1987, p. 68). Knowledge was intended as "the power of technical reason to determine what is correct" (Friedmann, 1987, p.58), something which would be beyond the reach of the masses, but rather the monopoly of "initiates" (Friedmann, 1987, p. 71) acting in the service of rulers. Here, the term "initiates" recalls John Stuart Mill's accusation that Comte's positivism pursued a form of spiritual domination comparable to the old religion which Comte himself originally opposed. This accusation exposes the positivist attitude towards a secular endorsement of the singularity of truth. According to Friedmann, these premises gave way to different intellectual traditions, upholding different interpretations of the role of science in the exercise of power in society, the organizing principle of his typology of planning theories. He visualizes these traditions chronologically as a set of parallel lines, from the most conservative to the most radical interpretation. Here, he groups thinkers across most of the set under the label of engineering sciences, defined by the trust in technical reason to determine what is correct into a single objective reality. This is the model of the ecole polytechnique, with its focus, as he puts with a von Hayek's quote (Friedmann, 1987, p. 59), on the deliberate and conscious construction of the world. This idea of the world included both the physical and the social reality, both considered as artifacts. Yuval Portugali (2021), describing this idea of the world as mechanistic, clarifies:

> "artifacts are 'facts of art' – products of human intention, imagination and action – whether they are artistic entities, socio-cultural organizations or machines. Modern science started with 'the world as a clockwork' – the machine as a metaphor for the natural universe at large. […] The generality of this mechanistic world view that dominated science for more than 300 years was falsified at the beginning of the twentieth century following Einstein's relativity, quantum theory, and, more recently, complexity theory. What was falsified was not the existence of a mechanistic domain, but its generality, namely, the view that its basic properties apply to nature, society and culture." (Portugali, 2021, p. 15)

The plausibility of technical reason uncontroversially determining what is correct relied on the assumption of the singularity of truth according to this mechanistic idea of the world. This assumption trickles down into derivative assumptions attributed by Friedmann to smaller sub-sets, narrowing the focus from technical reason, to technocratic decision-making, and further to the objectivity of knowledge and to its certainty. In Friedmann's reading, the trust in truth-endowed technocratic decision making characterizes both conservative and reformist thinkers, sparing only the most radical ones. Moreover, conservative thinkers justify this trust by assuming the objectivity and political neutrality of expert knowledge and technical reason, serving the state and those who are in power. Furthermore, system engineering, placed on the conservative end of the set, including cybernetics, game theory, information theory, computer science, and robotics, adds the trust in prediction of the consequences of action in relation to desired objectives. In this regard, Friedmann also blames futurology as a sign of crisis in the social sciences, “a bogus science [where] our seeming inability to understand the world by studying its past, [pushes to] the flight into the future” (Friedmann, 1987, p. 73).

Friedmann’s typology adopted an historical and disciplinary perspective, without engaging with the categories proposed in the 1980’s debate on the typology of urban planning theories (Yiftachel, 1989). Two years after the publication of Friedmann's seminal book, Oren Yiftachel reviewed the previous debate on typologies to propose a new one. This review departs from Andreas Faludi’s “ 'procedural' and 'substantive' planning theories, termed theories of planning and theories in planning, respectively“ (Yiftachel, 1989 p. 24), followed by an alternative dichotomy between explanatory and prescriptive theories based on Taylor’s critique of Faludi. Against this background, Yiftachel proposes his classification, which is incommensurable to Friedmann’s, even though they share meaningful commonalities. These commonalities include the chronological and linear structure, though Yiftachel’s starts with the XX century while Friedmann’s from 1789. They also share a common focus on the dichotomy between conservative neutrality and partisan change. Yet, they place this dichotomy in different parts of their respective chronologies. For Friedmann the distinction separates different parallel traditions all along the history of planning. Yiftachel, instead, frames the distinction between “openly politicised approaches and persisting technical-neutral orientations” (Yiftachel, 1989, p. 23) as an historical shift from the latter to the former occurring in the mid-1960s. He considers this shift as part of the paradigm breakdown which splits his chronology in a before and an after. The main reason for the incommensurability of the two typologies most probably lies in the different definitions of planning they refer to. Indeed, Yiftachel refers to urban land use planning, while Friedmann to scientific based planning, excluding “other forms of planning, such as urban design, piecemeal social reforms and administrative city planning [which...] did not yet embody a scientific practice.” (Friedmann, 1987, p. 53). Regardless of these differences, Yiftachel's observation that planners portrayal “as neutral and apolitical experts” (Yiftachel, 1989, p. 36) dominated the first half of the XX century confirms the hegemony of the engineering mindset at the onset of modern spatial planning practice.

Allmendinger (2002) provides an example of the later reception of both works, reacting to Yiftachel’s typology in an article about post-positivism in planning thought, where he also includes a reference to Friedmann’s classification. Arguing in favor of a post-positivist typology of planning thought, he criticizes the evolutionary character of both Friedmann's and Yiftachel's chronologies for formalizing a linear progressive view of planning theory. Instead, he calls for a post-positivist typology “identifying and tracing influences and how theories are transformed, mediated and used in a linear and non-linear way and different contexts including time and space" (Allmendinger, 2002, p. 89). He also stresses how most developments in planning theory at the time of his writing stem from a post-positivist perspective, including collaborative, neo-pragmatist and postmodern approaches to, and feminist perspectives on, planning. In this regard, he stresses: "What is important to note is not that there has been linear progress or evolution but that at different times and in different places over the past 2500 years or so the basic positions have been held simultaneously as they still are now." (Allmendinger, 2002, p. 86). Options are open, as they were in the past, for scholars and practitioners to chose. Yet, positivism remains highly influential in planning practice, even though the occasional endorsement of new devices, identified by Simin Davoudi as network analysis, relational functional regions, fuzzy maps, scenario building and experiential knowledge, signals a search for alternatives by planning practitioners (Davoudi, 2012).

Indeed, the turn of the millennium brought a wide recognition of a post-positivist drive in spatial planning, even though different observers associated this drive to different examples and even to different categories of examples (Fainstein, 2000; Allmendinger, 2002; Davoudi, 2012). This literature provides a comprehensive and at times conflicting interpretation of the different aspects marking the distinction between positivist and post-positivist planning approaches. This article focuses on aspects of positivism highlighted by Friedmann such as the trust in technocratic decision making, the objectivity of expert knowledge, and the validity of certainty, as expressions of the positivist commitment to the singularity of truth. Despite their different takes on the subject, the three above mentioned sources agree on the pluralist post-positivist shift towards what altogether they address as contingency, variance, diversity, fragmentation, multiplicity, polyvocality and pluralism (Fainstein, 2000; Allmendinger, 2002; Davoudi, 2012). Moreover, the emphasis on variance in interpretation and explanation puts in the spotlight the question of meaning (Allmendinger, 2002; Davoudi, 2012). "A post-positivist approach requires 'shifting from causal reasoning as a basis for plan-making to discovering and confirming meaning' (Moore-Milroy, 1991: 182)" (Allmendinger, 2002, p. 87). "Rather than recourse to objective evidence or reality, the emphasis in post-positivist planning is on language and 'making meaning' through language." (Allmendinger, 2002, p. 88). According to Davoudi, "meaning refers to what is consciously and individually intended as well as what is commonly and often unintentionally significant [...] Place is defined subjectively with people living not 'in a framework of geometric relationships but a world of meaning' (Hubbard et al., 2004, p. 5)" (2012, p. 430-432). This interpretation requires planning to acknowledge "the influence of the cognitive, social and institutional environment in which decisions, or more precisely practical judgments, are made" (Davoudi, 2012, p. 437). According to Davoudi, planning practice is far from endorsing post-positivism. She points to evidence-based planning and system thinking, echoing Friedmann's interpretation of system engineering, as pressures towards positivist technical rational approaches. She considers these pressures as heralds of a new and on the rise scientism characterized by "over-emphasis on rationality and objectivity, and the over-confidence in the power of reason to control time and space" (Davoudi, 2012, p. 439). The next paragraphs look at the domain labelled by Friedmann as system engineering, to highlight how the undeniable positivist drive of system thinking does not prevent its permeability to pluralist approaches. These paragraphs focus on more recent contributions in computer science, knowledge engineering and system theory applied to spatial analysis, pursuing pluralist approaches in the decades following the publication of Friedmann's book.

Looking at computer science, this paragraph highlights post-positivist and pluralist concerns in philosophical and semantic-cognitive approaches. Then the following paragraph's focus on uncertainty and open systems completes the picture with the shift from modeling to open-ended simulation in system thinking, overcoming the predictive tenet of positivist science (Batty & Torrens, 2001). Helen Couclelis features as the first reference of this section in direct dialogue with John Friedmann’s 1987 description of computer science and system engineering as helplessly positivistic. On the one hand, the significance of her scholarship on the philosophical underpinnings of geographic information science is comparable to that of Friedmann in planning theory. Moreover, the time span of her research covers the decades following the publication of Friedmann’s book, starting a few years earlier. Arguing, at the onset of her career, in favour of abandoning positivist epistemology in human geography and the social sciences, Couclelis (1983) provides a telling description of post-positivist science which is worth an extended quote:

> “not truth and objectivity, but clarity of argument and internal coherence in discourse; not quantification, but the creative use of mathematical language, be it of a quantitative or of a more general qualitative sort; not accuracy of measurement and the discovery of general laws, but the thorough definition of the logical classes in which we order the phenomena we study, and an appreciation of the function of the formal tautologies inherent in abstract mathematical structure in securing logical consistency in theory […]; not the possibility to reproduce a tidily structured external world, but the ability to make intelligible to man an in itself unfathomable realm of external 'happenings'; not the privileged access to the 'real world', but the capacity to push to its creative limits the world-defining potential of theoretical language. For one of the central messages to emerge out of contemporary theoretical scientific advances surely concerns the extent to which the world we know is the product of the linguistic component in our knowledge.” (Couclelis, 1983, p. 32)

Argument, creativity, ordering, intelligibility, definition and linguistic production echo the previously mentioned interest of post-positivist planning theory in meaning. Along the same lines, this terminology implies the possibility of plurality, and the related need for conceptual coherency and transparency, a key concern in semantic-cognitive approaches to computer science. In the past thirty years this concern has given way to the articulation of formal ontologies. Formal ontologies provide stable terms of reference for setting up and operating models, and for interoperability between information systems. More broadly they establish a semantic and conceptual consensus to support interaction and communication between both artificial and human agents (Gaio et al., 2010). Using the countable plural already gets to the point, as opposed to the uncountable ‘ontology’, often written with the upper case (Guarino, 1998; Varzi, 2019), a branch of metaphysics and philosophy studying the prerogatives of being and existence. In fact, formal ontologies appeal to pluralism because they clarify the different options available for the interpretation of a conceptualization, implying the viability of different possible conceptualizations. They are cognitive artifacts providing a representation of a domain as a structure defined by the properties set through axiomatization (Ferrario, 2006). Indeed, pluralism is not a main topic of the literature in this domain. Nonetheless, it can be considered as a background assumption for some, as confirmed by occasional direct references to pluralism and richness as attributes of a desirable ontology (Casati & Varzi, 1999, p.4). For instance, in the context of a debate on the ontological foundations of conceptual modeling, Guarino and Guizzardi (2006) stand in favour of ontological pluralism to set their work apart from ontologies committed to reductionist monism, or the idea that all aspects of being can be reduced to a single definition. Here, they also feel the urge to claim that "a non-reductionist ontology is not necessarily a non-scientific ontology" (Guarino & Guizzardi, 2006, p. 121) to discard an evidently sticky stereotype. Looking at the idea that ontologies can commit either to monism or to pluralism, Achille Varzi (2019) brings in the dichotomy between conceptualism and realism. By this dichotomy, he explains the difference between ontologies working with conceptualizations within computer science and Ontology working with the truth of being in the context of metaphysics and philosophy. In this context, he admits that both conceptualists and realists can in principle be either monist or pluralist. But then he concludes that while "the laws of being are not up for grabs […] As a matter of general attitude, conceptualists don't care about the world; they care about conceptualizations. And the laws of conceptualizations are up for grabs." (Varzi, 2019, p. 8). He also supports his statement providing the example of the DOLCE ontology (Gaio et al., 2010), explicitly developed by Guarino and colleagues "with the vision that a unique universal ontology for knowledge representation cannot exist" (Borgo & Masolo, 2009, p. 372, cit. in Varzi, 2019, p. 8). Here, a contradiction may arise between this vision and the development of foundational ontologies such as DOLCE. The attribute foundational refers to a type of formal ontologies which aims to provide a domain-independent general reference, requiring universal validity to support interaction across domains. This requirement can easily be confused with the aspiration to singularity, which is clearly contradicted by the proliferation between the mid 1990's and the late 2010's of at least ten foundational ontologies (Borgo et al., 2022; Varzi, 2019). According to Varzi:

> "Such abundance of systems is by itself indicative of how much the field has grown since the early days. But each system deviates from the others in significant ways, not only by employing different methods and techniques but also, crucially, by relying on different ontological categories and principles. And herein lies the trouble" (Varzi, 2019, p. 8)

Varzi describes such trouble as trying to overcome the problem of the "database Tower of Babel" (Smith, 2003, p. 158, cit. in Varzi, 2019, p. 8) by encountering a parallel problem at a higher level, the problem of the "ontology Tower of Babel" (Kusnierczyk, p. 41, cit. in Varzi, 2019, p. 8). In 2017, the FOUST workshop engaged with this proliferation to "discuss the concrete use-cases that could be employed to illustrate and elaborate the differences between the popular foundational systems in addressing basic modeling problems" (Borgo et al., 2022, p. 2). Admitting that different ontologies may be more suitable than others in each modeling case of application, this endeavour proposed a comparative framework to turn the tower of Babel into a plurality of options for knowledge engineers to choose. Ultimately, ontological pluralism appears as a necessary backdrop of the plurality of knowledge, the second dimension of pluralism discussed above.

Moving to the problem of uncertainty or unpredictability in urban and environmental modeling, Batty & Torrens (2001) place the shift from a certain to an uncertain world, at least in human perception, in the second half of the XX century CE. They trace back to this shift the "growing need [...] for ever more complex models and the increasing difficulties in their validation" (Batty & Torrens, 2001, p. 4). As a result, they stress, "our science has become less orientated to prediction but more an aid to understanding, to structure debate" (Batty & Torrens, 2001, p. 4) through a plurality of what-if scenarios whose purpose shall become more akin to exploration and calibration rather than prediction. According to Peter Allen (2021), this exploration shall be approached as an unending process of sense-making. As he puts it:

> "there is no scientific or unique way to modify our beliefs when they have failed, and so we are condemned to carry on throughout our lifetime trying to make sense of what is going on, what it means and what might happen. […] even though the development and use of interpretive frameworks is always going to be imperfect, it is still better to have this framework than not to have it. Acting without any model to test is simply trial and error without any learning." (Allen, 2021, p. 87)

In the field of environmental planning, Borri et al. (2006) point to the reconsideration of cybernetic models with their linear and deterministic logic, which is ill-prepared to deal with probabilistic and chaotic phenomena. Their reference to cybernetics recalls Friedmann's description of system engineering. While all these sources refer to complexity, they focus on different qualities, emergence and heterogeneity. Batty and Torrens, together with Allen, explicitly build on complexity science to simulate the emergent properties of complex systems. Borri et al. focus on the "pluri-logic procedures" (Borri et al., 2006, p. 563) of multi-agent planning situations in the context of participatory decision support systems. In line with previous observations on the plurality of decision-making agents and of knowledge, Borri et al. touch upon the first two dimensions of pluralism discussed in this article in contrast to positivist reliance on technocratic decision-making and the objectivity of expert knowledge. In both cases plurality undermines determinism, yet the focus of complexity science goes to the extensive plurality of states intended as the responses of the system to its environment. This plurality of states determines systemic uncertainty and unpredictability (Batty & Torrens, 2001), the third dimension of pluralism discussed in this article. Both focuses substantiate the finding that modeling has gone a long way compared to Friedmann's account of system engineering, and that it did so in different dimensions. Complexity science contributed to pluralist breakthroughs in system thinking related to the dimension of uncertainty. The engagement with uncertainty can be better understood in the context of the shifts occurred between the original understanding of systems, and therefore the type of models built to represent them, and the new understanding inspired by complexity science. Batty & Torrens (2001) explain this shift by the three key principles of model-building which grounded the assumption of certainty in the early days of system engineering. The first principle is about system boundaries and the crisp separation between a system and its environment, the inside and the outside. The second principle is about equilibrium and the stability and linearity of trajectories of change within the system. The third principle is the homogeneity, regularity and order exhibited by the elements of the system. Just like the three dimensions of pluralism, these three principles can also be placed along a circle of mutual influence. As put by Batty and Torrens:

> "these principles did once appear to be implementable for urban systems but it is now easy to argue that none of these apply to even the simplest system of interest to policy-makers. Systems of any interest are impossible to close, their usual state is far from-equilibrium; often no such equilibrium ever exists. They are composed of heterogeneous agents and objects, indeed their very richness comes from such heterogeneity" (Batty & Torrens, 2001, p. 4).

These insights call into question the notions of open and closed systems in system theory[3]. A discussion on openness and closure is particularly relevant to the study of urban systems, given the consensus on the explosions and implosions characterizing urbanization processes (Batty, 2022; Brenner, ed. 2014) and the intense debate in urban studies on the extent and scales of urbanization (Brenner, 2018; Schmid, 2018). The notion of open systems, lacking fixed limitations to the exchanges with their environment, exacerbates the aggregation problem typical of general system theory (Batty, 2000). This problem is the result of this theory attempt "to counter science's long-standing quest to reduce everything to fundamental particles" (Batty, 2000, p.167). Such reduction requires explaining the process through which a number of parts come together to form a whole, but also admitting that this does not happen once and for all. According to Batty, the lack of this explanation leaves system theories of the city describing "wholes in terms of an equilibrium which could not cope with any form of change other than that with the most local impacts" (Batty, 2000, p. 167). Over the last four decades, complexity theories of cities developed the study of cities as complex adaptive systems in constant flux and mostly far away from equilibrium. In these systems, the evolutionary process of adaptation drives the emergence of new variables, levels of organization and new boundaries according to non-linear trajectories and evolving combinations of heterogeneous elements (Portugali, 2021). Cities, economies, and ecologies are a typical example of these kinds of "systems whose structure is emergent […] where new and surprising elements evolve within their structure. […] This newness and surprise [...is] unusual enough to be largely inexplicable using our traditional approaches." (Batty, 2000, p.168). This dynamic understanding of urban and environmental systems, their heterogeneity, their constant renewal, makes any boundary between the outside and the inside a feature of a frozen cross section in time. Considering disequilibrium "the 'normal' mode in which systems in general operate" (Batty, 2000, p.168) adds a diachronic notion of plurality to the previously addressed synchronic ones. In this sense, complex adaptive systems require models tracking discontinuities, positive and negative feedbacks in the evolution of a system, comparing different possible explanations of divergent trajectories of change in distinct yet apparently similar locations (Batty, 2000). Such models ought to be both diachronically and diatopically pluralist to attend the principle of non-causality, described by Yuval Portugali as the impossibility of establishing a direct correspondence between ifs and thens. According to Portugali:

> "With machines, once you have all the ifs, you can, in principle, know all the 'thens'; with complex systems this is not so. Some say that this is because technical limitations in that

3 In his review of the thesis, Riccardo De Benedictis hinted at the possibility of comparing these notions to the closed world assumption and open world assumption in query evaluation in data base management systems (Reiter, 1978).

complex systems have so many parts […] that identifying all ifs is technically not possible. However, in principle, if it was possible, then determining the 'thens' would be possible. Some (myself included) say that this is ontologically so – there is no limited number of 'ifs' and 'thens'; complex systems are inhexaustible. (Portugali, 2021, p. 15).”[4]

In this light, the problem of open systems expands from rethinking the relation between a system and its environment to rethinking wholeness and the process of aggregation of parts in a system. The dynamism of such aggregation creates plurality of states and uncertainty on various levels: knowledge, the relation between knowledge and decision, and between decisions and outcomes. In this light, uncertainty in complexity science, in addition to the plurality of decision-makers and knowledge(s) in participatory approaches to planning, can be considered as an herald of pluralism in system engineering and system thinking.

The legacy of positivism and the engineering mindset in planning thought has been analysed in detail elsewhere (Friedman, 1987; Davoudi, 2012). This section focuses on three tenets of this legacy, the trust in technocratic decision making, in the objectivity of expert knowledge, and in certainty. Since these tenets converge in reinforcing the reductionist idea of the singularity of truth, scientific pluralism can be considered as an antidote to positivism across domains. By comparing these original tenets to more recent advancements towards scientific pluralism in planning theory, computer science and digital modeling, this section serves three needs. In the first place, the influence on planning practice of a new and on the rise scientism (Davoudi, 2012) points to the need to keep revisiting the tenets of positivism and their surviving influence in spatial planning. Moreover, the frenzy around AI developments points to the need to challenge flattening and polarized perceptions of computer science applications in planning, tracking motives and attitudes behind perceptions and understandings of new discoveries and inventions. Finally, acknowledging a shared commitment to operate in multi-agent decision making environments (vs. technocratic decision), with multiple knowledges (vs. undisputable expert knowledge), and comprehensively dealing with plural system states and uncertain responses (vs. immutable laws and certainty), encourages like-minded scholars to foster pluralist approaches across domains. Such collaboration defuses both enthusiasms and anxieties regarding the augmentation of positivist planning practice through AI applications. In this light, this section goes beyond “identifying and tracing [...] how theories are transformed, mediated and used” (Allmendinger, 2002, p. 89). It wishes to trigger a conversation to lay a common ground for inter-operability, mutual influences and integration of efforts across domains.

Indeed, the purpose of the proposed conversation requires further clarification, as highlighted, for example, with the previously mentioned Tower of Babel effect (Varzi, 2019). To begin with, the notion of pluralism, as intended here, shall be set apart from that of relativism, even though both converge on the contestation of the singularity of truth. Pluralism engages with diversity as a collaborative learning process. It expresses and clarifies axes of conflict, and develops shared

4 In his review of the thesis, Riccardo De Benedictis stressed that explanation and reasoning in machines takes logical inference in both directions, from an observed cause to an inferred consequance, as if and then conditional inferences, and from an observed consequence to an inferred cause, as abduction (Aliseda, 2006), reflected also in programming paradigms such as Prolog.

vocabularies, through dialogic approaches such as the science of muddling through (Lindblom, 1959) or the device of local trading zones (Balducci & Mäntysalo, 2013). On the contrary, the relativist appeal to diversity tends to compartmentalization. It heightens risks of overlooking mutual influences and the continuity between processes of knowledge differentiation, intersection and confusion. It is inclined to losing sense of direction among “a myriad of ‘language games’, personal opinion and ultimately incommensurable ideology” (Allmendinger, 2002, p. 93). This distinction is key to the pursuit of interoperability between systems and knowledges. In turn, this pursuit is key to make any alternative to positivist reductionism operationally viable. In the case of AI powered planning support systems, this pursuit requires interpretative and conceptualist approaches to human-computer interaction. Pluralist approaches disentangle the wish to increase the computing abilities of machines from the positivist drive to calculate one’s way to the discovery of the immutable laws prospected by Saint-Simon. Instead, they exploit the inherent mutuality of human-computer interaction to integrate hermeneutics in the very process of computation. In this sense, the post-positivist emphasis on interpretation and meaning in planning (Allmendinger, 2002; Davoudi, 2012) speaks to the efforts in conceptual coherency and transparency deployed by cognitive-semantic approaches to computer science. In terms of intellectual traditions, this correspondence resonates in the opposition to realism shared by interpretationism and conceptualism, as put respectively by Davoudi and Varzi, as long as there is no slip into idealism, nor into relativism. In other words, these references confirm that working with interpretation and concepts, rather than with undisputable or mutually incommensurable truths, stands as a shared endeavour across domains. Moreover, for interoperability to adapt to system change and work beyond the fixity of certainty, modeling open systems, as proposed by Peter Allen, brings to the conversation the benefits of recursive experimental learning regarding the multiple states emerging from complexity and wholeness. Overall, a pluralist commitment requires embarking on the learning processes of muddling through diversity and complexity. Indeed, interpretative and conceptualist devices pursuing conceptual coherency and transparency sustain learners' sense of direction away from the positivist mould, by making the muddling process more intelligible, and therefore liable to scrutiny. When data-driven applications in planning support systems bypass conceptual coherency and transparency checks, they contribute to the embroilment of planning practice in the positivist mould. For example, advertising narratives about these applications tend to shift attention away from the need to monitor their procedural and material flaws. By confusing tools, means and ends, the AI for sustainable, circular or equitable, cities brands create the illusion that the proposed tools are intrinsically geared to the pursuit of allegedly good intentions. This illusion overshadows the analytical biases entrenched in the choice of data sources or in the design of the algorithmic logic, not to mention the under-researched footprint of their physical infrastructure in terms of energy and water consumption. Instead, these problems need to be reckoned with as an intrinsic liability and addressed with appropriate mitigation methods and measures. Overlooking analytical biases supports positivist assumptions that data and algorithms are factors of objectivity and certainty per se, granting validity and solidity once and for all, and ignoring the need to pursue their recursive enhancement via semantic interoperability, ergo transparency. By focusing attention on the nobility of alleged ends, these narratives reinforce the technocratic flatness of the assumption that appropriate calculation will ensure certainty in the pursuit of these ends. Overall, these brands dissimulate the fact that tools like AI have no intentions, noble or despicable as human intentions may be. These tools can be engaged for means such as monitoring through large scale data analytics based on automated sensing and data mining, or scenario building and problem solving, for example through reinforced learning. In turn, these means may work towards both intentional and unintentional, noble or despicable, ends. No matter the tools' computational capabilities, the pursuit of intentional ends, and of the ways in which means powered by AI tools are used towards these ends, are the prerogative of human agents. Moreover, this pursuit is not a matter of AI nor of human calculation. Instead it is a matter of human deliberation and sense-making (Schön, 1983; von Glasersfeld, 1995) channelled into the arguments engendering connection between encoders and decoders, writers and readers. This connection is tied to arguing and interpreting. It exceeds AI copycat competences, just like writing and reading for transformation exceeds the standardized uniformity of a large language model's outputs (Lim, 2025). Increasing the aptness of modeling tools to recursive enhancement, pluralist approaches informed by semantic-cognitive and complexity paradigms improve modeling outputs suitability to meaningful argumentation and interpretation. In this way, these approaches can steer AI capabilities in the service of post-positivist interpretative and hermeneutic planning. This proposal assumes that AI capabilities require actual integration with human capabilities, because of their intrinsic difference. It resists both enthusiastically relinquishing human capabilities by blindly relying on AI outputs, and anxiously rejecting AI as an absolute threat, implicitly framing it as a legitimate competitor.

Locating this dissertation in relation to shared intellectual traditions in planning and computer science, this section sets the conceptual ground for raising research questions rooted in applied ontology, legitimizing their relevance in the domain of spatial planning.

2.b Knowledge representation, semantics, sense-making and the design disciplines

This section[5] offers a commentary on the question of knowledge in the design disciplines, focusing on the concepts used to make sense of a design problem. It highlights the reciprocity between the human and the artificial in automated reasoning processes, referring to methods for knowledge representation used in the design of algorithms for artificial intelligence to solve problems. Ongoing debates on these issues usually understand reciprocity as a two-way exchange, where humans formulate information and communication protocols that enable machines to replace us in various other, less appealing, tasks. In these debates, much attention goes to the extent to which, as we instil it in artificial agents, intelligence ceases to be our distinctive prerogative. This section points to a third round of reciprocity, inspired by the intuition that helping machines to help us back might also benefit our own reasoning, particularly when thinking in action (Schön, 1983). Far from making any assumption on the comparison of human and artificial minds in any direction, this intuition refers to the exchange between teacher and learner, no matter how differently they may think. In this light, this section argues for the benefit of domain experts

5 A draft of this section was presented at the Symposium AlterEgo at the Department of Architecture of the University of Genoa, on April the 4th, 2024 and was accepted for publication as part of an edited volume by the Genova University Press.

engaging with semantic annotation through transdisciplinary collaboration with logicians and computer scientists. Starting with a description of semantics trans-disciplinary applications in digital modeling, it contextualizes its suggestion of a third layer of reciprocity between human teachers and machine learners. It then connects insights on “designerly ways of knowing” (Cross, 2001) and the role of problem setting (Schön, 1983) in addressing wicked problems (Rittel & Webber, 1973) with radical constructivism theory of knowledge (von Glasersfeld, 1995). This theoretical framework links sense-making and purpose, providing the rationale for a synergy between semantics and design, under the assumption that “intelligence organizes the world [design] by organizing itself [semantics]” (Jean Piaget, cit. in von Glasersfeld, 2007).

Indeed, it is plausible to say that semantics organizes intelligence by defining the concepts, or mental representations (Margolis & Laurence, 1999), engaged in the cognitive processes that lead to knowledge representation. Concerned with the meaning of language and of its concepts, semantics studies the quadruple correspondence between entities and phenomena in the physical world, in its cognitive, in its analogue and in its digital representations. Articulating and organizing the different possible meanings of the concepts used to describe entities, qualities and relations in a model, it explains how to interpret these concepts in representing the physical world at each of the other three levels. Through the development of formal ontologies, it has a wide variety of applications in computer science. These include aspects related to human usability, such as information retrieval, data storage coherency, interoperability between information systems, as well as to machine learning and artificial intelligence. In such wise, semantics is a key though not so renowned factor of the reliability of digital models, and of their heuristic value for scenario building and interpretation by decision makers, particularly in decision-support systems.

In any scientific domain, semantics establishes meanings for what is known, contributing primarily to the completeness and consistency of representation in digital models, and ultimately to the coherence of their information architecture. After its foundational role at the onset of artificial intelligence, it was sidelined by machine learning, betting on exponentially increasing computational capabilities to manage inconsistencies in progress, instead of seeking to prevent them by semantic annotation (Paleyes et al., 2022). Depending on the purposes of each model, and on knowledge engineering priorities, cognitive or symbolic approaches were often eschewed in favour of data driven approaches for being too labour intensive and rigid. Yet, in recent years, this imbalance is being redressed, with neuro-symbolic methods increasingly stirring interest to exploit the advantages of both approaches (Hohenecker & Lukasiewicz, 2020; Morel, 2021).

In the domain of design disciplines, at the intersection of science and art (Schön, 1991), knowledge and action (Friedmann, 1987), information and purpose (Couclelis, 2009), what is known foregrounds what can be done. If what is known is a conceptual construct (von Glasersfeld, 1995), a clear definition of the meanings at play provides an enabling condition to streamline the decision-making process about what can be done. If concepts are subjective yet shareable sub-propositional mental representations (Margolis & Laurence, 1999), semantic annotation of their meaning states ontological constraints in reasoning, providing a shared ground to trace designers’ path from knowing to doing. Despite the involvement of hard sciences such as logic in the process, this is far from a call “to ‘scientise’ design” (Cross, 2001, p. 49). It is more of a supporting argument to the idea of a design discipline that deploys rigorous ways of knowing of its own, based on a reflective practice (Schön, 1983; Cross, 2001) open to both self-scrutiny and validation by interlocutors. This practice can rely on methods that make subjective assumptions explicit, stating whether they are based on propositional or tacit knowledge (Schön, 1983; Shaathun, 2022), enabling shared assessments of the cases when each assumption holds and when it doesn’t. These assessments build the body of shareable evidence that is key to organizational learning for both human and artificial intelligence, where the artificial learner becomes a mirror and a magnifier of the level of coherence, or incoherence, in the human teacher’s reasoning.

This argument assumes the pivotal role of problem setting (Schön, 1983), or problem formulation as a process (Ball & Christensen, 2019), in enabling designers to deal with wicked problems, and with the sociality of their formulation (Rittel & Webber, 1973; Coyne, 2005). In Schön’s words, problem setting sounds quite similar to what semantic annotation does for modeling: “When we set the problem, we select what we will treat as the ‘things' of the situation, we set the boundaries of our attention to it, and we impose upon it a coherence which allows us to say what is wrong and in what directions the situation needs to be changed.” (Schön, 1983, p. 40). Moreover, this argument calls for a constructivist approach to knowledge, which is also at the heart of Schön’s interest in problem setting, when he writes:

> “In real-world practice, problems do not present themselves to the practitioners as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain. To convert a problematic situation to a problem, a practitioner must do a certain kind of work. He must make sense of an uncertain situation that initially makes no sense.” (Schön, 1983, p. 40).

Sense-making here is crucial to the construction of knowledge and to problem setting. Sense-making is a key concept in the theory of cognition (Newell, 1994), as well as in von Glasersfeld’s constructivist theory of knowledge (von Glasersfeld, 1995), both stressing its role as a bridge between sensorial experience, knowledge and decision making. Semantics is indicative here of an ontological bundle, where the same lexeme means both the input, sense as in sensing, and the output, sense as in making sense, of a cognitive process. Nonetheless, it is the term ‘making’ that is key to the constructivist lens, which helps us rethink the status of knowledge at the intersection of discovery and invention. According to von Glasersfeld, the experiencing subject generates knowledge as a “builder of cognitive structures”, rather than as “an explorer who is condemned to seek ‘structural properties’ of an inaccessible reality” (von Glasersfeld, 2007, p.8-9). In this perspective, the value of knowledge depends not on truth, but on its viability as a mean to solve the problems that the knowing subject “perceives or conceives» (von Glasersfeld, 2007, p. 9).

> “Making sense […means] fitting available conceptual elements into a pattern that is circumscribed by specific constraints. […] inherent in the way in which we have come to segment and organize experience […] it [is not] a matter of matching an original. If our interpretation of experience allows us to achieve our purpose, we are quite satisfied that we know.” (von Glasersfeld, 2007, p. 12).

By providing explicit and shareable constraints to the meaning of concepts, semantics sets favourable conditions for shared sense-making and problem setting in a design process. These conditions encourage scrutiny and evaluation of consequentiality between problem-setting and decision-making towards design purposes, enabling human and artificial, or hybrid, intelligence, to improve design processes. If, as put by von Glasersfeld, "The world we live in, from the vantage point of this new perspective, is always and necessarily the world as we conceptualize it" (von Glasersfeld, 2007, p. 9), indeed semantics may help design a better world by reflection-in-action.

This section explained the disciplinary relevance of applied ontology, representation and semantics within the design disciplines in general, to justify the endeavour of raising research questions regarding meanings and representation in its broadest sense, towards the construction of knowledge, sense-making and problem-setting in all design disciplines.

2.c Ontology and transitional spatial imaginaries from knowledge to action

Moving along this chapter set up of the theoretical framework and problem definition behind this research objectives, this section[6] explores the role of ontology, knowledge representation and semantics in spatial planning. It builds on John Friedmann classic definition of planning as the relation between knowledge and action (Friedmann, 1987), and on literature on technological transitions and on social and spatial imaginaries, broadening the interpretation of this latter notion based on its intersections with representation and sense-making, and therefore with problem setting as explained in section 2.b. By comparing these insights with the role of ontology in computer science, it argues for an ontological approach to spatial representation in spatial planning. After introducing the theoretical framework to define the role of ontology in computer science, and specifically in geographic information science, it lays down the rationale for its argument and proposal in three steps, listed below with headings in italics. It begins with a general explanation of the relevance of applied ontology to multi-agent decision making characterizing planning behaviour in general. It contextualizes this relevance specifically in contemporary conditions of crisis and transition. It then focuses on spatiality and spatial planning to explore the intersection between an ontological approach to spatial representation in spatial planning and the construction of spatial imaginaries. After the previous sections respectively identified the theoretical bridges between computer science and spatial planning, and highlighted the roles of semantics, sense-making and representation in design disciplines as a whole, this section explores the interface of spatial planning and applied ontology in semantic-cognitive approaches to computer science.

Assuming planning as a domain defined by the mutual relation of knowledge and action, as per John Friedmann classic definition (Friedmann, 1987), knowledge stands as a common concern between planning (Davoudi, 2015) and computer science, most specifically in the fields of knowledge engineering and knowledge representation (Guarino, 1998). According to Nicola

6 A draft of this section was presented at the 2024 AISRE Conference at the University of Torino on September the 4th, 2024.

Guarino (1995), the understanding of knowledge in computer science is split between functional definitions, focused on task-dependent analysis of an agent rational behaviour to achieve a given goal and devoid of ontological foundations, and foundational definitions focused on task-independent analysis of a domain or problem. In this split, foundational definitions are more akin to the pluralist perspective addressed in section 2.a, precisely because explicit definitions enable scrutiny, differentiation and alternative definitions, whereas working in an ontological black box preserves absoluteness and indisputability. Here, the significance assigned to tasks defines the status of knowledge. Defending a foundational approach to knowledge engineering, Guarino argues for the need for the systematic introduction of formal ontological principles in the practice of knowledge engineering (Guarino, 1995). Comparing the philosophical and the engineering perspectives on ontology (Guarino, 1998), he points to the similarity between two dichotomies. The first is the dichotomy of ontology, "the study of the forms of being", and epistemology, "the study of the forms of knowledge" (Guarino, 1995, p. 629). The second is that of representation, as the discernment, description, or measurement in the case of spatial representation, of entities and their relations, and reasoning as the selection and organization of information about those entities, "deriving new knowledge from the given information" (Cohn & Renz, 2008, p. 572). This similarity points to the relevance of an ontological lens in domains concerned with representation such as planning (Davoudi, 2012). Moreover, it points once again to the role of ontology in a pluralist approach to knowledge as compared to positivist assumptions about the singularity of expert-driven truth. While knowledge representation and reasoning are considered complementary areas within the domain of Artificial Intelligence (Lifschitz et al., 2008), functional approaches overlook the need to establish ontological foundations for representation as they focus on extracting knowledge from an expert's mind. Again, pluralism ought not be confused with relativism. In this sense, Guarino's foundational argument departs from endorsing "a modeling activity whose object is the observed behaviour of an intelligent agent embedded in an external environment" (Guarino, 1995, p. 625, quoting from W.J. Clancey), to point to the need for knowledge to account for an objective reality, stressing the irrelevance of tasks or actions in this context. In this sense, establishing ontological foundations for representation does not mean that modeling excludes the agent's behaviour, but rather that it includes the external environment excluded by the functional approach. In this sense, task-independent does not mean that actions are necessarily considered irrelevant in the foundational approach. They may be, or not, in the formulation of an ontology, just as agents can be considered constitutive elements of ontologies for example through theories of roles (Borgo et al., 2022). In this light, just like reasoning implies knowledge representation, an ontology provides the coordinates to take decisions and perform tasks in the context of an objective reality, and the construction of knowledge of such reality requires these coordinates to avoid replicating black box singular absolute truth. Helen Couclelis states the complementarity of ontology and epistemology precisely by clarifying the possibility of taking into consideration actions and agents in geographic information science. She does so by introducing the notion of purpose, recalling the Aristotelian triangulation of ontology, epistemology and teleology. As she puts it:

> "While ontology deals with what exists in a given world, epistemology is concerned with the nature and scope of knowledge, and teleology with the *reasons* (not causes) why the world

is as it is and why and how it is changing. Reasons derive from the beliefs, thoughts, hopes and desires that lead people to strive towards particular purposes or goals, whereas causes have effects regardless of any reference to human intentionality […] linking current conceptions of ontology in geographic information science with teleology as well as with epistemology would allow new kinds of scientific questions to be addressed would expand the scope of ontology itself towards novel and fruitful directions. In developing the argument for epistemology and teleology this paper explores the implications of basing ontology construction in geographic information science on the dual principles of *information* and *purpose*. In-formation, a fundamental epistemological notion […] is a relational rather than an absolute concept, expressing an intrinsic relationship between in-formation source and recipient (Williamson 1994; Huchard et al. 2007). This establishes a basis for taking into account the interests of the user and thus for forging a link between ontology and teleology. […] *Purpose*, the hallmark of teleology, is not a notion emphasized in existing ontologies of geographic information science, and yet every geo-graphic representation is developed for some purpose." (Couclelis, 2009, p. 4-5).

While the complementarity between ontology and epistemology is also implicit in Guarino's perspective (Guarino, 1995), Couclelis adds teleology stepping aside from Guarino's take on the irrelevance of tasks and actions, while maintaining the role of ontology to ensure objectivity grasps embeddedness in an external environment. By adding teleology, Couclelis introduces a constructivist interpretation of ontology and epistemology development, while hinting to an interesting distinction between her reference to purpose as intention and the strictly functional approach reference to goals understood in absolute causal terms. Indeed, her reference to reason and intentionality looks away from the causal relationship intrinsic in the strictly functional and result-oriented assumption that achieving a goal is the direct consequence, and indicator, of the agent's knowledge, as explained by Guarino. In this sense, Couclelis's insights steer away from the strictly functional approach to knowledge criticized by Guarino, while matching the utilitarian or action-related consideration of knowledge most typical of planning and other organizational disciplines. Where the strictly functional approach focuses on tasks as mechanistic disembedded joints of cause and effect, Couclelis's broader utilitarian approach focuses on the relation between ontological assumptions about the environment, the validity of knowledge and the intentionality of the actions embedded in such environment. Stressing the intentional nature of human cognition, her approach explains how humans conceptualize the geographic world towards a given purpose, whether this purpose is explicit or not. For example, in the case of the creation of administrative and property boundaries, "the purpose of surveillance, control and manipulation of both the natural and the social worlds requires things to be objectified that are not, strictly speaking, objects." (Couclelis, 1992, p. 73). This distinction between the strictly functional and the broader utilitarian approach, and between causes and reasons as purpose, matter in different yet cognate directions. Steering away from causes towards reasons in the interpretation of the relation of knowledge and action grounds the readiness of planning intentionality to deal with the uncertainty and complexity of evolutionary processes (De Roo & Boelens, 2016), even more so nowadays, confronting recurrent crisis and expecting a transition. Moreover, along the same lines, Couclelis's understanding also speaks to John Friedmann's suggestion from the early 90's regarding the need for a non-euclidean mode of planning (Friedmann, 1993, 1994) in the wake of the emergence of “a non-Euclidian world of many space-time geographies” (Friedmann, 1993, p.482). Meanwhile, steering away from the strictly functional approach to knowledge criticized by Guarino grounds the possibility to apply ontological foundations to planning knowledge and action. Linking ontology to teleology roots the objectivity of the reality to be modelled into the actual purpose or reason for modeling. This interpretation provides the overarching framework for explaining the constitutive role of representation, sense-making and semantics in the planning knowledge production and normative action on the spatial organization of the built environment. In this perspective, applied ontology provides the framework according to which semantics articulates and organizes meanings in the domain of spatial planning, ensuring the stability of decision-making processes. Also, semantics and ontology work as stepping stones for representation. Although Couclelis’s and Guarino’s respectively utilitarian and foundational approaches may not fully match, they converge on challenging the “strictly functional” approach to modeling pointed out by Guarino, by pursuing the complementarity of representation and reasoning and that of ontology and epistemology. Moreover, Couclelis's stress on the relation between information and purpose, knowledge and intentionality, seems compatible with the idea of foundational ontologies in action, where alternative ontologies apply differently to different use cases (Borgo et al., 2022). Against this background, the role of ontology and semantics in planning behaviour can be progressively specified in three steps, defining the role of meaning in sense-making and of problem setting in the construction of knowledge (von Glasersfeld, 1995) in terms of stability or instability of the framework, regardless of the uncertainty of the content.

Step 1, ontology and semantics for planning: stabilizing meanings for crispier and shareable problem setting.

Recalling section 2.b, planning convenes often patchy cohorts of practitioners and stakeholders to deal with the sociality of the formulation of wicked problems (Rittel & Webber, 1973) and engage in problem setting to “make sense of an uncertain situation that initially makes no sense” (Schön, 1983, p. 40). This scenario can be unpacked in at least two layers. First, it can be stressed that sense-making as semantic articulation of the meanings of concepts in use holds a key to problem setting, and that semantic annotation based on ontological foundations consolidates the descriptive and the heuristic power of concepts. Indeed, formal ontology, “a theory of a priori distinctions among the entities of the world […and among] the meta-level categories used to model the world” (Guarino, 1995, p. 628), is said to be foundational for how it organizes the set of distinctions against which semantic assumptions and ambiguities can be questioned and redressed. Supporting a rigorous description of all forms and modes of being, ontological commitments provide a solid backdrop to sense-making. Understanding concepts as subjective but shareable mental representations (Margolis & Laurence, 1999), semantic annotation stabilizes meanings and provides crispier, or more accurate, knowledge representation on both sharp, or precise, and vague content. Second, adding the sociality layer, one may as well agree that articulating meanings holds a key to their sharing towards collaborative problem setting, and to the construction of bodies of shareable evidence to inform participatory decision making. In computer science, this step corresponds to the use of ontology to ensure semantic interoperability between information systems (Guizzardi & Guarino, 2024). Beyond problem setting, articulating meanings supports collaborative validation of evidence to formulate and communicate planning ends, as well as their scrutiny and endorsement. Indeed, crisp mental representations support punctual monitoring and evaluation of the impacts of socio-economic and environmental policies and of the application of prescriptions about spatial ordering (Alexander E. R. et al., 2012).

Step 2, ontology and semantics for planning in times of crisis: stabilizing meanings to streamline individual, collaborative and trans-disciplinary theory-practice reflective feedback loops for planning for/in transition.

Nowadays spatial planning in times of crisis means working on two fronts. On the external front, the many crises characterizing the second and the third decade of the second millennium CE are preparing a transition in the socio-ecological organization of human settlement processes (Alberti, 2016). On the internal front, the crisis in the ability of spatial planning to govern these processes is preparing a transition in the socio-technical organization of its broad set of approaches and techniques. The possibility of planning *for* a desirable transition to overcome societal conditions of crisis concurs with the engagement of planning expertise *in* undertaking a desirable transition of its own, overcoming the crisis of its prerogatives. Highlighting this concurrence contextualizes this section's interest in the contribution of semantics to spatial planning at the intersection of these two crises and towards a double edge transition. Beginning with the first front, the current post-pandemic years are radically putting into question the compartmentalized understanding of crisis and recovery dynamics that have characterized much of recovery planning and policy before and during the pandemic. Acknowledging the nested crisis condition (Carastathis, 2018; Mohandesi, 2020) of the post-pandemic, connecting, to the least, political, environmental, social and economic drivers, challenges the very notion of recovery as restoring, or getting back to, the pre-crisis state. It makes the case for abandoning expectations to resume business as usual in any of those arenas, and to acknowledge the ongoing transitional process. In this context, the idea that seizing the moment to bring about a desirable transition requires major transformations in the organization of human life is gaining momentum within a growing body of scholarship (Magnaghi, 2020; Savini et al. eds., 2022; Kaika et al. eds., 2023). This leads to calls for a socio-ecological transition that would stabilize these transformations in the long-term, with the emergence and dissemination of new organizational set ups (Alberti, 2016). Coming to the second front, shortcomings in the government of human settlement processes (Jacobs, 1961), and in the quality of the urban form delivered by these processes (Alexander, C., 1979; Caniggia & Maffei, 2001) were diagnosed since the second half of the nineteenth century. Notwithstanding the development of a broad set of path-forwarding approaches and methods, the crisis of the planning profession has been long in the making, with planning intentionality often seen as drifting in the face of power (Forester, 1999; Flyvbjerg, 2004), or along with the intersecting tides of the multi-level rationality of planning behaviour (De Roo & Perrone, 2020). Considering the richness of contributions devoted in the past decades to clarify the epistemological grounds (eg. communicative, complexity, south-eastern perspective, assemblages or more-than-human) and the implementation horizons (eg. polycentrism, diver-city, post-growth, bioregionalism, urban ecology) of spatial planning, the solution of this crisis does not seem to lie in adding one more niche (Geels, 2002) of planning innovation on either of these levels. Hearing the perspectives of researchers and professional officers in public debates convening both sides, a slight interpretational split emerges, even in those occasions when the same person would speak about one's own work in either of the two contexts. On the one hand, many researchers devote their attention to the gap between theory and practice (Alexander E. R., 2016), and, in a more pragmatic sense, between academic research and professional office (Hurley et al., 2016), though the two gaps do not exactly overlap. On the other hand, many officers explain shortcomings in their work by stressing the influence of contextual constraints posed by stakeholders or by the legal and procedural framework (Tasan-Kok et al., 2016). The constraints encountered by officers can indeed be charged of causing a gap in relation to aspirational content from academic research. Nonetheless, the theory practice gap covers a wider scope which operates diagonally across academy and professional office. At least part of this extra width holds on mismatches in the use of concepts across both cohorts in the absence of explicit formulations. For example, concepts such as sustainability, complexity, distance, scale, or boundary, if used with unstable implicit assumptions about their meanings, easily lend themselves to rhetorical manipulation taking advantage of the opacity of benchmarks. In this light, the room for mismatching depends on the degree of crispness of the concepts at hand, where both researchers and officers can evenly contribute to the transparency, or not, of problem setting and sense-making by reflection-in-action (Schön, 1983). This is, again, where semantic annotation may come in handy, even though reducing the width of the gap is not about closing it as an end state, but more of a mean to exploit the polarity between theory and practice, or between conceptual formulation and use, as a fertile field for reflection and evolution. In this sense, stressing on reflection as a progressively questioning critical attitude, planners can look at filling the gap as the endless endeavour of keeping the size of the gap in a healthy tension, considering transparency and opacity respectively as conditions for progress and for arrest along this process. Now, reflection by both groups can be stratified in three layers, from individual to collaborative and then transdisciplinary or trans-sectorial reflection. The more transparent sense-making is, the more stable and disposable the mental representations connecting notions and phenomena can keep becoming in all layers. Therefore, sense-making based on progressively crispier mental representations by semantic annotation and re-annotation stabilizes reflection and progressive problem setting and resetting by both researchers and officers, tracing a theory-practice feedback loop to spirally fill the gap to a size of healthy intensity. Endorsing theory and practice, concept (re)formulation and use, as diagonally cross-cutting both groups, researchers' and/or officers' cohorts can collaboratively engage in the loop, based on stable commitments in terms of meaning and representation by semantic annotation (Kuhn, 2009; Saquicela et al., 2022). The proposed role of ontology and semantics in transitions builds on the role ascribed to culture in eco-evolutionary dynamics and in technological transitions. According to Marina Alberti (Fig. 2.2):

> "co-evolutionary interactions between species or genes can mediate evolutionary feedbacks through either strictly genetic co-evolution or through gene-culture co-evolution. [… Therefore gene-culture co-evolution lies at the onset of the] urban-driven changes in the attributes of populations, communities, and eco-systems that influence phenotypes via selection and plasticity and potential feed-backs" (Alberti, 2016, p. 137).

This is why, Alberti contends, “to fully understand the potential implications of eco-evolutionary feed-backs in urbanizing environments, it is critical to expand the framework of eco-evolutionary feedback to include genetic and cultural co-evolution through both inheritance and social learning [...Therefore, one of her] four overarching hypotheses linking urbanization to eco-evolutionary dynamics and its potential role in promoting or buffering eco-evolutionary change [...reads] H3: Humans affect eco-evolutionary feedback through both genetic and cultural changes resulting from their co-evolutionary dynamics with other social organisms.” (Alberti, 2016, pp. 138,142).

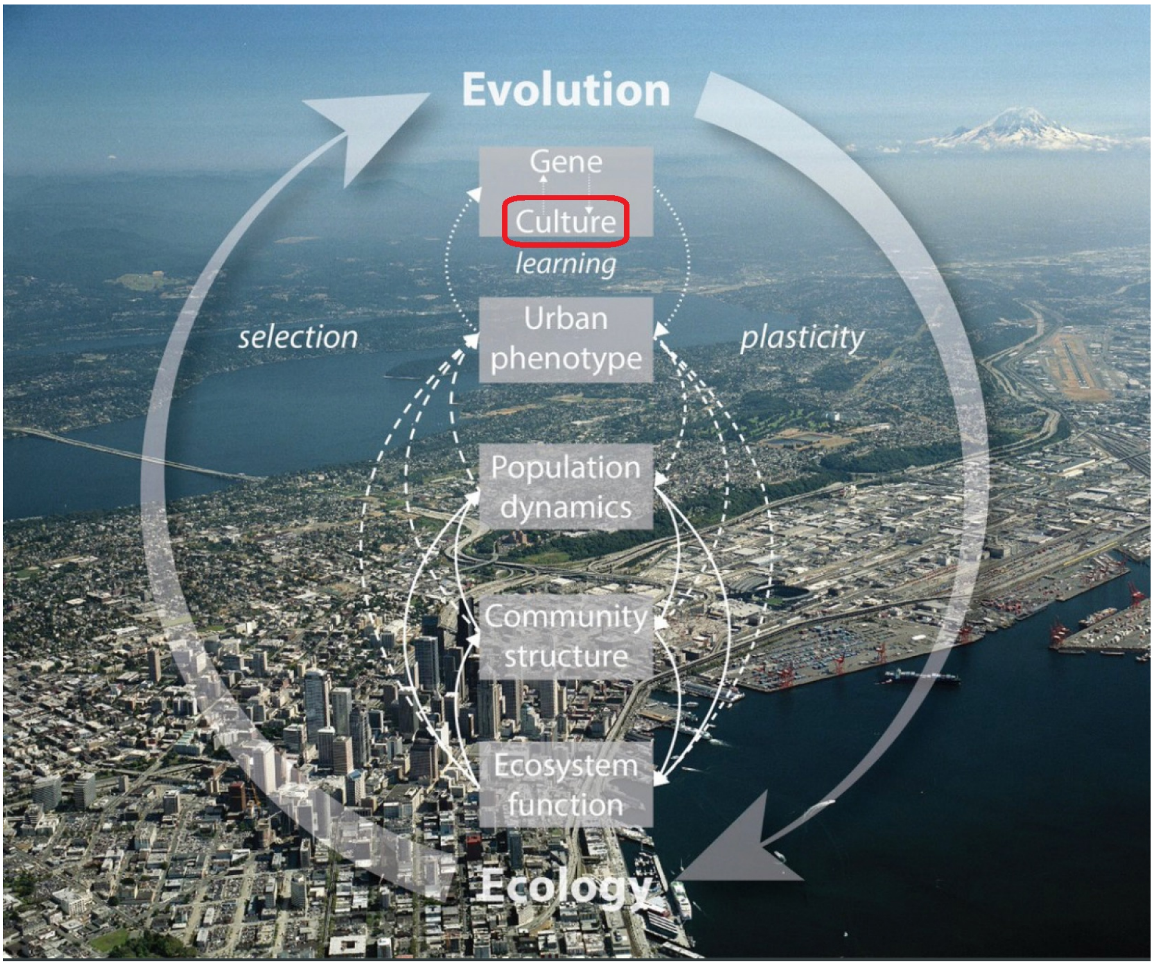

Fig. 2.2 “Eco-evolutionary dynamics in urbanizing eco-systems” (Alberti, 2016, p. 138). Red frame added.

The observation regarding gene-culture co-evolution can also be read in relation to Alberti's focus on imagination, which is even more remarkable considering her background in biology, beside architecture. And so she states: “Cities are the product of natural and human history and evolution. But they are also the product of human imagination” (Alberti, 2016, p. XII), anticipating upcoming insights on spatial imaginaries. Her observation about gene-culture co-evolution also implies the sterility of stances marked by abstract vs. concrete, immaterial vs. material dichotomies, framing theory and practice in opposition to one another. On the one hand, these stances are all too rooted in common sense, particularly in architecture and planning professional cohorts, as often surfaced in conversations regarding the scope of this dissertation. On the other hand, the semantic character of what exists, the notion of material culture as text, and the role of common sense, meaning and symbols as constitutive elements of material culture, and, we can now add, of gene-culture co-evolution, stand as the bedrock of both structuralist and post-structuralist philosophy and anthropology since their early steps (Geertz, 1975; Schneider, 1987). So much so, that the equivalence between culture, symbols and meaning can be nowadays taken for granted, as in Frank W. Geels (2002) perspective on the all too material technological transitions, associating culture and symbolic meaning (Fig. 2.3). According to Geels (2002), societal functions such as human settlement are fulfilled by socio-technical configurations linking together a heterogeneous set of elements. In this respect, technological transitions, as evolutionary reconfiguration processes, "consist of a change from one socio-technical configuration to another, involving substitution of technology, as well as changes in other elements" (Geels, 2002, p. 1258). These elements are broad categories to be specified into actual features for each socio-technical configuration. One of these elements, culture and symbolic meanings, refers to the representation of values and beliefs of substantial relevance to the culture characterizing a given socio-technical configuration. According to Geels, "TT [as technological transitions] do not only involve changes in technology, but also changes in user practices, regulation, industrial networks, infrastructure, and symbolic meaning or culture" (Geels, 2002, p. 1257). He mentions for example freedom and individuality in relation to the socio-technical configuration of personal transportation (Geels, 2002, p. 1258). Along this chain of thoughts, the ties established between culture and eco-evolution, and between meaning and technological transitions corroborate the relevance of semantics and ontology in planning for/in transition.

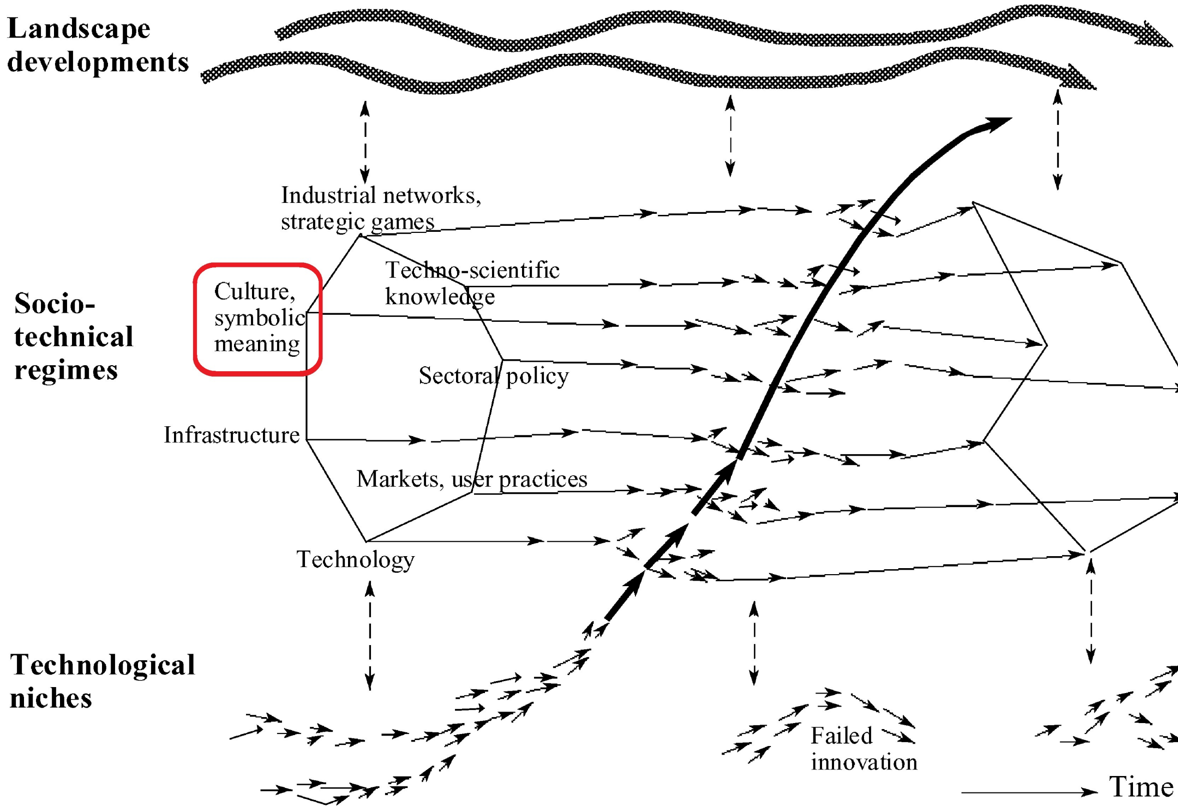

Fig. 2.3 "A dynamic multi-level perspective on technological transitions" (Geels, 2002, p. 1263). Red frame added.

Step 3, ontology, semantics and the representation of space: stabilizing and widening the range of options about meanings in spatially sensitive problem setting in planning for/in transition.

Building on previous steps, and on section 2.b observations on semantics' contribution to the construction of knowledge in the design disciplines as a whole, this step addresses the challenge of how can spatial planning "make[s] sense of an uncertain situation that initially makes no sense" (Schön, 1983, p. 40) in a spatially sensitive manner. Even with the addition of the spatial focus, the same rationale applies for spatial concepts just like for any other type of concept. Nonetheless, the representations implicit in the meanings of spatial concepts, like for example area, line, point, distance, scale or boundary, to name but a few, are seldom a subject for reflection in spatial planning. Though these terms are common features in most studies, their meanings tend to be taken for granted by officers and by most researchers, except for occasional inquiries into specific concepts by those more attentive to the epistemic interpretation of spatial problems (Paba & Perrone, 2017). This means that purely spatial mental representations enjoy a kind of inertia among spatial planners that further complicates the opacity of implicit assumptions in their meanings and the treatment of their instability. This is especially so since the gap between formulation and use in this case is also characterized by a disciplinary split where spatial planners, in line with the dwindling disciplinary status of our domain of expertise, tend to use conceptual models formulated by scholars from other disciplines. As a result, reflection on purely spatial concepts by spatial reasoning and knowledge representation remains tightly confined within the disciplinary boundaries of logic, geometry and computer science. Moreover, another disciplinary split applies to composite socio-spatial conceptualizations borrowed from human geography, such as the notion of spatiality (Merriman et al., 2012). While these conceptualizations are somehow appealing to some planners' reflective inquiry, others deem this appeal a liability for the propositional character essential to our mission, discouraging their systematic appropriation by collegial user led reformulation. This means that, while planning for a desirable transition requires the regulation of the spatiality of the transition, in other words, the regulation of the spatial organization of human life, and therefore of the built environment, the implications of the use of geometric conceptual models of space for this regulation are not taken into consideration, since their adoption is taken for granted. One of the aspects often overlooked is the understanding of spatially sensitive as aware of the complementarity between space as produced by and space as producing (Merriman et al., 2012) future transitional set ups. This insight, among others, often falls short of trickling down from human geography into mainstream spatial planning. In its light, the conversation about the spatiality of the transition can be framed from at least two angles. Looking at the ways in which the transition may produce spatial organization focuses institutional planning intent on socio-economic and environmental policy making. Conversely, looking at the ways in which spatial organization may produce the transition, focuses institutional planning intent on spatially explicit policies and spatial ordering (Alexander E. R. et al., 2012). The complementarity between these two angles is essential for the contribution of spatial planning to the pursuit of a desirable transition. Spatial representation, spatial conceptual models and related language and meanings play a role at both angles, through the interference of common sense representation and models with policy implementation at the first angle, and directly as spatial ordering principles at the second angle. These roles reflect the influence of language and meaning on the actualization of planning intentionality. Human geography interprets the role of language and meaning within the relation between reasoning and purpose, or knowledge and action, in two alternative ways, defined as representational and performative discourse. Referring to the debate on these interpretations in the literature on spatial imaginaries (Watkins, 2015), these two options justify, in a way or another, the relevance of ontology and semantics in spatial planning. This justification is based on the role of meaning, cognition and materiality in human geography conceptualizations of spatiality, considered as an emergent configuration (Soja, 1985; Merriman et al., 2012; Davoudi, 2018). Accordingly, meaning is deemed as a factor in the construction of the spatial imaginaries reflecting and reflected in such emergence (Davoudi, 2018). In this context, by spatial imaginaries scholars refer to models of geographical places and territorial organization - according to Watkins, places, idealized spaces, spatial transformations, elsewhere named as imaginative geographies (Said, 1978; Gregory, 1995). Yet, post-structuralist approaches to human geography (Wylie, 2006) interpret the role of meaning in the relation between knowledge and action in two distinct ways, depending on whether knowledge or reasoning and its outputs are considered as representational discourse or as performative discourse (Watkins, 2015; Davoudi, 2018). Representational discourse entails that purpose possibly follows reasoning as its consequence by selection. In this case, semantics' contribution to the transparency and stability of meanings in spatial sense-making is said to enable and sustain the accuracy of knowledge representation, which in turn, may be endorsed, or not, to enable and sustain accurately selected planning practice options. Instead, performative discourse entails that reasoning and purpose reflexively, simultaneously and reciprocally, determine one another. According to Watkins (2015), the performative interpretation collapses temporal and causal distinctions between meaning, linguistic circulation and material practices, suggesting the possibility of considering meaning, and semantics, in spatial sense-making as a planning practice which directly shapes, and is shaped by, the material configuration of places. The debate on these interpretative options does not fall within the purview of spatial planning. Yet, awareness of their distinction prevents implicit assumptions in favour of one or the other. Nonetheless, since both justify the triangulation between meaning, reasoning and purpose, albeit a different one, the relevance of the research topic for spatial planning can be justified either way. Along these lines, this dissertation experiments towards an extended interpretation of the notion of spatial imaginaries beyond models of geographical places and territorial organization. This extended interpretation includes spatial concepts, intended as the mental representations (Margolis & Laurence, 1999) describing the spatiality of those models. Indeed, Josh Watkins defines spatial imaginaries as social imaginaries whose "meanings are related to spatiality, while a social imaginary need not be. An example of this distinction is Anderson's (2006) idea of the nation as an imaginary community, or social imaginary. While the nation may be linked to spatial relations (a homeland, for instance), its constitution is more sociological than spatial: shared pasts, languages, comparable lifestyles, etc. (Anderson 2006)." (Watkins, 2015, p. 511). Moreover, according to Davoudi, spatiality emerges "from the relationship between the [abstractly] spatial, temporal, social, material and cognitive worlds" (Davoudi, 2018, p. 98), which can be understood as a whole, as always already intersecting worlds. Hence, stating that the spatiality of imaginaries is established through meaning, and that it intersects the cognitive and the material, socio-spatio-temporal, dimensions, this combined reading confirms the validity of a semantic approach focused on the role of spatial concepts in the construction of spatial imaginaries, and the fallouts this can have on the evolutionary reconfiguration of human settlement processes. This is even more so, considering Davoudi's distinction between "imagination as the work of the individual mind […and] imagination […which] operates at an intersubjective level […, the] collective imagination that is called the social imaginary" (Davoudi, 2018, p. 99), justifying the relevance of semantic stabilization of concepts as shareable, and therefore inter-subjective, mental representations (Margolis & Laurence, 1999). If it applies to social imaginaries, this relevance may as well apply to spatial imaginaries, where their spatiality-related meanings, as per Watkins's definition, justifies acknowledging the specific role spatial concepts play in their construction. This original take on the topic of spatial imaginaries in comparison to the literature reviewed looks beyond the three types of spatial imaginaries identified by Watkins (2015), places, idealized spaces and spatial transformations, in order to problematize the specifically spatial layouts of these imaginaries. This take stands as one of two original analytical contributions of this section, and it is particularly relevant to spatial planning because of its distinctive socio-spatial concerns as compared to those of human geography. Trying to capture this slight distinction, one possible simplistic interpretation may consider planning as concerned with the spatial organization of society, hence the relevance of the concepts constitutive of spatial layouts, while human geography to be more oriented to study the social organization of space, hence the inclination towards models of geographical places. The second original contribution of this section lies in the suggestion of the role ontology and semantics may play in the construction of spatial imaginaries. This role would consist of providing a stable and crisp set of meanings in the shared construction of spatial imaginaries as "collective understandings of socio-spatial relationships" (Davoudi, 2018, p. 101), based on Davoudi's observations about their constructed, their emergent, contingent and dynamic, and their collective character. These three aspects recall this section reading of the theory-practice feedback loop addressed under step 2. Construction recalls the construction of knowledge through sense making and problem setting. Emergence recalls the progressive nature of reflection by semantic annotation and reannotation towards problem setting and resetting, while contingency addresses the susceptibility to change of any construct. Collective understanding recalls the necessity of shareable problem setting and cross cutting collaboration across disciplines and cohorts such as spatial researchers, officers and residents. Overall making sense, and giving sense, is particularly prominent in Davoudi's account of the practical fallouts of spatial imaginaries. As she states, spatial imaginaries:

> "are performed by, give sense to, make possible and change collective socio-spatial practices. […] They are tacit, taken-for-granted understandings of spatiality that give sense to, enable and legitimate collective spatial practices. […] These tacit and taken-for-granted spatial orders are so weightless and invisible that we hardly even think about them, let alone have to justify them." (Davoudi, 2018, p. 101-102).

These insights further detail the material fallouts of spatial imaginaries on the evolutionary reconfiguration of human settlements processes, justifying the role of ontology and semantics in decreasing the opacity of these tacit understandings, increasing transparency on the assumptions behind their emergence. Most significantly, this is notably relevant to the use of spatial concepts such as area or region, line, point and network, distance or boundary, who's tacit and taken-for-granted character is particularly marked in spatial planning. So far, this section predominantly addressed the construction of spatial imaginaries as a generically social endeavour, while it argues for the distinctive relevance of ontology and semantics in the domain of spatial planning. According to Davoudi, spatial imaginaries influence spatial relations and planning practice by “both describing identities and ascribing them to places […when they are] adopted and enacted as unproblematic representations of places” (Davoudi, 2018, p. 97). Among the two interpretative options on the role of meaning in the relation between knowledge and action, Davoudi prefers the performative discourse reading, claiming that spatial imaginaries represent and directly create places. Most important in the context of spatial planning, she stresses the connection between the epistemic and the normative character of spatial imaginaries, where description and prescription blend in the creation of zones of actual land marked by the attributes of representations. This blend features also in Lidia Decandia's work on perspective, the drawing technique codified in the Italian Renaissance, as “the imposition of order onto the world” (Decandia, 2008, p. 14; see also Farinelli, 2003). Here, she matches Davoudi's account of spatial imaginaries as creative, performative and normative, and also Davoudi's interest in meaning. Stating that ontologies of space and time influence both ways of knowing and ways of organizing and designing human settlements, cities and regions, Decandia addresses uses as signifying practices (“pratiche d'uso e di significazione”, Decandia, 2008, p. 46), in turn matching Stuart Hall's definition of representation (Hall, 1997). These insights echo the previously suggested connection between representation, reasoning and modeling. To conclude on the role of spatial imaginaries in spatial planning, arguing for transformative imagination, Davoudi states: “Planning as politics of place is a key site where alternative spatial imaginaries can originate and flourish through dialogue and practice, and, crucially, through the acts of imagination which are ‘the capacity to see in a thing what it is not, to see it other than it is’ (Castoriadis, 1987, 81)” (Davoudi, 2018, p. 105). This section argues for ontology and semantics to support planning dialogue and practice in this direction through the entry points presented in the next paragraph. In this context, going back to Geels’s insights in the case of the sociotechnical configuration of human settlement, the meaning of spatial concepts can be examined as one of the relevant aspects for the susceptibility to change of any situated human settlement culture. Moreover, Geels’ mention of meaning and culture as interdependent aspects resonates with the relation between semantics and spatial imaginaries. Indeed, imaginaries in general are considered cultural artifacts by critics like Benedict Anderson (cit. in Davoudi, 2018, p. 100), while Simin Davoudi stresses “the role of spatial imaginaries in social and cultural identity” (Davoudi, 2018, p. 103). This link between technological transitions and spatial imaginaries suggests understanding spatial imaginaries, in the ontological and semantic extended notion proposed in this section, as a factor of transitional dynamics in the ways in which socio-technical configurations, such as spatial planning, fulfill societal functions, such as human settlement. This suggestion requires further investigation into the possible involvement of ontology and semantics in tracing trajectories of niche-cumulation (Geels, 2002) between application domains, towards breakthroughs in spatial planning for and in transition. Most specifically, further investigation is required to widen the thin-edge this section walks on, given the lack of dialogue between the research areas of post-modern geography and geo-ontologies, notwithstanding their common themes (Tambassi, 2017, 2018a). In this regard, this section justifies the plausibility of a convergence between ontology and semantics on the one hand and the construction of spatial imaginaries in planning for and in transition (Geels, 2002) on the other, pointing to spatial imaginaries as tacit understandings informing description and prescription of human socio-spatial organization (Davoudi, 2018). The interest of this plausibility lies in the search for approaches to streamline a critical perspective on the representation of geographic entities in spatial planning. In other words, by this search, this dissertation wishes to engage ontological distinctions (Guarino, 1995) to support critical spatial thinking in the domain of spatial planning, based on the relevance of critical spatial thinking to the integration of spatial information in the humanities and social sciences (Goodchild & Janelle, 2010), and more generally in transdisciplinary research (Kuhn, 2012). This means to nurture a critical perspective on the formulation and use of spatial concepts, "concepts that are needed to underpin the critical spatial thinking skills that we might expect of spatially aware scholars." (Goodchild & Janelle, 2010, p. 9). Even though spatial planners tend to think of themselves as necessarily spatially aware, critical thinking in the formulation and use of spatial representations and concepts is not commonly associated to such awareness, given the previously highlighted taken-for-granted understandings. Recalling this section insights, Goodchild and Janelle describe critical spatial thinking as the act of reflecting on the mental processes that accompany the use of spatial concepts and representations.

> "we use the word critical in the sense of reflective, sceptical, or analytic, implying that the successful application of spatial perspectives can never be rote, but must always involve the mind of the researcher in an active questioning and examination of assumptions, techniques, and data if it is to meet the rigorous standards of good scholarship. One way to define critical spatial thinking is in relation to the use of spatial tools and data—as the mental processes that accompany the use of these technologies" (Goodchild and Janelle, 2010, p. 9).

Attending to this understanding of critical thinking, this section argues for the use of ontological and formal analysis to help spatial thinkers unpack the assumptions underlying spatial data and the concepts to which these are attached. In this regard, it is important to conclude by stressing this dissertation human centred perspective on the construction of knowledge in general, and of planning knowledge in particular, to forestall reductive interpretations of the dissertation's interest in computer science domains such as ontology, semantics and knowledge representation. This perspective implies that, while planners willing to use artificial intelligence may possibly find inspiration in this dissertation, this research primarily looks at streamlining human reasoning in spatial planning, investing on semantics guidance for human, and possibly hybrid, intelligence, regardless of the tools each planner wishes to adopt or not.

This section explained the disciplinary relevance of applied ontology, semantics and representation in spatial planning for and in transition to justify the endeavour of raising research questions regarding meanings, representation, and spatial representation in particular, to foster critical spatial thinking and transitional spatial imaginaries at the intersection of description and prescription in spatial planning.

3. Methodology: the representation of space across formal logic and natural language

"the human mind still remains the most accomplished system for the representation, explanation, and prediction of geographic phenomena. […] it is useful to think of 'cognitive geography' as both the starting point and the guiding thread for the construction of meaningful, applicable formal geographies. Scientific representations of geographic space, and GIS in particular, cannot and should not try to mimic spatial cognition. On the other hand, in its search for better spatial languages and representations, the brash newcomer still has a great deal to learn from the old master."

(Couclelis, 1992, p. 74-75)

Indeed, it is the task of formal logic to establish not which statements are true, nor why true statements are true, but only what logical connections between different statements stand up given their truth-conditions. Likewise, formal ontology is concerned with establishing not which entities exist, or why they exist, but only which connections between different entities stand up, given their conditions of existence[7] (Varzi, 2005).

3.a Borrowing ontology and qualitative spatial representation towards a repository of principles for the representation of spatiality in spatial planning

This section explains how applied ontology and QSR contribute to answering the research questions, providing the framework for ontological and formal analysis of concepts of spatial information. It lays down entry points for transdisciplinary collaboration about conceptual models for spatial representation from a review of contributions in geo-information science, in ontology in general and geo-ontology in particular, and in QSR. Given the discipline-wise outsider perspective of the writer, this section adopts a textual approach indulging in extensive direct quotes from its references. In doing so, the following literature review stylistically spills over into the format of an anthology to encourage readers' direct engagement with its sources, and to keep track of the semantic nuances between different definitions of key concepts and avoid transdisciplinary misinterpretations. The entry points highlight key concerns and questions in these research areas relevant to the previously mentioned critical, as "reflective, skeptical or analytic" (Goodchild and Janelle, 2010, p. 9), perspective on the representation of geographic entities in spatial planning. This relevance comes with a general justification and with a specific one. Generally speaking, formalism in ontology and QSR improve argumentation and explanation regarding spatiality with the inferential rigour which characterizes the potential contribution of logic to any discipline (Salmon, 2013). Moreover, spatial logics (Aiello et al., 2007) systematic questioning regarding the meanings implicit in the representation of geographic entities in natural language specifically contributes to the rigour of argumentation and explanation about these entities. This specific

7 This passage presents the author's paraphrase in English of the following quote: "Come infatti spetta alla logica formale stabilire non quali asserzioni siano vere, né perché le asserzioni vere siano vere, ma solo quali nessi sussistano tra le diverse asserzioni in virtù delle loro condizioni di verità, così l'ontologia formale si preoccupa di stabilire non quali entità esistano, o perché esistano, ma solo quali nessi sussistano tra le diverse entità in virtù delle loro condizioni di esistenza." (Varzi, 2005, p. 24)

contribution lies in the role of representation in argumentation and explanation in natural language, based on its role in the construction of meaning (Hall, 1997). This contribution comes along a round-trip from natural language to formalism and back. Formalism's job is to make meanings explicit by systematic questioning of inferential chains in representation and reasoning regarding abstract models of reality in natural language. The approach proposed here takes these questions back into natural language, to inspire an applied reinterpretation of spatial representation in its argumentation and explanation regarding specific issues, for example issues relevant to spatial planning problems. One example of this two-way ride are the notions of composition and decomposition in relation to land subdivision, where different criteria may be formulated for example in relation to the restricted notion of decomposition and the unrestricted notion of composition in extensional mereology as addressed below. Another example is the infinite cardinality and divisibility implicit in Euclidean space and how Euclidean geometry inform the representation of land as infinitely dividable. In this light, the scope of the following overview extends beyond the focus of this dissertation to provide a reference for future follow-up.

To clarify the scope of research areas relevant to this section for a readership of planners, here follows a brief overview on where they stand in relation to one another. Considering computer science (Guarino, 1998) as an umbrella expression denoting the overall discipline, we can identify artificial intelligence as its sub-discipline, and, within that, the fields of knowledge engineering and knowledge representation, intersecting philosophy, linguistics and cognitive sciences (Borgo et al. 2022). Since different yet related uses of the same terms may occur across disciplines, it is also worth spending a few words for terminological clarification about the research areas or sub-fields of focus in this study. Just like information science can be specified into spatial information or geographic information science, the same happens with QSRR which is a specification of knowledge representation and qualitative reasoning (Cohn & Renz, 2008), like for example temporal representation and reasoning (Lifshitz et al., 2008). Bridging Guarino's account (1995) of representation and reasoning, and Cohn & Renz (2008) overview of the many aspects of QSR, formal ontology can be associated to knowledge representation as a technique to represent certain aspects of knowledge, providing a framework for semantic interpretation. This definition refers to one of three possible interpretations of the term ontology and can be properly located according to the clarifications offered by Guarino (1998). Putting aside the Ontology with the capital o, as a philosophical research area, we are still left with two distinct though related interpretations of the "ontologies" corresponding to the philosophical and the engineering perspectives. The former understands an ontology as a "a particular system of categories accounting for a certain vision of the world" (Guarino, 1998, p. 4) regarding what exists in this world, while the latter would go as "a set of logical axioms designed to account for the intended meaning of a vocabulary" (Guarino, 1998, p. 6) landing into semantics. In this sense, the above-mentioned set of logical axioms provides the framework for semantic interpretation by providing "a theory of a priori distinctions among the entities of the world […and among] the meta-level categories used to model the world" (Guarino, 1995, p. 628). Objects, events and roles constitute the main meta-level categories to be distinguished and organized in any model. Key axes of distinction, for example qualifying the distinction between objects and events include those of endurants and perdurants, or continuants and occurrents, while other distinctions include universals and particulars, concrete and abstract, and substance and accident to account for properties or qualities (Borgo et al. 2022). In this context, spatial ontology or geo-ontology focus on spatial and geographic knowledge and information. This focus poses the problem of which spatial unit would be considered as the primitive element of spatial composition and decomposition, as discussed below in the paragraph about entities. While the stress on knowledge or on information may sometimes reflect a slight inclination either towards philosophy and logic or towards engineering, this distinction does not seem relevant to the scope of this section. For this reason, the difference between the two terms or the two inclinations is not problematized here, as it would be relevant to other debates in planning and within these research areas. In this context, the following paragraphs feature concerns and questions proposed as entry points for spatial planning to engage with geospatial semantics (Janowicz et al., 2012), based on ontological commitments or constraints for the formulation, use and interpretation of concepts of spatial information (Kuhn, 2009). As key concerns of above-mentioned research areas, these entry points show that the last thirty years have brought solid alternatives to Euclidean geometry in spatial representation, increasing and diversifying options for the representation of spatial organization, including that of the built environment. For example, within a debate still confined by the standards of metric representation, in the early nineties Helen Couclelis was asking: "Is the geographic world a jig-saw puzzle of polygons, or a club-sandwich of data layers?" (Couclelis, 1992, p. 65). Along these lines, the following entry points lay the ground for transdisciplinary collaboration to unpack the ontological assumptions regarding the geographic world carried by concepts of spatial information. In turn, unpacking allows to explore the opportunities and constraints these assumptions pose for knowledge production and normative action in spatial planning, even beyond the answers provided in this dissertation. Ultimately, the following paragraphs in this section display the wealth of questions spatial cognition raises for spatial representation, showing how applied ontology and semantics can help spatial planners to better ponder their options beyond assuming that metric models of space are the only possible form of geographic representation. To support information retrieval, the text is broken down into five topics and corresponding headings in italics - entities, relations, connection, location and common sense -, with the first three including related subheadings laid as bullet points.

Entities

Spatial ontology is primarily concerned with the question of what kind of spatial entities shall be admitted by committing to a particular ontology of space, and consequently which spatial unit shall be considered as the primitive element of spatial composition and decomposition. These elements structure the representation of spatial organization. In Euclidean representation of space such primitive is provided by the concept of point. Yet, "no one has ever perceived a point, or ever will do so, whereas people have perceived individuals of finite extent", (Simons, cit. in Cohn & Renz, 2008, p.555, n. 3). This question leads to another about how does reasoning and modeling (see Fig. 2.1) differ when they work with representations of "purely spatial entities such as points, lines and regions, rather than entities which have spatial extension, such as physical objects of geographic regions”? (Cohn & Renz, 2008, p.554). It also refers to the controversy between the atomicity of finite worlds and the atomlessness associated to the infinite cardinality and divisibility of primitives with no spatial extension such as points, where “atomistic mereologies admit of significant simplifications in the axioms” (Varzi, 2007, p. 962). “An example of [… a] model […of infinite cardinality] is provided by the regular open sets of a Euclidean space” (; see also Couclelis, 1999 on the infinite divisibility of Euclidean space).

> “the issue is particularly significant from the perspective of a mereological theory aimed at modeling the spatial world, especially if the theory is to countenance concrete spatial entities along with the regions of space that such entities may occupy. It is, after all, a plausible thought that while the question of atomism may be left open with regard to the mereological structure of material objects (pending empirical findings from physics, for example), it must receive a definite answer with regard to the structure of space itself.” (Varzi, 2007, p. 963).

These insights lead us to consider the following spatial entities as alternative options for the representation of spatial organization.

– *Regions*

> “If one is interested in using the spatial theory for reasoning about physical objects, then one might argue that the spatial extension of any physical object must be region-like rather than a lower dimension entity. […] Whether points or regions are taken as primitive, it is clear that regions nevertheless are conceptually important in modeling physical and geographic objects.” (Varzi, 2007, p. 555).

In this light, the possibility of a pointless theory of space (Borgo et al., 1996) or of pointless geometries (Gerla, 1995) are well established among QSRR scholars (Borgo & Masolo, 2010). Moreover, planning scholarship may question how its reasoning and modeling would differ if it admitted abstractions like purely spatial entities, points or regions, existing outside space and time, or instead if it admitted only concrete entities treating times as occurrents and places as continuants (Borgo et al., 2022). Other questions specific to the notion of region include the following: admitting or not the existence of a null region depending on either technical logical convenience or adherence to physical evidence; the possibility of regions of irregular shape or of differing dimensionalities; the distinction between regular-open and regular-closed region; the possibility of disconnected regions and the distinction between interior-connected and exterior-connected regions (Cohn & Renz, 2008).

– *Objects*

The notion of object is a staple of geographic information science.

> “[Objects] describe *individuals* that have an identity as well as spatial, temporal, and thematic properties. […] The notion of an object implies *boundedness*. This does not mean that the object’s boundaries need to be known or even knowable, but that there are (crisp) limits outside of which there are no parts of the object. Many objects (particularly natural ones) do not have crisp *boundaries* (Burrough & Frank 1996). Examples are geographic regions or body parts such as hands or heads. Differences between spatial information from

> multiple sources are then often caused by more or less arbitrary delimitations through context-dependent boundaries. […] whether modeling objects with explicit boundaries is necessary or desirable has to be carefully assessed for each application. […] Like surface fields in raster data, collections of features in vector data can be organized into thematic *layers*." (Kuhn, 2012).

GIS vectorial objects are

> "firmly rooted in the view of geography as spatial science, formulated in the 1950's and 60's, which resulted in the geometrization of the geographic world and its reduction to a body of theories about relations between points, lines, polygons, and areas. Points, lines, polygons and areas representing geographic entities thus became geometric 'objects', inheriting the sensible qualities of the prototypical objects that surround us: their discrete and independent existence, their relative permanence of identity, attribute, and shape, and their manipulability. Objects in a vector GIS may be counted, moved about, stacked, rotated, colored, labeled, cut, split, sliced, stuck together, viewed from different angles, shaded, inflated, shrunk, stored, and retrieved, and in general, handled like a variety of everyday solid objects that bear no particular relationship to geography." (Couclelis, 1992, p. 66).

Here Couclelis seems to suggest that the development of GIS somehow intensified this manipulability of what has come to be known as geographic objects. This suggestion is particularly relevant for spatial planning insofar as decision making regarding land and spatial organization can be intended as manipulation. Moreover, Couclelis refers to Robert D. Sack's work on human territoriality (1986) to stress how objects miss

> "out a good part of relevant relations in human geography, namely the relations characterizing territorial behaviour. […As he puts it,] 'Focussing on the latter has led geography and social science to emphasize the effects on human behaviour of such metrical properties of space as distance. Unfortunately, this focus has been too constraining to permit development of a complex spatial logic' (p 216)". (Couclelis, 1992, p. 68)

In order to distinguish references to this notion of object from more generic uses of the term "object", references to this notion are formulated below as vectorial objects.

– *Fields*

Just like objects, fields reflect a metric conceptualization of the geographic world. Yet, if the object concept assumes that "there exist things in time and space which have (known and unknown) attributes […,the field concept assumes that] the spatio-temporal clusters of known attributes are the things" (Couclelis, 1992, p. 69). In this sense, field based spatial information represents attributes, either measured or computed. Therefore, the downside of fields is that they ignore the existence of what human cognition normally identifies as the things in the world. According to Kuhn (2012), while objects control the theme and measure space, fields control space (and time) and measure theme. As he puts it:

> "The cells jointly partition the space of interest and can all have the same shape (forming a regular grid of square, triangular, hexagonal, or cubic cells), as in raster models for spatial data; or they can have irregular shapes, adaptable to the variation of the attribute, as in

finite element models or terrain representations. Similarly, point samples can be spaced regularly or irregularly." (Kuhn, 2012).

According to Couclelis, "scientific description of the geographic world is best compatible with the field perspective" (Couclelis, 1992, p. 73). Describing spatial cognition as "flexible, dynamic, eclectic, and opportunistic" (Couclelis, 1992, p. 71), she says that "the geographical world is understood as a function of […] geographic scale […and] human intentionality, or purpose" (Couclelis, 1992, p. 71). In this light:

> "it appears that the perception of a Newtonian space of Euclidean objects is confined to spaces […] below the range of geographical scales proper. The experience of landscapes and territories, by contrast, is most active at the levels of cognition (perceptual, syntactic, cultural) which are not directly grounded in the world of classic Newtonian bodies, and their physical and kinesthetic properties. Spatial experience of a natural landscape seen from above […] is more field-like than object-like. There are things in it- valleys, hills, marshes, forests and fog banks - but these are not 'objects' to pick up and move about: they are salient features, breaks in a plenum that is otherwise continuous, not by the mathematical criterion of infinite subdivisibility, but because of the indefinite number of different ways one could draw boundaries around these features." (Couclelis, 1992, p. 72)

In order to distinguish references to this notion of field from more generic uses of the term "field", references to this notion are formulated below as raster fields.

- *Networks, nodes and edges*

> "The concept of a network captures binary relationships among arbitrary numbers of objects, called the nodes or vertices of the network. Any relation of interest can connect the nodes and be represented by edges (also known as links or arcs). The spatiality of a network results from positioning the nodes in some space. It may, furthermore, involve geometric properties of the edges, such as their length or shape. If the embedding space is a surface, networks can also be organized into thematic layers. Network information answers questions about connectivity […]. The two main kinds of networks encountered in spatial information are link and path networks […respectively regarding] logical or other abstract relationships between nodes, […and] matter, energy or information flows. […] Network applications benefit from the well-studied representations of networks as graphs and the correspondingly vast choice of algorithms. Partly due to this sound mathematical and computational basis, networks are the spatial concept that is most broadly recognized and applied across disciplines. One may speculate from this success story that a similar level of understanding and formalization of the other core concepts will encourage their use in transdisciplinary work. As the exposure here shows, such a level has not yet been reached in many cases." (Kuhn, 2012)

- *Space, regions of abstract space and concrete spatial entities*

"what is the nature of the embedding space, i.e. the universal spatial entity"? (Cohn & Renz, 2008, p.555). Depending on the application, different models of space may be preferable (Cohn & Renz, 2008). In addition to the most common Newtonian notion of continuous n-dimensional space, other models may include: (i) discrete space, intended in opposition to continuous or infinitely divisible space (Galton, 1999; Hegenhofer and Shamra, 1993; Masolo & Vieu, 1999; all cit. in Cohn & Renz, 2008), where discreteness can be defined as non-overlapping (Bennet & Düntsch, 2007, p. 25); (ii) finite space, intended as sharply delimited, such as the Earth surface or other spherical surfaces (Gotts, 1996 cit. in Cohn & Renz, 2008); (iii) non-convex as for example straight or concave space, or non-connected space made of separate pieces (Cohn & Renz, 2008). The distinction between continuous and discrete space, respectively associated to vector and raster representations (Hegenhofer and Shamra, 1993, cit. in Cohn & Renz, 2008), recalls larger and deep controversies in physics and philosophy. In her inquiries on the most appropriate conceptualization of geographic space, Helen Couclelis provided a comprehensive overview of these controversies, laying the ground for further investigation of this question in the domain of geographic information science (Couclelis, 1999). Comparing object-based and field-based spatial representation, such as vector and raster respectively, she refers to "the opposition between the atomic and plenum ontologies in the philosophy of physics" (Couclelis, 1992, p. 65).

> "Put in a spatial context, the atomic-plenum debate is also one between the Newtonian view of space as inert container populated with objects, and the more contemporary, dynamic view whereby space is a "plenum" characterized by a ubiquitous field. As Einstein (1960) wrote in Relativity, 'There is no such thing as empty space, i.e. space without field. Space-time does not claim existence on its own, but only as a structural quality of the field.' (p. 155)" (Couclelis, 1992, p. 70).

Beside the conventional hold on scientific knowledge of the Newtonian representation of space as a vacuum, its validity in common sense terms is rather contested, while at the same time defiant to dismissals. As put by Achille Varzi:

> "Even when we reason about empty places, we typically do so with an eye to the anatomy of their potential tenants: space as such is perceptually remote and we can hardly understand its structure without imagining what *could* fill the void. […] At the same time, one might argue that our understanding of the spatial structure of objects and events, including their spatial relationships, depends significantly on our understanding of the structure of space per se: that the spatial features we attribute to objects and events are somehow inherited from those of the spatial regions they occupy. Thus, for example, we are inclined to say that ordinary objects have parts insofar as their spatial regions have parts. […] This tension (not to say this ambiguity) between concrete object-oriented thinking and abstract space-oriented thinking is responsible for many of the philosophical issues that lie behind any formal theory of spatial reasoning. On the one hand, it is natural (if not necessary) to supplement the theory with an explicit account of what kinds of thing may enter into its scope, an account of the sorts of entity that can be located in space—in short, an account of what may be collected under the rubric of 'spatial entities'. On the other hand, we also want the theory to be independent of any specific ontological biases we might have. […This is because] our reasoning about their spatial properties and relations appears to be governed by the same general principles, and it is natural to think that such principles must reflect our understanding of the structural features of the spatial environment in which such entities are located." (Varzi, 2007, p. 945-946).

The tension, according to Varzi, can be better understood as “the subtle interplay between purely spatial intuitions and intuitions about concrete spatial entities [… and how this] shows up in the construction of a formal theory” (Varzi, 2007, p. 946). The ambiguity here lies also in the ways in which each scholar explains the two options corresponding respectively to the plenum and vacuum ontologies of space. While Couclelis’s *field view* corresponds to what Varzi calls *concrete object-oriented thinking*, Couclelis’s *object view* corresponds to Varzi’s *abstract space-oriented thinking*. Moreover, the first corresponds to what has been named relative space, as in Couclelis’s words, or relationism in Varzi’s, and the second to what has been named absolute space, as in Couclelis’s words, or substantivalism in Varzi’s. On the other hand Couclelis's use of the term atomic with regard to the atomic-plenum or object-field debate should not be confused with Varzi's references to atomist and atomless ontologies (Varzi, 2007, p. 962)

In Couclelis’s interpretation,

> “cognitive geography will not side with either the object nor the field side of the controversy, but supports a little of each, and much beyond […, where beyond means that] geographic entities were defined in neither an absolute nor a relative, but in a relational space, where object identity itself is at least in part a function of the nexus of contextual relations with other objects.” (Couclelis, 1992, p.71-74)

This consideration takes us straight to address the status of relations in formal ontology and QSR.

– *Cognition, perceptions and cognitive entities*

> “Is ontology about the 'real world' (as seen, say, by a physicist)? Or, rather, should it take cognition into account, including the complex interactions and dependencies between our ecological niche and us? We will not attempt a general answer to this question, but we believe that the latter position is very useful when building ontologies for practical purposes. As knowledge systems manage information relevant to human agents, their ontologies need to make room for entities that depend on our perception and language, and ultimately on the way we use reality to survive and communicate. Some of these entities will depend on specific groups of human beings (with their own culture, language, and so on); others will reflect common cognitive structures that depend on our sensorial interaction with reality. A general-purpose ontology is specially interested to the latter kind of entities, which help generalize our specific knowledge of the world. This position reflects the so-called “interactionist” paradigm, which (though not prevalent) has strong support in psychology of perception and cognitive linguistics [Gibson 1977, Lakoff and Johnson 1999] and seems to be a good compromise between hard 'referentialist' ontology and purely context-oriented semiotics. An extreme example of how ontologically relevant entities depend on our perceptive and cognitive structures is the notion of constellation: is a constellation a genuine thing, different from a collection of stars? This is not so clear at a first sight. But, if we distinguish between stars and their specific arrangements, we are able to understand how constellations may be considered as cognitive things dependent on states of mind. To see a "Taurus" in the sky does not mean, obviously, that an animal is flying in the space or (less obviously) that a bull-shaped astronomic object (different from a collection of stars) is localized in a region of the sky. Rather, the perspective we embrace consists in recognizing a

> cognitive entity dependent on the way we perceive some particular arrangement of stars. It is to this entity that we (often) refer when we use the term "Taurus constellation" in our language. Including cognitive entities in our ontology seems therefore a good idea if natural language plays a relevant role in our applications." (Gangemi et al., 2001, p. 1-2).

Relations, mereology, topology and location

– *Sets of spatial relations*

"It is one of the basic assumptions of qualitative representation and reasoning that situations are represented by specifying the relationships between the considered entities" (Cohn & Renz, 2008, p. 556) leading to obtain an algebra of relations. Two examples of sets of spatial relations developed in this context, and considered the most studied aspect of QSRR (Cohn & Renz, 2008, see also Smith, 1996), can be found in mereology, or the theory of parthood, and in mereotopology which integrates mereology and topology in different ways (Varzi, 1994, 1996). According to Guarino:

> "A fundamental role is played in formal ontology by mereology (the theory of the part-whole relation) and topology (intended as the theory of the connection relation). Despite the possibility of these two theories to collapse one in the other in the case of a purely extensional domain limited to spatial or temporal entities, they need to be kept separate in order to characterize an entity independently of its spatio-temporal extension (Varzi, 1994)." (Guarino, 1995, p. 628)

In his definition of the two theories, Varzi opts for the plural regarding relations and clarifies the focus of the two theories, when he defines them respectively as "the theory of parthood relations, […and what is] broadly understood as a theory of qualitative spatial relations such as continuity and contiguity" (Varzi, 2007, p. 946). According to Varzi, the relation between the two theories stems from the fact that "one need go beyond the bounds of a pure theory of parthood to come out with a true theory of parts and *wholes*. For as we have already mentioned, mereology by itself cannot do justice to the notion of a whole […] Parthood is a relational concept, wholeness a global property, and the latter just runs afoul of the former." (Varzi, 2007, p. 975). On the contrary, "a topological extension of mereology" (Varzi, 2007, p. 978) could do the job. Meanwhile, Varzi insists that the integration between mereology and topology occurs "on independent grounds" (Varzi, 2007, p. 977) recalling his insight on their separation reported by Guarino. In this sense, topology-as-extension is only one of the possible 'combinations', 'integrations' or 'interactions' among the two, provided the supply of "some mixed principles to establish an explicit 'bridge' " (Varzi, 2007, p. 980) justifying the use of the term mereotopology notwithstanding the need for separation (Varzi, 1994, 1996). Moreover, in his assessment of the relation between spatial reasoning and ontology, Varzi also looks at the relation between entities and their spatio-temporal extension, adding a third focus with "the theory of location proper, which deals explicitly with the relationship between an entity and the spatial region it occupies" (Varzi, 2007). To recap, if one agrees that spatial planning ought not to consider entities independently of their spatio-temporal extension, then mereotopology together with the theory of location may be up to the challenge of supporting reasoning and modeling spatial relations in this domain. Once this is agreed, it should then be considered that representation and reasoning on regions and abstract space is considered uncontroversially extensional and the same cannot be uncontroversially excluded for reasoning on entities with a spatial extension (Varzi, 2007). In this light, engaging with spatial mereology, intended as the mereology of spatial entities of either type, as well as with mereotopology, in spatial planning would require an assessment of two orders of implications. The more general implications refer to the possibility of navigating between a purely formal theory and applied logic in the study of parts, wholes and their relations in the built environment. The more specific implications refer to the assumptions that could be considered to hold unrestrictedly without overlooking any significant aspect of the spatial organization of the built environment. These assumptions include issues raised either in mereology, mereotopology and the theory of location. One group of assumptions regarding mereology include, among others, the validity of decomposing wholes based on the strong supplementation principle within extensional mereology, and the limits to the principles of complementation and fusion in relation to connection and composition (Varzi, 2007). These assumptions imply that a whole is exhaustively defined by its constituent parts, and that additional parts would necessarily refer to a distinct whole. They apply to spatial parthood across a wide range of different criteria for the identification of parts, as exemplified in Fig. 3.1, including detached, disconnected, arbitrary, gerrymandered or immaterial parts, according to Varzi's terminology (2007, p. 948). According to the above mentioned principles, spatial parthood accounts for the spatial organization of the built environment across these differences. Moreover, in the context of extensional mereology applied to the built environment, two further assumptions consider composition finite regardless of the possibility of detached and disconnected parts. Conversely, decomposition may be considered not finite in the case of arbitrary, gerrymandered or immaterial parts. The following paragraphs about connection and location further explore the principles of composition and decomposition according to mereotopology and the theory of location.

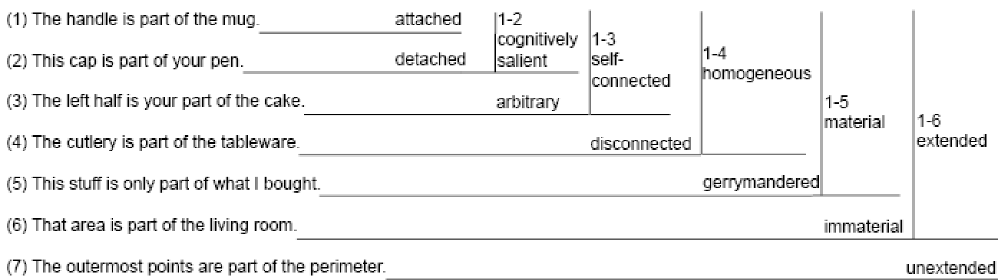

Fig. 3.1 Examples of parthood provided some common situations are realized (Author's layout from Varzi, 2007, p. 948)

- *Decomposition and composition of spatial entities or regions of space*

Overall, these principles are meant to distinguish parthood relations from other types of partial orderings by stating the conditions under which an entity can be considered a whole by decomposition, or a part among other parts by composition. According to Varzi, extensional mereology defines the conditions for decomposition, while composition, given the challenges of specifying the circumstances for its existence, is accepted as unrestricted in most formal theories, including "wholes that are composed of two or more disjoint entities" (Varzi, 2007, p. 969), where disjointness is defined as the lack of overlap (Varzi, 2007, p. 953). The next chapter will show the relevance of these problems in the case of spatially explicit policy making addressed by the case study. If supported by evidence from additional cases, one may also assess the influence of different assumptions regarding these problems on the choice between what Varzi calls concrete object-oriented thinking vs. abstract space-oriented in the representation of the spatial organization of the built environment. One may also weigh whether, once applied to the built environment, "the limited ontological neutrality of extensional mereology" would preclude essential opportunities for representation. On the contrary, it may also be considered that extensionality in representation and reasoning with parts of the built environment can be justified by the fact that the controversies about the necessity of extensionality depend on metaphysical questions which "cannot be assessed by appealing to our intuitions about the meaning of 'part'" (Varzi, 2007, p.958-959). As put by Varzi regarding the question on the necessity of extensional mereology:

> "the answer may differ crucially depending on whether we are interested in modeling a domain of concrete spatial entities or just the domain of the regions of space that they occupy. In the latter case there is little room for controversy: spatial regions are extensional, if anything is, unless of course we favour a Whiteheadian conception of space. In the former case, however, the answer is controversial. There are two sorts of objection worth considering. On the one hand, it is sometimes argued that sameness of parts is not *sufficient* for identity, as some entities may differ exclusively with respect to the arrangement of their parts. […] On the other hand, it is sometimes argued that sameness of parts is not *necessary* for identity, as some entities may survive mereological change. If a cat survives the annihilation of its tail, then the tailed cat (before the accident) and the tailless cat (after the accident) are one and the same in spite of their having different proper parts (Wiggins 1980)." (Varzi, 2007, p. 957-958)

One example regarding above mentioned implications would be the corollary that "an object is exhaustively defined by its constituent parts" (Varzi, 2007, p. 957), which Varzi also recalls as a problem of composition and identity (Varzi, 2007, p. 969). The validity of this corollary would, for instance, contradict the possibility of considering spatial entities, purely spatial regions and possibly also entities which have spatial extension, as complex systems, at least according to Herbert Simon's definition:

> "Roughly, by a complex system I mean one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. In the face of complexity, an in-principle reductionist may be at the same time a pragmatic holist." (Simon, 1962, p. 468)

This comparison stems from the prominence acquired by approaches to spatial planning inspired by complexity science and known as Complexity Theories of Cities (De Roo et al. eds., 2020, Portugali, ed., 2021), and from the prominence of parthood relations in their foundational texts (Alexander Ch., 2002; Jacobs, 1961; Simon, 1962). In this regard, it is important to stress the key role of change and of the time dimension to the definition of complexity in relation to emergence and uncertainty, where each time fraction present a different whole in terms of extensional mereology, while urban studies and spatial planning would refer to the same evolving entity or phenomenon. This problem refers to above mentioned Varzi's distinction between modeling concrete spatial entities or the regions of space these entities occupy. It also compares open and closed systems and open and closed regions, recalled below in relation to boundaries.

Connection

- *Connection, parthood, and fusion, or unity*

Connection, or connectedness, is one of two basic relations between spatial entities or regions of space in mereotopology, together with parthood. The couple is defined as jointly exhaustive and pairwise disjoint (JEPD) in the sense that “the relationship between any two spatial entities of the considered domain must be exactly one of” them (Cohn & Renz, 2008, p. 556), and the set of all possible mereotopological relations between entities corresponds to all possible combinations of these JEPD relations. Parthood was previously introduced with reference to mereology, in the paragraph on relations, mereology, topology and location. Moreover, fusion is defined as the mereological sum, based on “the idea that whenever there are some things there exists a whole that consists exactly of those things” (Varzi, 2007, p. 954). Yet, according to Varzi, it is controversial whether this principle can hold unrestrictedly (Varzi, 2007). Further looking into the principles bridging parthood and connection, Varzi uses the term unity to identify the conditional principle binding connection to overlap (Varzi, 2007, p. 981). Instead, Gangemi et al. (2001) provide a different definition of unity as a formal ontological property, based on the formal relation of membership in a set, beside mereology and topology. This definition is the one referenced by the term unity in sections 3.b and 4.2.a. According to the authors, this definition points to the distinction between different kinds of wholes (Gangemi et al., 2001). This definition

> “captures more carefully the notion of member of a division [...where] any member of x is a special part of x. So we need a property that individuates the members within the parts of x. Observe that, if x forms a unity under a unifying relation R, then the property we need must only pick up the parts of x that belong to R’s domain. All other parts can be ignored […] For the purpose of ontological analysis, it is interesting to explore how various unifying relations can be defined on the basis of simpler relations, called characteristic relations ([Simons, 1987] p.330). This analysis can be used to introduce different kinds of wholes. In particular, from the cognitive point of view, it is very interesting to consider topological connection as a characteristic relation. More exactly, the cognitively relevant characteristic relations are those that restrict topological connection to hold between physical entities of the same kind, such as matter, color, or physical bodies (otherwise, using topological connection only, the only whole would be the universe). ” (Gangemi et al., 2001, p. 6-7)

These insights lead to identify the properties of singularity, corresponding to a topological whole, and plurality, which is said to contain a topological whole while not being itself a topological whole, although “nothing excludes a topological whole (under a certain kind of connection) to include other topological wholes (under a different kind of connection)” (Gangemi et al., 2001, p. 7). Moreover, they point to few additional properties. These properties include collection, defined as a special kind of plurality, a sum of wholes which are all members of the collection, in addition to homogeneity and non-homogeneity, defined as kinds of singularity, where the characteristic relation describes either a single body or an assembly of different bodies (Gangemi et al., 2001).

– *Cohesion, continuity or contiguity*

According to Varzi (2007), an ontology may admit different types of wholes depending on the interpretation of connection as continuity or contiguity. As shown in Fig. 3.2, where the right-hand example is particularly relevant to the case study discussed in chapter 4, connection between x and y and the self-connectedness of z may contradict one another. This depends on what interpretation of the diagrams one choses between “a truly topological notion of connection and a merely metric notion of contact” (Gangemi et al., 2001, p. 977). While both refer to continuity between parts, the first corresponds to the cohesion or the adherence of parts into a single whole and the second to a degree of closeness. Focusing on topological connection between closed regions, this occurs “between any two entities that share *at least* a boundary. In this sense, mereological overlap qualifies as connection, too” (Gangemi et al., 2001, p. 979). Moreover, a notion of indirect or mediate connection as contiguity, in turn based on one of by-connection, can be introduced to make up for the non-transitivity of connection as cohesion. This allows to admit the transitivity of the union of all mediate n-connection relations, all the way to transitive connection (Gangemi et al., 2001, p. 979-980) and path connectedness, provided the necessary reference to a sub-interval and its relative complement (Gangemi et al., 2001, p. 988). Mediate connection also allows admitting the anti-symmetry of the relation of enclosure (i.e. partial ordering), once assumed that connection is extensional, meaning “that things that are connected exactly to the same entities are identical” (Varzi, 2007, p. 980).

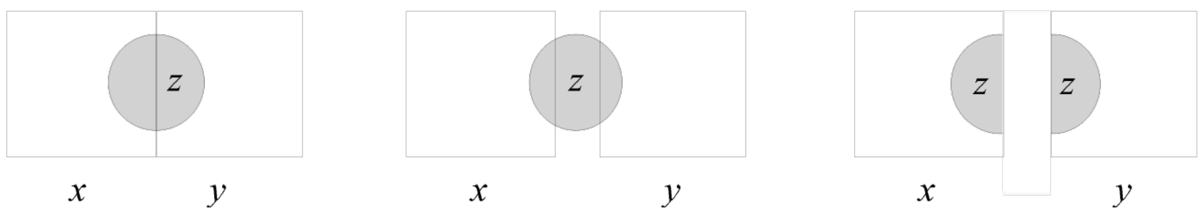

Fig. 3.2 “A connected sum (left) and two disconnected sums (middle, right)” (Varzi, 2007, p. 976).

– *Overlap, underlap, abut, enclosure, interior and tangential parts, exterior and tangential extension*

The different interpretative options of the three basic relations and their derivatives, such as overlapping, abutting, tangential, interior or boundary, sum, product, difference, complement, interior, exterior, closure, etc. (for definitions see Cohn & Renz, 2008, p. 560), reflect the variety of possible relations of connection in representation of and reasoning on parts of the built environment. For example, “Some calculi [21, 65] insist that regions are connected (i.e. one-piece). A yet stronger condition would be that they are interior connected.” (Cohn & Renz, 2008, p. 555). These insights point to the variety of semantic possibilities in the representation of spatial entities, overall revolving around the interpretation of the pair-wise connection among complement, interior, tangential, exterior, closure and boundary parts of any entity (Cohn & Renz, 2008). Varzi (2007) also adds the relation of underlap between parts of the same whole. According to Varzi (2007), mereological primitives do not properly address these problems, while topology supplies the means to account for notions “such as the distinction between a completely interior part and a tangential part that is connected with the exterior, [or] the difference between an open entity and a closed one” (Varzi, 2007, p. 976). These means correspond to what Varzi (2007) calls bridging principles between parthood and connection, departing from the assumption that parts and wholes are connected based on the principle of the integrity of wholes, regardless of whether any two parts may be disconnected or “detached” or “mereologically disjoint” as non-overlapping (Varzi, 2007, p. 981) from any other part. This principle is relevant for the case study of this dissertation. According to Varzi, its weakness requires additional principles to capture the full implications of the departing assumption. One additional principle states that, while parthood implies overlap, overlap implies connection just like sharing a common boundary does. Another principle, admitting the distinction between open and closed regions, states that parthood implies enclosure ensuring that connection preserves the order of parthood (i.e. monotonicity). The principle of the monotonicity of connection with respect to parthood grounds the definition of several spatial relations which cannot be defined based on mereology alone. These relations include the notion of external connection between two mereologically disjoint entities, a notion “which makes all the difference between mereology and mereotopology” (Varzi, 2007, p. 981). They also include notions expressing “the difference between a proper part that lies entirely within the interior of the whole and a proper part that is connected with the exterior” (Varzi, 2007, p. 982), such as interior proper parthood, tangential proper parthood, and the respective notions regarding the complement, such as exterior proper extension and tangential proper extension. The above mentioned mereotopological principles and the notions based on their combination are relevant to the problems of spatial representation posed by the case study. A further discussion of the notion that enclosure may imply parthood leads to the question of the possibility of defining parthood in terms of connection (Varzi, 2007, p. 982-986). Likewise, a further discussion on self-connectedness and fusion (Varzi, 2007, p. 987-988) for any pair of connected entities brings back in the possibility of defining connection in terms of parthood, previously rejected by Varzi (2007, p. 976). Yet, the discussion on the relation between the two theories in either direction does not provide relevant insights on the problems posed by the case study, while its relevance to the study of the spatial organization of the built environment in general cannot be assessed without a larger caseload of problems. Therefore, it will not be further explored here. Meanwhile, the discussion on enclosure touches upon the possibility of boundarylessness on the one hand, upon that of spatial co-location, and upon that of collapsing connection onto contact or overlap between concrete entities by deriving the mereotopology of spatial entities from the mereotopology of pure space. Since these possibilities are relevant to the problems posed by the case study, they are accounted for separately in the following paragraphs about boundaries and about location. Meanwhile, it is worth noting that previously mentioned notions need further definition “owing to the delicate role played by boundaries in the proper understanding of the connection relation” (Varzi, 2007, p. 982). For example, external connection is relevant to the case study of this dissertation because it could apply to two entities sharing a boundary while not enjoying a parthood relation other than the most general one. The validity attributed to this notion in the representation of the spatial organization of the built environment will be further discussed in sections 4.a.2 and 4.a.3. As shown in Fig. 3.3, different interpretations of connection between regions depend on the distinction between open and closed regions and on the notion of boundary, but ultimately, they are based on the constraints posed by any chosen theory of space, “one’s specific view […on] matters of ontology” (Varzi, 2007, p. 1002; Cohn & Renz, 2008). Likewise, the possibility of “distinguishing connection ties of different strength” (Varzi, 2007, p. 1004), from a single point of contact, to an extended portion of a common boundary or an entire boundary, from firm connection to complete and perfect connection, requires explicit appeal to the underlying ontology regarding the structure of space (Varzi, 2007). Yet, even though they agree on the relation between the expressivity of a theory and its ontological presuppositions and examine the same range of interpretations, different sources do so towards different ends. Varzi heads towards the validation of a particular mereotopological theory, such as KGEMT (2007). Cohn and Renz head towards an overview of a range of theories and their intended options for the treatment of problems in spatial representation and reasoning (Cohn & Renz, 2008). This review showcases a range of arguments as a repository of possible interpretations to address the problems of spatial representation posed by the case study or other cases, exploring what differences these interpretations would make for reasoning and modeling in spatial planning. For this reason, the review notes the different intent of its sources, treating them as complementary overviews of possible interpretations. In this sense, the review maintains that theories in mereotopology can be divided into boundary-tolerant theories and boundary-free theories, “theories that leave out boundaries from the universe of discourse in the intended models” (Cohn & Renz, 2008, p. 563). This distinction corresponds to what Varzi respectively calls the realist and the anti-realist options (Varzi, 2007, p. 994 and 996), where realism shouldn’t nonetheless be allowed the monopoly of ontological plausibility.

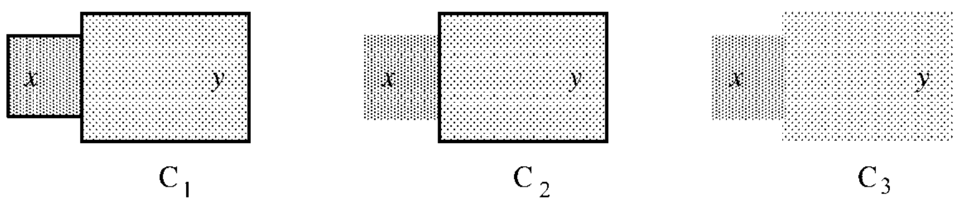

Fig. 3.3 “The three C relations (limit cases); a solid line indicates closure” (Cohn & Renz, 2008, p. 559).

– *Boundaries*

Boundaries can be considered one of the basic features through which spatial planning makes sense of geography and spatial organization, in analogic and digital cartography and in the visualization and identification of areas. Beside their delicate role in the connection relation, Varzi stresses that “to draw the boundaries of something is to confer ontological dignity to it” (Varzi, 2007, pag. 1010), a statement which one may choose to consider either as an assumption or as the result of an observation. Indeed, common sense cannot but confirm this statement, even though it is not easy to agree on any common-sense definition of what exactly a boundary is as a part of pure space. Moreover, those reading into this statement that drawing boundaries is the only way of conferring ontological dignity to something should be reminded of the problem of the existence of mountains given the impossibility of drawing a boundary distinguishing a mountain from its surroundings (Smith & Mark, 2003). This problem may be ascribed to the topic of vagueness (Varzi, 2007), therefore to the possibility of admitting boundaries of different degrees of vagueness and of considering the indeterminacy of the open/closed distinction as “pragmatic, perhaps semantic, not ontological” (Varzi, 2007, p. 994). Yet, there remains the possibility of considering the most extreme degree of vagueness as absence of a boundary altogether. In this sense, Cohn & Renz report on “the intuitive difficulties that arise out of the notion of a boundary, and correspondingly of the distinction between open and closed entities […and add that] the main difficulties in reducing mereology to topology lies precisely in the presence of boundaries” (Cohn & Renz, 2008, p. 563). The notion of boundary can admit ontological dependency or independency. Dependency implies that only open entities can have boundaries (Smith, 1996). Independency implies that boundaries are spatial entities per se, leading to question whether they can be considered as regions themselves or whether the existence of types of spatial entities other than regions shall be admitted. If a theory of space admits no boundary element, it can be postulated that all entities in the universe under consideration are mereological regions. This means that there is no distinction between open and closed regions, and also that all spatial entities have interior parts (Cohn & Renz, 2008). Cohn and Renz (2008) overview of boundary-tolerant and boundary-free theories suggests various ways of questioning assumptions about boundaries in spatial planning in terms of the adequacy of the resulting representation of spatial organization. Are boundaries connected to interior parts? Are they connected to the complement of the bounded region? Should one consider these connections as overlaps or as external connections? In full mereotopological theories, where parthood and connection rely on the same primitive relation, is admitting boundaries worth the consequent collapse of the distinction between tangential and interior parthood and between tangential and interior overlap? Is this collapse irrelevant for an adequate representation of the spatial organization of the built environment? Or is admitting boundaries and therefore preserving the distinction of closed and open regions, with the related assumption that contact is not possible between regions in the same category, worth the validity of corollary that “no region is connected to its complement, hence [implying] that the universe is bound to be disconnected” (Cohn & Renz, 2008, p. 564)? Is excluding boundaries and collapsing the distinction between open and closed regions worth giving up the principle that parthood implies supplementation by a distinct part of the same whole, otherwise known as weak supplementation? In this regard, Varzi states that the distinction between open and closed regions contradicts common sense and yields genuine paradoxes:

> “what does it mean to draw a similar distinction in the realm of concrete spatial entities, where the very notion of a boundary is the result of a conceptual idealization? What does it

mean to say that some objects are closed and some are not, and that contact is only possible between objects of one type and objects of the other?" (Varzi, 2007, p. 991)

Nonetheless, as previously anticipated, Varzi expresses these paradoxes building on Peirce's puzzle, moving forward to explain why they do not require a dismissal of the open closed distinction, as he defends the validity of KGEMT:

> "What color is the line of demarcation between a black spot and its white background? […]. More generally, given any object, *x*, does the boundary belong to *x* or to its complement? […] Here one might reply that figure/ground considerations will help. […] the black spot is closed, so the line is black. But what is figure and what is ground when it comes Leonardo's case? We do talk about the surface *of* the water, not of the air. But what goes on at the seashore? Three things meet—water, air, soil; how can figure/ground considerations help in such contexts? Perhaps such dilemmas are not real. Galton (2003, pp. 167ff), for example, argues that they arise as an artifact of the modeling process: surely properties like color or material constitution only apply to extended bodies, so it wouldn't make sense to ask whether a boundary-like entity is air, water, or colored. There is, however, a less dismissive way to meet the challenge on behalf of *KGEMT*. For one may acknowledge that such dilemmas are real and yet insist on a friendly attitude towards the open/closed distinction. The actual ownership of a boundary—one might argue—is not an issue that a mereotopological theory must be able to settle. The theory only needs to explain what it means for two things to be connected. Which things are open and which are closed is a metaphysical question that, plausibly enough, goes beyond the concerns of the theory. If the ocean is a closed body, then it can only touch the air if the latter is open. If it isn't, then it can only touch the air if the latter is closed. And if both water and air are open, they cannot truly touch, though they may touch a closed piece of land. That's all the theory says, and there is no reason to think that the theory is wrong just because it is difficult to classify actual things into open and closed." (Varzi, 2007, p. 993).

According to Cohn and Renz (2008), among full mereotopologies, the one corresponding to what Varzi identifies as KGEMT is the only viable option for boundary tolerant theories. On the other hand, boundary-free full mereotopological theories "led to an extended body of results and applications in the area of spatial reasoning" (Cohn & Renz, 2008, p. 563), still affording indirect ways to model boundaries. Nonetheless boundary-free theories yield non-standard, i.e. non-extensional, mereologies, where "everything must have interior proper parts" (Varzi, 2007, p. 1005). These mereologies are considered less mainstream because they violate the weak supplementation principle regardless of variations in the distinction between open and closed regions. In this sense, Varzi links the postulate of boundarylessness to a Whiteheadian conception of space, which in turn collapses the distinction between the mereotopology of spatial entities and that of pure space, based on the assumption of considering spatial co-location as "metaphysically impossible" (Varzi, 2007, p. 986). Varzi also addresses the question of the ontological dependency of boundaries as follows:

> "boundaries are genuine denizens of the world of spatial entities, but their lack of proper interior parts makes them peculiar in two important respects (Brentano 1976, part I). First, they can never exist except as belonging to entities of higher dimension. […they are]

dependent entities. Second, and more to the point, insofar as boundaries are not possessed of divisible bulk, they do not occupy any space and can therefore share the same location with other boundaries. They can *coincide*, and the topological relation of external connection is to be explained, not via the open/closed opposition, but in terms of genuine boundary coincidence. Thus, we can speak of *the* surface of an object. But this single surface is to be recognized as being made up of two parts, two perfectly coinciding boundaries bounding the object and its complement, respectively." (Varzi, 2007, p. 995).

Such coincidence leads to identify an additional operator in the interface between two entities as "the product of their boundaries" (Varzi, 2007, p. 1011). As suggested by Varzi himself, this argument shows that boundaries require primitives such as coincidence and location which go beyond the scope of mereotopology only when dealing with spatial entities as ordinary objects. Instead, the distinction of open and closed regions of pure space can be preserved in a substantivalist or Newtonian conception of space. While Varzi, Cohn and Renz agree that doing away with the closed/open distinction, hence with the distinction between interior and closure, is the, or one of the, main reasons to go boundary-free, Varzi adds the possibility of restricted boundarylessness, a moderate variant of the boundarylessness axiom "in which the variable is suitably restricted so as to range over entities of a certain sort" (Varzi, 2007, p. 997). Moreover, he stresses the distinction between stating that an entity possesses or not a boundary and that an entity connects or does not connect externally, provided that open entities, as revised in a boundary-free theory, never touch anything. In so doing, he points to the lack of a systematic comparison between the original operators sum, product, difference, complement, universe, interior, exterior, closure and boundary, in a boundary-tolerant theory and the revised operators in a boundary-free one. He finally concludes his account of what he tellingly calls "omitting boundaries" by stating that fully boundary free theories fail to explain contact relations. Therefore, regardless of their references to similar arguments, the latter two sources mention different aspects regarding the viability of the boundarylessness axiom. Regarding the consequences of such viability, or lack thereof, for the relation between spatial entities and pure space, Couclelis suggests, as previously highlighted, that "boundaries carve out distinct objects in space, characterized by the prototypical object qualities of discrete identity, relative permanence of structure and attribute, and potential to be manipulated" (Couclelis, 1992, p. 67).

To conclude this long paragraph on boundaries, it is appropriate to clarify the concept of interface in relation to that of boundaries, as introduced by Varzi (2007) in his examination of dissectivity, simple connectedness and the status of holes. Varzi argues:

"Suppose we take holes seriously: a hole in an object is something with well-defined boundaries. Then the fine-grained distinctions mentioned above can be recovered by looking at the mereotopological interplay between matter and void, at the properties of the boundary where an object comes into contact with its holes. More precisely, let the interface between two entities *x* and *y* be the product of their boundaries […] And let the internal skin of an object *x* be the interface between *x* and the fusion of its holes." (Varzi, 2007, p. 1011).

This argument entails that admitting holes assumes the existence of boundaries on the internal skins of the objects under consideration, even in the absence of exterior boundaries.

Location

> "Let us finally turn to the relation of spatial location. Intuitively, this is the relation that holds between an entity and the spatial region that it occupies, and we have already seen that this relation can hardly be reduced to a chapter of mereology and/or topology. Even if it were—as someone inclined to favor a Leibnizian, relationist conception of space against its Newtonian, substantivalist foes would urge — methodological prudence would suggest that we regard the reduction as a theorem, not as a starting point, hence that the relation of location be treated as an independent primitive next to parthood and connection. Exactly how this relation should be characterized, and how it should interact with the principles governing those other primitives, is precisely the sort of question that a good theory of location should aim to answer." (Varzi, 2007, p.1012).

Natural language tends to use locative predicates to express mereotopological relations, such as parthood, interior proper parthood or external connection. In turn, these predicates may be used to imply a relation of location. Yet, the main concern of a theory of location are those predicates addressing a particular spatial region. In this sense, any theory of location relies on a substantivalist ontology of space. In this context, four notions of location can be identified by specific attributes: exact for cases where object and region perfectly match; generic for any case of an object or part of it located within a region; entire for cases where no part of the object lies outside of the region; ubiquitous for cases where an object or part of it fill up the whole of the region under consideration. Among basic principles, it is assumed that each object can have only one exact location. One further substantivalist assumption would be that everything is located somewhere. Varzi compares these two assumptions with Aristotle's notion of universals which exist "whenever and wherever they are exemplified" (Varzi, 2007, p. 1015). In this regard, Varzi bypasses the problem by taking location as a relation characteristic of particulars. One more problem arises with the notion of regionhood. In this regard, Varzi asks whether "spatial regions are themselves entitites located somewhere […, and in that case they] can only be located at themselves […,] or whether they do not have a location [because] they are location" (Varzi, 2007, p. 1015-1016). In the first case, a region plainly corresponds to the place where an object is located. In the second case, this correspondence only works if one holds at least two committments. These committments include the ontological possibility of entities that are located nowhere, and the impossibility of unoccupied regions, which in turn denies the possibility of existence of boundary-like region in the absence of boundary-like objects. In this regard, Varzi favors "a minimal theory of (exact) spatial location" (Varzi, 2007, p. 1017) which rejects these two committments. From here on, additional axioms may state "that regionhood is both dissective and cumulative, i.e., that any part of a region is itself a region, and that the sum of any regions (if it exists) is a region" (Varzi, 2007, p. 1017). Then, comparing regions with other entities, there arises the question of the mereotopological principles which shall equally apply or not to regions and to the entities that occupy them. For example, regarding extensionality, one may admit that having the same proper parts implies sameness for regions even though this may not be the case for the entities that occupy them. This question leads to examine the relation "between the two terms of the location relation—the structure of regions *and* the structure of their tenants." (Varzi, 2007, p.

1018). Along with this examination, Varzi identifies mirroring principles between mereotopology and location, by which, for example, both entire and ubiquitous location can be differentiated into tangential and interior. In this light, he concludes that:

> "the resulting variety of locative relations is defined with reference to the mereotopological structure of the *range* of L— the structure of space. But one could also consider the obvious alternative, and characterize locative relations by reference to the mereotopological structure of the *domain* of L—the structure of space's tenants." (Varzi, 2007, p. 1018)

Varzi continues by asking whether these two characterizations should coincide, either by admitting the latter based on the former (top-mirroring) or the other way around (bottom-mirroring). "By requiring that the structure of space mirror the structure of its tenants, [...bottom mirroring] rules out the possibility that mereotopologically distinct entities be co-located, i.e., located at the same region." (Varzi, 2007, p. 1020). Counter examples to this apparently intuitive exclusion include: i) the example that distinguishes the sum of the tailess cat and its tail from the tailed cat while assuming that they are located in teh same region; ii) the spatial coincidence of boundaries which can be distinct and coincide at the same time once assumed that they do not occupy space. A similar argument is made regarding distinct events occurring to the same object and therefore sharing the same location of the object. Moreover, shadows or other immaterial or ethereal entities also constitute a case of possible co-location, given the impossibility of their interpenetration with material entities. Conversely, as previously mentioned, top mirroring excludes the possibility that, given certain conditions, there might exist unoccupied regions. According to Varzi, "this is a substantive presupposition that few might grant, regardless of their views concerning purely mereotopological matters. " (Varzi, 2007, p. 1021). This is because of different reasons. For example, the given conditions imply that "every region ubiquitously occupied by an object is exactly occupied by a part of that object" (Varzi, 2007, p. 1021), excluding the existence of spatially extended mereological atoms which cannot be divided into parts, and which, since Democritus, were conceived as infinitely diverse in shape and size. Furthermore, the given conditions also contradict the validity of the example of the cat surviving the removal of its tail, excluding the possibility "that ordinary material bodies can gain or lose some parts" (Varzi, 2007, p. 1022). This discussion matters because "the lack of a full correspondence between the mereotopology of space and the mereotopology of its tenants may find expression in the failure of other principles or equivalences" (Varzi, 2007, p. 1023). In this regard Varzi highlights that:

> "There are lots of redundancies and empty relations in this picture […] Nonetheless, it is only through a careful study of such intricacies—and of the corresponding mirroring principles, at the moment vastly unexplored—that a reasonably complete theory of location can emerge." (Varzi, 2007, p. 1024).

The correspondence between the mereotopology of space and the mereotopology of its tenants can be further explored with regard to relative locations. This is particularly relevant in those cases in which location is expressed by a relation between two objects which cannot be considered mereologically related, while the regions these objects occupy are. In these cases, such as for example that of hollow objects and objects located within their cavities, the mereotopology of space reflects the relation of spatial location with no correspondence in the mereotopology of its tenants. Applying this problem in the case of the built environment can help clarify the mereotopological assumptions behind a given representation of the spatial organization of an urban area. In addition to the case of cavities, Varzi further develops the topic of relative locations by highlighting the “distinction between object-centered frames of reference [...] and observer-centered frames“ (Varzi, 2007, p. 1025). In the latter case, spatial prepositions such as next, behind, etc., account for relative locations which express a spatial relation between two objects as a relation between the first object and the place, or region, where the second object is located. According to Varzi, this case demonstrates how relative locations require a committment to the ontological independence of location from objects. But this committment, he maintains, would be hard to endorse for both methodological and phylosophical reasons from both a relationist and a substantivalist perspective about space. This is because both consider spatial objects “conceptually prior to their locations” (Varzi, 2007, p. 1026). Therefore, relative locations constitute an exception in the above mentioned standard treatment of the correspondence between the mereotopology of space and the mereotopology of its tenants. Overall, Varzi concludes:

> “the ontological intertwining between locative and mereotopological concepts cannot be assessed without a clear stand on some very basic semantic issues concerning those concepts. […] We face, here, the fundamental limit of topology—and mereotopology—as a general theory of space. One way or the other, the *analysis situs* cannot do proper justice to the fact that objects are *situated*, which is why the theory of location is independently needed. One way or the other, spatial reasoning must come to terms with the fundamental metaphysical mystery on which it depends—embedding in space.” (Varzi, 2007, p. 1029-1030).

Common sense and natural language

To what extent spatial planning concerns can be considered to include commonsense situations? In other words, to what extent spatial planners consider the spatial concepts in use to describe and prescribe spatial organization based on common sense?
Guarino stresses "the use of ontological and linguistic analysis to model commonsense reality" (Guarino, 1995, p. 631). This was also the focus of a special issue of the journal Applied Ontology in 2022, stressing that in many areas such as ontology of time, space, motion, and causality, a “major concern […] has been the development of systematic approaches to 'commonsense' reasoning, as set out for example in the Naïve Physics project”, or in naïve geography. According to Cohn and Renz, "in natural language, the use and interpretation of spatial propositions tend to be ambiguous.” (2008, p. 554), and previously, “arguably, the next generation GIS will be built on concepts arising from Naive Geography [70]” (Cohn & Renz, 2008, p. 553). According to Guarino,

> "what is needed is a way to constrain and to make explicit the intended models of a KR [knowledge representation] language, in order to facilitate large-scale knowledge integration and to limit the possibility to state something that is reasonable for the system but not reasonable in the real world" (Guarino, 1995, p. 632).

And further on the purpose of ontological distinctions:

> “they allow the knowledge engineer to make clear the intended meaning of a particular predicate symbol. This is especially important since we are constantly using natural language words for predicate symbols, relying on them to make our statements readable and to convey meanings not explicitly stated. However, since words are ambiguous in natural language, it may be important to ‘tag’ these words with a semantic category, in association with a suitable axiomatization, in order to guarantee a consistent interpretation. This is unavoidable in our opinion if we want to share theories across different domains” (Guarino, 1995, p.636).

According to Varzi, deciding which model of human spatial competence “is better depends on the seriousness with which we handle the spatial ontology of common sense” (Varzi, 2007, p. 1004), where the reference to seriousness implies that common sense ontology offers a stable reference which one can choose to rely upon or not. The expert knowledge involved in spatial planning may look at odds with this association to common sense, yet common sense and natural language are deeply engaged with the tacit and taken-for-granted character of spatial concepts adopted and enacted in spatial planning. These concepts convey common sense meanings not explicitly stated which inform expert and experiential knowledge alike (Kakhee et al., 2000). Common sense also corresponds to Couclelis's reference to cognitive geography, which according to her, invites us to

> “consider the possibility of spatial data structures that are neither raster- nor vector-oriented […;] be open to the notion of spatial representations that may not be mappable, and to GIS that do not work primarily through map-like displays […;] ask whether we can represent *relational* as well as absolute and relative space, i.e., a space in which spatial units carry information about their relations to other relevant spatial units in the vicinity […for example by] a generalization of the potential field concept […; and remember that even if] the most significant geographic spaces may never make it into a computer, the quest for their representation may prove the most exciting kind of geography we've ever done.” (Couclelis, 1992, p. 75-76).

In this light, addressing as ‘borrowing’ this engagement of ontology, QSR, and of mereotopology in the next section, expresses the uncharted operation related to the transfer of inferential chains back from formal languages to natural language and common sense.

3.b Borrowing ontology and qualitative spatial representation within observant participation in spatially explicit policy making

This section explains how the activities conducted during the internship at the Unità Portici Patrimonio Mondiale, Direzione Generale of the Municipality of Bologna (from now on the PPM Unit), contribute to answering the research questions. This internship provided the institutional framework to carry out the field work for the case study. It allowed for direct involvement in the reporting process which followed ICOMOS evaluation of the proposed justification for inscription of the porticoes in the UNESCO World Heritage List (WHL), including the Periodic Report to the World Heritage Committee and the preparation for the joint World Heritage Center/ICOMOS advisory mission to Bologna (June 12-16, 2023). Between October 2022 and June 2023, the internship supported the PPM Unit in addressing ICOMOS recommendations to review the justification, and to revise the definition of the asset nominated as UNESCO World Heritage. This section presents the approach adopted during the internship with different interlocutors, to draw observations relevant to the research questions, while supporting the PPM Unit throughout the reporting process. Section 4.a.2 describes the evidence gathered in this process. The scope of the observations is not meant to achieve a full-fledged analysis of the nomination process, but rather to focus on the questions of spatial representaton posed during the process. The observations cover the extent to which the conceptual models adopted by interlocutors for the representation of the porticoes as an heritage asset relate to mereological and mereotopological principles. Assessing the appeal of these principles from the perspectives of different interlocutors sheds light on the ontological assumptions behind their choice of the conceptual model. Moreover, the comparison of their different perspectives highlights opportunities and constraints posed by these assumptions for knowledge production and normative action on the nominated asset.

Interlocutors belong to four groups playing different roles in the reporting process:

- Group 1: the municipal officers working for the PPM Unit;
- Group 2: the academicians who conducted the studies which informed the reporting process since the early conception of the nomination;
- Group 3: WHL experts such as UNESCO World Heritage Center representative and ICOMOS independent consultant;
- Group 4: the spatial planning office in the Municipality responsible for the local heritage protection regulations included in Municipal planning instruments.

Each group expressed specific concerns and interests regarding the representation of the nominated asset. Some of these concerns and interests can be related to a number of mereological and mereotopogical principles, taken as a starting point for the development of the methodology. Nonetheless, given the commonly taken-for-granted conflation of spatial representation with Euclidean geometry, the explicit consideration of these and related principles in the representation of the nominated asset required calibrated prompting inputs by the researcher. Calibration of the level of each group's exposure to the prompts took into consideration their openness to engage with the research based on the established degree of rapport. Accordingly, prompting topics reflected the academicians' and the WHL experts' exclusive focus on the WHL nomination, and the PPM Unit and the spatial planning office broader mandate regarding the significance of porticoes in the city. Calibration also reflected the PMM Unit role as the key gatekeeper, facilitating the researcher's access to interlocutors within the limited time span of the field work. Given these conditions, the intern-researcher built rapport with the interlocutors matched the their relation to the gatekeeper.

As explained in section 4.a.2, the observations on each group's contribution to the representation of the nominated asset reflect the interplay between the commonly endorsed conceptual model for spatial representation, the groups' specific interests and concerns and their reactions to the researcher's prompts. This interplay can be traced along three steps:

- definition of the heritage asset to be inscribed in the WHL;
- identification of the heritage policy target area;

– visualization of the heritage policy target area;

Because of the hold of the above-mentioned conflation on interlocutors' attitudes towards spatial representation, these steps usually converge on the metric Euclidean conceptual model as the only possible option. Nonetheless, they correspond to virtually distinct decisions in conceptual modeling for spatial representation. Pointing to this distinction allows for a more specific understanding of the scope of each group's engagement in the representation of the porticoes, since they did not all engage in every step. Indeed, academicians and the spatial planning office engaged primarily with the definition of the asset, whereas the PPM Unit engaged with all of the three steps, and the WHL experts with the first two, most probably out of assuming that the third regarding visualization was an obvious task. Moreover, the distinction helps explain the different ways in which the research borrowed mereological, mereotopological and more generally ontological principles with each group of interlocutors and the exposure of each group to different prompts. The following description of this tailored approach encompasses three aspects. One aspect refers to the different forms of interaction, research methods and sources through which each group provided evidence for the research, expressing their concerns and interests. For each group, specific research methods and related sources, such as interviews or review of written reports, identified specific interests. The second aspect refers to the concepts of spatial information and to the mereological, mereotopological and generally ontological principles related to these concerns and interests and to the steps each group engaged in. Here, for the sake of minimizing text length, mereological and ontological principles are specified as such only when disambiguation is required by the existence of homonyms, while mereological principles with no known topological homonymous and mereotopological principles are not specified as such. The third aspect indicates the targeted exposure of each group to prompts suggesting the adoption of these principles in the representation of the porticoes as an heritage asset, at each step relevant to the group. The interlocutors' concerns and interests, their implications for spatial representation and the results of the researcher's prompts are further discussed in section 4.a.2 as part of the research findings. As part of the research methodology, this section anticipates an overview of the logic tying research methods and sources, the principles for spatial representation related to interlocutors' interests and concerns, and the corresponding prompts. After an overview of the interaction with each group, and related research methods and sources of evidence, Tables 3.1, 3.2, 3.3 and 3.4 recap interests, principles and prompts for each group, associating specific principles to each step in the representation of porticoes.

The PPM Unit municipal officers interacted with the research as part of the teamwork related to the internship. The interaction relied on one-to-one conversations with each officer of the Unit during everyday workplace routines and on group conversations during both formal and informal meetings. The observations on their attitudes draw primarily on participant observation, which often translated into observant participation (Tedlock, 1991; Moeran, 2007; Seim, 2024). Besides the field notes, various official and internal reports constitute also a key source regarding their attitudes, in addition to two kick-off meetings with Federica Legnani PhD and Maria Beatrice Bettazzi PhD. Participant observation and interviews regarding ICOMOS reservations on the justification for inscription indicated the group's interest in clarifying the coherency between their systemic definition of the heritage asset and their identification of the target area as a serial set of components. Spatially, definition and identification created a tension between the concepts of network, implicitly associated to the notion of system as its spatial manifestation, and that of object. Moreover, participant observation and review of internal reports for the Periodic Reporting required from World Heritage sites indicated a second group's interest to integrate public and private stakeholders' efforts in the protection of porticoes. Spatially, this integration evoked the focus on attributes and degrees expressed by the field concept. In this context, the arguments regarding the definition of the asset and the identification of the target area evoked the principles indicated in Table 3.1. Nonetheless, and regardless of the acknowledged difficulty of setting stable criteria for tracing the boundaries (one-to-one conversation, June 15 2023), the assumption that visualization would require a geometric plan of the bounded area to represent the heritage asset was left unquestioned.

Group 1 PPM Unit Interests	coherency between a systemic definition and identification of the target area as a set of separate components	integration of public and private stakeholders' efforts in the protection of porticoes
Concepts and principles by step		
Definition of the asset: “the porticoes of Bologna”	object, network, parthood, underlap, open region, mediated connection ontological unity	field, overlap, tangential parthood, connection, mediated connection
Identification of the area: “the components”	object, composition, tangential extension, external connection, constellation	field, overlap, tangential parthood
Visualization of the area: “the boundaries”	object, underlap, open region, tangential extension, external connection, mediated connection	-
Prompts	to consider - the asset as an open region and an ontological unity based on a characteristic relation of mediated connection - the nominated property as a whole by unrestricted mereological composition or a constellation underlapped by the above mentioned unity, and further by the city as a whole	to consider the spatiality of private property of public use as overlap of tangential parts

Tab. 3.1 A recap of interests, principles and prompts by research interlocutors, group 1.

The academicians, architecture scholars and historians, interacted with the research primarily through direct invitation by the researcher. The interaction relied on one-to-one exchanges in the context of formal interviews with the architecture scholars, and informal conversations on the sidelines of formal meetings with the historians. In this context, the group's overall interest in articulating an exhaustive and cohesive definition of the nominated asset engaged both concepts of object and field. Objects shaped the typologies proposed by architecture scholars to ensure exhaustivity and justify the cohesion based on the variety of morphological configurations to be included in the definition of the asset. At the same time, a field view can be associated to the historians' references to qualitative gradients to explain the origin of porticoes as indoor-outdoor intermediary spaces as a a backdrop to the definition of their heritage value. Moreover the typology evoked the principles indicated in Table 3.2. In this light, the researcher used the prompts indicated in the same table regarding options for representation to reflect exhaustivity and cohesion of the definition of the nominated asset. In this particular case, the reference to the open region (Varzi, 2007; Cohn & Renz, 2008) built on the historians' insights on the status of boundaries at the time of the introduction of porticoes in the city and on the role this introduction played in their institutionalization (Venticelli, 2001; Smurra, 2008).

Group 2 Academicians Interests	an exhaustive and cohesive definition of the nominated asset
Concepts and principles by step	
Definition of the asset: "the porticoes of Bologna"	object, field, tangential parthood, tangential extension
Prompts	to consider the asset as an open region and an ontological unity based on a common characteristic relation across a range of tangential parthood relations

Tab. 3.2 A recap of interests, principles and prompts by research interlocutors, group 2.

WHL experts interacted with the research primarily through the reports they addressed to the PPM Unit, in addition to their comments in formal meetings attended by the researcher and to few short informal direct conversations initiated by the researcher during the World Heritage Center/ICOMOS advisory mission. Written reports and direct conversations indicated the group's interest in the formulation of holistic criteria for the identification of the target area, while upholding the very definition of the heritage asset as a system, proposed by the PPM Unit in the Nomination format (Comune di Bologna, 2020a). In this way, ICOMOS mixed up holistic and systemic approaches, explicitly referring to the notion of system, while explaining the practical application of the approach through notions of entirety more akin to holism (Scandurra, 2003). It also assumed that a systemic or holistic understanding would require to represent porticoes by the spatial concept of network, in turn polarizing the tension between the concept of object and that of network ("an urban system of covered walkways", ICOMOS, 2021, p. 400) to question the validity of nominating a series of separate components. The semantic ambiguity of using the word system while implicitly aiming to an holistic perspective is occasionally highlighted above and below by juxtaposing the two words, and further explained below regarding the adoption by the Municipal Planning Office of the concepts of historical urban landscape. Elsewhere, each word appears on its own to express the gap between holistic claims in heritage policies and the systemic representation of space pursued by this dissertation, and, albeit implicitly, by the PPM Unit approach to the WHL nomination. Therefore, the dissertation uses the word holistic in its specific references to historical urban landscape type of heritage approaches, as well as to the WHL experts' perspective based on the practical application envisioned in ICOMOS reports regarding the definition and indentification of the porticoes even if these reports label the portico as a system. In terms of spatial representation, as clarified during two informal conversations (June 2023), the holistic definition of the asset informing ICOMOS concerns relied on a principle of connection by continuity, by which components in separate locations cannot count as a whole. Moreover, comments in formal meetings stressed the group's intent of clarifying the criteria for boundary identification of each component, to justify inclusion or exclusion of buildings in and out of the target area as a whole. In this light, the researcher used the prompts indicated in Table 3.3.

Group 3 WHL Experts Interests	adoption of holistic criteria for identification of the target area	clarification of the criteria for what was included in and excluded from the overall nominated property and from each of its components
Concepts and principles by step		
Definition of the asset: “the porticoes of Bologna”	object, network, parthood, underlap, connection, tangential extension	-
Identification of the area: “the components”	external connection, mediated connection	composition, overlap
Prompts	to consider - the asset as an ontological unity based on a common characteristic relation across a range of tangential parthood relations, tangential extension and external connection - the nominated property as a whole by unrestricted mereological composition of parts as components connected by a range of types of mediated connection	to consider each component as a whole by mereological overlap between any two parts or any part and the whole based on the existence of something which is part of both

Tab. 3.3 A recap of interests, principles and prompts by research interlocutors, group 3.

The spatial planning office in the Municipality interacted with the research primarily through its support to the PPM Unit. The interaction relied on one brief interview with two officers, on the attendance to a presentation of the head of the office for the WHL experts in the occasion of their advisory mission to Bologna, and on the review of municipal plans and building codes issued by the office over the years. The observations on their attitudes draw primarily on the provisions regarding porticoes in the planning documents, and how these were interpreted by the concerned officers during the interview and the presentation. In this context, the group's general concern focused on the connectivity between adjacent porticoes, as observable in the building code provisions regarding porticoes. Moreover, a more contingent concern was to support the WHL nomination by highlighting the prominence of existing porticoes in the office latest spatial plan provisions for the protection of tangible architectural heritage. In both cases the notion of object was undisputed as a descriptor of porticoes. Meanwhile, the interview did not spot any interest towards the construction of new porticoes as a form of living heritage, or towards the preservation of the intangible heritage of the mix of statutory and customary normativity behind the construction of porticoes across different historical circumstances. In this light, the researchers' prompts addressed both interests, while hinting at the regulatory implications of spatial representation of the porticoed city as a whole subject to mereological change, to test the potential for openness towards acknowledging the value of porticoes both through conservation and development.

Group 4 Municipal Planning Office	highlighting the protection of the identified target area in the provisions of the latest spatial plan prepared by the unit	connectivity of porticoes alignments
Concepts and principles by step		
Definition of the asset: “the porticoes of Bologna”	object, parthood	tangential parthood, mereological overlap
Prompts	to consider the asset as an open region occupied by a concrete spatial entity subject to mereological change to be restricted by regulations and customary norms to encourage addition and prevent subtraction of parts	to consider different degrees of connection based on the principle of tangential parthood to connect adjacent parts by overlap, cumulatively extending into mediated connection and external connection

Tab. 3.4 A recap of interests, principles and prompts by research interlocutors, group 4.

The above report on the ways in which the research borrowed mereotopology in the interaction with research interlocutors provides the background for the field work findings presented in section 4.a.2. Borrowing mereotopology allowed the research to hint to a model for spatial representation alternative to Euclidean geometry. The tailored introduction of this alternative to each group provided the independent variables of the experiment, while the reactions observed during the field work and presented in section 4.a.2 constituted the dependent variable to be assessed in the experiment. The use of the term borrowing, here and in the previous section, wishes to express the adaptation of insights across domains belonging to different disciplines (Frodeman et al., 2010), where one domain refers to another domain as a source of inspiration. The appropriate standards for the accuracy of such adaptation require further transdisciplinary engagement, to be developed based on the shortcomings observed in the adaptation proposed here. The experimental approach to the interaction with interlocutors qualifies the field work during the internship as a pilot whose evaluation can provide criteria for standardization.

3.c Borrowing historiographical and ethnographical tools to gather evidence on the spatial organization of the built environment

This dissertation integrates different methods. It focuses on QSR and ontology as methods to represent the spatial organization of the built environment, presented in sections 3.a and 3.b. Moreover, it adopts historiographical, ethnographical and morphological tools to gather evidence in support of its core argument regarding the relevance of QSR, and particularly of parthood and connection relations, to the representation of the spatial organization of the built environment. These three lenses reflect the profile of the author as an historian and a spatial planner by formal training, and as an ethnographer based on her recurrent use of ethnographic methods in the research conducted for three previous dissertations and various previous professional engagements. They also reflect her intent to work with evidence according to the following standards. First, the historiographical lens, while responding to one of ICOMOS requirements regarding the justification for the WHL inscription of the porticoes, more broadly informs a change-sensitive approach to the systemic representation of space as opposed to the static character typical of geometric boundedness in cartography and other forms of spatial mapping (Bonfiglioli, 2024). Furthermore, the chronology proposed in section 4.a deliberately covers both urban history and planning history (Celik & Favro, 1988; Abbott & Adler, 1989; Sandercock, 1998; Abbott, 2006) to track associations, or lack thereof, between trends in the evolution of form and norm. Along these lines, the thematic chronology in section 4.a provides essential background information for both the analysis of the WHL nomination process of the porticoes of Bologna in section 4.b, and for the examination of their emergent spatial organization in section 4.c, beyond section 4.b focus on heritage preservation. The thematic chronology integrates general historical information with specific information gathered by art historian Maria Beatrice Bettazzi, PhD, on behalf of the PPM Unit, and included in two internal reports drafted by Dr. Bettazzi as part of the background research conducted by the Municipality of Bologna to address ICOMOS reservations to the nomination (Bettazzi, 2022). The interpretations of these information by the author of this dissertation further integrates the overall content. Second, the ethnographic methods inform two distinct approaches. On the one hand, standard tools, such as semi-structured interviews, participant observation and reports on informal conversations, are presented in section 3.b as sources of evidence regarding the WHL nomination process of the porticoes of Bologna and the relevance of mereological and mereotopological principles, discussed in section 4.b. Moreover, another standard tool, the focus group, complements the historical overview with findings regarding the contemporary perception of porticoes by high school students in section 4.a. On the other hand, the examination of the emergent spatial organization of the porticoes of Bologna in section 4.c relies on evidence gathered by more peculiar tools. Its key insights are based on retrospective anecdotes (Michael, 2012; Wood, 2023) from the researcher personal memories as a long term resident of Bologna, and corroborated by the findings of an auto-ethnography recently conducted by a geographer (Bonfiglioli, 2024). Then section 4.c further elaborates these insights in the light of morphological observations typical of urban planners and designers focus on building densities (Dovey & Pafka, 2014; McFarlane, 2016), on the relation of open and built up spaces and their respective interfaces (Dovey and Wood, 2017).

4. Case study: the porticoes of Bologna and the representation of parts of the built environment elusive to geometric representation

"natural human territories […] do not partition space, although they may share it"
(Couclelis, 1992, p. 68)

4.a Historical emergence of the porticoed city and its part-whole relations

The chronology presented in Fig 4.1 summarizes the history of the expansion of the porticoes of Bologna, complementing the following insights about the evolution of the porticoed city in Bologna since the Middle Ages, and suppporting the interpretation of the porticoed city as an emergent spatial imaginary. The summary interprets historical information on the urbanization process of the city of Bologna in the light of the thesis research problem. To this end, the table integrates the author's historical insights with the information included by the art historian Maria Beatrice Bettazzi, PhD, in two internal notes she drafted on behalf of the PPM Unit, as part of the background research conducted by the Municipality of Bologna to address ICOMOS reservations to the WHL nomination.

Regarding the historical overview in Fig. 4.1, two aspects are worth highlighting to set the broader context of the emergence of Bologna as a porticoed city, and clarify the place of each aspect with regard to the focus of this dissertation. First, the history of the expansion of porticoes in Bologna is related to their role in the process of negotiating the boundaries between public and private land in the medieval urban precinct (Smurra, 2008; Venticelli, 2001). This role adds to their relevance as a case study regarding the spatial representation of the built environment, particularly in the light of Helen Couclelis's insights on the role of property in the development of geometric representation of space. As she puts it:

> "The points, lines and polygons that do exist in the geographic world are practically all human artifacts, falling into two broad categories: *engineering* works […]and administrative and property *boundaries* (It is instructive to remember, in this context, the origin of geometry in the need to safeguard property boundaries in the ever-flooded Nile valley. As for the association of lines in the landscape with man-made projects, remember how earlier in this century, some recently observed linear features on Mars were interpreted as canals and seen as proof of the existence of Martians!). Throughout the history of Western culture, these two categories of Euclidean features have been essential to the regulation, domination and control of the geographic world: the natural world, in the case of engineering works; the social world, in the case of boundaries. The profound cultural significance of boundaries in particular has been extensively analysed by scholars in the traditions of political and critical geography. In an early essay on this subject, Soja (1971) discusses the Western bias of rigidly compartmentalized space, and the concomitant hierarchy of nested bounded areas, from the modern nation-state all the way down to the individual parcel. Western culture is apparently unique in its treatment of land as *property, as* commodity capable of being

Fig. 4.1
A choronology on the spread of porticoes in Bologna

Period		**1000-1327**
Phase		the Commune and the Studium
Scale of the porticoes' extent		the porticoed building and the early porticoed street frontage
Emergent urban morphology		definition of public-private boundaries in the XIII c. and alignment of buildings along street frontages
Porticoes' new functions		light and ventilation for crafts and commerce, densification, transit
Key records on the spread of porticoes	**1211**	obligation limiting porticoes to private land
	1250	obligation imposing porticoes in residential buildings on eastern street frontages
	1250, 1259	obligation to keep empty space for pedestrian transit
	1288	the 10th book of the Statutes on urban form, construction, and maintenance requires porticoes in residential buildings, preserved in the historical city centre until today
Key general events	**1088**	establishment of the Studium
	1116	Henry V endorses the Commune autority
	1192	completion of the second circle of city walls, the Torresotti circle
	1228	the Commune councils admit delegates of the *Compagnie d'Arti e Mestieri* after a popular revolt
	1245,1286,1294	Libri Terminorum fix and extend private-public boundaries in the city to larger areas
	1256	Liber Paradisus for the liberation of slaves
	1116-1274	infighting between Guelph and Ghibelline families for the Investiture Controversy stirs the construction of over a hundred towers inside the city walls

Image credits

a. Group of students in Bologna, from the Giovanni da Legnano's tomb. Source: https://www.meisterdrucke.pt/

b. Statute of the Carpenters' guild, Nicolaus de Rasiglio at work below the portico of his home (caption). Source: Francesca Bocchi

c. The Artemisi and Riccadonna towers demolished in 1918-19, with the Asinelli and garisenda towers in the background. Source: https://www.arte.it/calendario-arte/bologna/

d. An example of a rural portico. Source: Francesca Bocchi.

e. An example of a sporto. Source: author.

f. Palazzo Grassi, Via Marsala. Source: Francesca Bocchi



Period	**1327-1446**	**1446-1506**
Phase	**r**egional meddling and popular revolt	**t**he Bentivoglio rule
Scale of the porticoes' extent	**a**doption of porticoes in institutional buildings	**p**orticoed street frontage along entire roads
Emergent urban morphology	from defense to entertainment: **c**ollapsing or demolished towers and diversifying porticoes functions	**p**rince and notables build private palaces with porticoes of public access and implement public works
Porticoes' new functions	**m**onumental design of gathering and parade spaces showcasing influence and political power	
Key records on the spread of porticoes	**1382-1391** **c**onstruction of Palazzo della Mercanzia with a monumental portico facing the XIII c. Reggiani and Seracchioli wooden porticoes	**1454** **a** new document confirms the directives of previous Statutes regarding porticoes
	1335 - 1384 **c**onstruction and renewal of Palazzo dei Notai featuring a portico which was later removed	**1460-1478** **f**unctional and aesthetic renewal of the road grid connoted by porticoed palaces showcasing elites prestige
Key general events	**1327** **t**he arrival of the Pope's representative ends the Commune rule shifting power struggles outside the city	**1446** **S**ante Bentivoglio becomes governor of the city
	1327-1390 **c**onstruction of the Circla Walls, the third city enclosure built along a wood fence conceived in 1226	**1462-1506** **u**nder the rule of Giovanni II Bentivoglio, Bologna stands out among European Renaissance courts
	1348 **t**he Black Death, a bubonic plague pandemic, kills around a third of the population	

Image credits

g Episode from the conflict between the Communes of Bologna and Modena, 1325. Source: https://www.gonnelli.it/uk/auction-0028/tassoni-alessandro-la-secchia-rapita-poema-ero.asp

h Names and coat of arms of notable families, from Pompeo Scipione Dolfi. Cronologia delle famiglie nobili di Bologna (1670). Source: https://it.wikipedia.org/wiki/Famiglie_senatorie_bolognesi

i Ercole de' Roberti, Portraits of Giovanni II Bentivoglio and of Ginevra Sforza (around 1475, Washington, National Gallery of Art). Source: https://alchetron.com/Ginevra-Sforza

j Palazzo della Mercanzia. Source: https://www.gpsmycity.com/attractions/palazzo-della-mercanzia-(merchants-palace)-34403.html

k Palazzo Bentivoglio. SOurce: https://www.informagiovani-italia.com/palazzo_bentivoglio_bologna.htm



NOTIFICAZIONE
Per riſarcire le Salicate delle Strade, e Portici dentro la Città di Bologna

Essendo ſempre non meno lodeuole, che opportuno il riſarcimento con Saſſi delle Strade, Politie di eſſe, e Salicate de' Portici con Pietre cotte: E volendo l'Eminentiſſimo, e Reuerendiſſimo Signor Card. Caſoni della Città, e Contà di Bologna digniſſimo Legato à Latere, che le ſudette habbino in tempo il ſuo plenario effetto. Inherendo alla diſpoſitione del Bando Generale d'Ornato pub'icato ſotto il dì 10. Gennaro 1710., & al Capitolo ſopra il riſalicare le Strade, e Portici. E vedendo, che non ſi è dato per hora alcun principio, ne preparamento all'accomodamento ſudetto, e volendo S. E. che nel termine preſcritto nel Bando ſiano interamente reſarcite le ſudette Strade, e Portici.
Perciò l'Eminenza Sua Reuerendiſſima con conſenſo de gl'Illuſtriſſimi Signori Confaloniere di Giuſtizia, & Aſſonti ſopra l'Ornato conoſcendo quanto maggior pregiudizio habbino apportato alle Strade la longa, e troppo nociua traſcuragine nel farle accomodare, di modo che ſi renda difficile nel ſolito termine il riſarcimento delle Strade pre-

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Period		**1506-1796**		**1796-1815**
Phase		**t**he Senate and the Papal Delegate		**t**he Napoleonic rule
Scale of the porticoes' extent		**f**rom the porticoed road to the porticoed block or neighborhood		**t**he porticoed city opening extra muros
Emergent urban morphology		**p**edestrian transit meets urban decorum showcase while church porticoes merge congregation and civic activities		**l**ocal autorities plan porticoed blocks as local custom enshrines pedestrian comfort
Porticoes' new functions		**u**rban decorum and civic decency ceremonial showcase		**c**ustom and imaginary rooted in citizens' habits
Key records on the spread of porticoes	**1535**	**F**antuzzi palace portico exemption	**1801**	**d**ecision by the Commission of the health department of Reno to place the new city cemetery extra muros in San Girolamo di Casara Convent
	1567	**d**ecree to replace wood with stone		
	1580	**C**ard. Paleotti porticoed churches guidelines		
	16-1700	**t**wo Statutes recall the 1454 one building permits on porticoed extensions on public land and bollards restricting access		
	1619-1631	**D**iscalced Carmelitans build a portico pilgrimage path from Circla Walls Maggiore Gate to Santa Maria Lacrimosa degli Alemanni	**1811**	**t**he Department of Reno appoints Ercole Gasparini to design the new cemetery and the portico connecting it to Meloncello, a key junction of the San Luca portico, to facilitate the inhabitants' endorsement of the cemetery by the comfort of sheltered transit
	1638	**D**avia-Bargellini palace portico exemption		
	1674-1721	**a** citizens' fundraising committee builds a portico over the pilgrimage path paved by the Senate in 1589 from Circla Walls Saragozza Gate to *Santuario Beata Vergine di San Luca*		
	1759	**d**ecree regulates transit under porticoes		
Key general events	**1506-1822**	***A**ssunteria d'Ornato* manages urban design on behalf of the Senate	**1796**	**t**he French Jacobin army occupies Bologna under general Napoleon Bonaparte
			1797	**c**reation of Dipartimento del Reno by the Repubblica Cispadana, then Cisalpina
	1530	**i**ncoronation of emperor Charles V by the Pope Clemente VII	**1799, 1805, 1810**	**t**ransfer of religious orders' property to urban entrepreneurs and infrastructure projects like the new extra muros cemetery, three years prior to Edict of Saint Cloud
	1630	**t**he plague almost halves the city population		

Image credits

l Assunteria d'Ornato, 1710. Source: De Angelis & Roversi, 1994, p. 99.

m Portrait of Cardinal Gabriele Paleotti. Source: https://it.wikipedia.org/wiki/File:Gabriele_Paleotti.jpg

n Napoleon Bonaparte arrives in Bologna. Source: https://nonocentenario.comune.bologna.it/napoleone-bonaparte-a-bologna/

o Casa Saraceni. Source: https://www.finestresullarte.info/focus/casa-saraceni-bologna-apre-al-pubblico

p Church of Santa Maria della Pioggia. Source: https://www.lalucedimaria.it/

q Portico to La Certosa Cemetery. Source: https://corrieredibologna.corriere.it/

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LA GIUNTA CENTRALE PROVVISORIA
DI GOVERNO

Ritenuto che tutti i Veliti rimasti fino ad oggi in servizio debbono considerarsi avere aderito al nuovo Governo, e sono perciò obbligati al compimento della loro capitolazione militare.

Decreta:

Qualunque Velite abbandonerà il suo posto sarà considerato disertore e come tale giudicato da un Consiglio di Guerra, e punito con tutto il rigore del Codice penale.

Bologna, Dalla Residenza il 28 Giugno 1859.

La Giunta Provvisoria di Governo
LUIGI TANARI
ANTONIO MONTANARI
GIOVANNI MALVEZZI

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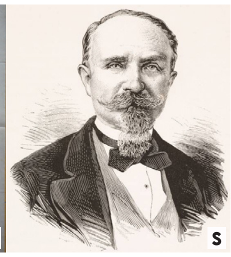

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Period	**1815-1886**	**1886-1955**
Phase	**t**he unification of Italy	**t**he modern city
Scale of the porticoes' extent	**a** consolidated custom and spatial imaginary in the self-fulfilling porticoed city	
Drivers of urban morphology	**l**ocal authorities require private owners to build and maintain porticoes	**p**orticoes set as core urban design standard like hygiene, security and monumentality
Porticoes' new functions	**p**hysical connectivity and visual coherence between urban renewal and preexisting fabric	**d**evice for local adaptation of Haussmanian urban design standards
Key records on the spread of porticoes	**1860** **d**emolitions for the creation of Piazza Cavour and enlargement of Via Farini **1865** **m**akeover of Via Saragozza last stretch **1874** **b**eginning of demolitions for the creation of Via Indipendenza	**1889** **P**iano regolatore mandates porticoes along new roads, from Circla Walls San Donato to Lame gates, and via Rizzoli and Ugo Bassi widening Mercato di mezzo; **1910** **1921** **1955** **B**uilding Code art. 26, 27, 28 and later revisions respectively address height and width, wood prohibition, and ground paving
Key general events	**1859-1860** **i**ndependence from the Papal States and plebiscite for annexation to the prospect Kingdom of Italy **1860** **F**arini Decree launches major public works and centralization of the Municipal technical bureau directed by Coriolano Monti **1861** **V**ittorio Emanuele II is king of Italy and Rome is its capital **1866** **s**uppression of all religious orders and transfer of property to the local administration **1871** **r**eplacement of the railway station building	**1886** **t**he Municipal council approves Piano Regolatore stating road hierarchy and size and the radial directions of future expansion **1889** **I**talian Parliament approves the law for the plan adoption **1902** demolition of XIV c. Circla Walls **1903** **t**he University shifts headquarter from Archiginnasio to Palazzo Poggi in via Zamboni **1906** **e**stablishment of the council estate authority, *Istituto Autonomo per le Case Popolari* **1929** **r**atification of the 1889 plan by the fascist government , to remain valid till 1955 *Piano Regolatore Generale*

Image credits

r June 12th 1859, Provisional Government decree. Source: https://www.storiaememoriadibologna.it/archivio/eventi/il-xii-giugno-1859

s Coriolano Monti, 1815-1880. Source: https://it.wikipedia.org/wiki/Coriolano_Monti

t Piano Regolatore Edilizio, 1886. Source: http://informa.comune.bologna.it/storiaamministrativa/facts/detail/40428

u Portici di Via Farini. Source: https://cultura.biografieonline.it/bologna-portici-patrimonio-unesco/

v Palazo Sanguinetti. Source: https://www.storiaememoriadibologna.it/archivio/luoghi/palazzo-sanguinetti

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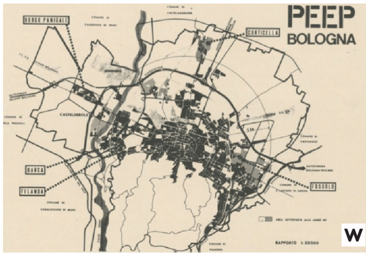
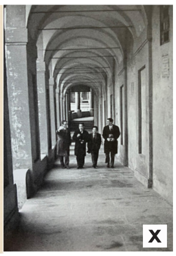
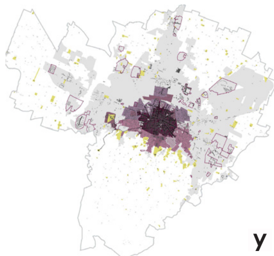






Period	**1955-1985**	**1985-today**
Phase	**p**ost II WW reconstruction and the 60's reformist urbanism	**t**he evolution of urban planning instruments
Scale of the porticoes' extent	**t**he porticoed suburbs and the historic city center preservation	**U**NESCO heritage revival and city branding device
Drivers of urban morphology	**l**ocal authorities sponsor modern porticoed buildings and preserve porticoes' form and uses in the historic city center	**l**ocal authorities committ to preservation in spite of social polarization, overtourism and globalization pressures
Porticoes' new functions	**c**onnectivity device for the city center sociality and commerce,	impressing architects' visions of suburbanization civic hubs
Key records on the spread of porticoes	**1955** **a**rt. 21 in the 1955 plan mandates the construction of porticoes along designated porticoed streets or by Mayoral ordinance, fixing height, width, paving and owners' maintenance duties **1957-1962** **c**ouncil housing built in the Barca district with a 600 m portico *Il Treno* by Giuseppe Vaccaro **1978-1983** **c**onstruction of the exhibition center designed by Kenzo Tange	**1985** **P**RG designates porticoed streets **1989** **a**rt. 67.3 of the building code reflects the 1955 plan, stressing the duty of private owners towards public transit, and respect of safety, lighting, aesthetics and dimensions ensuring overall connectivity of porticoes **2009- 24** **n**ew building codes focus on the existing with mention of optional adoption in new buildings in 2024 **2015** **h**andbook *Portici istruzioni per l'uso*
Key general events	**1949-1963** **I**NA Casa builds housing estates **1951-1961** **v**ast population influx **1955** **P**RG launches city center reconstruction, suburban council estates and land allocations for the bypass highway and the exhibition district **1960-1966** **G**iuseppe Campos Venuti, *Assessore Urbanistica* **1963** **t**he Municipal council approves council housing plan PEEP **1964-1967** **c**onstruction of by-pass highway **1964-1983(2011)** and of exhibition district **1969** **t**he Municipal council approves the conservation plan for the city centre **1970** **P**ier Luigi Cervellati, *Assessore Edilizia* **1972** **t**he Municiplal council approves *Variante* PEEP for the city center	**1985** *Piano Regolatore Generale* **2007** *Piano Strutturale Comunale* **2021** *Piano Urbano Generale*

Image credits

w Overview of PEEP plans in Bologna, Source: https://www.researchgate.net/figure/Schema-degli-interventi-dei-PEEP-nel-territorio-bolognese_fig9_307757446

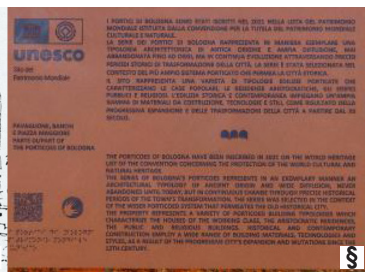
x Kenzo Tange visits the San Luca portico. Source: Francesco Evangelisti.

y Piano Urbano Generale 2012. Source: Francesco Evangelisti.

z Edificio "Il Treno" by Giuseppe Vaccaro. Source: Francesca Bocchi.

& Sketch by Kenzo tange for the exhibition district. Source: Francesco Evangelisti

§ The first plaque of the WHL site. Source: https://portici.comune.bologna.it/notizie/ecco-la-prima-targa



bought, subdivided, exchanged, and sold at the market place. It is at this lowest level of *real* estate (from the Latin *res,* meaning thing), that we find the cultural grounding of the notion of space as object." (Couclelis, 1992, p. 67-68)

The status of porticoes as private property of public use stands as a key attribute of their Outstanding Universal Value (OUV), as defined in their UNESCO WHL nomination format addressed below. In the context of this dissertation, it is important to stress the relation of this aspect with questions of spatial representation, as a background to the elusive character of the porticoes of Bologna to representation by vectorial objects, discussed in section 4.a.2.

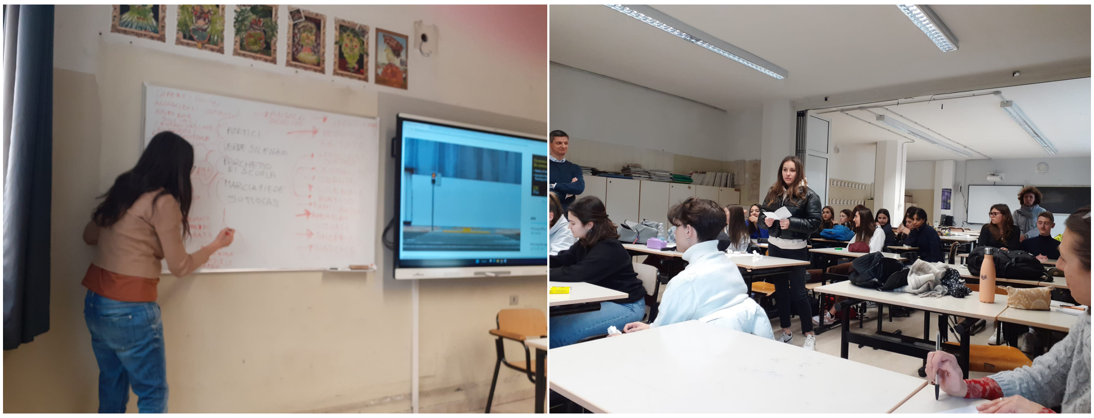


Fig. 4.2 Images from the PCTO workshop with high school students.

The second aspect is the quality of comfort, historically associated to the use of porticoes in the city. This aspect is not throughly examined within this dissertation as it would deserve. Yet, the following quick reference helps to contextualize the relevance of custom in the emergence of Bologna as a porticoed city. The weight of comfort in encouraging the construction of porticoes beyond regulatory obligations was tellingly acknowledged in the early XIX c. proposal for the portico connecting the Certosa cemetery to the city (Ercole Gasparini et. al. *Progetto di unire i portici di San Luca colle loggie del Cimitero Comunale di Bologna onde procurare a quest'ultimo stabilimento l'accesso a coperto il più economico*. Stampato a Bologna dalla tipografia Sassi nel 1811). Furthermore, in the context of the internship undertaken at the Municipality of Bologna as part of the research for this dissertation, one activity, supporting an educational programme about the porticoes for high school students, allowed gathering evidence on the appeal of porticoes to this cohort. On February 27, 2023, the intern-researcher conducted a workshop on comfort in open space in the context of the sessions curated by the PPM Unit within the "Percorso per le Competenze Trasversali e l'Orientamento (PCTO)" promoted by the University of Bologna (Fig. 4.2), targeting 36 students coming from two different high schools, under the title 'Youth leading the dissemination of the UNESCO core values and principles' (author's translation of "I giovani protagonisti della diffusione dei principi e dei valori fondanti dell'UNESCO"). After inviting the participants to share their feelings about different sites in open space among their usual hangouts, identifying the qualities and the sites they associate to comfort, the researcher asked the participants to rank the three qualities and the three sites they consider most comfortable. Scores were then calculated by adding 3 to each quality or site ranked the first by a participant, 2 to the second, and 1 to the third. The word clouds in Fig. 4.3 and 4.4 illustrate the results of this exercise, sizing each word three times the score assigned to each corresponding category. Porticoes (the highest ranking site) rank as high as green spaces (the highest ranking quality) in the perception of participants regarding environmental factors of well-being. Moreover the mention of several lower ranking qualities related to porticoes, such as safety, pedestrian, shelter, enveloping, and also aesthetic variability - a specific attribute of the porticoes of Bologna due to their specific history -, further confirms the association of the porticoes of Bologna to comfort in the participants' perceptions.

Fig. 4.3 The qualities associated to human comfort in urban open space

Fig. 4.4 The sites associated to human comfort in urban open space

4.b Heritage significance of the porticoed city and its part-whole relations

This section[8] describes the problems of representation of the porticoes of Bologna raised during the WHL nomination process. It highlights the relation between these problems and the history of

8 Preliminary insights for this section were presented at the ISUF 2023: Praxis of Urban Morphology Conference a the University of Belgrade on September the 5th, 2023.

porticoes presented in section 4.a. Further on, it interprets the representations adopted by the research interlocutors in the light of the spatial representation principles anticipated in section 3.b. An extended appreciation of this process allows to track the progressive cumulation of different representations. To this end, the nomination process is considered here as including the early surveys by the University of Bologna beginning in 2011 (Gaiani, personal communication, October 24, 2022), the actual preparation of the report for the nomination format (Comune di Bologna, 2020a), till the final settlement reached after the joint World Heritage Center/ICOMOS advisory mission to Bologna in June 2023. As mentioned in section 3.b, representation encompasses the definition of the porticoes as an heritage asset, the identification of the related spatial entity or target area of knowledge production and normative actions such as heritage protection, and the visualization of this area. The cumulation of representations during this process resulted from the search for coherence between the first two steps. The third step was taken for granted as necessarily relying on Euclidean geometry to mark the boundaries of a vectorial object assumed to correspond to the identified target area. The tendency to overlook the distinction between these steps hijacked most of the debate towards the nomination. It led to interpret the problem of coherence as a matter of choice between alternative areas, univocally binding definition and identification to the visualization of a given vectorial object, casting different objects as alternative to one another. The relative permanence of identity, attribute and shape of vectorial objects and their independent existence (Couclelis, 1992) leads to consider the target areas as mutually exclusive, therefore free of overlaps. Moreover, common sense associates the notion of individual vectorial object (Kuhn, 2012) to an inner homogeneity and cohesion that commonly requires geographical objects to display geometrical continuity. This association resists the idea that discrete and distant geographical objects may amount to a larger whole. Metric gaps implicitly exclude the possibility of sameness. Metric distance defines in-betweenness as a gap rather than as a result of the stratification of topological connections. The inner homogeneity and cohesion of, and the mutual exclusion between, vectorial objects are integral to the apparent necessity of chosing among alternative areas. Instead, this section explores options to consider distinct areas as parts of the same whole based on mereological and mereotopological relations.

Indeed, the studies for the nomination were keen on not isolating porticoes from their environment, implicitly evoking questions of parthood. This keenness attended to the holistic shift from an emphasis on architectural monuments to the interest in urban fabrics, in line with the UNESCO recommendation on the historical urban landscape (UNESCO, 2011), and, before that, with the 1960 Carta di Gubbio which inspired thereafter the renowned approach of the Municipality of Bologna to the conservation of its historic center (Cassani Simonetti, personal communication, May 21, 2023; Antonucci & Lipparini, 2022; Cervellati & Scannavini, 1973; Campos Venuti, 1991). In this sense, chopping the porticoes off from their morphological setting was assumed to be wrong. Nonetheless, the air of inevitability attributed by Smith & Waterton (2012) to authorized heritage discourse ensured cohexistence of this awareness with the drive towards spatial representation by vectorial objects. As a result, all research interlocutors overlooked the intrinsic contradiction between a holistic approach and the very UNESCO (2017) requirement of identifying the heritage asset with a vectorial object. In this research perspective, this requirement

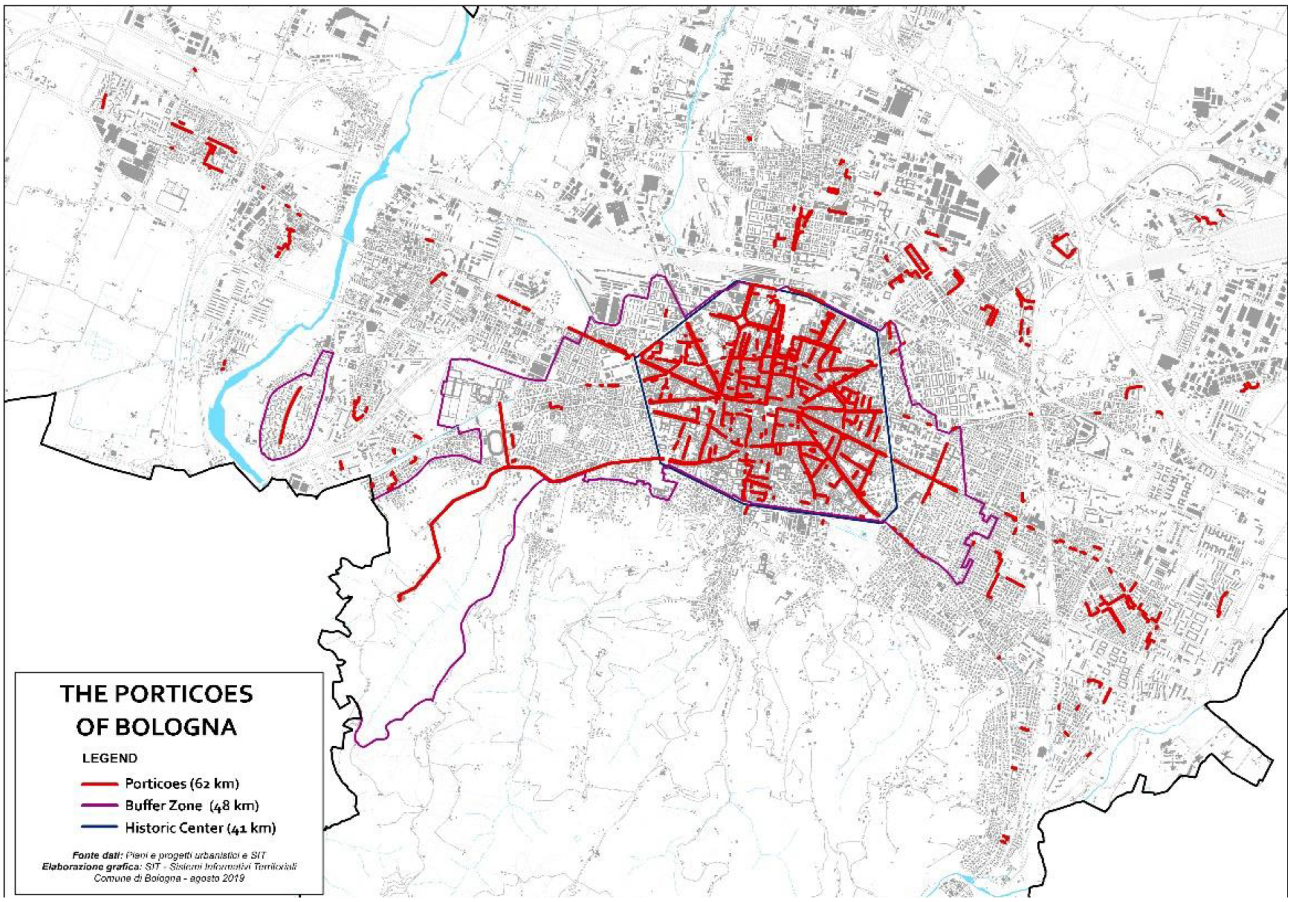


Fig. 4.5 The porticoes in and out Bologna historical city center (Comune di Bologna, 2020a, p. 29)

brings back through the window that very emphasis on monuments, simply enlarged into wider chops, which previous recommentations had thrown out of the door. In other words, such contradiction reduces the historical urban landscape approach to a decision on where to draw the line, based on what could be safely chopped off and what is instead considered integral to a monument's essence and heritage value, implicitly relying on the very notion of monument criticized in the Carta di Gubbio. The highly consequential question of where to draw the line also echoes similar geography and planning, as well as statistics, debates on conceiving and positioning boundaries in the identification of geographic entities at broader scales, such as for example statistical areas, metropolitan areas, supra-natioanl unions, and various kinds of natural features (Brenner & Schmid, 2015; Celata & Coletti, 2015; Smith & Mark, 2003). Accordingly, all proposals regarding the boundaries of the objects identified as integral to porticoes selectively addressed the criterion of landscape integrity by applying it only in relation to certain features, while excluding others. Beyond that, the identification of boundaries applied different ad hoc parameters regarding what these boundaries shall encompass or not, prioritizing either origin, form, style, ownership or other attributes. As a result, multiple interpretations of where to place the boundaries led to the identification of mutually exclusive objects. In turn, these objects raised competing claims regarding the coherency of each interpretation with the holistic, or systemic, definition of the heritage asset. This competition reflects the elusive character of the porticoes of Bologna to representation by vectorial objects. In this context, the need to dodge such elusiveness suggested the possibility of taking inspiration from QSR and mereotopological principles. This section explores a possible convergence between these principles and a systemic interpretation, seeking coherence between the definition of a unitary heritage asset and the identification of a dispersed target area. Section 4.c develops these insights on the representation of porticoes beyond the WHL nomination, futher explaning their elusivity to representation by vectorial objects as a special attribute of their heritage value for the city and for the world.

In the debate towards the nomination, the mutual exclusion between competing representations occurred at each step by different research interlocutors and on different levels. The definition of the asset got stocked at the conceptual level, where the WHL experts opposed the concept of network to definitions as one or more vectorial objects. Nonetheless, given the WHL requirement to enlist a bounded area, both definitions were to be visualized as vectorial objects, identifying target areas alternative to one another. Therefore, the object vs. network debate turned into a contest between multiple smaller bounded areas and a single larger bounded area (Fig. 4.5 and 4.7), which ICOMOS proposed to identify with the historical city center where the phenomenon started and amassed reaching its highest density (ICOMOS, 2021). Meanwhile, the academicians proposed a typological classification of abstract morphological units according to different extensions of porticoed spaces (Fig. 4.6) as a criteria for the identification of the target area. Yet, they did not formulate a principle of unification to correspond to the unitary definition of the heritage asset. Moreover the visualization of their morphological units as bounded objects did not

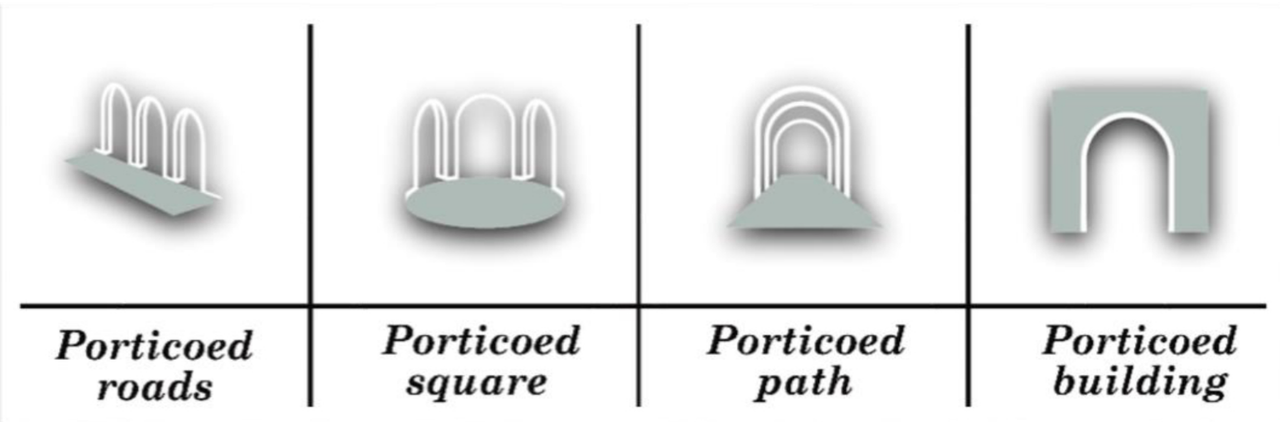


Fig. 4.6 The typology of porticoed morphological units (Comune di Bologna, 2020a, p. 31)

clarify what would make any actual site more representative of its category than others, suggesting ad hoc arbitrariness in the choice of the nominated property. Along these lines, the PPM Unit further translated this typological classification on the territorial level, opting to nominate a serial property constituted by separate target areas, reflecting the historical and functional diversity of the porticoes of Bologna as a whole into the identification of 12 bounded areas (Fig. 4.7). WHL serial sites usually feature in transnational nominations where a common characteristic singles out particular locations from the territory in which they lie. Yet, the principle undelying the seriality of the porticoes nomination was rather the opposite. Indeed, the porticoes series was defined by the variety of their characteristics against their overall similarity to the territory in which they lie, a territory which itself embodies in its porticoed system the actual justification for the OUV of the nomination. As a result of this mismatch, the serial nomination of the porticoes struggled to confront the question of sampling arbitrariness. The either or assumption of mutual exclusion between different vectorial objects and that of the necessity of inner continuity for an holistic or systemic representation framed the identification of a target area made of separate components as a reductionist stance. Moreover, the mutual exclusion between the vectorial object concept and the network concept played out as a direct opposition between a supposedly reductionist and a holistic or systemic identification of the target area. Instead, as argued below, the systemic appeal of the PPM unit representation of the porticoes of Bologna towards their WHL nomination can be explained and justified by historicizing spatiality, rather than interpretaing it according to contemporary conceptions of spatiality, binding wholeness to mutual exclusion and inner cohesion without admitting gaps or overlaps. Since Euclidean geometry necessarily understands a sum of discrete and distant vectorial objects as a gerrymandered whole, any selection of separate bounded areas raises questions regarding what was left out and what happens in between. Moreover, vectorial objects flatten overlaps between regions, erasing stratification into their own individual homogeneity, in turn misapprehending the pseudohomogeneity of these overlaps bridging metric gaps based on non-metric mereotopological and ontological notions of connection and unity. While this section focuses on the debate on the WHL nomination of the porticoes of Bologna, section 4.c further explains the role of connection and extensions over gaps, beyond the question of their preservation, towards their dissemination.

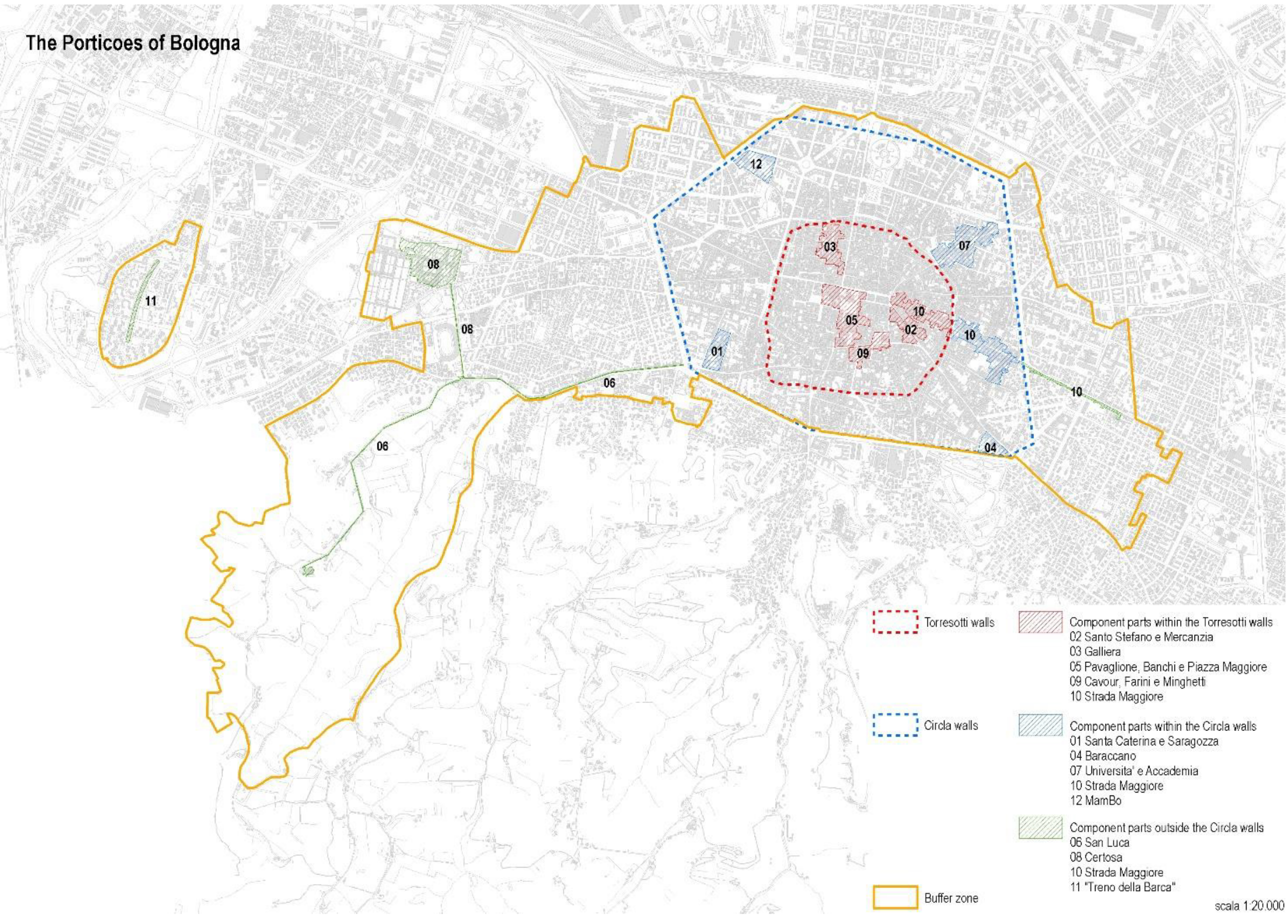


Fig. 4.7 The components nominated as UNESCO World Heritage (Comune di Bologna, 2021b)

Before presenting the competing representations and the related mereotopological principles at stake in the debate on the WHL nomination, let's then look at how to historicize spatiality, examining the evolution of models of spatial organization and its representation in the light of their embodiment into real places in the built environment. To do so, the elusive character of the porticoes of Bologna to representation by vectorial objects shall be contextualized in the history of the porticoes presented in section 4.a.1. The city of Bologna developed, and continues to develop today albeit at an occasional pace, its more than 60 km network of porticoes along a multi-level and multi-actor process spanning over almost a millenium based on the integration of public and private, intentional and spontaneous, stakeholders' efforts in the dissemination of porticoes. The spatial implications of these peculiarities are further explored in section 4.c. Yet, these peculiarities are also essential features in any historical contextualization of those characteristics of porticoes which raised problems of representation in the WHL nomination process. The above mentioned integration first materialized in the Middle Ages, when dwellers begun building porticoes in the city to satisfy their inhabitation needs, and, within few decades, were required to build them by municipal regulations, as part of the city's effort to stabilize the public-private divide in urban land (Bocchi, 1990; Venticelli, 2001; Smurra, 2008). Interestingly enough, this regulation pursued such stabilization by fixing the blur between property and use determined by porticoes, rather than erasing it through sharp and unequivocal boundaries. From then on, porticoes characterized the built environment in the city by blurring demarcations between public-private and indoor-outdoor space. Along with further construction, urban densification and expansion, blurring across facades of each porticoed building progressively scaled up through their dissemination (De Angelis & Roversi, 1994), partially blurring also demarcations between adjacent private properties, stitched together by the continuity between porticoed hallways (Ceccarelli & Magnani, 2021). In the 19th and the 20th century CE, municipal regulations protected this quality in the historical city with both dedicated urban design codes and general heritage protection guidelines (Claroni, 1971; Bernabei et al., 1984; Bettazzi, 2022). Modern and contemporary construction and reconstruction projects also reproduced this quality out of custom in a more dispersed manner. Dissemination outside of the historical city center followed two parallel trajectories in contiguity between separate locations in relative proximity. The first trajectory run along the main arteries inside the city and along those connecting to surrounding towns (linear). The second trajectory displays a mushrooming pattern in redeveloped and newly urbanizing lots outside the city center (scattered). Along these dissemination patterns, the public-private and private-private blurring qualities spreaded over the contemporary city and beyond in an occasional, yet extensive, fashion. Overall, the above mentioned development trajectories explain the configuration of the porticoes of Bologna as a manifold feature whose special combination of gaps and overlaps defies comprehensive representation as an ordinary vectorial object. This historical dissemination and the porticoes evolution in contemporary real estate developments, along with the evolution of the underlying models of spatial representation, from the medieval origin of porticoes onto modern conceptions, explains their value as living heritage. This value is not only due to the significance of porticoes built in the past to contemporary city life as a private property of public use, but also to the recurring increase of their presence through their adoption in new developments and redevelopments.

Fig. 4.8 21st c. CE porticoed building complexes respectively located at the external edge of the first belt around the city center and beyond the bypass highway, from left to right.

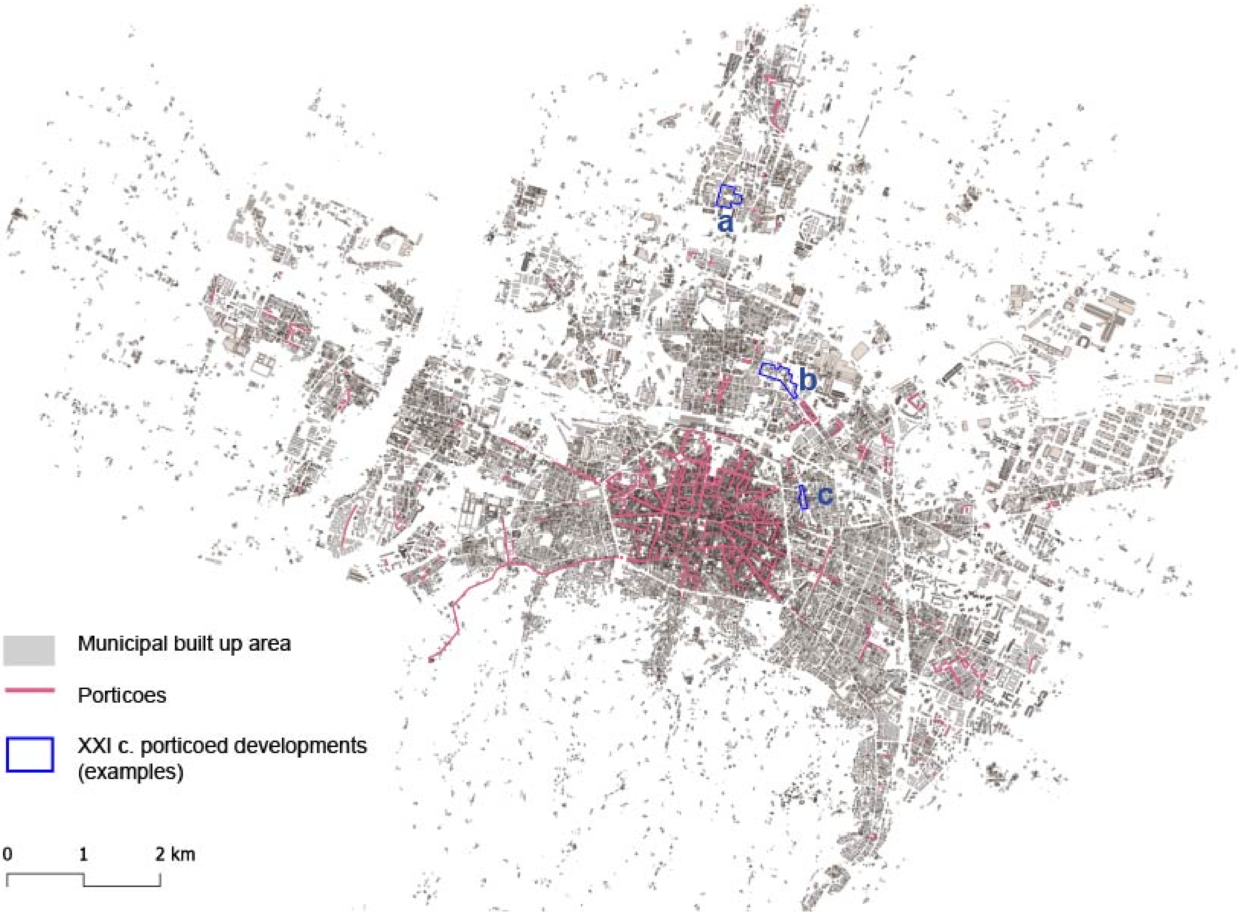


Fig. 4.9 Location of 21st c. CE porticoed building complexes
Note. Data source for porticoes and built up area: Piani e Progetti Urbanistici and SIT, Comune di Bologna, 2020a. Source for new porticoed developments and graphic layout: the author.

A preliminary observation of three recent building complexes adopting the porticoes as a leit-motif (Fig. 4.8 and 4.9) suggests the possibility of their evolving role in the socio-spatial dynamics of the city. This evolution makes the comparison with trends observed since a few decades in cities like New York and London all the more poignant, as new forms of property management have been globally refashioning the overall statute and experience of public-private divides and publicness into the form of Privately Owned Public Spaces (POPS) (Kayden et al., 2000; see also the Press section of the Bibliography). While the POPS phenomenon provides an interesting term of comparison to the role of porticoes in Bologna, this issue cannot be explored within the scope of this research, and features as one of the entries for future research follow up. Nonetheless a number of preliminary observations can be anticipated to close the historical review. and to explain the relevance of the case study chosen for this research to the more general problem definition distilled in the state of the art and specifically in section 2.d. Therefore, how are the porticoes of Bologna, at least in their evolution till the 20th century CE , different from POPS?

– origin: enforced and spontaneous behaviours in an evolutionary multi-level and multi-actor process vs. authorial architectural projects built by big developer companies;
– ownership: distributed, diverse and majority of small owners vs. corporate ownership;
– behaviors and norms: enforcement-spontaneity dialectic stabilized by both nomic and anomic regulation vs. corporate regulatory authority licenced by municipal outsourcing;
– emergence: a non-linear sequence of distributed and diverse intentionalities rooted in historical conditions vs. a result of purposeful planning behaviour;
– management: unstable customary balance between users, private owners and public authorities vs. corporate management and abuse prevention;

Altogether, these differences can be explained by the different political, legal, socio-economic and socio-technical conditions behind these phenomena. Moreover, in the light of the interpretation of the notion of spatial imaginaries introduced in section 2.d, these conditions can be also associated to a shift in spatial representation and how it shapes spatial imaginaries, with their creative, performative and normative character (Davoudi, 2018). In this sense, the medieval origin of the porticoes of Bologna point to the shifts occurred in spatial representation and imaginaries between the Middle Ages and the Modern Age, as part of the scientific revolution.

Section 3.a introduced the categories defining modern representation of space, with the debate between relationism or relative space on the one hand, and substantivalism or absolute space on the other. Associating these representations respectively to the “plenum” and “atomic” ontologies of space, or ontology of fields and ontology of objects, Helen Couclelis (1999) states that the reliance of classical Newtonian mechanics on the notion of absolute space turned this option into orthodoxy for at least three centuries. Moreover, referring to cartography and in particular to geographic information systems, she adds:

> “Whether in the ‘fields’ or ‘objects’ version, the map view is rooted in absolute Newtonian space and Euclidean geometry. The former is ill matched with the explicit representation and treatment of relations (witness the intractable problem posed in Newtonian physics by the ‘three-body problem’); the latter deals with discrete figures, volumes and surfaces defined through infinitely small points and infinitely thin and crisp lines and surfaces. Both presuppose a homogeneous, isotropic space that is a neutral container, and neither is integrated with time (indeed, time cannot even be defined within Euclidean geometry). These properties contradict many aspects of real world geographical entities and phenomena, which are strongly time dependent, not precisely bounded in either space or time, inhomogeneous and anisotropic as to their attributes and dynamic properties, not

properly representable either as geometric figures or as fields, and have complex relations in both space and time with other entities and phenomena."

According to Lidia Decandia (2008), the prevalent ontology of space and related spatial representation, or spatial imaginary, in the Middle Ages was rather different, suggesting that this key difference may affect the other differences between porticoes and POPS outlined above. Decandia describes the spatiality of the Middle Ages as "juxtaposed […], a collection [...based on a] topological conception […] a continuum of different situations […] impossible to subdue under the direction and control of a single gaze [, such as that of perspective...]. Indeed, if the modern space appears to us as an extended space, homogeneous, continuous, [smooth and therefore] isotropic and metrically measurable, [on the contrary] medieval space" is, respectively in the words of Alain Guerreau and Arno Borst she quotes, finite, heterogeneous, polarized, bumpy, qualitative, discontinuous, and elastic, dynamic, ambivalent (Decandia, 2008, p. 39). As she puts it, this immersive space made of cracks, rifts and fragments was conceived without detachment and frontality. Instead, it incorporated the knowing subject which lived inside it, not in front of it. Hence, even walled cities were "reorganized into parts […], as a sum […,] a juxtaposition of contiguous territories […] at times not even communicating […] at times separated by renaturalized emptyness [displaying...] leopard spots" (Decandia, 2008, p. 43). "Between these bodies existed intervals devoid of value" (Decandia, 2008, p. 47). Space was conceived as "a cosmos of 'centers of being', endowed of structure and order (Florenskij, 2003, p. 91)" (Decandia, 2008, p. 48), echoing Christopher Alexander's vision in "The nature of order" (Alexander, 2002).

Fig. 4.10 Porticoes and the early medieval spatial imaginary of the urban.
Note. Adapted *from Effetti del Buon Governo in città*, by Ambrogio Lorenzetti, c. 1338-1340, Parete di destra della Sala dei Nove o Sala della Pace, Palazzo Pubblico, Siena, Wikipedia (https://it.wikipedia.org/wiki/Palazzo_Pubblico_(Siena)#/media/File:Lorenzetti_Ambrogio_1337.jpg). In the public domain.

Key nodes along pilgrimage routes polarized territorial organization as magnets in medieval spatial imaginaries (Decandia, 2008), indirectly explaining part of the appeal of porticoes alignments in Bologna. Constitutive of this space was "a collection of places and diverse situations […] interlaced with one another at different scales and levels" (Decandia, 2008, p. 53), a mosaic or a patchwork involuntarily echoed in the PPM Unit's identification of separate components for the WHL nomination of the porticoes of Bologna. Indeed, this non systematic and rather composite quality was also typical of medieval culture in general, with its preference for collections, catalogues and series (Decandia, 2008). Likewise, images of cities were drawn "in the way it [the city] could have been etched in the memory of somebody [...] walking along the street and seeing buildings from different points of view" (Decandia, 2008, p. 68).[9] Documenting the role of porticoes in densifying medieval cities, the painting in Fig. 4.10 offers an example of an early, or better a *not yet* (Salerno, 2007), example of the geometric formalization of pespective. In this not yet, the image also illustrates Decandia's insights, depicting the motifs of the mosaic or patchwork, such as juxtaposition, collection, continuum in fragmentation, while hinting at the normalcy of intervals and emptyness inside walled cities. Likewise the spatiality guiding the PPM Unit's representation of the porticoes of Bologna in the WHL nomination process could also be described as conceptually in between a composite and a systematic approach, a collection of centers potentially polarizing, if preserved, the structure and order of the porticoed city in its various configurations. It could therefore be understood as not yet a reflection of modern reductionism, but rather as a reflection of medieval *collectionism*, with its peculiar sense of the systemic as a multiscalar patchwork, connecting centers through their relation to the cosmos, connecting parts through their relation to the whole. In this sense, patchworking can still aim to articulate a systematic composition as a never ending ongoing process, meandering behind the evolution of structure and order. Frozen in time, this articulation is inevitably anecdotal and incomplete. It can only be systematic as a pursuit, rather than as a state, and therefore it hardly fits in the procedure for a WHL nomination, not to mention in the work flows of public administrations and project management cycles of funding schemes. While looking anecdotal and therefore arbitrary from a detached and frontal perspective, the PPM Unit's representation of the porticoes of Bologna not only appeals to the systemic from an immersive and embedded perspective. It also stands as the offspring of the living intangible heritage of the multiscalar patchwork shaping the spatial imaginary of the porticoed city. In this regard, Christopher Alexander's model matches Decandia's bumps, cracks and rifts with crinkling folds and wrinkles. In doing so, he clarifies the difference between understanding collections as reductionist sums or as wholes unfolding by differentiation, where time and process are fundamental dimensions, as already mentioned in section 3.a, in relation to the reference to wholes in complexity theories. As he puts it:

> "every individual act of building is a process in which space gets differentiated. It is not a process of addition, in which pre-formed parts are combined to create a whole: but a

9 This paragraph includes the author's translation in English of parts of a book (Decandia, 2008) which was published in Italian. According to APA standards, unpublished translations are to be considered a paraphrase rather than a quote. The mentions of page numbers and the use of inverted commas and square brackets is not meant to present the text as a quote, but rather to guide the retrieval of the original text in its 2008 italian edition for the interested reader.

> process of unfolding, like the evolution of an embryo, in which the whole precedes its parts, and actually gives birth to them by splitting” (Alexander C., 1979, p. 370).
> “In nature, a thing is always born, and developed, as a whole. […] It is not a sequence of adding parts together, but a whole, which expands, crinkles, differentiate itself. A building, too, can only come to life when it grows as a whole.” (Alexander C., 1979, p. 383).

In this light, the evolution of the porticoed city described in section 4.a.1 and the PPM unit's representation of the porticoes of Bologna in the WHL nomination process can be better understood as respectively the expression and the reflection, or possibly the unconscious reminiscence, of a process of differentiation, unfolding, and of systemic patchworking of wholes rather than an addition of parts to other parts. The rest of this section builds on this understanding in its examination of the representations proposed during the nomination process in the light of the spatial representation principles anticipated in section 3.b. In doing so, it integrates these representations by mereotopological relations, instead of opposing them as competing alternatives between vectorial objects, or between a vectorial object and a network.

Mereotopological relations support the formal explanation of what Decandia pictorially describes as the heterogeneous, polarized, cracking and fragmented space of patchworks and leopard spots. Mereotopological formalism puts these leopard spots in the complex nested hierarchy of spaces envisioned by Ernst R. Alexander and quoted in the introduction to section 2. In this light, the rest of this section recalls the representation of porticoes by each group of research interlocutors to show how their concerns would have better fit in a mereotopological conceptual framework, rather than in the geometric representation of space which was taken for granted for visualization, steering the contestation of the previous two steps. Mereotopological conceptual framework means here a set of principles which cannot attend to the logical formalisms of the domains inspiring it. In this sense, the following constitutes an attempt to trickle down mereotopological formalisms back into natural language and common sense, just like formulas like Euclidean distance shape common sense by the synecdochical conflation of their representation of space with spatial representation as a whole. The lens of mereotopological principles provides the logical structure to integrate different parts of the built environment relevant to the representation of porticoes towards one comprehensive representation of the porticoes manifold set of qualities. The either or understanding of these qualities reflects the mutually exclusive character of the different objects endorsed by each group's representation of porticoes. This character is engrained in the Euclidean conceptual model centered on the vectorial object as the only spatial entity acknowledged ontological dignity. Conceptualizing as mereotopological regions the parts of the built environment addressed by each group in their respective representations of porticoes, the following tables provide a reconciling explanation. This explanation ultimately justifies the coherence between the PPM Unit definition of the asset and the identification of the protection policy target area, regardless of the neccessity of visualizing it as a set of bounded objects. The role of the PPM Unit as the manager of the nomination process put it at the center of the representation efforts of all research interlocutors, as the ultimate recipient of their contributions to the process. As a result, the representation of porticoes devised by the PPM Unit encompasses the others. Nonetheless the groups are considered here on the same level to meet the purpose of explaining the elusivity of porticoes to representation as vectorial objects, in the light of the specific features of each group's concerns. A wrap up paragraph closes the reports on each group.

PPM Unit

The OUV statement and the key attributes of the OUV of the porticoes, as identified in the 2023 Periodic Reporting, clarify key issues in the spatial representation of the porticoes of Bologna as an heritage asset. These state respectively:

> “The series of Bologna's porticoes represents in an exemplary manner an architectural typology of ancient origin and wide diffusion, never abandoned until today, but in continuous change through precise historical periods of the town's transformations. The series was selected in the context of the wider porticoed system that permeates the old historical city. The property represents a variety of porticoed building typologies which characterize the houses of the working class, the aristocratic residences, the public and religious buildings. Historical and contemporary construction employ a wide range of building materials, technologies and styles, as a result of the progressive city's expansion and mutations since the 12th century.” (UNESCO WHC The Porticoes of Bologna web page)
>
> “1. Complex of different porticoes typologies and their surrounding areas
> 2. The permanence of the original form, design and materials
> 3. The public use of porticoes and their social function for a sustainable urban lifestyle, a place of continuous interchange of human values, civil and religious
> 4. Interconnections of the porticoes system as a network of covered walkways within the perimeter of the property
> 5. The permanence of historic norms and conventions still alive to this very day”
> (Comune di Bologna, 2023, p. 3)

The OUV statement corresponds to criterion iv for inscription in the World Heritage List, which points to sites that are “an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history” (UNESCO WHC The Criteria for Selection web page). The assumption of singularity in the formulation of the criterion mirrors the mutually exclusive character attributed to vectorial objects. After conspicuous correspondence with ICOMOS and the joint ICOMOS WHC advisory mission to Bologna, the final revision of the OUV statement dodged this singularity by a cross-cutting approach to time and space as a factor of the oustanding value of the nominated property:

- cutting across the history of urban transformations from the historical origin to the contemporary adoption of porticoes through continuous change;
- cutting across the areas of urban expansion and the historical area of the porticoed system;

Hence, the systemic character was not attributed to the porticoes of the whole city but rather only to those located within the historical city, based on an implicit metric criterion of a minimum degree of density required to acknowledge the unity of the system, together with the assumption that the spatiality of systems corresponds to that of bounded vectorial objects. The pervasivity of this assumptions surfaces also in the representaton of the cross-cutting approach, locating the components of the nominated series into three concentric bounded areas as shown in Fig. 4.7, reinforcing the fragmented representation of the whole of 62+ km of porticoes. It also shows through the definition of attribute 4, particularly in the light of attribute 1 and in relation to the OUV statement stress on the location of the porticoed system within the old historical city, where attribute 4 claim regarding the systemic interconnections between porticoes seems to acquire legitimacy only if located within a perimeter. Nonetheless the stress on time and change in the OUV statement provides an interesting hook to the acknowledgement of the emergent character of the porticoed system and its progressive unfolding over the whole city, recalling Decandia's and Alexander's notions of respectively folded and unfolding space. Along the same lines, the focus on time and change regarding the phenomenon of the porticoed city, understood in section 4.a.1 as the result of a process steered by a mix of statutory and customary normativity integrating enforced and spontaneous behavior (De Roo, 2020), recalls the notion of cities as complex adaptive systems (Portugali, 2021), together with the definition of complex systems as systems where “the whole is more than the sum of the parts” (Simon, 1962, p. 468). Time, change and emergence are key aspects of that *more*, which spatial systems display as the property of unfolding wholes by differentiation of parts from the whole, rather than addition of pre-existing parts into a whole (Alexander C., 1979). While this property does not apply to extensional mereology assuming the fixity of a moment in time, it can still converge with notions of mereological change, unrestricted mereological composition, and mediated and external connection (Varzi, 2007). This means that a mereotopological approach to modeling the porticoes of Bologna presents the advantage of allowing infinitely recursive update of the model along with the unfolding of new parthood relations, building on the connection of any new part to the whole, regardless of it being disconnected from other parts (Varzi, 2007, p. 981). This is not possible in metric modeling approaches where the focus is on the relation between parts, and the number of relations to be represented in the model is to be decided in advance, for example by the number of the sides of cells in raster models. These observations point to the pervasivity of the assumption that the ontological dignity of spatial entities depends on their metric representation by vectorial object and perimeters or boundaries. At the same time they also highlight the limitations posed by this assumption to the representation of systemic connections cross-cutting time and space, since it requires focusing on the additive connections between parts, instead of focusing on the connection between part and whole resulting in relations of underlap between disjoint parts. These observations also reflect the implicit effectiveness of the intern-researcher's prompts introduced in section 3.b in justifying the nomination of a serial property for an exhaustive coverage of the porticoed city across space and time. Although the hold of metric approaches onto common sense did not allow the explicit adoption of the underlying mereotopological principles, the references to perimeters and bounded areas highlighted above in the representation of the nominated asset can be read as the result of an effort to fit mereotopological relations into metric language.

Academicians

The academicians from the Department of Architecture of the University of Bologna joined the process which led to the WHL nomination of the porticoes with the surveys conducted since 2011. Between 2011 and 2016 the surveys fed a set of 3D models intended to serve public management concerns with regard to monitoring and maintenance of the porticoes. In this light, and in line with the assumption that porticoes ought not to be chopped off their morphological setting, the 3D models showcased porticoes as part of the building facade (Fig. 4.11), the surface of buildings subject to public regulation. The specificity of porticoes was identified in their concave shape. Hence, 3D visualization was meant to meet these shapes requirements for representation (M. Gaiani, personal communication, October 24, 2022). The data for the 12 components of the nomination were later used for public outreach regarding the nomination by a dedicated web page (I Portici di Bologna Elaborazione SIT web page). This visualization corresponds to the linear definition of the first boundary identification for the nomination (Comune di Bologna, 2020a), "which privileged the porticoes' relationship to the street" (Comune di Bologna, 2021b, p. 4). The 3D models definition of the portico as part of the building facade mirrors the reference to porticoes in the 2021 Piano Urbano Generale (PUG) by the municipal Planning Office, particularly the definition used in the prescriptions for building interventions under Action 2.4c, regarding the conservation of architectural heritage. PUG prescriptions state that any portico and all its elements are to be understood as an integral part of building facades, implicitly subjecting them to the same prescriptions (Comune di Bologna, 2021a, p. 124, v1.2253).

Fig. 4.11 Two screenshots from the 3D model of Via Santa Caterina, one component of the WHL nominated property (I Portici di Bologna Elaborazione SIT web page). *Note.* In the public domain.

Yet, PUG applies prescriptions regarding building facades to all porticoes, along building facades and building sides, along roads or squares, including stand alone ones, such as for example Portico di Santa Maria dei Servi, based on the definition of portico provided under the same Action 2.4c two pages earlier (Comune di Bologna, 2021a, p. 122, v1.2241). The overall treatment of porticoes in the PUG is further discussed below. It was anticipated here to show the end use of the definition of porticoes as part of building facades. Moreover, the project for the creation of the 3D models included systematic semantic interpretation and annotation of architectural and landscape elements based on historical sources (Apollonio et al., 2014; Ballabeni et al. 2015). Yet its focus on the portico as an architectural element bypassed the problem of the semantic interpretation of the porticoed system in terms of spatial representation. Meanwhile, the University of Bologna architecture historians and medieval historians contributed to the same early boundary identification by formulating three intersecting classifications. In addition to the previously mentioned typological classification of abstract morphological units with porticoes of different extension (Fig. 4.6), the other two classifications respectively described the functions and the historical periods of their construction and corresponding architectural styles featured across the whole city set of porticoes (Fig. 4.12, Comune di Bologna, 2020a, p. 259-260). The intersection of these classifications provided a systematic and comprehensive rationale for the selection of the components of the nominated property, which covered all of the categories from the three classifications, with each component attributed a cluster of three categories. Indeed, the series effectively stroke a balanced and intersectional coverage of all the categories from the three classifications, proving to be representative of the whole system of porticoes. Nonetheless, entrusting the representation of these categories to vectorial objects, assigned to single categories within each classification, implicitly confirmed the compartimentalization of each component in the series, which failed to grasp the stratified character of most porticoes in the city.

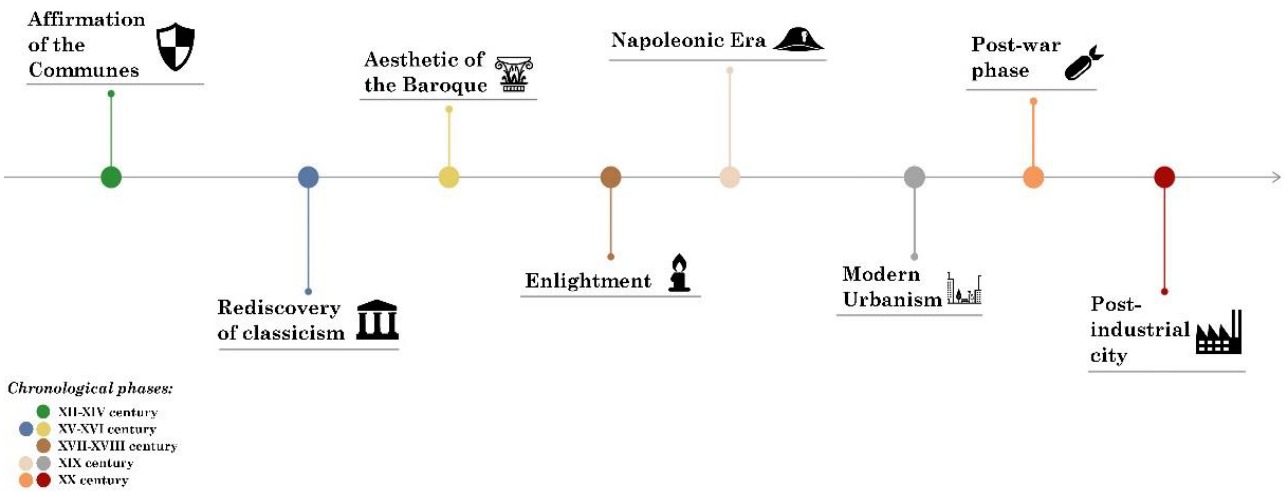


Fig. 4.12 The temporal and functional classifications of the porticoes of Bologna (Comune di Bologna, 2020a, pp. 259-260) Note. Courtesy of the PPM Unit.

Moreover, this compartimentalization obscured the most important aspect of the porticoed system, the connections it establishes across those categories, exposing the nomination to questions regarding the choice of each component and “why other porticoes were not considered or were excluded from the series” (ICOMOS, 2021, p. 394), questions which confirm the either-or perspective implicit in representation by vectorial objects. Instead, a focus on part-whole and mereotopological relations, such as for example tangential parthood within an open region, may get closer than vectorial space to represent systemic connection.

These connections and interfaces could still be classified by the same categories to ensure full coverage of the diversity of porticoes, bypassing the stress on both the geometric and categorical separation between vectorial components. Overall, the academicians' contributions to the nomination process confirmed the relevance of semantics, classification, and part-whole relations, key elements of an ontological approach, to the nomination process and to the challenges posed by the representation of the porticoes of Bologna as an heritage asset. Nonetheless, both above examined perspectives relied on bounded vectorial objects at the smallest possible scales of morphological composition, where the representation of the systemic character of the porticoes was limited to the display of the system spectrum of typological, functional and historical-stylistic variables. Such display was deemed satisfactory enough to downplay the need for complementary representations highlighted by the intern-researcher's prompts. While these perspectives focused on the definition of the porticoes as an heritage asset, they informed the decisions related to the identification of the target area of the heritage protection policy. Along these lines, the ground they provided for coherence between the two steps supported only to a limited extent the stress put in the nomination dossier on the systemic character of the porticoed city. Yet, this stress matched one enlightening reference in the study by the architecture historians, although it does not feature in the nomination dossier. Jacob Burckhardt's description of Bologna as "a surprising continuous fabric of buildings sewed together by a neverending Strassenhalle" (Jacob Burckhardt, 1855 p. 207, cit. in Ceccarelli & Guidotti Magnani, 2021, p. 27) supports the systemic interpretation of the porticoes of Bologna, yet it was not put to work in the identification of the nominated property, or target area of the heritage protection policy, while fully matching the attribute number 4 of the porticoes OUV. Indeed Burckhardt's sewing Strassenhalle carries the same representation challenge of the porticoes' nomination itself: if the OUV of the porticoes of Bologna lies in their role as stitches, sewing together the urban fabric, where is this sewing capability of the Strassenhalle at play? In other words, can it be put to work in support to the WHL nomination of porticoes outside of the city center to cater for the full sprectrum of the porticoes temporal and spatial emergence? Again, one possible answer to these questions takes issue from the representation of the Strassenhalle as a vectorial object, interpreting sewing by "a merely metric notion of contact" (Varzi, 2007, p. 977) between parts. This answer identifies the city center as the location of the porticoes OUV. A different answer takes issue from the representation of the Strassenhalle as a mereotopological open region or an ontological unity, interpreting sewing by a mereotopological notion of part-whole connection, accommodating any emergent part of the whole, regardless of it being disconnected from other parts (Varzi, 2007, p. 981). Accordingly, a classification of variance in tangential proper parts of porticoes by morphological, functional and historical stylistic typologies would insightfully represent its stitching capability officially acknowledged in the fourth attribute of the porticoes OUV. The next paragraph adds further insights to this discussion from the WHL experts' perspective.

WHL experts

> "In its Interim Report, ICOMOS noted that in the supplementary information submitted in November 2020, the State Party referred to the porticoes as a system, which make up a full-scale urban infrastructure. However, ICOMOS considered that the idea of the porticoes as an

urban system was not reflected through the twelve component parts as had been presented." (ICOMOS, 2021, p. 393).

The reservations posed by ICOMOS to the WHL nomination of the porticoes of Bologna touched upon different aspects. Nonetheless the core point which matters to the scope of this dissertation concerns the coherence between the definition of the asset and the identification of the boundaries of the nominated serial property. In this regard, ICOMOS pointed to the lack of "a robust justification for the selection of the component parts included in the nominated property, particularly when it comes to more recent porticoes" (ICOMOS, 2021, p. 394). This point can be summarized in two questions: why the twelve components being nominated should be considered to stand out as the bearers of the porticoes OUV?, "why other porticoes were not considered or were excluded from the series?" (ICOMOS, 2021, p.394). These questions stem from the upstream observation that

> "it is unclear what is the exact nature of the typology of the nominated property: the portico as an architectural element of a building; the four typologies defined by the State Party in the nomination (e.g. porticoed roads, porticoed squares, porticoed paths and porticoed buildings); or the porticoes as urban elements with the function of walkways, which could form the basis of a system." (ICOMOS, 2021, p. 395)

This statement exemplifies the either or assumption of mutual exclusion between different vectorial objects, framing as inconceivable the possibility that the nominated property could be understood as including all of these three, based on parthood and connection relations. As shown in the chronology in section 4.a.1, the heritage value of porticoes can be identified exactly in the emergence of the porticoed system as the whole which includes all of those elements set as alternative definitions in the above statements. Yet, this possibility was already apparent in ICOMOS interest in the process of multiplication which led the porticoes of Bologna to evolve "from an architectural element of a building, which when multiplied assumes a different identity and contributes to forming a different typology, that of the walkway providing an urban function" (ICOMOS, 2021, p. 395). Likewise, the lens of parthood relations as well as their role in the emergence and complexity (Simon, 1962) of systems was headline in ICOMOS understanding of the porticoes OUV and in its suggestion that to demonstrate the value of the nominated property required to demonstrate its "wholeness" (ICOMOS, 2021, p. 396). In ICOMOS understanding, this meant to demonstrate:

> "how the nominated property would reflect an urban system; that is, an identity that would be apparent beyond the sum of its constituent parts but show the connections between them as well" (ICOMOS, 2021, p. 396)
>
> [based on the consideration that] "the series, and particularly the delimitation of the component parts, should not be seen merely as a synthesis of a system but rather as reflecting the functional links between the porticoes. In this sense, it would reflect how collectively, through the articulation of the elements and interconnections between them, they generate a different entity, which is more than the sum of the component parts." (ICOMOS, 2021, p. 400)

Yet ICOMOS appeal to wholeness in this particular case, in a similar vein as the broader appeal to the protection of historical urban landscape (UNESCO, 2011), was bound to fit in a vectorial model.

This depended not only on UNESCO's (2017) own requirements. Most fundamentally it stemmed from ICOMOS experts' own assumption that the representation of a spatial system requires spatial continuity and cohesion, framing the identification of a target area made of separate components as a reductionist stance. This assumption was apparent in the logic behind three arguments:

– the conflation of the porticoed system with the network of walkways in the notion of "an urban system of covered walkways" (ICOMOS, 2021, p. 440) seen as constitutive the OUV of the nominated property;

This conflation includes several corollaries. Not only the interconnectedness of the network of walkways was understood in terms of linear continuity, excluding porticoes located in distant areas, as discussed below in the third point. The continuous path across porticoes, expressed by the PPM Unit under attribute 4, was also elevated to the status of systemic attribute. While spatial continuity along other trajectories, first and foremost the street-building or outdoor-indoor trajectory, expressed by the PPM unit under attribute number 3, albeit with a missing reference to the private side, was written off by associating it to the building scale. In so doing, ICOMOS perspective overlooked the outstanding combination of connections along different trajectories which enables the Strassenhalle to sew together the urban fabric. Moreover, regardless of the requirement to include within the boundaries part of the urban fabric as the porticoes' landscape setting, ICOMOS did not identify any particular value in this setting other than the plain fact of its existence as a container, somehow treated as Newtonian space.

– the juxtaposition of two rationales for the revision of the boundaries of the nominated property, first, a classic invitation to include, that is to represent, the landscape setting and urban fabric incorporating porticoes, and, second, a paradoxical yet normalized one, to include and represent the interconnections and links of the porticoed walkway by marking boundaries, treating interconnections as objects to be located within a perimeter;

> "These interconnections between the porticoes which define the city's identity and the sense of place would need to be tangibly expressed in the boundaries of the nominated property." (ICOMOS, 2021, p. 400)
>
> "refocus the proposed justification for Outstanding Universal Value on this urban system and how it evolved over time […]. Revise the boundaries to reflect not only the elements but also the interconnections of that system, by incorporating the functional links between the covered walkways within the perimeter of the nominated property" (ICOMOS, 2021, p. 401)
>
> "the immediate landscape setting of the porticoed path is integral to its significance and should be included within the boundaries of the component parts" (ICOMOS, 2021, p. 391)

– the skepticism towards the nomination of the two components built in the 20th c.;

As discussed in one informal conversation during the experts' advisory mission to Bologna (June 15, 2023), the experts deemed the components 11 "Treno della Barca" and 12 MAMBo (Fig. 4.6) to be disconnected from the rest of the nominated property, as if the rest could instead be conceded a connected and cohesive character. Nonetheless, the evidence in favour of this stance was not straightforwardly related to the metric distance between these sites and the other components of the series, nor to the lack of connection with adjacent porticoes. MAMBo is infact connected to a long stretch of continuous porticoes, albeit lying at one end of this stretch, at the inner edge of the city centre facing the line of the Circla Walls. "Il Treno della Barca" does not have any other porticoed building in its adjacency, yet its length of about 600 meters, expressed by its epiteth 'treno', which means train, legimately qualifies it as a path. The explanation for ICOMOS skepticism intertwines two variables as expressed in the following quote. These variables are the historical intangible normative factors behind the construction of porticoes, which ICOMOS identified exclusively with the 1288 Statutes, and the category from the typological classification assigned to the two sites by the academicians.

> “Based on the information received from the State Party, the area of influence of those Statutes referred to the civitas and the burgi, that is, the area enclosed by the Circla Walls, the line of which corresponds to the modern ring road. ICOMOS considers that this area should be the focus for the delimitation of the so-called urban system of porticoes with the exceptions of the Portici della Certosa and San Luca, since these extra moenia religious sites existed already in the medieval period. As such, ICOMOS also considers that the Edificio porticato del quartiere Barca and Edificio porticato del MAMbo should be excluded from the nominated property as they were created at a much later stage and shaped by different influences. In addition, the nomination explains that these two components were defined as belonging to a typology called 'porticoed buildings', used for isolated buildings in the suburbs and which are not part of a comprehensive system of covered walkways as in other parts of the city.” (ICOMOS, 2021, p. 401)

The multi-layered set of assumptions behind this statement was addressed more effectively during the experts advisory mission to Bologna than through exchange of written reports. First of all, the conversations highlighted the underlying reason for ICOMOS insistence on the need

> “for further information as to how the porticoes came to assume more of the function of a walkway over time, in order to better understand how these porticoes could be seen to constitute a system [...and to] further explain and especially to document the evolution of the portico from an architectural element of a building, which when multiplied assumes a different identity and contributes to forming a different typology, that of the walkway providing an urban function.” (ICOMOS, 2021, p. 395)

Indeed, the internal report prepared by Maria Beatrice Bettazzi PhD on behalf of the PPM Unit prior to the advisory mission responded precisely to this request. Moreover, the face to face conversations during the advisory mission clarified that the key misunderstanding was about the role of customary normativity in the evolution of the porticoes in Bologna, whereas ICOMOS focused exclusively on the role of statutory norms. In this light, the chronology proposed in section 4.a.1 focused on further clarifying the resulting integration of enforced and spontaneous behavior (De Roo, 2020) in the making of the porticoes of Bologna, which was also eventually acknowledged as part of the heritage value of the porticoes under attribute 5.

Moreover an informal conversation between the intern-researcher and one ICOMOS expert (June 15, 2023) during an on-site visit of the “Il Treno della Barca” provided the opportunity to prompt the expert understanding of the question of connection. This conversation clarified the expert consideration of the metric distance between this site and the city center as the core factor for its supposed exclusion from the system of covered walkways identified in the nominated property. It also offered the opportunity for proposing to the expert a more stratified notion of connection, based on principles of tangential extension, external connection, mediated connection and ontological unity. Regardless of the expert immediate reaction of denial to this prompt, this argument converged with the first one regarding customary norms. It can therefore be concluded that the role of customary norms and the intern-researcher's questioning of the assumption conflating connection with “a merely metric notion of contact” (Varzi, 2007, p. 977) were instrumental to the final settlement regarding the nomination of components 11 and 12. In short, the controversy eventually boiled down to taking larger chops:

> “to provide the full picture of their creation, use and place in the urban context [...] a different approach, focused on a broader urban context – the wider city or key parts of it – [may be...] considered in order to explicitly contextualize the distinctive urban character of Bologna, as a city of porticoes. In response to ICOMOS’s concerns, the State Party enlarged the areas of the component parts, as previously explained, and provided further clarifications on the scope and selection of the component parts.” (ICOMOS, 2021, p. 393).

The overall case has been analyzed also by Stefania Bonfiglioli:

> “Since there are 62 km of porticoes, the Municipality of Bologna, together with all the institutions involved in the candidacy, chose to nominate twelve portions of them, selected on the basis of their representativeness of the whole system. These portions are both in the center and the suburbs of Bologna; hence, they represented a problem for ICOMOS, since they are not circumscribed within the boundaries of a homogeneous area. In fact, ICOMOS’ perspective is a meaningful example of the interpretation of heritage conveyed by the ‘authorized heritage discourse’ (AHD). As argued by Smith, who coined this expression, the idea of ‘boundedness’ characterizes AHD, within which heritage is a site ‘with identifiable boundaries that can be mapped’. This is also stressed by Harvey’s analysis of some AHDs at a local scale: the notion of boundedness has ‘a profound effect on the heritage process’, ‘since heritage is often found at the very root’ of ‘the construction of stable, bounded and reactionary senses of place’. Hence, the idea of heritage arising from AHDs entails a modern ‘sedentary’ perspective, in Cresswell’s terms. On one hand, in fact, it involves a static sense of place, dealing with roots and boundedness; on the other, it involves a static conception of space, exactly that built by maps, that is, by modern ‘cartographic reason’ and its stable certainties, grounded on the definition of homogenous areas by means of clearcut boundaries.” (Bonfiglioli, 2024, p. 5)

This dissertation addresses what Bonfiglioli calls “the conception of space” in terms of spatial representation, focusing on the principles and semantic terms of reference set by alternative approaches to spatial representation such as geometry and QSR, and on the logic these principles share with common sense regarding spatiality. This focus wishes to take the conversation beyond the scope of heritage preservation. Here heritage preservation is one among other possible examples, highlighting the role of the notion of boundedness in spatial planning and spatially explicit policy making in general, intended as decision making on the spatial organization of the built environment at the different scales relevant to human settlement processes.

The Municipal Planning Office

The fourth group of research interlocutors is the one most directly concerned with the disciplinary belonging of this dissertation. However, the research kept the interaction with this group within the scope of their relation to the PPM Unit, the gatekeeper for the intern-researcher access to the field. In this light, the following discussion takes as its point of departure a general observation. The officers heard and the documents examined indicate that the office's consideration of the porticoes focused on the existing porticoes value as tangible heritage, while overlooking, at least in their explicit communication, two other interconnected issues. These issues are, first, the construction of new porticoes as a form of living heritage in the light of their potential present and future civic role as urban design devices, and, second, the valorization as intangible heritage of the mix of statutory and customary normativity behind the construction of porticoes across different historical circumstances. The first of these issues refers to attribute 3 of the WHL OUV, whereas the second refers to attribute 5. Nonetheless these issues were never discussed as matters of relevance to planning regulations by any interlocutor during the time span of the field work, nor are they addressed in municipal urban planning instruments. Accordingly, the interlocutors from this office did not react to the intern-researcher prompt referred to these issues (Trombetta and Disarò, personal communication, November 14th, 2022). Likewise, the document Disciplina del Piano (Comune di Bologna, 2021a) in the PUG[10] refers to porticoes as part of the provisions regarding architectural heritage based on the Legge Regionale 24/2017, under the objective focused on habitability and inclusion and in particular strategy 2.4, titled “Preserving the character of the historic urban landscape by renewing its role” (Comune di Bologna, 2021a, p. 113). In this way, the PUG treats porticoes as part of the historic urban landscape, overlooking its potential role as an asset for pedestrian comfort and civic activities in newly developing areas. At the same time, by mentioning historic urban landscape instead of the historic city center, it properly backs the PPM Unit approach, acknowledging the heritage value of parts of the suburban built environment, and covering the full spectrum of historical transformations of the porticoes in Bologna. The description of Action 2.4a defines historical urban landscape as “the entire urban area, comprising a complex historical stratification of cultural and natural values and characteristics” (Comune di Bologna, 2021a, p. 113, v1.2203). As already highlighted about ICOMOS implicit confusion of holistic and systemic approaches, the flat reference to the notion of entirety evokes a holistic perspective, while that of a complex stratification matches the systemic representation of “space as a complex nested hierarchy of spaces” (Alexander E. R., 1994, p. 373), collapsing the distinction between the two paradigms (Scandurra, 2003). Nonetheless, beside this mix of holistic and systemic frames, as shown with previously anticipated PUG prescriptive references to building facades (see the paragraph regarding Academicians), the interaction of description and prescription moves back and forth between buildings, facades and streets or squares, physical or functional, wider or narrower definitions of the parthood relations integral to the porticoes essence and heritage value. The whole landscape eventually gets to be represented by its chops. Indeed, the preservation of existing porticoes requires to identify them as part of categories of buildings, protected single buildings or groups of buildings, relying on representation by vectorial

10 The below textual references to this document are marked with inverted commas according to the English translation adopted in the presentation by Francesco Evangelisti, director of the municipal Planning Office, during the UNESCO and ICOMOS experts advisory mission to Bologna. According to APA standards, unpublished translations are to be considered a paraphrase rather than a quote. The mentions of page numbers and use of inverted commas and square brackets is not meant to present the text as a quote, but rather to acknowledge the paraphrase, and guide the retrieval of the passages original text. The Italian original text is provided between brackets in cases most prone to ambiguities.

objects. Beside scattered references to specific sites, PUG's general references to porticoes are found under action 2.4a, titled “Defending the habitability and the character of the historic city” (Comune di Bologna, 2021a, pp. 113-117), action 2.4c, titled “Ensuring the preservation of the heritage of historic architectural and cultural testimonial interest” (Comune di Bologna, 2021a, pp. 121-125), and action 2.4d, titled “Enhancement of architecture and agglomerations of cultural and testimonial interest of the second half of the 20th c.” (Comune di Bologna, 2021a, pp. 125-127). These three actions indicate the categories which PUG identifies as part of Bologna historical urban landscape and the historic city, in addition to single buildings of historical or cultural significance in different historical periods. While the historic city is categorized into four types of fabrics (Comune di Bologna, 2021a, p. 316-317, scheda d.9), the use of collective nouns such as heritage and architecture for fabrics outside of the historic city in the titles of action 2.4c and 2.4d does not dissimulate the chopping attitude of the categorization, catering for chops of different sizes such as single buildings and agglomerations. Indeed, PUG categorizes architectural heritage outside of the historic city into five types:

– “buildings of historical architectural interest”;
– “buildings of cultural and testimonial interest”;
– modern “buildings of historical architectural interest” (“edifici d'interesse storico-architettonico del Moderno”);
– “buildings of cultural and testimonial interest of the second half of the 20th c.” (Comune di Bologna, 2021d, p. 89).
– “agglomerations of cultural and testimonial interest of the second half of the 20th c.” (Comune di Bologna, 2021a, p. 257, scheda g.4)

The previous municipal plan, the 2008 Piano Strutturale Comunale, and its associated building code in the 2009 Regolamento Urbanistico Edilizio, referred to four categories covering until modern architecture. In line with its interpretation of the historic urban landscape, PUG devoted much attention to most recent buildings, as it reformulated the fourth of the previous categories and added the fifth one to extend municipal heritage protection to more recent buildings (Comune di Bologna, 2021a, p. 125). These categories include the buildings corresponding to components 11 “Treno della Barca” and 12 MAMBo of the WHL nominated property. Here:

> “The municipality integrates the policies for the valorisation of common and public spaces belonging to the agglomerations of the Second Twentieth Century or to the architecture of cultural and testimonial value of the Second Twentieth Century with the policies for the protection of porticoes, with particular reference to the Unesco candidacy.” (Comune di Bologna, 2021a, p. 126, v1.2265)

These categories indicate different interpretations of historical urban landscape and heritage when applied to the historic city and to the suburbs. The focus on fabrics in the historic city benefits from the legacy of the 1969 plan for the preservation of the historic city center (Antonucci & Lipparini, 2022; Cervellati & Scannavini, 1973; Campos Venuti, 1991). Outside of the historic city, PUG excludes the presence of fabrics by focusing on buildings and agglomerations. These choices can be considered from two different angles, possibly both simultaneously at play. On the one hand, the holistic perspective behind the focus on fabrics constitutes a methodological choice, requiring different conceptualization when applied to architectural heritage in different contexts.

On the other hand, denser fabrics, medieval fabrics, and futhermore a fabric sewed together by porticoes, as suggested by Jacob Burckhardt (1855 p. 207, cit. in Ceccarelli & Guidotti Magnani, 2021, p. 27), call for such definition more than other morphological types. For example, suburban fabrics in Bologna are certainly more prone to dissection into separate objects as such dissection was already intrisic in the representation of space and the spatial imaginary behind their conception. Nonetheless, the categories for the historic city also include one dedicated to buildings devoid of specific interest within those fabrics (Comune di Bologna, 2021a, p. 275). This category is particularly relevant to this dissertation argument regarding porticoes. While the holistic focus on the fabrics of the historic city does not require to mention porticoes explicitly to ensure their protection, the only reference to porticoes under action 2.4a comes in relation to buildings devoid of specific interest:

> "In the case of demolition and reconstruction of buildings devoid of specific interest within the historic city fabrics included in a porticoed curtain wall, the project must provide for the completion of the portico system and its connection with adjacent sections. The construction of porticoes must be carried out with reference to the indications contained in the Building Regulations - Art. 36." (Comune di Bologna, 2021a, p. 115, v1.2219)

This provision highlights the office concern with the connectivity of porticoes alignments in the historic city, possibly in relation to their above mentioned role as stitches sewing together the urban fabric. Here, the parthood of porticoes in an alignment takes priority to its parthood within the building it belongs to structurally and property wise, sharing, unlike the building it belongs to, the same protected status of the alignment, and of the urban fabric it is part of. The written text effectively explains and endorses these overlaps, even though they hardly fit in the representation of space by vectorial objects. Indeed these overlaps entail both the nested hierarchy of spaces proposed by Ernst R. Alexander and possibly reflected in mereological relations, and the mereotopological relations of external connection and tangential parthood. Nonetheless, outside of the historic city, porticoes take back the status of parts of a building. The next general reference to porticoes follows under action 2.4c, "Ensure the preservation of the heritage of historical architectural and cultural testimonial interest":

> "The Plan recognises the buildings and elements that belong to the historic urban heritage […] Recognition of the value of the historical heritage is also pursued through the valorisation of the porticos and historical appurtenances, which complete the identity features of the historical urban landscape of Bologna." (Comune di Bologna, 2021a, p. 121, v1.2234 and v1.2236)

While the term fabrics disappears, the above focus on buildings and elements reflects the representation of space by vectorial objects, with the portico featuring in the next page in the singular form, albeit seamlessly overlapping parthood in a building or in more buildings, and parthood in a street or square:

> "The Plan also identifies the following elements: […] porticoes: a portico or arcade is a covered building element on the ground floor of buildings, interspersed with columns or pillars open on one or more sides towards the external fronts of the building. The portico may be a decorative element in the façade or side of buildings, or a walkway or shelter area along streets and around squares;" (Comune di Bologna, 2021a, p. 122, v1.2241)

This definition collapses the academicians' four morphological types into a single item, casually shifting from defining a portico as an appendix of a building, to associating it, still in the singular form, to a group of buildings, till altoghether overturning the association towards the public realm. Nonetheless, as previously mentioned, when it comes to their physical renovation, the characteristics of the building set the standards for prescritions about the choice of materials, and other aspects of fabrication, while prescriptions addressing access and use of porticoes associate it to the public realm (Comune di Bologna, 2021a, p. 121, v1.2253). This neat distinction gets somehow blurred in the building code, which dedicates to porticoes one article. Art. 36 (Comune di Bologna, 2020b, pp. 116-121) focuses its first point on the dissemination of porticoes within the historical city and beyond, defining the whole as an urban system of sheltered pedestrian paths or walkways. It therefore bypasses the question of metric contact between the different porticoes inside and outside the historic city. Building on this definition, the second point confirms that ground floor porticoes of shared ownership are to be considered part of the building, yet they cannot be rebuilt as closed rooms and all installations that may alter its micro-climate are forbidden. In addition to parthood in the facade, and parthood in the building, the second point also stresses the need to treat the pavement of porticoes as if they are part of sidewalks, using the same materials and laying techniques. Among a number of other details regarding sizes, shapes and materials of small elements in porticoes, one reccommendation points to the possibility to mark the edge between two buildings along a portico alignment with a separation profile to mark their primary part-whole relation, while pavements shall be as much as possible the same “to emphasize the continuity of the pedestrian paths” (Comune di Bologna, 2020b, p. 118). These provisions clearly lay down a hierarchy of parthood relations, first with the portico alignment, then with buildings and with sidewalks. Regarding the office's focus on the porticoes as heritage, the first point acknowledgement of all porticoes in the city as part of one system indicates the office's assumption that the notion of heritage extends to all historical phases, including the most recent. Accordingly, a passage in Action 2.4c states that “the Municipality encourages the conservation of all porticos as part of the city's heritage and requires care and attention in interventions and forms of occupation” (Comune di Bologna, 2021a, p. 123, v1.2243). Moreover both Action 2.4c in Disciplina del Piano (Comune di Bologna, 2021a) and art. 36 in the building code (Comune di Bologna, 2020b) delegate the construction of new porticoes to further regulatory instruments, opening to the possibility of a wider recognition of the porticoes value beyond the focus on heritage preservation, while not immediately affirming it. The former states:

> “The construction of porticoes intended for public transit is obligatory when provided for by urban planning interventions that envisage porticoed streets and where the portico is deemed necessary by the Municipal Administration in relation to the characteristics of the street or the physiognomy of the environment. The construction of porticoes must be carried out with reference to the indications contained in the Building Regulation - Art. 36” (Comune di Bologna, 2021a, p.124, v1.2254)

In this regard, Art. 36 of the building code states the criteria for construction of new porticoes, apparently assuming that such decision depends entirely on the will of the private sector, while implicitly suggesting that this will exists, hence the need to regulate it. Beside the minimal width and height, the parametes provided for the portico dimensions imply the portico double parthood, by requiring dimensions proportional to the size of buildings and at the same time coherent with their function as public path, paying attention to junctures (Comune di Bologna, 2020b, p. 120). The typical solution for this double belonging is to have same width as other porticoes and different heights according to the building. One feature that often stays in between is the type of ceiling of porticoes, which tends to be specific to each building but is also in many cases uniform across different buildings. Overall PUG provisions regarding porticoes show the relevance of parthood and connection relations to its regulatory principles, highlighting the shortcomings of spatial representation by vectorial objects regarding these provisions, even though such mismatch has not been explicitly acknowledged by the research interlocutors working in the municipal planning office. Indeed, the seamless flow in PUG's written text between the different and coexisting part-whole relations involving porticoes is more akin to a mereotopological order, or spatial organization, based on the monotonicity between parthood and connection, and therefore on the overlapping coexistence between different nested hierarchies of spaces.

Wrapping up on the representation of porticoes along the UNESCO nomination process.

Overall the above description of the problems of representation of the porticoes of Bologna shows that parthood and connection relations were essential to their definitions as an heritage asset by all research interlocutors. The PPM Unit ultimately succeded by nominating a property that reflect the presence of porticoes in the whole city by exhaustively including among its components the full range of part-whole connections between single porticoes and the porticoed city. The academicians provided a set of criteria for the choice of components focusing on part-whole connections, albeit all too implicitly. The WHL experts extensively referred to parthood and connection relations in their reporting. The municipal planning office implicitly assumed the monotonicity of parthood and connection and the overlap of multiple parthood relations in the PUG normative formulations. The same can be said for the identification of policy target areas, concerning primarily the PPM Unit with regard to the UNESCO nomination and the Municipal Planning Office with regard to the PUG provisions for porticoes, albeit with the notable exception of the WHL experts. This is because the WHL experts never acknowledged the ambiguity between their endorsement of the concept of historical urban landscape (UNESCO, 2011) and their approach to boundary identification (UNESCO, 2017) oriented towards a single continuous and homogenous area (ICOMOS, 2021, p. 401). They rather presented the second as a corollary of the first. Nonetheless, these findings do not unequivocally confirm the hypothesis that mereology and mereotopology may provide spatial planning with an alternative option to spatial representation by vectorial objects. Two aspects withhold this confirmation. First, regardless of the multiple references by research interlocutors to connection and parthood relations in the representation of porticoes, and regardless of the constraints faced in the translation of such representation into one or more vectorial objects, none of the research interlocutors explicitly acknowledged and endorsed the focus on these relations as a full fledged approach alternative to that of metric vectorial objects. Instead they intended this focus as specifically required by the exceptional or outstanding nature of the subject matter, possibly a further confirmation of its heritage value. This observation points to the question regarding the generalization of the research findings, and whether this exploration of options for the representation of the spatial organization of the built environment ought to apply to the built environment in general, or instead only to local instances of specific features, such as the porticoes of Bologna. Second, none of the interlocutors raised reservations regarding the ultimate need to fit this focus into a representation by vectorial objects, regardless of the exceptional character of the porticoes of Bologna. This observation points to the question of the integration of this focus into representation by vectorial objects as opposed to cosidering them as alternative lenses requiring alternative representations. The two questions are related on two levels. On the first level, it can be argued that research interlocutors endorsement ought not to be considered the only criteria for assessing the validity of an hypothesis, particularly in controversial cases which were not settled through one explicit consensual interpretation of the problem, but rather through acceptance of the latency of an open question (Bonfiglioli, 2024). At the very least, the latency of the question and related contradiction demonstrates that the topic is a worth subject of inquiry. Moreover, the coherence between the PPM Unit and the municipal planning office approaches, and the fact that the WHL nomination of the porticoes of Bologna was confirmed regardless of this open question, demonstrate that the nomination focus on parthood relations held its ground despite WHL experts reservations. On the second level, the case study demonstrates how the porticoes of Bologna elude spatial representation by vectorial objects in municipal urban design regulations and heritage policies, and how fitting them into such representation requires to identify multiple partially overlapping objects and to specify their parthood and connections relations. Accordingly, the very existence in such position of a specific feature of the built environment, or even of a local instance of this feature, points to the question whether alternative approaches to spatial representation may actually match the characteristics of a wider range of features of the built environment, providing more, possibly all, inclusive alternatives to representation by vectorial objects. This dissertation contributes to research in this direction. The validity of this question and the possibility to generalize the findings regarding the porticoes of Bologna is further corroborated by the relevance of parthood relations in classic studies on urban form and the spatial organization of the built environment (Caniggia & Maffei, 2001; Alexander, C., 2002; Jacobs, 1961). This possibility requires further exploration, possibly along the paths proposed in the conclusion chapter of this dissertation, among other paths. Before that, section 4.c provides a work in progress example of a possible explicit application of mereological and mereotopological principles to the representation of porticoes and of the built environment as a whole, for future evaluation and validation against additional case studies.

4.c Intermediary spaces, connection, extension, emergent parts and unfolding wholes: a work in progress classification of entities and relations in the built environment

This section presents two work in progress exercises pursuing the application of QSR principles to model porticoes and the built environment they are part of. The first exercise looks at mereological relations between adjacent parts of the built environment. The second exercise extends its scope to include mereotopological relations among distant parts. The two exercises take as a starting point two WHL experts' questions about what was being nominated, implicitly referring to the part-whole relations of porticoes with their surroundings, and about the connections between parts of the porticoes of Bologna as a whole. ICOMOS listed three possible answers to the first question as deduced from the PPM Unit proposal for the nomination: "the portico as an architectural element of a building; the four typologies defined by the State Party in the nomination (e.g. porticoed roads, porticoed squares, porticoed paths and porticoed buildings); or the porticoes as urban elements with the function of walkways, which could form the basis of a system" (ICOMOS, 2021, p. 395). The third answer to the first question points to the second question. Overall the list points to the relevance of relations between parts and whole and connection between parts in the debate around the nomination, explicitly acknowledged by ICOMOS as it argued that by showing the connections between the parts of the porticoes of Bologna as a whole, "the nominated property would reflect an urban system; that is, an identity that would be apparent beyond the sum of its constituent parts" (ICOMOS, 2021, p. 396). The two questions can be generalized in two steps. Beyond the focus on heritage preservation, they could translate into: what features, and related selection criteria, shall an exhaustive model of the porticoes of Bologna include? Also, beyond the focus on porticoes: what features shall an exhaustive model of any part of the built environment include? which selection criteria could be generalized? The following exercises address these questions by considering features that define the role of the porticoes of Bologna in the spatial organization of the built environment according to the part-whole relations between porticoes and these features. Assuming the monotonicity of parthood and connection, a single portico, as part of a single building, takes part to different wholes. In turn, these wholes overlap in each portico. The results of the exercises, and the overall ontological and formal analysis, carry some ambiguities. Solving these ambiguities would require a multi-disciplinary team to develop the approach piloted by this research. In this sense, this dissertation provides a starting point, building the case for adapting QSR principles to increase and diversify options for the representation of the spatial organization of the built environment in spatial planning. As anticipated in section 3.c, the assumptions behind these exercises draw on observations of the porticoes of Bologna part-whole relations from four sources:

- historical evidence presented in the chronology in section 4.a;
- characteristics identified by the research interlocutors, and stakeholders in the WHL nomination process, to define the porticoes of Bologna as a heritage asset and to identify the target areas of heritage protection policies, as presented in section 4.b;
- ethnographical observations inspired by retrospective anecdotes (Michael, 2012; Wood, 2023) from the researcher personal memories as a long term resident of Bologna, and corroborated by the findings of a recently conducted auto-ethnography (Bonfiglioli, 2024);
- morphological, spatial planning and urban design observations regarding densification and the relations between open and built up spaces and their respective interfaces.

The first exercise classifies parts of the built environment based on the arrangement of transitions between adjacent parts. These transitions trace the trajectories along which parts aggregate into wholes. Three trajectories correspond to width, depth and height of parts and wholes intended as relative to the orientation of the portico under consdieration (Fig. 4.13). When different wholes overlap, the overlapping part generates a derivative fourth centripetal trajectory. Intermediary spaces, such as hybrid indoor-outdoor spaces like porticoes, porches, verandas and arcades, provide a typical example of these overlaps (Box 4.1).

Fig. 4.13 The four trajectories of part-whole relations in the built environment

Generally speaking, in hybrid indoor-outdoor spaces, overlaps between different wholes occur along two trajectories:

- x: horizontal linear convergence between indoor and outdoor

The first two items in ICOMOS's list refer to the public private, indoor outdoor interface quality, representing overlapping wholes as discrete objects. Such interface corresponds to Bonfiglioli's definition of the porticoes of Bologna as threshold, as multi-trajectory as thresholds can be (Bonfiglioli, 2024).

- y: vertical diversification of ground floor and elevation

Morphological observations add a vertical interface quality allowing downstairs sheltered outdoor comfort and upstairs floor space. This interface overlaps ceiling and open ground, reconciling pedestrian comfort with building densification and roads dominated by vehicular traffic.

Then, the w centripetal convergence takes place as a by-product of the overlap along the x indoor-outdoor convergence.

- w: horizontal circular centripetal convergence

Ethnographic observations (the researcher's anecdotes; references to the porticoes as stages for encounters in Bonfiglioli, 2024) add the centripetal quality manifesting in fluxes.

Yet, the peculiarity of the porticoes of Bologna lies along the second horizontal linear trajectory.

- z: horizontal linear alignment in a network of pathways

ICOMOS's reference to the system of walkways as the third item in the above mentioned list, and the related quality of porticoes' interlocking and stitching buildings to one another (Jacob Burckhardt, 1855, cit. in Ceccarelli & Guidotti Magnani, 2021, p. 27), reflects the outstanding extension and diversification of this network in Bologna compared to other cities. Indeed, this extension adds the walkway among the wholes overlapping in a single portico, amounting in Bologna to multiple possible combinations of paths. In turn, the combination of overlaps along x and z also intensifies w centripetal convergence, similarly to whirlpools in between water currents.

Box 4.1: The porticoes of Bologna among hybrid outdoor-indoor spaces

Porticoes share with other hybrid indoor-outdoor spaces the same physical structure. This physical structure splits into different morphotypes defined by different forms of spatial organization. Veranda, porch, arcade and portico are sometimes interchangeable, yet discernible architectural morphotypes. These concepts represent the same physical structure combining beams, walls and pillars, together with the rooms this structure encloses on one side and exposes to open space on the other. These rooms provide an interface between building envelopes and their surroundings, an intermediate layer in the otherwise abrupt juxtaposition of indoor and outdoor space. The kinds of agents involved depend on the attributes of the indoor and outdoor spaces at stake, expressing the differences between the four morphotypes. Porch and veranda are most typically about the mediation of environmental conditions associated to building interiors and exteriors, mainly inside one property, with higher homogeneity of human agents, and, possibly, higher heterogeneity of non-human animal agents in sparsely built areas. The porch, annexed to the façade of detached residential buildings with broad setbacks from the property boundaries, hosts interactions between staying or dwelling agents, and with incoming guests. The veranda, annexed to buildings of different types mainly towards the backyard, hosts interactions defined primarily by environmental conditions such as natural lighting and ventilation. Arcade and portico are most typically about the mediation of private and public space in densely built areas. The arcade tends to be more introvert, while the portico extroversion results from its location on building facades along the very boundary between private properties and the public domain. The former tends therefore to host interactions between a more selected range of agents, whereas in the second, the range of agents widens along the full spectrum of the human, institutional and artificial heterogeneity intensified by urban density (McFarlane, 2016). Therefore, compared to other intermediary spaces, porticoes carry a wider range of variables. Moreover, in Bologna, their expansion into an urban network of pathways further widens their role from the building scale to the urban scale.

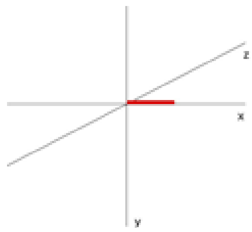
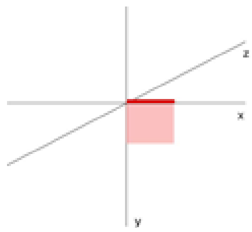
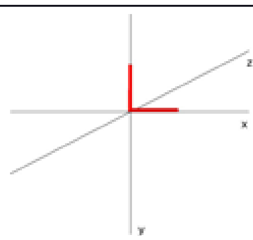
This exercise classification of parts of the built environment and their transitions to adjacent parts focuses on abstract umbrella entries. These entries demonstrate the comprehensiveness of the classification including all possible cases and displaying a standardized set of transition arrangements. The comparison of transition arrangements displayed by any two parts grounds the definition of three types of wholes, respectively including parts displaying same, different or similar sets of transition arrangements, isomorphic, anisomorphic and pseudomorphic wholes. The exercise also defines the basic vocabulary used in the formulation of the three definitions. The classification defines porticoes in comparison to other hybrid indoor-outdoor and to indoor or outdoor morphotypes, or morphological subclasses, each identifying one part of the built environment displaying a standardized set of transition arrangements to other adjacent parts. This comparison shows that the abstract umbrella entry including porticoes presents the largest pseudomorphic cluster among the cases considered, and the largest number of pseudomorphisms of the highest order, as counted below by the number of transitions displaying the same transition arrangement. These observations led to a selection of morphotypes for more detailed definitions of the transition arrangements subclasses, allowing for a specific modeling of porticoes and other pseudomorphic morphotypes, among the commonly found forms in the city of Bologna. Transition arrangements are differentiated below into four classes and 14 subclasses, defining each morphotype by their transition arrangements and by their open or ceiled status, instead of relying on intrinsic individual characteristics (Tab. 4.1). The resulting classification defines the porticoes morphotype by its part-whole relations in three types of wholes, isomorphic, anisomorphic and pseudomorphic wholes. This classification builds on the evidence provided in sections 4.a and 4.b regarding respectively the historical evolution of porticoes in Bologna, and the different representations which characterized their WHL nomination. It generalizes beyond the focus on heritage preservation the analysis of ontological implications, and of opportunities and constraints posed by above mentioned representations of porticoes. By this generalization, it uses the exceptional status of porticoes as a testing ground regarding the viability of a set of concepts for a classification of parts of the built environment and their part-whole relations. Looking beyond section 4.b examination of the WHL nomination process, this classification draws a definition of porticoes based on the observation of their multiple and overlapping part-whole relations and what these relations say about the spatial organization of the built environment. Based on this definition, the classification also identifies key characteristics of the porticoes of Bologna to model their spatial organization as part of the built environment according to mereological principles. The classification ought to provide an example regarding the suitability of mereological principles to model the porticoes of Bologna, and possibly to pave the way for developing alternatives to geometric representation of the built environment. The Cartesian and Euclidean framework evoked in the reference to trajectories visualized as axes indicates that the possibility of this alternative is still out of reach. Nonetheless, the exercise challenges the assumption of the discrete and independent existence of parts of the built environment represented as vectorial objects.

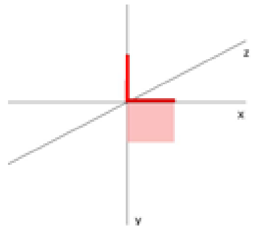
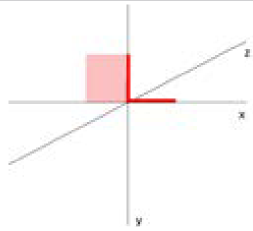
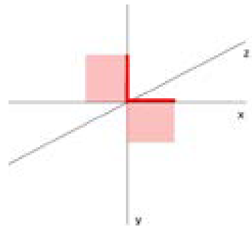
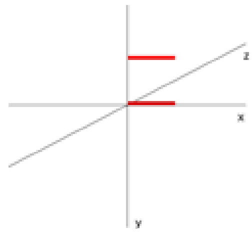
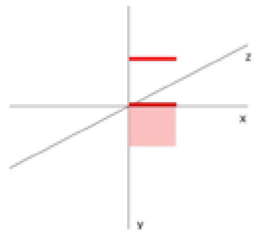
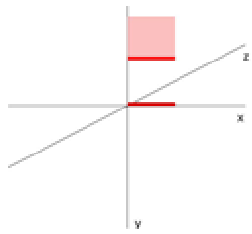
<table>
<tr><td colspan="2">Classes</td><td>Subclasses</td></tr>
<tr><td rowspan="6">pass,
if connected through void</td><td rowspan="3">to sky: towards an open space</td><td>meet-hallway: through void only</td></tr>
<tr><td>dodge-pillars: through void and small blocks</td></tr>
<tr><td>sit-low wall: through void and one large block</td></tr>
<tr><td rowspan="3">to roof: towards a ceiled space</td><td>meet-hallway: through void only</td></tr>
<tr><td>dodge-pillars: through void and small blocks</td></tr>
<tr><td>sit-low wall: through void and one large block</td></tr>
<tr><td rowspan="8">lean,
if connected through walls</td><td rowspan="4">to sky: towards an open space</td><td>knock-door: through wall with ground void</td></tr>
<tr><td>hang out-window: through wall with upper void</td></tr>
<tr><td>view-glass: through transparent wall</td></tr>
<tr><td>miss-wall: through wall only</td></tr>
<tr><td rowspan="4">to roof: towards a ceiled space</td><td>knock-door: through wall with ground void</td></tr>
<tr><td>hang out-window: through wall with upper void</td></tr>
<tr><td>view-glass: through transparent wall</td></tr>
<tr><td>miss-wall: through wall only</td></tr>
</table>

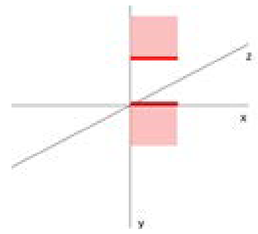
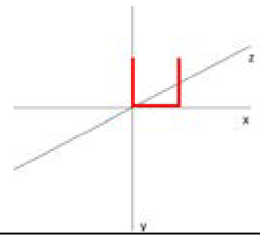
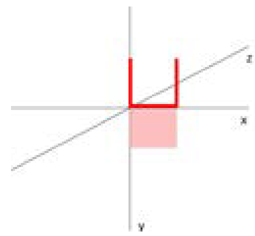
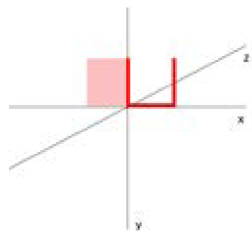
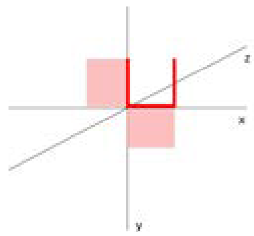
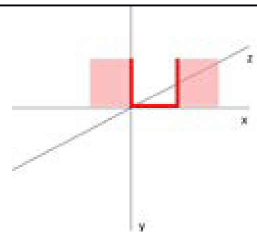
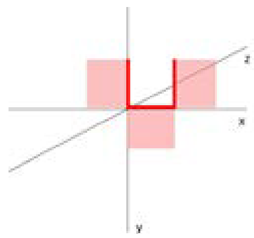
Tab. 4.1 A classification on transition arrangements between adjacent morphotypes.

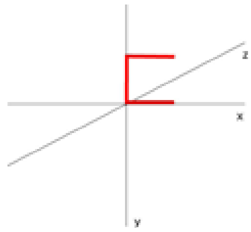
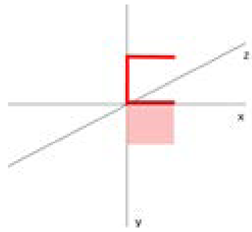
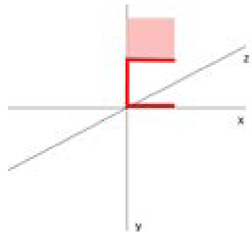
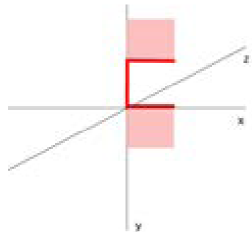
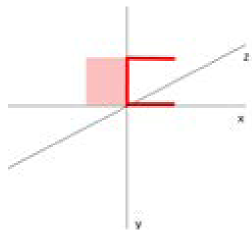
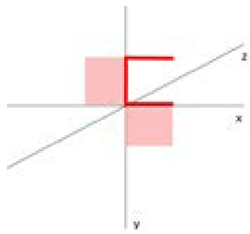
In line with an ontological approach, the proposed classification (Tab. 4.2) aims to consider all the possible transition arrangements along both sides of the x (x left and x right) and y (y down and y up) axes, respectively representing the width and height trajectories, while focusing on those which can be assumed to be more common than others as material architectural manifestations. The left, right, up and down annotations indicate sides, respectively reflecting the horizontal direction of the x axis and the vertical direction of the y axis. At this stage, the scope of the classification focuses on intermediary spaces such as hybrid indoor-outdoor spaces as primary sites of morphological emergence and unfolding (Alexander, 2002; Portugali, 2011; Portugali & Haken, 2021). To focus on porticoes and other hybrid indoor-outdoor spaces, the coverage of the classification is limited to all the possible configurations connected through void on at least one side of the z axis, which the 2D diagrams depict as a flat monodimensional slice referring to only one of the z sides of the morphotype, with no mention of the form of adjacent morphotypes along z. Meanwhile, the w axis is assumed to be a by-product of the combination of x and z, and therefore it is not explicitly considered here. Its intensity should be estimated proportionally to the connectivity of paths along the z axis and to the polarization between the two sides of the x axis. Moreover, the below graphics further simplify the caseload to focus on the most generic conditions in place in the built environment as a material manifestation, by:

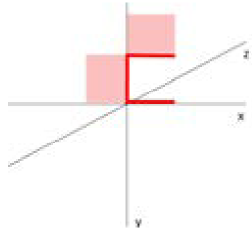
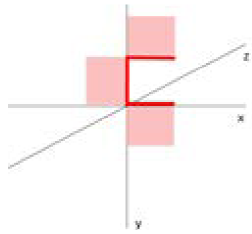
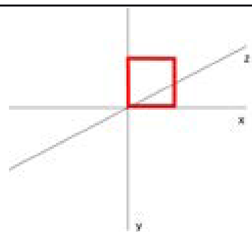
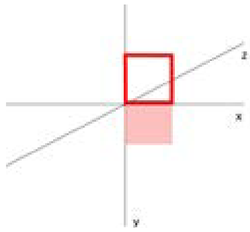
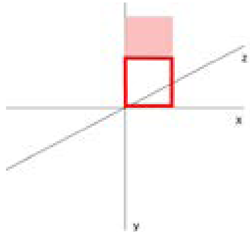
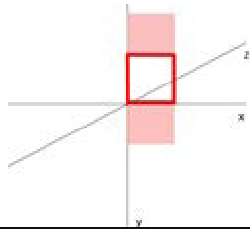
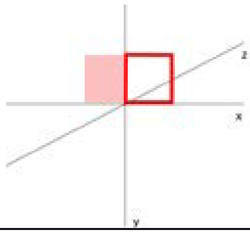
- featuring only the *pass meet* and *lean miss* subclasses as the two ends of the spectrum covered by the subclasses;
- featuring only two subclasses regarding y down, *lean* for paved ground and *lean to roof* for pavement over an underground room;
- featuring only lean to sky, lean to roof and pass to sky subclasses excluding for example seamless unbuilt connections towards a ceiled room;
- entirely excluding unpaved soil as a neutral value.

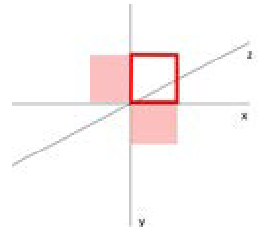
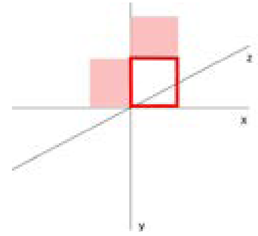
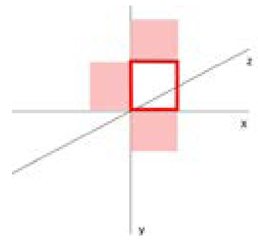
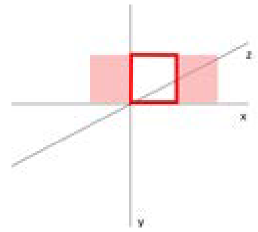
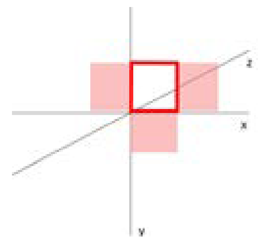
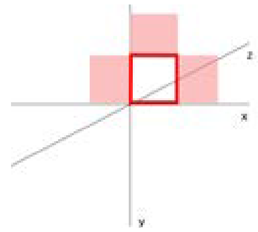
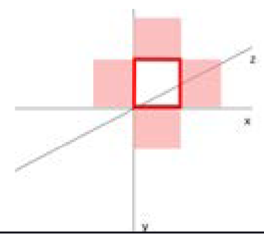
Tab. 4.2 A classification of morphotypes by all possible transition arrangements along 2 axes	
A.1) A lot is said to be x and yup: pass to sky; ydown: lean. This morphotype may correspond to a paved path.	
A.1+) A lot is said to be x and yup: pass to sky; ydown: lean to roof. This morphotype may correspond to a paved path above an underground built-up area.	
B.1) A lot is said to be xright and yup: pass to sky; xleft: lean to sky; ydown: lean. This morphotype may correspond to a sidewalk along a fence.	

B.1+) A lot is said to be xright and yup: pass to sky; xleft: lean to sky; ydown: lean to roof. This morphotype may correspond to a sidewalk above an underground built-up area along a fence.	
B.2) A lot is said to be xright and yup: pass to sky; xleft: lean to roof; ydown: lean. This morphotype may correspond to a sidewalk along a built-up area.	
B.2+) A lot is said to be xright and yup: pass to sky; xleft and ydown: lean to roof. This morphotype may correspond to a sidewalk above an underground built-up area along a built-up area.	
C.1) A lot is said to be x: pass to sky; yup: lean to sky; ydown: lean. This morphotype may correspond to a paved passage below a shed.	
C.1+) A lot is said to be x: pass to sky; yup: lean miss to sky; ydown: lean to roof. This morphotype may correspond to a paved passage above an underground built-up area below a shed.	
C.2) A lot is said to be x: pass to sky; yup: lean to roof; ydown: lean. This morphotype may correspond to a paved passage under a built-up area.	

C.2+) A lot is said to be x: pass to sky; y: lean miss to roof. This morphotype may correspond to a paved passage above an underground built-up area under a built-up area.	
D.1) A lot is said to be x: lean to sky; yup: pass to sky; ydown: lean. This morphotype may correspond to an alley between two fences.	
D.1+) A lot is said to be x: lean to sky; yup: pass to sky; ydown: lean to roof. This morphotype may correspond to an alley above an underground built-up area between two fences.	
D.2) A lot is said to be xright: lean to sky; xleft: lean to roof; yup: pass to sky; ydown: lean. This morphotype may correspond to an alley between a fence and a built-up area.	
D.2+) A lot is said to be xright: lean to sky; xleft and ydown: lean to roof; yup: pass to sky. This morphotype may correspond to an alley above an underground built-up area between a fence and a built-up area.	
D.3) A lot is said to be x: lean to roof; yup: pass to sky; ydown: lean. This morphotype may correspond to an alley between two built-up areas.	
D.3+) A lot is said to be x: lean to roof; yup: pass to sky; ydown: lean to roof. This morphotype may correspond to an alley above an underground built-up area between two built-up areas.	

E.1) A lot is said to be xright: pass to sky; xleft: lean to sky; yup: lean to sky; ydown: lean. This morphotype may correspond to a sidewalk below a shed along a fence.	
E.1+) A lot is said to be xright: pass to sky; xleft: lean to sky; yup: lean to sky; ydown: lean to roof. This morphotype may correspond to a sidewalk above an underground built-up area below a shed along a fence.	
E.2) A lot is said to be xright: pass to sky; xleft: lean to sky; yup: lean to roof; ydown: lean. This morphotype may correspond to a sidewalk below a built-up area along a fence.	
E.2+) A lot is said to be xright: pass to sky; xleft: lean to sky; y: lean to roof. This morphotype may correspond to a sidewalk above an underground built-up area below a built-up area along a fence.	
E.3) A lot is said to be xright: pass to sky; xleft: lean to roof; yup: lean to sky; ydown: lean. This morphotype may correspond to a sidewalk below a shed along a built-up area.	
E.3+) A lot is said to be xright: pass to sky; xleft and ydown: lean to roof; yup: lean to sky. This morphotype may correspond to a sidewalk above an underground built-up area below a shed along a built-up area.	

E.4) A lot is said to be xright: pass to sky; xleft and yup: lean to roof; ydown: lean. This morphotype may correspond to a sidewalk below a built-up area along a built-up area.	
E.4+) A lot is said to be xright: pass to sky; xleft and y: lean to roof. This morphotype may correspond to a sidewalk above an underground built-up area, below a built-up area and along a built-up area.	
F.1) A lot is said to be x and yup: lean to sky; ydown: lean. This morphotype may correspond to an alley below a shed between two fences.	
F.1+) A lot is said to be x and yup: lean to sky; ydown: lean to roof. This morphotype may correspond to an alley above an underground built-up area below a shed between two fences.	
F.2) A lot is said to be x: lean to sky; yup: lean to roof; ydown: lean. This morphotype may correspond to an alley below a built-up area between two fences.	
F.2+) A lot is said to be x: lean to sky; y: lean to roof. This morphotype may correspond to an alley above an underground built-up area below a built-up area between two fences.	
F.3) A lot is said to be xright and yup: lean to sky; xleft: lean to roof; ydown: lean. This morphotype may correspond to an alley below a shed between a built-up area and a fence.	

F.3+) A lot is said to be xright and yup: lean to sky; xleft and ydown: lean to roof. This morphotype may correspond to an alley above an underground built-up area below a shed between a built-up area and a fence.	
F.4) A lot is said to be xright: lean to sky; xleft and yup: lean to roof; ydown: lean. This morphotype may correspond to an alley below a built-up area between a built-up area and a fence.	
F.4+) A lot is said to be xright: lean to sky; xleft and y: lean to roof. This morphotype may correspond to an alley above an underground built-up area, below a built-up area and between a built-up area and a fence.	
F.5) A lot is said to be x: lean to roof; yup: lean to sky; ydown: lean. This morphotype may correspond to an alley below a shed between two built-up areas.	
F.5+) A lot is said to be x and ydown: lean to roof; yup: lean to sky. This morphotype may correspond to an alley above an underground built-up area, below a shed and between two built-up areas.	
F.6) A lot is said to be x and yup: lean to roof. This morphotype may correspond to an alley below a built-up area between two built-up areas	
F.6+) A lot is said to be x and y: lean to roof. This morphotype may correspond to an alley above an underground built-up area, below a built-up area and between two built-up areas.	

Based on this classification, it is possible to identify hybrid outdoor-indoor and other intermediary spaces as a pseudo-morphic whole connected to different isomorphic wholes as its parts, within the overall anisomorphic whole corresponding to the built environment and its anisomorphic parts at different scales, such as neighoborhoods, blocks and buildings. Pseudomorphism is proposed here as the characteristic of wholes underlapping separate isomorphic wholes such as portico alignments, therefore establishing a specific type of connection between them regardless of their discontinuity. In order to define isomorphic, pseudomorphic and anisomorphic types of wholes, it is necessary to first introduce definitions of basic concepts.

ENTITIES		
Wholes and parts	**Clusters and components**	**Unions and members**
Any spatial unit is said to be a *part*, if it can be described as a simple or as a composite phenomenon which holds a position within a whole and may not be the same when divided from it.	Any spatial unit is said to be a *component*, if it can be described as a simple or composite phenomenon which holds a position within a cluster, is pairwise disjoint from any other component in the cluster and is the same when divided from the cluster.	Any spatial unit is said to be a *member*, if it can be described as a simple or composite phenomenon which holds a position within a union, it is jointly exhaustive with other members in the union and is not the same when divided from the whole.
Any whole is said to be a *composition* of parts, and the parts are said to be a *decomposition* of the whole, if the set of these parts covers the entire whole.	Any cluster is said to be the *proper composition*[11] of its parts, and the parts are said to be a *proper decomposition,* if the set of these parts covers the entire cluster, and all these parts are components of the cluster.	Any union is said to be the *unification* of its parts, and the parts are said to be a disunification, if the set of these parts covers the entire unit, and all the parts are members of the union.
Each whole that has a part which is itself a whole is said to contain nested decompositions.	Each cluster that has a component which is itself a cluster, is said to contain nested proper decompositions.	Each union that has a member which is itself a union, is said to contain respectively nested proper disunifications.

11 “no two pieces have parts in common”, p. 109, and the proper composition principle (Varzi, 2008, p. 110).

RELATIONS		
Connection and parthood	**Addition and inclusion**	**Unity and membership**
The relation that holds between the parts of a whole is said to be *connection*[12]*,* if each of these parts can be described as connected to oneself (reflexivity), and connected to any part that is connected to it (symmetry). They may also be described as connected to any part that is connected to any part they are connected to (transitivity), or not (non-transitivity), depending on the connection criterion, and not to be connected (non-transitivity) to any part that is connected to any part they are connected to according to a different connection criterion.	The connection relation that holds between the components of a cluster is said to be *addition*.	The connection relation that holds between the members of a union is said to be *unity*.
The relation that holds between a whole and its parts is said to be *parthood*, if each of these parts can be described as part of itself (reflexivity), as part of a whole which is not part of it (anti-symmetry), and as part of any whole where any of the wholes it is part of takes itself part (transitivity).	The parthood relation that holds between a cluster and its components is said to be *inclusion*.	The parthood relation that holds between a union and its members is said to be *membership*.

ENVIRONMENT
A spatial unit is said to be an *environment* if it provides a receptacle for the inhabitation of one or more agents.
Different units are said to be parts or members of the environment as a union type of whole.
An environment is said to be of a particular *type* if its form is generated by agents of the same kind, or jointly by agents of different kinds as one group (e.g. biome), as a receptacle for the inhabitation of these or other agents.
Different kinds of agent, or different groups of agents are said to generate different kinds of environments.

12 See section 4.3.

Different types of environments are said to be parts or components of the environment as a cluster type of whole[13].		
Forms are said to be of *wild origin*, or belong to wilderness, if they are generated and maintained by non-human agents[14].	Forms are said to be of built origin, or belong to the built environment, if they are generated and maintained by human agents or by human-made artificial agents[15].	Forms are said to be of *hybrid origin*, or belong to the hybrid environment, if they are generated and maintained by both non-human and human agents.

BUILT ENVIRONMENT
An environment is said to be *built environment* or to be part of the built environment, if its form is generated and maintained by human agents or by human-made artificial agents.
A spatial unit is said to be a *lot* if it is a part of the built environment.
The exterior of a lot in any given direction is said to be the interior of a distinct lot, if the location of the lot is not next to wilderness or hybrid environment.
Lots are said to be jointly exhaustive parts, can be described as members, and the parthood relation can be described as a unity, if parthood refers to a region corresponding to a union type of whole, such as union-like parts of the built environment, or the built environment or the environment taken as absolutes.
The exterior of a lot in any given direction is said to be the interior of separate units in wilderness or the hybrid environment, if the location of the lot is next to one of these.
Lots are said to be pairwise disjoint parts, can be described as components, and the parthood relation can be described as an addition, if parthood refers to a a subregion of the environment as a whole corresponding to a cluster type of whole, such as cluster-like parts of the built environment, or different kinds of environment taken in relation to one another.

URBAN FORM		
Two lots are said to be *isomorphic*, or to be the same morphotype, if their urban form respectively displays the same set of transition arrangement classes at least on one side of the x and the z axis and on the upper side of the y axis, and the same subclass on the other side of the x axis.	Two lots are said to be *pseudomorphic*, or to be different yet partially similar morphotypes, if their urban form respectively displays the same set of transition arrangement classes at least on one side of the x axis, of the y axis, and of the z axis.	Two lots that are neither isomorphic nor pseudomorphic are said to be *anisomorphic*, or to be completely different morphotypes.

13 The typology of origin is one example of pairwise disjoint parthood as a component-cluster part-whole relation, and the related attribute applies transitively at different levels of spatial decomposition so that any region can include a component of wild origin, a component of hybrid origin, and/or a component of built origin.

14 The distinction between non-human biological and human biological agents, and the status of wilderness are here taken as givens.

15 The association between human agents and human-made artificial agents is taken as a given assuming that actions performed by human made artificial agents are, transitively, of human origin.

All lots that are isomorphic to a particular lot are also isomorphic to one another.	Lots that are pseudomorphic to a particular lot are not necessarily pseudomorphic to one another.	
A lot is said to be *an isomorphic whole, or cluster,* if it includes adjacent and neighbouring isomorphic pairwise disjoint parts[16], and if it is part of anisomorphic wholes of comparable size at any given level of spatial proper decomposition, and transitively at larger levels of spatial proper decomposition.	A lot is said to be *a pseudomorphic whole, or cluster,* if it includes adjacent and neighboring pseudomorphic pairwise disjoint parts, and if it is part of anisomorphic wholes of comparable size at any given of spatial proper decomposition, and transitively at larger levels of spatial proper decomposition.	A lot is said to be *an anisomorphic whole, or unit,* if it unifies adjacent anisomorphic jointly exhaustive parts[17] and those adjacent to these within a given level of spatial disunification, if it contains isomorphic and pseudomorphic wholes of comparable size within a given level of spatial disunification, and it is part of anisomorphic wholes transitively at larger levels of spatial disunification (e.g. single building, building complex, building block, neighbourhood, district).

Based on the above mentioned definitions, lots said to be isomorphic form isomorphic wholes, while pseudomorphic wholes can be described as formed of pseudomorphic lots, as well as formed of different isomorphic clusters of lots. Attending to the definition of pseudomorphic wholes, Table 4.3 identifies for each morphotype the ones which are pseudomorphic to it, given that pseudomorphism is not transitive, and therefore each pseudomorphic whole depends on a single morphotype working as a clustering principle. For example, the A.1 umbrella entry presents the same transition arrangement on the right side of the x axis, on the down side of y axis, and on both or at least one side of the z axis as B.1, C.1 and E.1. From now on, the case load ignores the presence of an underground built-up area (see the + sign in the codes of the above entries), taking as a given the either-or status of ydown. Like Table 4.3, also Tab. 4.4 counts the entries in the pseudomorphic cluster relative to each morphotype. Given the relativity of directions on the horizontal axes, subclass sameness does not depend on sides sameness (eg. D.2. right counted as same to E.2 left).

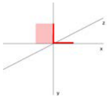
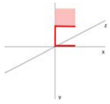
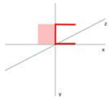
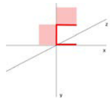
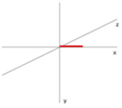
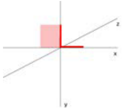
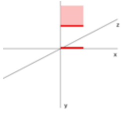
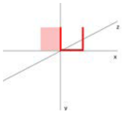
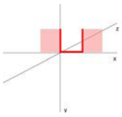
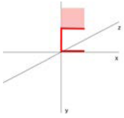
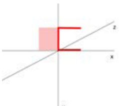
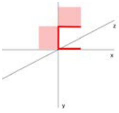
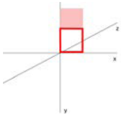
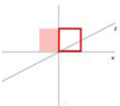
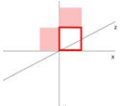
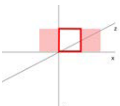
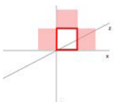
16 Like in the corresponding statement about pseudomorphic wholes, the inclusion of both adjacent and neighbouring parts allows for clusters to include lots that have one or more distinct clusters in between them, therefore spatial clusters like isomorphic and pseudomorphic wholes can have gaps, though they cannot have overlaps by definition.

17 The inclusion of only adjacent parts prevents units to include lots that have one or more distinct units in between them, because spatial units like anisomorphic wholes cannot have gaps by definition, though they can have overlaps.

Tab. 4.3	A.1	B.1	C.1	D.1	E.1	F.1
A.1		V	V		V	
B.1	V		V	V	V	V
C.1	V	V			V	
D.1		V			V	V
E.1	V	V	V	V		V
F.1		V		V	V	

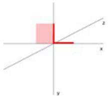
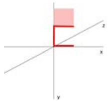
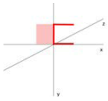
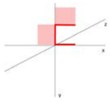
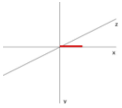
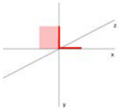
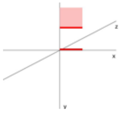
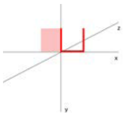
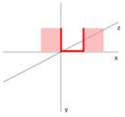
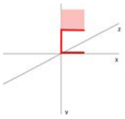
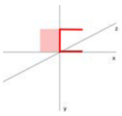
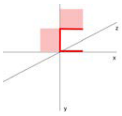
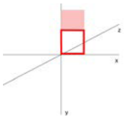
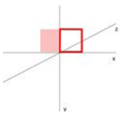
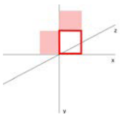
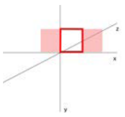
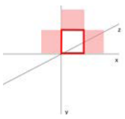
Since Table 4.3 identifies B and E, highlighted by the red scoring marks, as the groups of morphotypes enjoying the broader set of pseudomorphisms, Table 4.4 focuses on these two groups. The clustering patterns of the sample in Table 4.4 point to B.2, the sidewalk, and to E.3, the sidewalk below a shed, and E.4, the sidewalk below a built-up area along a built-up area, the umbrella entry implying porticoes, as the entries enjoying the largest number of pseudomorphic additions. Not only they enjoy the same number of pseudomorphic additions, but they also add to the same entries, and do not add to the same entry, F.2, the alley below a built-up area between two fences. These clustering patterns call for a more detailed definition of the three entries towards a vocabulary defining their distinctive features to support a coherent model of the porticoes. Therefore, the three entries are selected for the final comparative shortlist describing in further detail a range of morphotypes by specifying relevant transition arrangements subclasses.

Then, Table 4.5 counts the number of times in which corresponding sides for each couple of entries enjoy the same transition arrangement. Given that the lower side of the y axis is assumed to be the same already in the sampling criteria, and that the sample includes only entries with seamless unbuilt transitions on both sides of the z axis, the minimum number of sides in the same class is three, while pseudomorphic lots will display values higher or equal to four. Yet, some of the couples displaying values equal to four will still not be pseudomorphic in those cases when none of those four refer to the x axis. Therefore, the x axis provides here the most direct indicator of pseudomorphism. The axes referred to by each value are indicated next to it for clarity.

Tab. 4.4	 B.2	 E.2	 E.3	 E.4
 A.1	V	V	V	V
 B.2		V	V	V
 C.2	V	V	V	V
 D.2	V	V	V	V
 D.3	V		V	V
 E.2	V		V	V
 E.3	V	V		V
 E.4	V	V	V	
 F.2		V		
 F.3	V	V	V	V
 F.4	V	V	V	V
 F.5	V		V	V
 F.6	V		V	V

The scores in Table 4.5 point to the uniqueness of E.4, the sidewalk below a built-up area along a built-up area, and of the portico as one of the morphotypes associated to it. Indeed, E.4 is the entry presenting the largest cluster of 5xyz additions. Unsurprisingly, within this cluster, we find the B.2 and E.3 entries selected through the previous comparison, in addition to other four. In this light, the entries enjoying 5xyz additions to E.4 are shortlisted for the final comparative shortlist, to define the distinctive features of porticoes specifying the relevant transition arrangements subclasses.

The final shortlist in Table 4.6 focuses on the six entries which enjoy a 5xyz pseudomorphic addition to E.4, as identified in Table 4.5, for a total of seven morphotypes including E.4. The comparison across the final shortlist keeps the previous focus on transition arrangements classes, and adds in the fifth column the reference to the subclass of seamless transition marked by a pillar line (dodge-pillars, shortened into dodge) to identify porticoes and other morphotypes within the shortlist. It ignores the other transition arrangements subclasses for their lack of relevance in this case. Overall Tab. 4.6 indicates the main shared characteristics between E.4 and the other shortlisted morphotypes. Th first column addresses the characteristics related to the previously mentioned assumptions of an either-or paved lot on ydown (*lean* or *lean to roof*), and of a *pass* transition arrangement with no mention of the form of the mirroring lots along z. The second, third and fourth column address three characteristics of the shortlisted morphotypes for the pseudomorphisms under consideration referred to transition arrangements classes. Finally, as anticipated, the fifth column addresses the characteristic referred to the above mentioned subclass typical of porticoes. The first characteristic is the presence of a wall and of a ceiled built-up area on one side of the x axis (*xleft: lean to roof*), corresponding to the entries B.2, E.3, E.4, F.4, and F.6. The second characteristic is the presence of a seamless transition on at least one side of the x axis (*xright: pass to sky*), corresponding to the entries B.2, E.2, E.3 and E.4. The third characteristic is the presence of a ceiled built-up area on the upper side of the y axis (*yup: lean to roof*), corresponding to the entries C.2, E.2 and E.4. Finally, E.4 shares with other three entries the additional characteristic of the pillar line along the seamless transition on one side of the x axis, which is expressed through the subclass *pass dodge to sky*, and counted as half the value of pseudomorphic additions. With the introduction of a transition arrangement subclass, the analysis begins to move from the abstractions informing the definitions of umbrella entries to their material architectural manifestations. Considering structural and functional requirements and the consequent likelihood of construction of subclasses, without aiming to be exhaustive, Table 4.7 associates to each abstract entry one of its morphological subclasses among the commonly found forms in the city of Bologna. Adding the specification of some of the subclasses, the definitions take for granted above mentioned assumptions about z and ydown and focus on the other directions.

Tab. 4.5	 B.2	 E.2	 E.3	 E.4
 A.1	5xyz	4xyz	4xyz	4xyz
 B.2		4xyz	5xyz	5xyz
 C.2	4xyz	4xyz	4xyz	5xyz
 D.2	5xyz	4xyz	4xyz	4xyz
 D.3	5xyz	3yz	4xyz	4xyz
 E.2	4xyz		4xyz	5xyz
 E.3	5xyz	4xyz		5xyz
 E.4	5xyz	5xyz	5xyz	
 F.2	3yz	5xyz	3yz	4yz
 F.3	4xyz	4xyz	5xyz	4xyz
 F.4	4xyz	5xyz	4xyz	5xyz
 F.5	4xyz	3yz	5xyz	4xyz
 F.6	4xyz	4yz	4xyz	5xyz

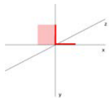
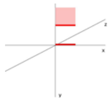
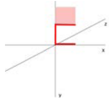
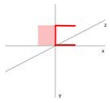
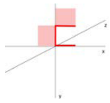
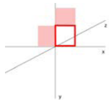
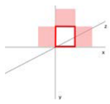
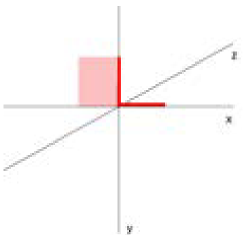
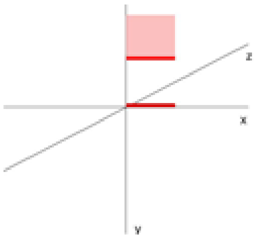
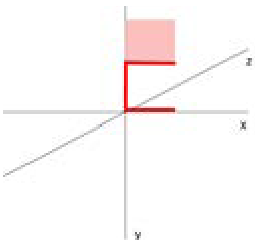
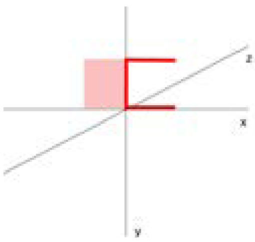
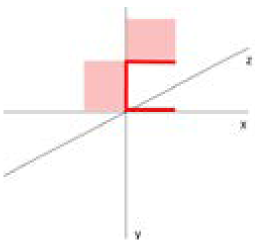
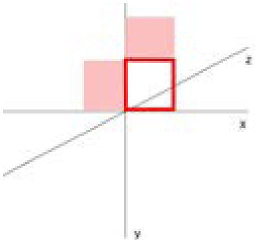
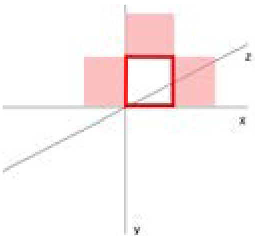
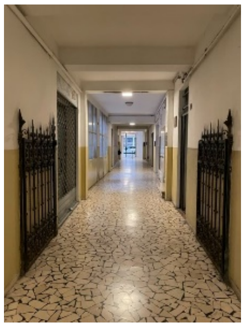
Tab. 4.6 Morphotypes	*z pass ydown lean (or lean to roof)* 3	xleft lean to roof 1	xright pass to sky 1	yup lean to roof 1	xright pass dodge to sky 1
 B.2	3yz	1x	1x	-	-
 C.2	3yz	-	1x	1y	Pilotis floor 0.5x
 E.2	3yz	-	1x	1y	Stand alone 0.5x
 E.3	3yz	1x	1x	-	
 E.4	3yz	1x	1x	1y	Built in portico 0.5x
 F.4	3yz	1x	-	1y	-
 F.6	3yz	1x	-	1y	-

Table 4.7 comparatively identifies the distinctive characteristics of the porticoes, as well as of the other morphotypes composing its pseudomorphic cluster. As an umbrella definition, the E.4 entry describes the volumetric distribution of solid and void for the pseudomorphic types classified as *lean to roof* on xleft and yup, as *pass to sky* on xright, and as *pass* on z. Among these morphotypes, the portico morphotype can be defined as as a distinct morphological component:
xright: *pass dodge to sky*; xleft and yup: *lean miss to roof*; z: *pass meet to roof* OR *to sky*.

Tab. 4.7 Umbrella entry	From umbrella entries to one example	Morphotype class pictures
 B.2	A sidewalk along a built-up area: xright and yup: pass to sky; xleft: lean to roof; > xright: pass dodge to sky; yup: pass meet to sky; xleft: lean miss to roof;	
 C.2	A paved passage under a built-up area x: pass dodge to sky; yup: lean to roof; > A paved passage under a built-up area supported by pillars xright: pass dodge to sky; yup: lean miss to roof; xleft: pass meet to roof;	
 E.2	A sidewalk below a built-up area along a fence. xright: pass to sky; yup: lean to roof; xleft: lean to sky; > A sidewalk below a built-up area supported by pillars along a windowed fence xright: pass dodge to sky; yup: lean miss to roof; xleft: lean miss view/knock to sky[18];	
 E.3	A sidewalk below a shed along a built-up area: xright: pass to sky; yup: lean to sky; xleft: lean to roof; > xright: pass meet to sky; yup: lean miss to sky; xleft: lean miss to roof;	
 E.4	A sidewalk below a built-up area along a built-up area: xright: pass to sky; xleft and yup: lean to roof; > A sidewalk shielded by columns below a built-up area supported by pillars along a built-up area (or a portico): xright: pass dodge to sky; xleft and yup: lean miss to roof;	

18 The example in the picture corresponds to the description in its building structure, although it is located right next to other buildings giving the illusion that it was identical to E.4, xleft to be described as *lean miss view/knock to roof*.

 F.4	An alley below a built-up area between a built-up area and a fence: xright: lean to sky; xleft and yup: lean to roof; > A hall below a built-up area between a built-up area and a windowed fence: xright: lean hangout/view/knock to sky; xleft and yup: lean miss to roof;	
 F.6	An alley below a built-up area between two built-up areas: x and yup: lean to roof;> x and yup: lean miss to roof;	

In the physical architectural heritage of the city of Bologna porticoes can therefore be defined by their relation to three types of wholes:

1. the isomorphic whole properly composed of porticoes;
2. the pseudomorphic whole properly composed of the lots belonging to the morphotypes listed in Table 4.7;
3. the anisomorphic whole unifying the porticoes with the surrounding lots described by the transition arrangements of each portico lot;

Defining the portico in relation to these wholes by the mereotopological lens allows to bypass the inherent contradiction of identifying the target of heritage preservation as a vectorial object. The contradiction between the multiple possible definitions of the porticoes as bounded geometric objects arouses from the will to include the essential elements of their architectural context in the definition, given that one of the basic principles of the preservation of architectural heritage is that it ought not to be cut off the from the environmental and the architectural fabric in which it unfolds. The need to state once and for all in the tracing of geometric boundaries what ought to be included and what not among those essential elements gives rise to the contradiction between divergent definitions. The proposed definition according to the mereotopological lens devises a stratified identification of the porticoes spatial part-whole relations, bypassing the contradiction. The proposed definition also provides the background for the hypothesis that the larger the isomorphic cluster and the pseudomorphic cluster of a morphotype, the stronger the possibility of expansion of the isomorphic cluster in neighboring areas regardless of adjacency, provided the continuity of given anisomorphic conditions in these neighbouring areas. This hypothesis wishes to explain the historical emergence of the porticoed city in Bologna as described in section 4.a, together with the possible patterns of its expansion in the future.

The second exercise of this section presents a proposal to examine the patterns of such expansion in the case of the porticoes of Bologna, at the same time addressing the challenges faced by the WHL nomination of the porticoes of Bologna. The proposed examination is based on a typology of porticoes as tangential parts in porticoed anisomorphic wholes, where each type of portico can be defined by three variables, referred to the above mentioned three linear trajectories, coded as x, y and z for visual immediacy. The first variable C is about the characters of the morphotypes which face, or are connected to, the portico along the three trajectories, meaning:

- the open space, street or square, adjacent to it and the morphotype facing the street on its other side;
- the ends of the portico alignment;
- the upper floor(s) (underground could be added to the analysis depending on the availability of data one the extent of underground rooms);

The second variable MC reaches out to distant parts along the width and depth trajectories, looking at the distribution of the closest disjoint porticoes in the neighbourhood, related to the portico by what can be considered as a gap between isomorphic parts as much as a chain of mediated connections involving pseudomorphic lots along the depth trajectory and anisomorphic lots along the width trajectory. The third variable TE reaches out to an even higher distance along the width and depth trajectories, looking at the characters of the morphotypes which are part of anisomorphic wholes within tangential or external extensions disconnected from the portico under observation. The reference to concepts such as tangential parthood, connection, mediated connection and extension expresses the mereotopological character of the approach of this examination. The focus on tangential parts reflects the interest in the role of intermediary spaces and hybrid indoor-outdoor spaces. Here the examination qualifies tangential parts by trajectory, focusing on the trajectories along which each part expresses its tangential character. This examination, presented in Fig. 4.14 as a preliminary example regarding the first component of the porticoes WHL nominated serial property, wishes to take all of the 12 components of the UNESCO world heritage site as a starting point towards three objectives. First, it wishes to further document how the selected components embody the outstanding universal value of the porticoes of Bologna, because of the range of different types of connection, mediated connection and extension along the porticoed walkways, for example distinguishing single portico alignments on one side of the street, or double portico alignment on both sides of the street. Second, it wishes to appeal to the PPM Unit main focus to trigger a conversation regarding the broader aim of this work, as follows. Third, it wishes to look beyond the horizon of preservation to envision the role of these different types of connection (C), mediated connection (MC) and tangential extension (TE) in the past and future emergence and unfolding of porticoes in the city. These types can be defined based on the morphological characteristics of the parts of the built environment associated to porticoes by each of the three relations, which in the case of width and depth split into two of the four cardinal directions, indicated below by their initial (W, E, N, S). In the case of height, the connection relation, the only applicable one, can split into up and down (U and D). Some of the terminology describing these characteristics such as row house, in line house, courtyard house, pertinent area, matrix route, planned building route, connecting route, break-through route and diagonal route refers to typo-morphological categories formulated by Gianfranco Caniggia

(Marzot, 1997). Additional terminology shall adapt to morphological configurations emerged after Caniggia's studies (Caniggia & Maffei, 1997). The representation focuses on a single portico alignment within each component, specified below the name of the component. In those components including separate portico alignments, it intentionally selects one particular portico in order to address the set up which better embodies the outstanding value of the component. The same logic applies to the selection of a single site of reference for the width trajectory, though in some cases this choice will be completely random if the same conditions apply along the whole portico. The chains of relations involving the selected portico alignment could then identify the parts of the built environment to be included in the target area of any given regulation or policy of interest. The exterior extension relation potentially involves any site outside of the portico of interest, depending on the scope assigned to the complement, yet the below identification of extensions is restricted to tangential extensions (Cohn & Renz, 2008; Varzi, 2007). Nonetheless the whole complement and external connection are taken into consideration for specific types of portico alignments whose specific role in the typology lies exactly in their relation to other porticoes through external connection only, when mediated connection relations do not connect to any separate portico alignment. For mediated connection to apply, it is assumed here that the mediator element could extend to any scale but shall nonetheless correspond to a standard unit in urban morphology, such as for example a building, a building and its pertinent area, a physically enclosed cadastral parcel, a building compound or a group of cadastral parcels merged inside a single physical enclosure, a block, a superblock, a neighborhood as defined at different scales by surrounding major routes, a district as defined by major urban scale infrastructure, the whole urban built up area, to mention but solid elements. Void elements, such as for example roads, intersections, squares or gardens would also apply as mediators, excluding in any case arbitrary volumes or patches of land with no reference to the actual configuration of the built environment on the ground. Accordingly, the maps represent mediated connection by a dotted line crossing the whole extent of the mediator element. At this stage it is assumed that the boundaries marked in the cadastral base map correspond with no exception to physical enclosure, though this assumption has not been validated through direct observation. Instead, the diagrams bear no reference to distance, size or status of streets, featuring only buildings and expressing open space of any kind through empty intervals between features. Moreover, the graphics do not reflect locations within the city specified in the text such as intra moenia or extra moenia, and they only reflect the two ends of the spectrum of the transition arrangements subclasses, the *pass meet* and *lean miss* subclasses, while the text is more specific to each case, for example by differentiating fences from blind walls. The textual descriptions of a number of sites will provide the basis for a work in progress standardization of the categories, open to new additions and distinctions as need be.

Towards ontological analysis, the following list of features departs from the features identified in the classifications presented in this section and adds additional options by symmetrical differentiation. It is meant to serve as a menu for the identification of connection, mediated connection and extension relations between porticoes, considered as tangential parts of buildings and of streets, and their surrounding features.

portico – portico alignment – long portico alignment (block scale) – extra long portico alignment (superblock scale) – ultra long portico alignment (neighborhood scale) - double portico alignment – sidewalk – elevated sidewalk - sporto – shed - arcade
blind wall – fence – blind building facade – building facade with openings – dead end wall
row house – in line house – courtyard house – high rise building -
loose knit fabric – tight knit fabric - block – super-block – neighborhood - district
/front, back or side
matrix route - planned building route - connecting route - break-through route - diagonal route
radial matrix route – radial break-through route – main cardus in its original form – main decumanus in its original form – cardus break-through route – decumanus breakthrough route – dead end – alleyway – dead end
front yard – back yard - large square – small square – large garden – small garden
ALL/intra moenia or extra moenia

The difference between the scope of this classification and the classifications proposed by the academicians within the WHL nomination process does not only reflect the shift from spatial representation based on vectorial objects and spatial representation based on mereological and mereotopological principles. This difference, and the shift in focus from objects to relations, could also be associated to the fundamental difference between an architecture perspective used to focus on the building scale and an urban planning and design perspective used to focus at the urban scale.

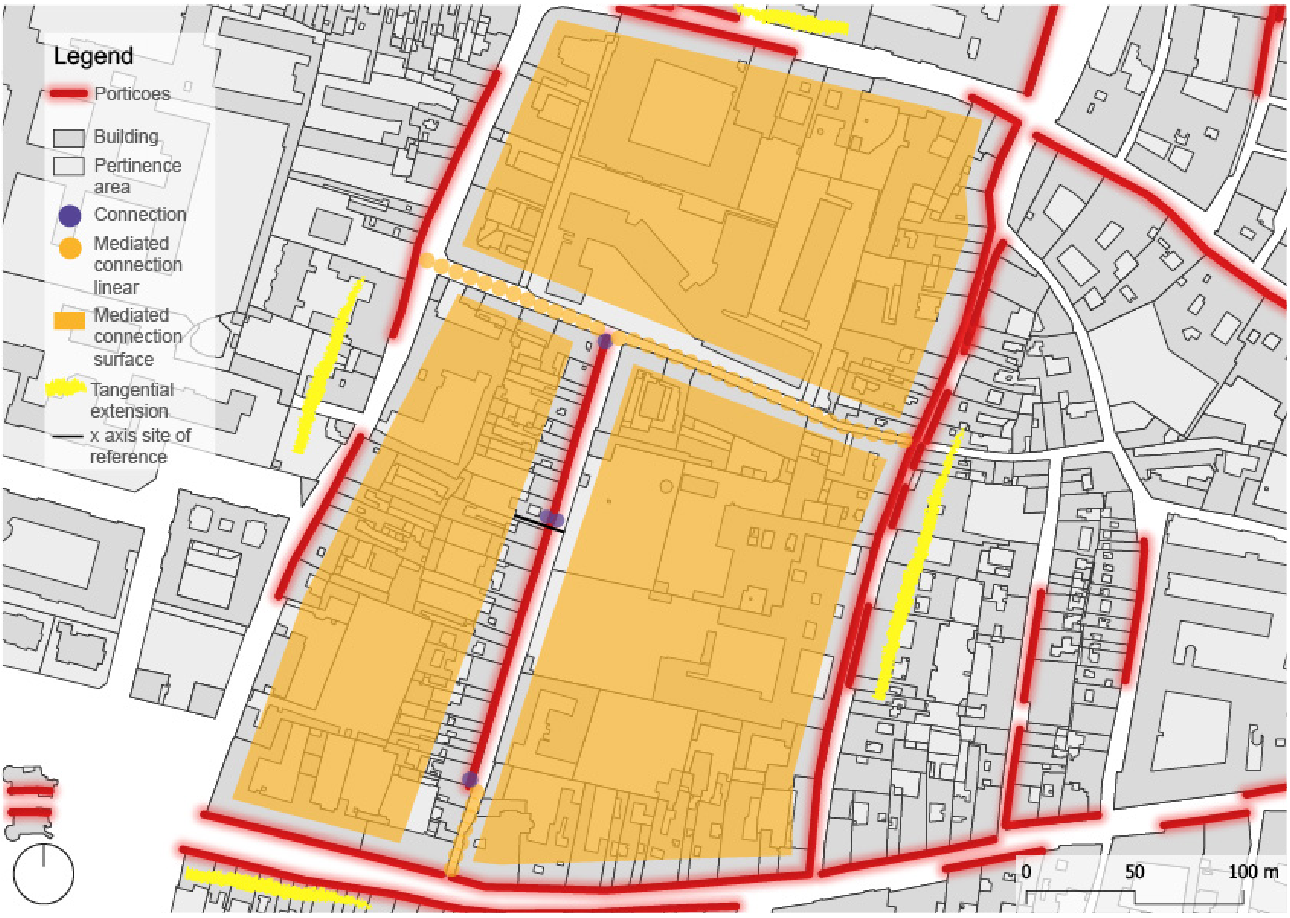
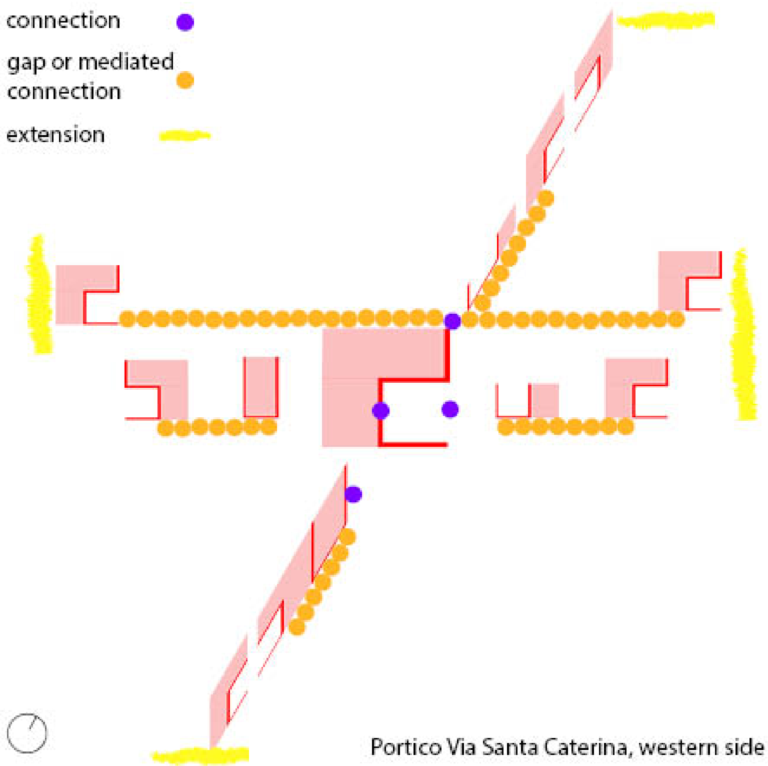


Fig. 4.14 Component 1:
Santa Caterina Saragozza
Via Santa Caterina, portico.
(x): C_ W row house front; E planned building route.
MC_ W portico alignment and planned building route through buildings and pertinent areas; E extralong portico alignment and planned building route through blind wall and block.
TE_ W loose knit fabric; E in line houses.
(y): C_U low rise building
(z): C_ N connecting route; S dead end wall.
MC_ N double portico alignment and intra moenia radial matrix route through fence and block; S long double portico alignment and intra. moenia radial matrix route through buildings.
TE_ N loose knit fabric; S in line houses.



5. Research results across research problem, methods and findings

This section recalls the main results of the research presented in this dissertation, including the insights informing the problem definition gathered throughout the state of the art, the key methodological cues taken from applied ontology and mereological and mereotopological approaches in QSR, and the findings regarding the research questions as obtained from the case study. They are presented below in these three groups.

– The insights gathered throughout the state of the art include the following.

Post-positivist and hermeneutic approaches to spatial planning, semantic-cognitive approaches to computer science and knowledge representation and modeling techniques inspired by complexity science converge towards a pluralist perspective grounded on the denial of the singularity of truth, and based on assumptions such as the necessity, or the plain fact, of distributed multi-criteria decision-making, the legitimacy of different sources and types of knowledge, and the inevitability of uncertainty. (section 2.a)

Semantics, as a technique to articulate and organize the meanings of concepts and linguistic expressions, can play a prominent role in sense-making and problem setting as decisive means for the construction of knowledge in the design disciplines, at the intersection of science and art, knowledge and action, information and purpose, where what is known foregrounds what can be done. As such, semantics enables planning to improve transparency and stability of meanings, reducing ambiguities in communication. This is particularly relevant given the challenges of sense-making and problem setting in conditions of uncertainty and the sociality of wicked problems requiring multi-stakeholder consultation in all design disciplines. It is even more relevant in the case of concepts of spatial information used in spatial planning, given their specific condition of implicitness. In this context, making the assumptions about the use of concepts of spatial information explicit brings two benefits. It supports communication and collaborative decision making, and it also allows to track more systematically the coherency of these meanings with both the intent and the paradigm of reference in the planning process at stake. (section 2.b)

The role of applied ontology in providing the framework and the a-priori distinctions, according to which semantics articulates and organizes meanings, explains its contribution to knowledge sharing and consensual decision making in multi-agent, multi-level and multi-disciplinary domains such as spatial planning, particularly when dealing with wicked problems, and with the epistemological and teleological challenges posed by the uncertainty and complexity of evolutionary processes. (section 2.c)

The role of applied ontology in providing the framework according to which semantics articulates and organizes meanings contributes to streamline theory-practice feed back loops in planning for and in transition in the context of nested crises. (section 2.c)

The role of applied ontology in providing the framework according to which semantics articulates and organizes the meanings of concepts with which we represent and identify parts of the built environment in spatial planning widens the range of options regarding concepts of spatial information and the meanings they convey, contributing to shape spatial imaginaries at the intersection of description and prescription. This interpretation is corroborated by the literature review pointing to the role of meaning as a qualifier of spatial imaginaries, to the urgency of facing the challenges of current extreme conditions of crisis with a transitional imagination, and to how transitions depend on changes at the level of meaning among other levels. The case study encourages further inquiry in this direction. It interprets "the porticoed city" as a spatial imaginary shared by multiple historical agents of urban development in Bologna. It also observes how models of spatial representation based on vectorial objects, networks or on QSR convey different forms of spatial organization into this imaginary. Overall, this block of takeaways triggers a conversation about the influence of determinism in computer science, as well as in planning in general, and spatial planning in particular. In this regard, the state of the art of this dissertation suggests understanding determinism in terms of absolutist vs pluralist approaches. Depending on the approach of choice, determining meanings and imaginaries may shift from absolutist command and control to a way to acknowledge a wider range of options for decision making. (section 2.c)

The role of applied ontology in providing the framework according to which semantics articulates and organizes the meanings of concepts with which we represent and identify parts of the built environment in spatial planning contributes to critical spatial thinking regarding the implicit assumptions behind the use of concepts of spatial information. This contribution requires endorsing a broader meaning of representation than the one commonly assumed in spatial planning, to open the domain to a broader range of options for the representation of the spatial organization of the built environment. (section 2.c)

- The key methodological cues taken from applied ontology and QSR (see section 3.a) include the following.

Ontology and QSR, with their focus on relationships, provide a framework for a relational understanding of space, one where the definition of spatial entities include information about their relations to one another, widening the range of options for the representation of space in addition to the absolute space underscoring vectorial objects and the relative space underscoring raster fields, as codified in geographic information science.

QSR principles regarding mereological relations or part-whole relations, topological relations or connection relations between parts, and mereotopological relations as a combination of those two, provide a logically solid option for the definition and identification of spatial entities in addition to the geometric principles, commonly assumed to be the only possible ones by the implicit conflation of Euclidean geometry and spatial representation.

The key ontological distinction between endurants and perdurants, or continuants and occurrents, challenges the representation of space to make explicit choices regarding the contradiction between the static representation of space understood as inert substrate and the dynamism of territorial evolutionary processes and their spatiality.

Even though foundational ontologies are meant to be task-independent, each applies differently to different use cases. When building an ontology for a practical purpose, it shall be noted how certain entities dependent on human cognition may reflect common cognitive structures. Focusing on these entities supports interaction between perceptive and cognitive structures and ontological foundations, finding a middle ground between one-size-fits-all foundational ontologies and purely context-oriented functionalist approaches. This is particularly appropriate for applications devoted to the development of systematic approaches to common-sense, where natural language plays a significant role in both expert and experiential knowledge alike, as in the case of planning. Since spatial propositions in natural language tend to ambiguity, the main goal is to constrain and to make explicit intended models, guaranteeing a consistent interpretation to share theories across different domains.

Regarding the structure of space and its ontology, the most common Newtonian abstract notion of continuous n-dimensional space as a vacuum ought not to be considered the mostly viable one, nor the concrete notion of spatial entities constituting space as a plenum shall be considered as the only alternative. Yet, other available ontologies of space require each a specific inquiry in terms of their implications for the representation of the built environment, while the vector and raster views corresponding to the first two options are rather well established.

QSR opens up the question of which spatial unit may be considered as the primitive element of spatial composition and decomposition. Outside of this domain, the answer to this question is usually univocally bound to euclidean points, lines and surfaces, and their characteristic infinite cardinality and manipulability, ignoring for example the possibility of pointless theories of space, or of representing space by atomistic mereology of finite worlds, treating the spatial extension of physical entities such as the parts of the built environment as region-like instead of looking for lower dimensions. Such treatment provides an alternative option compared to principles of land subdivision based on infinitely divisible Euclidean primitives.

The mereotopological distinction between regular-open and regular-closed region points to the notion of boundedness, leading to question the actual need for an object boundaries to be known or even knowable. Questions regarding this need arise for example regarding entities which do not have crisp boundaries, particularly natural ones such as mountains, or hands and heads, but also artificial ones such as urban areas, at least according to contemporary notions of the urban. Likewise, arbitrary boundary identification causes mismatches between different sources of spatial information, jeopardizing their integration and confirming the controversial status of boundaries. In the domain of geographic information science, boundaries act as devices for the manipulability of entities. Yet, it is not easy to agree on any common-sense definition of what exactly a boundary is as a part of pure space. In QSR, the notion of boundary can admit ontological independency or dependency, meaning that they can be considered spatial entities per se or not. Also, if the former option applies, they shall be considered as regions themselves, unless one admits the existence of types of spatial entities other than regions. Based on the sensitive role boundaries play in the understanding of the connection relation, theories in mereotopology can be divided in boundary-tolerant and boundary-free theories. In the realm of concrete spatial entities, boundaries are the result of conceptual idealization. If a theory of space admits no boundary element, it can be postulated that all entities in the universe under consideration are mereological regions. This means that there is no distinction between open and closed regions, and that all spatial entities have interior parts. Instead, if a theory of space admits boundaries, the distinctions between tangential and interior parthood and between tangential and interior overlap collapse, and contact is not possible between regions in the same category, including between regions and their complement. Also, there is no consensual standard to postulate whether a boundary is part of the region it bounds or of its complement. These questions can be sidelined as going beyond the scope of mereotopology, since the theory only needs to explain what it means for two things to be connected. Instead, which things are open and which are closed is a metaphysical question that, plausibly enough, goes beyond the concerns of the theory. Among full mereotopologies, there is only one viable option for boundary-tolerant theories, while boundary-free full mereotopological theories have developed an extended body of results and applications, still modeling boundaries in indirect ways. Yet the former is considered mainstream because it relies on extensional mereology, where wholes exactly consisting of the same parts are considered identical, while the latter postulate non extensional mereologies, collapsing the distinction between mereotopology of spatial entities and that of pure space, and considering spatial co-location impossible. Meanwhile, within the precinct of the above mentioned boundary-tolerant theory, the status of the notion of boundary and the treatment of boundlessness involve variations in types of connection. For example external connection is considered to apply to entities sharing a boundary while not enjoying a parthood relation, while it would not apply in case of boundlessness. Moreover, different types of connection range from a single point of contact, to an extended portion of a common boundary or an entire boundary, from firm connection to complete and perfect connection, depending on the underlying ontology regarding the structure of space. Looking at the relation between boundaries and regions, there arise the question regarding whether it can itself be considered a type of connection, an overlap or an external connection. And if so, what would boundaries be connected to, interior parts and/or the complement of the bounded region? Yet, these questions can be directed beyond the scope a boundary-tolerant mereotopology because their answers require primitives of coincidence and location. Along these lines, the possibility of restricted boundlessness applying only to entities of a certain sort has also been theorized. For example, admitting holes assumes the existence of boundaries at least for the internal skins of the objects under consideration, even if they do not have any boundaries with their exterior. In this context, the interface between two entities is defined as the product of their boundaries. Finally, the theory of location interferes with mereotopological boundary tolerant theories by clarifying that, if spatial regions corresponding to the locations of entities cannot be considered themselves to be located somewhere, i.e. at themselves, then at least three postulates would need to be admitted. Entities that are located nowhere would need to be admitted together with the impossibility of unoccupied regions and the impossibility of boundary-like region in the absence of boundary-like objects, such as many instances of political-administrative boundaries, but also many instances of rivers arbitrarily considering as a boundary like objects.

The principles of composition and decomposition state the conditions under which an entity can be considered a whole by decomposition, or a part among other parts by composition. In mainstream extensional mereology, a restricted notion of decomposition, i.e. existing in given circumstances, and an unrestricted notion of composition, i.e. the circumstances for its existence left unspecified, allow for the possibility of detached and disconnected, as non overlapping, parts to belong to the same whole.

Extensional mereology assumptions regarding decomposition according to the strong supplementation principle imply that a whole is exhaustively defined by its constituent parts, and that additional parts would necessarily refer to a distinct whole. This assumption apply to spatial parthood across a wide range of different relations between parts, including detached, disconnected, arbitrary, gerrymandered or immaterial parts. In this context, composition is assumed to be finite regardless of the possibility of detached and disconnected parts. Conversely, decomposition may be considered not finite in the case of arbitrary, gerrymandered or immaterial parts. Any of these criteria for the identification of parts may apply to the representation of the spatial organization of the built environment. Therefore the use of any criterion can be made explicit.

Modeling domains of the regions of space occupied by concrete entities is predominantly treated as requiring extensional mereology, with Whiteheadian conceptions of space being the only well established exception. Instead, modeling a domain of concrete spatial entities, intuitively more akin to modeling the built environment, faces the objections that sameness of parts may not be sufficient for identity, in case of different arrangements of parts, as well as it may not be necessary for identity, in case of entities surviving mereological change. Examples regarding sufficiency include different words made of the same letters. Those regarding necessity include the case of tailless cats. The application of these objections regarding composition and identity to the built environment require further examination and diversification of cases of application. This examination echoes the question of whether concrete spatial entities such as parts of the built environment can be defined as complex systems, defined as systems where the properties of the whole cannot be inferred from the properties of the parts. Although this question is usually dismissed by the distinction between agentive entities and artifacts, momentarily leaving this distinction aside makes room to envision a comparison of the notions of mereological change in extensional mereology and of emergence in complexity science, which may carry fruitful insights regarding the question, and even regarding the distinction.

The success of the concept of network in scholarly definitions of urban systems may overstate its actual relevance to each case of application. This success is tellingly associated to the wide extent of studies regarding the representations of networks as graphs and related algorithms. It seems therefore advisable to ensure careful consideration of the properties of networks, with particular attention to the properties of nodes, before identifying any spatial configuration as a network.

An ontological notion of unity based on membership as a special form of parthood offers the possibility to distinguish different types of wholes, and the possibility that a topological whole defined under a given type of connection may include different topological wholes under a different type of connection. It also allows to define plural unions. These include unions which contain a topological whole while not being themselves topological wholes, as well as collections defined as a special kind of plurality whose members are all wholes. Moreover, singular topological wholes can be defined as homogeneous or non-homogeneous unities respectively consisting of a single body or an assemblage of bodies.

The relation of connection can be interpreted in terms of continuity or contiguity, paying attention to discern the topological notion of connection from the metric notion of contact, where the first corresponds to the cohesion of parts into one whole and the second to a degree of closeness, though both are associated to continuity. For example, collapsing connection onto contact or overlap between concrete entities relies on the possibility of deriving the mereotopology of spatial entities from the mereotopology of pure space. Moreover, a notion of indirect or mediate connection as contiguity, in turn based on one of by-connection, can be introduced to make up for the non-transitivity of connection as contact. This allows to admit the transitivity of the union of all mediate n-connection relations, all the way to transitive connection and path connectedness, provided the necessary reference to a sub-interval and its relative complement. Mediate connection also allows admitting the anti-symmetry of the relation of enclosure (i.e. partial ordering), once assumed that connection is extensional, meaning that entities that are connected exactly to the same entities are identical.

Mereotopology provides various principles to express conditions for parthood, connection and related relations between spatial entities. These principles include overlap, underlap, abutting, interior connection, tangential connection, boundary connection, by-connection, enclosure together with the notions of complement, open region, closed region, interior, exterior, tangential extension, external extension, mediate connection and path connectedness. The principle of the integrity of wholes applies regardless of whether any two parts may be mereologically disjoint or disconnected as non-overlapping.

The theory of location refers to the relation between regions and their tenants, and raises the question of which mereotopological principles shall equally apply to regions and to the entities that occupy them. For example, regarding extensionality, one may admit that having the same proper parts implies sameness for regions even though this may not be the case for the entities that occupy them. Likewise, mereotopological attributes like tangential or interior may apply to location in different ways depending if one defines location based on the structure of space, or based on the structure of its tenants. The first option requires admitting the possibility that mereotopologically distinct entities be co-located, meaning that they have the same location, and excluding that there might exist unoccupied regions, as well as the possibility of mereological change, meaning that material entities may gain or lose parts while preserving sameness, such as in the case of the tailless cat. Instead, the second option requires ruling out co-location of mereotopologically distinct entities, and admitting unoccupied regions and mereological change. One example of co-location is the spatial coincidence of boundaries which can be distinct and coincide at the same time, once assumed that they do not occupy space. Another example is that of shadows or other immaterial or ethereal entities. Overall, several yet unanswered questions regarding the theory of location show how far progress in spatial reasoning depends on progress regarding the question of the embeddedness of entities in space, and the ontology of space underlying relations between entities with a spatial extension.

- The key findings obtained from the case study include the following.

The historical emergence of Bologna as a porticoed city begins with the progressive negotiation of the boundaries between public and private land in the construction of popular housing in the mediaeval period. While the construction of low income porticoed buildings triggering this negotiation continues during the Renaissance, the spread of porticoes takes root as part of the shift from defense to entertainment as the overarching motive behind the construction of local aristocratic residences. Then, while porticoes during the Renaissance become a fundamental element of monumental urban design for parades showcasing the princes' influence and political power, they then broaden their scope serving institutional buildings and churches, as stages for the celebration of values of civic decency and congregational belonging. Along this path, at the dawn of enlightment and of the invention of nation states, they were already so embedded in local custom as a fixture of pedestrian comfort that major urban infrastructure and urban renewal projects adopted porticoes as a factor of popular acceptance of radical urban design decisions by the local administration. Along these lines, post World War II urbanization relied on porticoes as civic hubs and devices of suburbanization, to instill a sense familiarity with areas of recent urbanization far from the city center.

The morphological patterns traced by the dissemination of porticoes and the emergence of Bologna as a porticoed city are the result of a multi-level and multi-actor process spanning over almost a millenium, and continuing today albeit at an occasional pace. This process, run along different territorial trajectories at different scales, explaining the configuration of the porticoes of Bologna as a manifold feature whose special combination of gaps and overlaps defies comprehensive representation as an ordinary vectorial object.

In the case of the nomination of the Porticoes of Bologna to the UNESCO WHL, representation encompassed the definition of the porticoes as an heritage asset, the identification of the related spatial entity or target area of knowledge production and normative actions such as heritage protection, and the visualization of this area. The cumulation of different representations during this process resulted from the search for coherence between the first two steps. The third step was taken for granted as necessarily relying on Euclidean geometry to mark the boundaries of a vectorial object assumed to correspond to the identified target area. The tendency to overlook the distinction between these steps hijacked most of the debate towards the nomination.

The review of reports and the interviews with research interlocutors points to the coexistence or association between certain assumptions and a number of expectations. Although the actual occurrence of some form of consequentiality between these assumptions and expectations would need to be verified through more in-depth inquiry and wider samples, it is still possible to draw some hypothesis for future validation. The assumption binding definition and identification to the visualization of the nominated property as a vectorial object, with its relative permanence of identity, attribute and shape, and its independent existence, may explain the tendency to consider different representations of porticoes as mutually exclusive alternative options, allegedly corresponding to competing interpretations of what is considered to be integral to their heritage value. Moreover, the inner homogeneity and cohesion expected from vectorial objects may be traced back to the assumption that metric gaps implicitly exclude the possibility of connection, since metric distance defines in-betweenness as a gap rather than as a result of the stratification or overlay of topological connections. In turn, this expectation that any such object shall display geometrical continuity, resisting the idea that discrete and distant geographical objects may amount to one larger whole, may also add up to support the tendency to frame the nomination of the porticoes of Bologna as a competition among alternative proposals. This competition explains the elusive character of the porticoes of Bologna to representation by vectorial objects. In this context, the need to get around such elusiveness suggested the possibility of taking inspiration from QSR and mereotopological principles. Based on the morphological patterns traced by the emergence of Bologna as a porticoed city, this dissertation explores interpretative options to bypass above mentioned expectations by considering the possibility of treating disjoint regions as parts of a whole based on mereological and mereotopological relations.

Heritage conservation policies offer a textbook example of the persistence in spatially explicit policy making of assumptions about geometric models as the only possible option for the representation of the built environment and its parts. This persistence is particularly striking in architectural heritage conservation because of the long held beliefs about the benefits of holistic approaches, developed at international level around the UNESCO concept of historical urban landscape. Moreover, a similar approach to the conservation of Italian historical city centers has been widely praised since the 1960 Carta di Gubbio, which steered away the focus of heritage conservation from single monuments to historical city centers as a whole, and found in the 1970s plans for the Bologna city center its first and most renowned case of application. These commitments notwithstanding, boundary identification has been officially identified by UNESCO as the key step in the nomination of world heritage sites, imposing what has been criticized as the air of inevitability of authorized heritage discourse. This air of inevitability ensures the uncontested cohexistence of claims regarding holistic approaches with the requirement of boundary identification, resulting into the corollary assumption that an holistic approach requires these boundaries to identify one cohesive area corresponding to a single vectorial object. This interpretation reduces the historical urban landscape approach to a decision on where to draw the line, based on what could be safely chopped off and what is instead considered integral to the heritage of interest. As a result, all proposals regarding the boundaries of the objects identified as integral to porticoes selectively addressed the criterion of landscape integrity by applying it only in relation to certain features, while excluding others. This reduction reflects two implicit connotations in the interpretation of holistic approaches among research interlocutors, displaying a flat understanding of the concept of entirety, and using the word system and the concept of network to express this understanding, therefore lacking consideration of the change-sensitive stratification which should characterize a systemic understanding of spatiality both in networks and beyond. This lack of consideration hijacked the PPM Unit attempt to apply a systemic approach to the representation of porticoes by diverting it towards a flat holistic interpretation of its own definition of the nominated asset.

The approach of the Municipality of Bologna, represented by the PPM Unit, to the nomination revolved around the efforts to demonstrate the systemic character of their selection of a serial property for the nomination, and the coherence between the definition of a unitary heritage asset and their identification of a dispersed target area made of disjoint components as a whole. This dissertation takes issue with recorded interpretations of the identification of a target area made of separate components as a reductionist stance, based on previously mentioned assumptions. This interpretation revealed its paradoxical trajectory when it identified the identification of a single cohesive bounded object as the blueprint for a holistic or systemic approach. As a result, this dissertation seeks to explain the coherence between the PPM Unit definition and identification demonstrating the systemic character of the PPM Unit selection of components.

The adoption of porticoes in new development and redevelopments in the contemporary city confirms their significance as living heritage. It also provides the opportunity to draw observations on the evolution of the spatial imaginary, and of the spatial ontology behind it, from their medieval origin onto modern conceptions. The spatial organization of recent building complexes adopting porticoes in Bologna, together with the phenomenon of Privately Owned Public Spaces in New York and London, and the medieval spatial ontology, as explained by Lidia Decandia, provide interesting terms of comparison in this regard. The spatiality guiding the PPM Unit's representation of the porticoes of Bologna in the WHL nomination process could also be described, according to the principles ascribed by Decandia to medieval spatial ontology, as a collection of centers potentially polarizing, if preserved, the structure and order of the porticoed city as whole, with its various configurations. It could therefore be understood as not yet a reflection of modern reductionism, but rather as a reflection of medieval *collectionism*, with its peculiar sense of the systemic as a multiscalar patchwork, connecting centers through their relation to the cosmos, connecting parts through their relation to the whole. In this sense, patchworking can still aim to articulate a systematic composition as a never ending process, meandering behind the evolution of structure and order. Frozen in time, this articulation is inevitably anecdotal and incomplete. It can only be systematic as a pursuit, rather than as a state, and therefore it hardly fits in the procedure for a WHL nomination, not to mention in the work flows of public administrations and project management cycles of funding schemes. While looking anecdotal and therefore arbitrary from a detached and frontal perspective, the PPM Unit's representation of the porticoes of Bologna not only appeals to the systemic from an immersive and embedded perspective. It also stands as the offspring of the living intangible heritage of the multiscalar patchwork shaping the spatial imaginary of the porticoed city. Mereotopological relations support the formal explanation of what Decandia pictorially describes as the heterogeneous, polarized, cracking and fragmented space of patchworks and leopard spots. Mereotopological formalism puts these leopard spots in the complex nested hierarchy of spaces characterizing contemporary spatialities.

ICOMOS interest in the process of multiplication which led the porticoes of Bologna to evolve from an architectural element to a system of walkways, and its suggestion that to demonstrate the value of the nominated property required to demonstrate its “wholeness” as an entity which goes beyond the sum of its component parts, confirm the prominence of parthood relations as well as their role in the emergence and complexity of systems. Nonetheless, the assumptions behind ICOMOS reservations on the WHL nomination of the porticoes of Bologna did not associate the systemic character of the porticoes to those in the whole city of Bologna, but rather only to those located within the historical city center. By the paradoxical assumptions integrating the concept of historical urban landscape with the inevitability of boundedness in WHL listings, ICOMOS requirement to include part of the urban fabric within the boundaries as the porticoes' landscape setting did not specify any particular value in this setting other than the plain fact of its existence as a container, somehow treated as Newtonian space. In this space, an implicit metric criterion of a minimum degree of density defined the unity of the system, by the assumption that the spatiality of systems corresponds to that of bounded vectorial objects. This latter assumption also percolated in the representation produced by the Municipality and the PPM Unit in response to ICOMOS reservations, portraying its approach to the nomination cross cutting the history of urban transformations and the areas of urban expansion by locating the components of the nominated series into three concentric bounded areas as shown in Fig. 4.7, as well as legitimizing the systemic interconnections between porticoes by locating them within a perimeter, as stated by attribute 4 of the porticoes OUV. At the same time, the reference to time and change in the OUV statement reflects the Municipality and the PPM Unit acknowledgement of the emergent character of the porticoed system and its progressive unfolding over the whole city. Along the same lines, the focus on time and change regarding the phenomenon of the porticoed city add up to its interpretation as the result of a process steered by a mix of statutory and customary normativity integrating enforced and spontaneous behavior (De Roo, 2020), altogether evoking the notion of cities as complex adaptive systems (Portugali, 2021), and the definition of complex systems as systems where “the whole is more than the sum of the parts” (Simon, 1962, p. 468). Time, change and emergence are key aspects of that more, which spatial systems display as the property of unfolding wholes by differentiation of parts form the whole, rather than addition of pre-existing parts into a whole (Alexander C., 1979). While this property does not apply to extensional mereology assuming the fixity of a moment in time, it can still converge with notions of mereological change, unrestricted mereological composition, and mediated and external connection (Varzi, 2007). This means that a mereotopological approach to modeling the porticoes of Bologna presents the advantage of allowing infinitely recursive update of the model along with the unfolding of new parthood relations, building on the connection of any new part to the whole, regardless of it being disconnected from other parts (Varzi, 2007, p. 981). This is not possible in metric modeling approaches, where the focus is on the relation between parts and the number of relations to be represented in the model is to be decided in advance, for example by the number of the sides of cells in raster models. These observations point to the pervasivity of the assumption that the ontological dignity of spatial entities depends on their metric representation by perimeters or boundaries. At the same time they also highlight the limitations posed by this assumption to the representation of systemic connections cross-cutting time and space, as this assumption focuses on the additive connections between parts, instead of focusing on the connection between part and whole resulting in relations of underlap between disjoint parts. Along these lines, a focus on part-whole and mereotopological relations, such as for example tangential parthood within an open region, may get closer to represent systemic connection than geometric space, bypassing the stress on both the geometric and categorical separation between both vectorial and raster components, and adopting a more stratified notion of connection based on principles of tangential extension, external connection, mediated connection and ontological unity. These observations also reflect the implicit effectiveness of the intern-researcher's prompts introduced in section 3.b in confirming the validity of the nomination of a serial property for an exhaustive coverage of the porticoed city across space and time. Although the hold of metric approaches onto common sense did not allow the explicit adoption of the underlying mereotopological principles, the references to perimeters and bounded areas highlighted above in the representation of the nominated asset can be read as the result of an effort to fit mereotopological relations into metric language.

The academicians contributions to the nomination process confirmed the relevance of semantics, classification, and part-whole relations, key elements of an ontological approach, to the nomination process and to the challenges posed by the representation of the porticoes of Bologna as an heritage asset. Nonetheless, the academicians perspectives relied on bounded vectorial objects at the smallest possible scales of morphological composition, where the representation of the systemic character of the porticoes was limited to the display of the system spectrum of typological, functional and historical-stylistic variables. The difference between this approach and the one developed throughout this dissertation, with its shift in focus from objects to relations, could also be associated to the fundamental difference between an architecture perspective used to focus on the building scale and an urban planning and design perspective used to focus at the urban scale.

Jacob Burckhardt's description of Bologna as “a surprising continuous fabric of buildings sewed together by a neverending Strassenhalle” (Jacob Burckhardt, 1855 p. 207, cit. in Ceccarelli & Guidotti Magnani, 2021, p. 27) supports the systemic interpretation of the porticoes of Bologna.

Indeed Burckhardt's sewing Strassenhalle carries the same representation challenge of the porticoes' nomination itself: if the OUV of the porticoes of Bologna lie in their role as stitches, sewing together the urban fabric, where is this sewing capability of the Strassenhalle at play? In other words, can it be put to work in support to the WHL nomination of porticoes outside of the city center to cater for the full sprectrum of the porticoes temporal and spatial emergence? Again, one possible answer to these questions takes issue from the representation of the Strassenhalle as a vectorial object, interpreting sewing by “a merely metric notion of contact” (Varzi, 2007, p. 977) between parts. This answer identifies the city center as the location of the porticoes OUV. A different answer takes issue from the representation of the Strassenhalle as a mereotopological open region or an ontological unity, interpreting sewing by a mereotopological notion of part-whole connection, accommodating any emergent part of the whole, regardless of it being disconnected from other parts (Varzi, 2007, p. 981). Accordingly, a classification of variance in tangential proper parts of porticoes by morphological, functional and historical stylistic typologies would insightfully represent its stitching capability officially identified in the fourth attribute of the porticoes' OUV. The vectorial representation of the Strassenhalle is also reflected in ICOMOS conflation of the porticoed system with the network of walkways in the linear notion of an urban system of covered walkways, overlooking the outstanding combination of connections along different trajectories which enables the Strassenhalle to sew together the urban fabric.

The controversy around the nomination of component 11 and 12 depended on two misunderstandings of the PPM Unit approach informing ICOMOS reservations. In addition to previously mentioned ICOMOS assumptions regarding connection, during ICOMOS advisory mission to Bologna it also became apparent how its focus on the role of statutory norms entailed overlooking the role of customary normativity in the evolution of the porticoes in Bologna. This particular misunderstanding highlights the intersections between a systemic relational approach to the definition of the porticoes as an heritage asset and the integration of different forms of normativity, of enforced and spontaneous behavior, in the making of the porticoed city, acknowledged as part of the heritage value of the porticoes under attribute 5 of the OUV. Overall, the role of customary norms and the intern-researcher's prompts questioning the validity of the assumption conflating connection with “a merely metric notion of contact” (Varzi, 2007, p. 977) were instrumental to the final settlement regarding the nomination of components 11 and 12 as part of the porticoes WHL serial property.

The municipal Planning Office consideration of the porticoes focused on the exisiting porticoes value as tangible heritage, while overlooking, at least in their explicit communication, two other interconnected issues. These issues are the construction of new porticoes as a form of living heritage in the light of their potential present and future civic role as urban design devices, and the valorization of the mix of statutory and customary normativity behind the construction of porticoes across different historical circumstances as intangible heritage. The first of these issues refers to attribute 3 of the WHL OUV, whereas the second refers to attribute 5. With regard to the first issue, it is nonetheless noteworthy that Art. 36 of the 2020 Building Code states the criteria for construction of new porticoes, apparently assuming that such decision depends entirely on the will of the private sector, while implicitly suggesting that this will exists hence the need to regulate it. Moreover, the analysis of the text of the last general urban plan, the 2021 PUG, highlights few other aspects of the representation of porticoes by the Planning Office. PUG treats porticoes as part of the historic urban landscape, overlooking its potential role as an asset for pedestrian comfort and civic activities in newly developing areas. At the same time, by defining historic urban landscape as the entire urban area instead of the historic city center, it properly backs the PPM Unit approach, acknowledging the heritage value of parts of the suburban built environment, and covering the full spectrum of historical transformations of the porticoes in Bologna, acknowledging that the notion of heritage extends to all historical phases, including the most recent. Yet, interacting descriptions and prescriptions move back and forth between buildings, facades and streets or squares, physical or functional, wider or narrower definitions of the parthood relations integral to the porticoes essence and heritage value. The whole landscape eventually gets to be represented by its chops. Indeed, the preservation of existing porticoes requires to identify them as part of categories of buildings, protected single buildings or groups of buildings, referring to representation by vectorial objects. The text reveals different interpretations of historical urban landscape and heritage when applied to the historic city and to the suburbs. The focus on fabrics in the historic city benefits from the legacy of the 1969 plan for the preservation of the historic city center. Outside of the historic city, PUG excludes the presence of fabrics by focusing on buildings and agglomerations. Indeed, denser fabrics, medieval fabrics, and furthermore a fabric sewed together by porticoes, as suggested by Jacob Burckhardt, call for definitions as fabric more than other morphological types. For example, suburban fabrics in Bologna are certainly more prone to dissection into separate objects as such dissection was already intrisic in the representation of space and the spatial imaginary behind their conception and construction. Moreover, PUG provisions regarding buildings devoid of specific interest highlight the Planning Office concern with the connectivity of porticoes alignments in the historic city, possibly in relation to their above mentioned role as stitches sewing together the urban fabric. Here, the parthood of porticoes in an alignment takes priority to its parthood within the building it belongs to structurally and property wise, sharing the same protected status of the alignment, and of the urban fabric it is part of, unlike the building it belongs to. The written text effectively explains and endorses these overlaps, nonetheless they hardly fit in the representation of space by vectorial objects. Indeed these provisions entail both the nested hierarchy of spaces possibly reflected in mereological relations, and the mereotopological relations of external connection and tangential parthood. Nonetheless, outside of the historic city, porticoes take back the status of parts of a building. Moreover, the 2020 Building Code reference to porticoes in the whole city, the historic city center and beyond, defines the whole as an urban system of sheltered pedestrian paths or walkways, bypassing the question of metric contact between the different porticoes inside and outside the historic city. Indeed, its provisions clearly lay down a hierarchy of parthood relations, first with the portico alignment, and then with buildings. For example, the criteria for construction of new porticoes imply the portico double parthood, by requiring dimensions proportional to the size of buildings as well as of adjacent porticoes or sidewalks, coherently to their function of public path. Overall PUG provisions regarding porticoes show the relevance of parthood and connection relations to its regulatory principles, further highlighting the shortcomings of spatial representation by vectorial objects regarding these provisions, even though such mismatch has not been explicitly acknowledged by the research interlocutors working in the municipal planning office. Indeed, the seamless flow in PUG's written text between the different and coexisting part-whole relations involving porticoes is more akin to a mereotopological order, or spatial organization, based on the monotonicity between parthood and connection, and therefore on the overlapping coexistence between different nested hierarchies of spaces.

The observations regarding the spatial qualities of porticoes of Bologna provide insights on the opportunities and constraints posed to spatial representation by the concepts of spatial information evoked throughout the WHL nomination process. These insights provide a starting point for a prospect study presented in section 7.2. Bounded vectorial objects are effective in setting distinctions between parts of the built environment but overlook dynamics, part-part, part-whole relations and conditions of embeddedness. Spatial clustering algorithms may partially overcome this limitation expressing aggregate configurations of data points to represent sets and subsets of objects. Nonetheless, sets and subsets cannot account for the full spectrum of part-whole relations as in fact they correspond to only one among their different types, and they would still require limiting the extent of embeddedness to the boundaries of the set. Networks are effective in tracking dynamics and flows, and are potentially indefinitely modularly extendable, but they overstate the self-reliance of nodes and edges, overlooking their conditions of embeddedness in their environment and extra-network part-whole relations. This limitation may be overcome by cellular automata, though the cell grid limits the number of parts that can be related to one another to the adjacent ones and would require developing a new model with an adapted grid for every detected exception to the previous model. A dynamic and unlimited representation of part-whole relations, capable of accommodating exceptions emerging from trans-scalar conditions of embeddedness within the same model, can be expressed by mereotopological models. Nonetheless, the disciplinary rootedness of this approach limits its accessibility and handiness for scholars untrained in logic and mathematics. In the domain of spatial planning this is a main cause of resistance to this modeling approach, since scholars with such training tend to prefer strictly quantitative metric approaches, whereas scholars more versed in qualitative approaches tend to be less invested in such training. As previously stated, these observations assume the application of the reviewed concepts to the case of the porticoes of Bologna. Generalizing these observations to demonstrate what aspects of the knowledge base, and which regulatory and policy outcomes, gets highlighted or overlooked by each concept requires additional case studies, both in terms of modeling other parts of the built environment, as well as of examining related decision-making processes.

6. Conclusion: ontological and formal analysis across description and prescription in spatial planning

> "intuition and common sense suggest that some and only some mereological composites exist, not all; yet it is doubtful whether the question of *which* composites exist—van Inwagen's 'special composition question' — can be answered successfully"
> (Varzi, 2007, p. 969)

The research project behind this dissertation inquired on the role of representation in knowledge construction and normative action, description and prescription, in spatial planning and planning behaviour, understood as the multi-level (De Roo & Perrone, 2020) decision-making processes of individuals, communities and institutions aimed at organizing the built environment. Understanding representation as encompassing a broad range of signifying practices (Hall, 1997), and organization as both result of and act in the multi-agent process of introducing a certain degree of order (Moroni et al., 2020) into a given context, the inquiry focused on the representation of spatial organization as both descriptive and prescriptive, describing a result and prescribing, as pre-determining in its Latin etymological sense as "writing in advance", the agencies and the acts delivering related results. This focus leads the research to problematize the role of meaning and semantics in representation, particularly in cases characterized by indulgence in implicit assumptions and ambiguities generating conceptual mismatches and misunderstandings regarding the meanings of language expressions in shared knowledge and decision making. Establishing the connection between the representation of spatial organization and the decisions by which spatial planning contributes to organize the built environment, the project departed from the assumption that diversifying options for the former diversifies options for the latter, and that diversification goes hand in hand with making assumptions explicit and clarifying ambiguities of meanings in representation. In this light, the research points to ontological and formal analysis as a method to dig into the assumptions and ambiguities characterizing the semantics of spatial representation in natural language as used in spatial planning, based on the relation between ontology and representation set in the domains of knowledge engineering and geographic information systems (Guarino, 1995; Couclelis, 2009). The transdisciplinary and unprecedented choice of the method required cross-referencing different sources, justifying its relevance to the design disciplines and to spatial planning in particular around a composite set of concepts such as sense-making (Schön, 1983; von Glasersfeld, 1995) and spatial imaginaries (Davoudi, 2016) for planning for and in transition (Alberti, 2016; Geels, 2002), within a pluralistic and post-positivist approach to scientific knowledge (Friedmann, 1987; Allmendinger, 2002; Davoudi, 2012; Guarino & Guizzardi, 2006; Varzi, 2019)). It also led to conduct a case study, addressing a problem of misunderstandings and conceptual mismatches within spatially explicit municipal policy making regarding a feature of the built environment presenting characteristics elusive to geometric representation (Bonfiglioli, 2024), the standard method of spatial representation adopted in spatial planning. The field work conducted for the case study occurred in the framework of an internship in which the researcher directly contributed to the reporting process regarding municipal activities relevant to the case, joined and conducted workshops and interviews, and interacted with a wide range of relevant stakeholders. The case was documented by an historical review of the emergence of the feature of the built environment of interest, and an examination of the conceptual mismatches and ambiguities characterizing the different representations of this feature by the stakeholders involved in relevant policy making. In this context, an ontological and formal analysis of spatial relations as defined in the domain of QSR provided a set of concepts apt to the representation of characteristics elusive to geometric representation, such as the part-whole relations and the different types of connections between parts. In turn, the organizational spatial patterns assembling parts into wholes through these relations provided a plausible blueprint for the identification of target areas of spatial planning regulations and spatially explicit policies, such as heritage protection in the case under examination. Departing from the identification of key characteristics of the porticoes of Bologna, the model of spatial organization of the built environment inspired by the blueprint identified three types of wholes, isomorphic, pseudomorphic and anisomorphic. Along these lines, a set of mereological, mereotopological and ontological relations provided the criteria to justify the identification of areas for heritage protection in the case study based on relations supported by formal definitions in QSR. Although the proposed model is not completely free of ambiguities, it can be considered as a starting point, building the case for adapting QSR principles to increase and diversify options for the representation of the spatial organization of the built environment in spatial planning. In case favourable conditions arise, a workshop gathering relevant multi-disciplinary expertises will be considered to further develop the research project beyond this starting point, depending on the actual availability of competent participants.

The rest of this chapter concludes this dissertation in three steps. First, it wraps up the main scientific contribution of this dissertation in three points. Second, it lists the observed outcomes of the application of an ontological approach in spatial planning towards generalization, to provide benchmarks for future validation through further studies. Third, it proposes a number of topics for future follow up of the research launched with this dissertation.

Beginning with the scientific contribution of this dissertation, three points can be highlighted, where the research mainly worked by connecting existing dots, in addition to proposing original interpretations regarding three aspects.

First, the dissertation identifies a theoretical framework and a field of inquiry for transdisciplinary collaboration between spatial planners and computer scientists who share a pluralist standpoint regarding the construction and sharing of knowledge through representation. The theoretical framework builds on the existing literature on post-positivist and hermeneutic planning approaches and semantic-cognitive approaches to computer science. The very identification of the field of inquiry regarding the ontological implications of the representation of the built environment in spatial planning and spatially explicit policy making, constitutes the first original contribution of this dissertation. By this identification, the dissertation argues for spatial planners to engage with spatial logics and QSR, as a field of knowledge engineering and most specifically relevant to semantic-cognitive approaches to computer science, and to re-frame the common understanding of the very notion of representation in spatial planning, asserting its ontological foundation and its influence on the classic planning dyad of knowledge and action. This theoretical framework may be of interest, beyond spatial planning and specifically spatial representation, in all other disciplines bridging knowledge and action, information and purpose, such as management and other organizational disciplines to inquire on the role of representation in the layout of such bridge .

Second, the dissertation draws from existing literature a critique of the limitations set by taking for granted one ontology of space and the related set of concepts of spatial information, as if they were the only possible ones. It therefore argues for the relevance of spatial logics and QSR to support critical spatial thinking among planners and policy makers to broaden the set of possible options for spatial representation. By this critique, the dissertation highlights how these limitations also affect the spatial imaginaries working across description and prescription in spatial planning, showing how, in the case of porticoes, they play out in customary and statutory normativity. In this regard, the second among the dissertation's original contribution is to expand the notion of spatial imaginaries to include the role played by spatial ontology and spatial representation based on their common concern with meaning and representation.

Third, this dissertation presents the results of a pilot experiment focused on the porticoes of Bologna as a peculiar morphological feature of the built environment. Here, the dissertation connects the dots marked by different perspectives in the existing literature on how to define the porticoes of Bologna and identify the portion of the built environment relevant to such definition, integrating these perspectives by visualizing them along two trajectories on a bi-dimensional plane. Furthermore, it delivers its third original contribution by interpreting these perspectives according to principles inspired by QSR, and more specifically mereology and mereotopology, towards a classification of the spatial organization of the built environment. This interpretation proposes the lens of part-whole relations and connections between parts as a key to understand, describe and prescribe, in thought and in deed, the spatial organization of the built environment. By this interpretation, the dissertation formulates a definition of porticoes based on their relations of connection as parts of the built environment along four trajectories, adding two trajectories to those addressed in the literature about porticoes. Along these lines, the dissertation proposes to read part-whole relations and connections between parts of the built environment on a four dimensional plane as a framework to model and classify intermediary spaces such as porticoes, and possibly, by further pilots, other parts of the built environment. This proposal sets the stage to acknowledge the role of parthood and connection relations as principles of and for the spatial organization of the built environment.

Moving to the observed outcomes of the application of an ontological approach in spatial planning, this paragraph pinpoints for further validation and generalization a number of preliminary observations regarding the specific contribution of ontology, semantics and QSR compared to other approaches to the study of spatial problems, for example from the, post-spatial turn, social sciences. Despite various critiques of the ontological assumptions informing the modern metric representation of geographic space in spatial planning (Alexander, 2002; Couclelis, 1992, 1999; Davoudi, 2012; Decandia, 2008; Friedmann cit. in Savini, 2021; Lefebvre cit. in Schmid, 2022; Webber, cit. in Paba & Perrone, 2017), experiences in planning oriented geo-spatial analysis based on non metric theories of space are still confined into experimental niches (Hahman & Gruninger, 2012). Meanwhile, the critique of cartographic reason (Farinelli, 2009) grounds concerned geographers' preference for verbal narratives for the representation of spatial phenomena, instead of cartographic mapping (Bonfiglioli, 2024), just like municipal plans compensate for the limitations posed by cartographic vectorial representation through verbal descriptions (Comune di Bologna, 2020b, 2021a). At the same time, a lack of dialogue persists between the research areas of post-modern geography and geo-ontologies, notwithstanding their common themes (Tambassi, 2017, 2018a). In this context, this dissertation demonstrates the relevance of mereological and mereotopological principles for the representation of the spatial organization of the built environment to grasp characteristics elusive to geometric representation, given the opportunities and constraints posed by spatial ontological assumptions observed in municipal knowledge production and normative action regarding the porticoes of Bologna. By demonstrating such relevance, this dissertation highlights the following outcomes of the application of an ontological approach to spatial representation in spatial planning, as compared to narrative approaches from the social sciences. Two general outcomes applicable to any ontological application to decision making complement two outcomes specific to the treatment of spatiality:

- Coherency check: providing a framework for checking the coherency between the different assumptions shaping the vocabulary spatial planners use in the representation of the geographic world, for example with regard to the status of boundaries, to the existence of open and closed regions, to the status of location and to the status of tenancy;
- Stabilization of the vocabulary: articulating the vocabulary informing the production of spatial imaginaries, thereby providing references for the orientation of interpretations at a foundational semantic-cognitive level, compared to the opportunistic, and therefore unconditionally volatile, vocabularies characterizing the narratives commonly associated to spatial imaginaries;
- Spatial focus: focusing on spatial, or space-time, variables and dynamics instead of considering these as a mere reflection of social or biological dynamics, setting the stage for inquiring on the agency of the built environment, and on socio-spatial phenomena as a kind of interaction between alive and inert agents;
- Accommodating manifold and trans-scalar definitions of spatial entities: integrating different definitions of features of the built environment in a single interpretative framework encompassing different forms and different scales, instead of pitching different geometric objects of different extensions as alternative definitions of a feature, as observed with vectorial approaches to the definition of the porticoes of Bologna;

Coming to the proposed topics for further inquiry, the previous overview of general outcomes of the application of an ontological approach anticipates two topics. One is the comparison of different modeling approaches to demonstrate the actual outcomes of the application of an ontological approach in spatial planning. The other topic is the agency of the built environment. Two abstracts for research follow up in these two directions are therefore provided in the appendix of this dissertation. Moreover, additional topics may provide opportunities for further development of this research.

One group of topics develops questions previously introduced in this dissertation in the methodology and in the definition of the porticoes of Bologna as a socio-spatial imaginary. Taking methodological inspiration from mereology and mereotopology in the representation of the porticoes of Bologna raised the question of the appropriate standards for the accuracy of the adaptation of QSR principles in the natural language at play in a collegial decision making context. Further research may support the development of criteria for standardization of the adaptation piloted in this dissertation. In this context, a multi-disciplinary research team may address questions regarding the aspects of the spatial organization of the built environment which might be overlooked through the lens of QSR principles. Topics for questioning may include: the necessity of extensionality in spatial mereology; the thesis of complementation; the problems of connection and composition in relation to the question of mereological change; the conditions under which an entity may be considered a whole, either in a fixed point in time, or across mereological change, and how these conditions orient representation of the spatial organization of the built environment.

A second group of topics concerns the range of case studies which may contribute to the generalization of the research findings. Indeed, further research may develop the study of the porticoes of Bologna as an emergent feature, while other case studies may be added on similar decision making processes concerned with the definition of a built environment or landscape feature, and the identification of a related target area of a planning regulation or policy. The development of the study of porticoes may include further inquiry on the relation between the four trajectories defining the spatial organization of the porticoes of Bologna in this dissertation. This line of inquiry would consolidate the understanding of how the four trajectories work together to determine the peculiar spatial organization of porticoes in the city, offsetting definitions of the porticoes which isolate single trajectories as privileged defining principles. It may also explore options to bypass the Cartesian and Euclidean framework evoked in the reference to trajectories visualized as axes, in order to achieve coherency with a topological perspective. Further development may also follow the trajectories of the porticoes' dissemination around Bologna historic city center. It may cover their contemporary evolution in new suburban residential developments in Bologna municipal area, particularly in comparison to other international cases of property management refashioning of public space, such as Privately Owned Public Spaces. It could also study the historical unfolding of porticoes along Bologna's decumanus maximus and consular road, the Via Emilia, connecting several cities from Rimini to Piacenza, for example in the section between Sant'Ilario d'Enza, in the Parma province, and Sant'Arcangelo di Romagna, as well as in towns along other main radial connections between Bologna and surrounding cities, such as the road to Ferrara. Otherwise, additional case studies providing interesting terms of comparison with the porticoes of Bologna may be: the case of balconies studied by Juval Portugali in his analysis of the emergence of order parameters in cities as complex adaptive systems (Portugali, 2011; Portugali & Haken, 2021); other features typical of medieval urban morphologies, and observable in the Mediterranean area and in the Arab world, such as courtyards, known as hosh in Arabic among other terms, and closed bridges between buildings, known in Arabic as tayyaras among other terms.

Finally, one last closing question for further research takes issue with the reactions triggered by the presentations of the research problem for this dissertation along with the PhD course progress. Along this progress, recurrent misunderstandings about the research topic mirrored the misunderstandings observed in the porticoes of Bologna WHL nomination process. Documenting these misunderstandings, together with similar experiences of cognitive dissonance experienced by planners regarding the vocabulary for spatial representation at hand vis-a-vis the challenges posed to the profession by contemporary urbanization trends, may also provide a useful reference for further developing the techniques of spatial representation in use. This point constitutes the ideal closure of this dissertation as it refers to what can be considered at the same time the starting point and the ultimate objective of this research.

7. Appendixes

7.a How do the porticoes of Bologna act in the city? and who/what do they interact with?

Urban and regional planning and design work at the intersection of biological and artificial systems.[19] In a rapidly urbanizing world, socio-ecological and socio-technical dynamics shape cities and regions interconnecting natural and built environments. These dynamics can be explained according to different notions of agency, interaction and social behaviour. Anthropocentric or biocentric notions focus on human or sentient and intentional subjects. Other notions include machines or landscape features lacking intentionality or representational mental states (Schlosser, 2019). Further lowering its minimal requirements, an even broader notion of agentive and social characters may encompass inert bodies. This notion applies in the conceptualization of the habitat as a socio-spatial construct, result of the behaviours of the inhabiting and the inhabited as agents of inhabitation and of habitability. Here, spatiality, and therefore urban form, are both produced by and producing (Merriman et al., 2012), structured by and structuring (Dovey, 1999), ways of living and socializing. In this light, this article addresses two questions on the productive role of parts of the built environment, such as buildings, rooms, or paths, shedding light on the agency of inert bodies and its engagement in interaction and social behaviour. The first question concerns the interaction among the built environment and human behaviour, producing and produced by one another. The second question explores the possibility that the parts of the built environment may interact among one another, determining one another's character and possibly their own reproduction. This article addresses these questions in the case of the porticoes of Bologna, in Italy, a specific type of intermediary space. Intermediary spaces characterize the spatiality of systemic interconnectedness in cities and regions, as interfaces between radically different spaces such as indoor and outdoor, public and private, transit and dwelling, natural and artificial, or else.

Intermediary spaces stage space-sharing interactions through convergence between their adjacent spaces. The porticoes of Bologna, enlisted by UNESCO as World Heritage in 2022, offer a special example of intermediary spaces. They are indeed a peculiar spatial arrangement, developed in different parts of the city along eight centuries into a 62+ km network of sheltered pathways. Although porticoes are present in many cities in the world, their extension is nowhere comparable to the case of Bologna. The following comparison with other cognate hybrid indoor-outdoor spaces provides the rationale for choosing this specific case. Porticoes share with their cognates the same physical structure, equally applying to the veranda, the porch, the arcade and the portico. This structure combines ceilings, beams, walls and pillars, together with the rooms it encloses on one side and exposes to open space on the other. The rooms provide an interface between building envelopes and their surroundings, an intermediate layer in the otherwise abrupt juxtaposition of indoor and outdoor space. The attributes of the indoor and outdoor spaces at stake express the differences between the four types. Porch and veranda most typically blend

19 This project was developed through participation in the ForMoRe Workshops at the Department of Sociology, University of Trento, between 2023 and 2025.

environmental conditions between interiors and exteriors homogeneously belonging to a single property in more sparsely built areas. Arcade and portico most typically blend private and public space in densely built areas. The arcade is more introvert and selective, while the portico extroversion results from its location on building facades, along the boundary between private and shared or public spaces, fully enjoying the heterogeneity intensified by urban density (McFarlane, 2016). Therefore, porticoes present a wider range of variables than the others. Moreover, in Bologna, their expansion into an urban network further widens their interactions from the building to the urban scale.

This article builds on complexity theories of cities (CTC) and social theory of space. CTC point to the complementarity of intentional and spontaneous, or non-intentional, behaviour in the making of cities and regions, interfering in the path from intent to result in urban planning (De Roo, 2020). Social theory of space points to the embeddedness of social phenomena in time and space, conceptualizing spatiality as a decisive medium of actions and interactions (Lefevbre, 1991; Soja, 1980), in line with similar interpretations in biology, landscape and urban design (Clément, 2012; Dovey, 1999). The resulting immersive notion of action suggests that space mediates action, interaction and behaviour. While space features as a legitimate subject of the verb, it is open to debate whether to mediate describes an action, a condition or experience (Cambridge Dictionaries, “Verb”, n.d.). Accordingly, environments or places could be a specific kind of agent or non-agentive conditional factors. Yet, if spatial mediation produces and structures, then the built environment participates as a non-intentional inert agent in the making of cities and regions as socio-spatial constructs. Likewise, socio-spatial construction qualifies as interaction among intentional and non-intentional, alive and inert, agents, mutually producing one another.

The first research question leads to analyse the case of the porticoes of Bologna according to three conceptualizations of the agentive behaviour of the built environment, framing (Dovey, 1999), affording (Gibson, 1979) and regulating (Lorini and Moroni, 2022). Frames, affordances and regulation are treated as interactive devices, by which inert inhabited agents produce and structure the lives of inhabitants, inasmuch as the inhabitants accustom themselves to these devices through acts of inhabitation as interpretation. The second research question looks at interactions among parts of the built environment. This focus comes with an inference regarding the mutuality of mediation between the built environment and human behaviour. Just like spatiality mediates human interactions, use and construction by humans mediate relations among parts of the built environment. Therefore, if humans are endowed with the prerogative of interacting through spatial mediation, the same shall apply to parts of the built environment, interacting through the human mediation determining their use or construction. In this light, space-sharing interactions among parts of the built environment result into spatial organization, understood as the agency of places, environments and habitats, expressed in the interaction among their inert elements. Organization refers to the process of introducing a certain degree of order (Moroni et al., 2020) into a given context, and to the layout embodying such order as a result of this process. In this context, order and organization imply that certain parts behave as wholes by space-sharing. Moreover, the spatial attribute entails that the context at stake has a spatial extension, and therefore a certain degree of inertia. This notion of spatial organization integrates social and spatial agency in the making of cities and regions, explaining socio-spatial organization as an emergent order involving intentional and non-intentional agency, by sentient and inert agents. In this light, interaction between parts of the built environment becomes a legitimate subject of analysis.

Collecting empirical evidence on space-sharing interactions with and between porticoes poses the problem of how to document the behaviour of inert agents. While agentive notions of artifacts are widely adopted in the social sciences through various approaches (Chua and Salmond, 2012), the reference to inert bodies takes a different scope in two ways. Firstly, while the notion of artifact refers only to the built environment, inert or quasi-inert bodies characterize both biological and artificial systems in cities and regions, matching the full scope of work of urban and regional planning and design. Secondly, the agency of artifacts usually refers to their interactions with alive, and already legitimate, agents, thereby excluding the second research question. Indeed, the more experimental nature of such question, with its exclusive focus on inert agents, calls for evidence on interaction in stillness. Here stillness does not exclude long term change through construction and redevelopment which determine spatial organization dynamics. Therefore, its evidence requires both diachronic and synchronic perspectives. The former rely on historical evidence on the construction of porticoes in the city along with its expansion, since the Middle Ages till today. The latter rely on photography and cartography about junctures, part-whole relations, adjacency and alignment setups, describing how parts of the built environment mediate one another's character through spatial organization. Finally, diagrammatic drawing highlight observed features of interaction in stillness. As a result, the scientific contribution of this article encompasses domain based and methodological inputs for further research. Investigating the extent to which porticoes in Bologna mediate the behaviours of inhabitants and of other elements of the built environment, this article contributes to debates in four directions. It highlights the relevance of spatiality and urban form in interdisciplinary scholarship about interaction and social behaviour. It deepens the understanding of the agency of the built environment in urban planning and cognate disciplines. It also enriches the assessment of the intangible value of the porticoes’ heritage for its protection. Finally, the selection of tools to document the behaviour of inert agents provides a benchmark for further methodological experimentation.

7.b An assessment of three modeling approaches to the representation of the porticoes of Bologna

Spatial planning and spatially explicit policy making rely on models of geographic space to explain existing or intended spatial configurations, such as the vector models typical of land use cadastral maps, or the raster models of land cover maps based on satellite imagery.[20] These models are built around concepts of spatial information which serve different purposes in the representation of

20 This project was developed in the context of a visiting studentship at the University of Vienna, Department of Geography and Regional Research, under the supervision of Prof. Krzysztof Janovicz.

geographical entities and phenomena (Kuhn, 2012). In this context, this section examines the explanatory power of some concepts of spatial information and of their application in selected modeling approaches. To do so, it focuses its inquiry on the ways in which spatial planning can define as a distinct and united whole the target area of a regulation or policy in cases where the features of interest:
- depend for their identification on their simultaneous embeddedness between, and within, the multiple and entirely separate other features they are adjacent to, where the features of interest work as - spatial, temporal or spatio-temporal - interstices, either horizontally, vertically, diagonally (x,y, z), or along two of these trajectories at the same time;
- present an irregular spatial distribution following either an horizontal or diagonal direction, and include both adjacent and distant locations;

Examples of these cases can be identified at different scales with different regulatory and policy implications. In the context of the built environment, they may include bridges between buildings, courtyards (spatial betweenness), zebra crossings, railroad crossings, tram-cycle-pedestrian lanes crossings (temporal betweenness), roadways cutting through squares or parks, urban green areas, water bodies, solar or wind farms, natural areas in urbanized regions (spatio-temporal betweenness) (brainstorming to be consolidated). Overall, these cases display systemic connectedness as a double character, based on their interstitial embeddedness in other features and their irregularly distributed and dispersed configuration. This double systemic connectedness is the core quality against which this section discusses the explanatory power of particular core concepts of spatial information. Focusing on spatial interstices in the built environment, the inquiry exploits the peculiarity of the porticoes of Bologna, a building-street interface which has reached an outstanding extension in this Italian city. In this light, it focuses the above-mentioned question on a particular case, looking at the ways in which the porticoes of Bologna can be defined in spatial planning regulations or policies as a distinct and united target area, subject as a whole to a regulation or policy.

The selection of concepts under examination aims to cover different ways of conceptualizing space. It includes the basics of data-driven metric methods such as vector and raster, together with concepts rooted in cognitive methods such as affordances and mereotopological regions. The examination will highlight the aspects of the spatial configuration of the porticoes of Bologna which can or cannot be exhaustively explained within a single model according to each modeling approach. By engaging with both kinds of information modeling methods, this section aims to contribute to the understanding of each one’s advantages, in line with recent orientations towards reaping the benefits of both sub-symbolic and symbolic methods by hybrid neuro-symbolic methods (Oltramari et al., 2020; Hitzler and Sarker, 2022).

The examination begins with the vector representation of spatial information based on the “object” concept, because of its pervasiveness in descriptive and regulatory cartographies. Objects are discrete and conceptually impervious to relational views of space. Nonetheless, clustering algorithms can express aggregate configurations of data points that represent sets of objects, explaining systemic connectedness by the similarities among the data points. Different types of clustering can explain particular aspects of similarities and connections at stake. For example, hierarchical clustering may define a target area as a stratified object where different clusters of features are connected through relations of inclusion between sets and subsets. Probing the extent of the exclusion of particular features as clustering outliers may provide a key benchmark for the performance of this modeling approach.

The raster representation and its core "field" concept come next as the standard counterweight to vectorial objects in geographic information science (Couclelis, 1992). Fields are concerned with attributes. They are unresponsive to features such as morphological elements or any other geographical feature, raising concerns on how to establish the precise location where a certain decision applies and where it does not. Nonetheless, cellular automata have successfully interpreted the raster cell grid to trace evolutionary patterns in urban systems (Batty et al., 1997). They may therefore express the connectedness between morphological features in the built environment as an emergent property and help identify target areas based on actual and simulated potential conditions.

Probing the limitations of this type of models in expressing embeddedness and overlaps between features may provide a key benchmark for the performance of this modeling approach.

Moving to cognitive and ontology-based methods, the concept of affordance (Gibson,1979) seems particularly suitable to link the attributes of features in the built environment to the agents that inhabit it. Agent based models constitute core applications of system thinking and complexity theories of cities (Batty, 2007). They may therefore express connectedness between systems and sub-systems, identifying a target area based on the distribution of affordances in the built environment. In this case, the performance benchmark may lie in probing the extent to which a multi-agent model integrating a manageable set of affordances would be ontologically binding for the systemic connectedness between the features of interest.

Finally, mereotopology closes the review of modeling approaches as a non-metric option for spatial reasoning. Mereotopological regions bridge part-whole and locational relations, including relations of adjacency, overlap and containment, and could effectively express the embeddedness of the features of interest in multiple other features. They also allow for transitions in the configuration of these relations, as new information arises, or if the situation changes. Nonetheless, based on extensional mereology, mereotopological conceptualizations do not offer a straightforward solution to represent systemic connectedness between parts with a spatial extension, particularly in case of spatial disjointness between them, defined as the lack of overlaps between them. Nonetheless the principle of monotonicity of connection with respect to parthood as following the same order of parthood from part to whole provides the basis to conceptualize systemic connectedness between parts and wholes even in case of disjointness between the parts (Varzi, 2007, p. 969 and p. 981).

Since the extensional view of classical mereology focuses on actual parts and is not concerned with the non-spatial properties of these parts, any definition of connectedness based on the properties of a feature is not relevant to classical mereology. Probing the possibility to devise a formal definition of the features of interest that does not rely on their properties or attributes, but rather exclusively refers to its spatial or physical configuration, may provide a key benchmark for the performance of this modeling approach.

This range of approaches provides a rich overview of the different ways in which spatial planning and spatially explicit policy making can explain existing or intended spatial configurations. This overview orients planners and policy makers in the selection of modeling options, to account for the systemic connectedness of the geographical entities and phenomena at stake in the target areas of regulations or policies.

To do so, this proposal focuses on solutions to represent the systemic connectedness of a portico in its relationship to the morpho-typological units it is embedded in, and along the whole body of porticoes in the city, by a single digital model. In other words, it explores which aspects of this double systemic connectedness can be comprehensively represented by integration of different variables in a single model, and which ones would require the creation of additional models, following each modeling approach.

8. References

Interviews

June 2022, e-mail correspondence with Dino Borri, Professore emerito, Tecnica e pianificazione urbanistica, DICATECh, Politecnico di Bari.

October 6th, 2022, meeting with Arch. PhD Federica Legnani, Responsabile, Unità Intermedia Portici Patrimonio Mondiale, Direzione Generale, Comune di Bologna.

October 12th, 2022, online video call with Francesco Ceccarelli, Professore ordinario, Storia dell'architettura, Dipartimento di Architettura, Università degli Studi di Bologna.

October 24th, 2022, meeting with Marco Gaiani, Professore ordinario, Disegno, Dipartimento di Architettura, Università degli Studi di Bologna.

October 28th, 2022, meeting with Maria Beatrice Bettazzi PhD, Unità Intermedia Portici Patrimonio Mondiale, Direzione Generale, Comune di Bologna.

November 14th, 2022, online video call with Samantha Trombetta and Valentina Disarò, Unità Intermedia Progettazione Urbanistica Ufficio di Piano, Dipartimento Urbanistica, Casa e Ambiente, Comune di Bologna.

May 21st, 2023, online video call with Matteo Cassani Simonetti, Professore Associato, Storia dell'architettura, Dipartimento di Architettura, Università degli Studi di Bologna.

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