Operationalizing places in GIScience: A review

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Abstract

The space–place dichotomy has long been discussed in geography, psychology, philosophy, and more recently in geographic information science. The attempts to integrate vague notions of place into geographic information systems (GIS) constitute the foundations of the place-based GIS stream of research, but the rationale and methods for operationalizing place differ considerably in the literature. We present a literature review in an attempt to identify and discuss the distinct yet overlapping frameworks that aim to bridge the gap between space, place, and GIS. The review shows that most studies designed knowledge-based models in the urban context based on concepts drawn from human geography. Using mixed methods, we synthesize the findings, thus encouraging future research in building new conceptual and methodological models that are able to expand and solidify the scope of place-based GIS.

1. Introduction

A decade ago, Goodchild and Li (2011) called for an integration of the place-based viewpoint into geographic information science (GIScience) and systems (GIS). This commitment has grown in the literature through distinct attempts to formalize and operationalize the elusive human-centered notion of place using GIS as tools and GIScience as the multidisciplinary paradigm (Merschdorf & Blaschke, 2018). The main aim of these attempts is ultimately to confront the subjective character of places shaped by human experience and discourse with the objective coordinate-based space upon which systems and standards rely (Winter, Kuhn, & Krüger, 2009). In GIScience, the concept of "place-based GIS" and the terms *placial/platial* have emerged to characterize the novel approaches being applied to incorporate place into geographic information technologies, as opposed to the traditional spatial perspective (Cho & Yuan, 2019; Gao, Janowicz, McKenzie, & Li, 2013). The term *platial* as an adjective seems to have been first used by Casey (1993) in the context of environmental philosophy, whereas in the GIScience literature scholars have employed both *platial* and *placial* to designate place-based concepts and methods (Cho & Yuan, 2019; Wagner, Zipf, & Westerholt, 2020). Nonetheless, the *platial* stream of research in GIScience is still fragmented since the frameworks utilized to formalize, operationalize, and model *platial* concepts are grounded in different theoretical and methodological foundations, which in turn are designed to answer specific research questions (Hamzei, Winter, & Tomko, 2020; Purves, Winter, & Kuhn, 2019).

The exploratory character of most place-based GIS research demonstrates the lack of consensus in the community regarding the definitions and conceptualizations of place (Wagner et al., 2020). Consequently, the interface

between place and GIScience seems to be rather disconnected in terms of theory and methodologies, mostly because it is a relatively new frontier of investigation. While suggestions for future directions toward operationalizing place within GIS or through the use of geoinformation are abundant in the literature, actual attempts to integrate place into the GIS framework are relatively infrequent (Westerholt, 2019). Obtaining the current picture of how literature has been working towards place-based GIS becomes crucial in understanding and characterizing the different efforts made in this scope, through providing similarities, discrepancies, and future research avenues. Previous reviews have contributed significantly to mapping, compiling, and investigating the status quo of the construct of place within the context of GIScience and place-related research. Merschdorf and Blaschke (2018) outlined an in-depth framing of multi-disciplinary and multi-paradigmatic place-related studies, arguing that place-based GIS has asserted itself as a valid stream within the GIScience research agenda. Purves et al. (2019) contextualized and formalized the notion of place grounded on principles and standards of information science. In the same year, Hamzei et al. (2020) conducted a review to identify the numerous facets and terminologies to which place has been attributed in GIScience, geography, social sciences, and environmental psychology. More recently, Wagner et al. (2020) systematically reviewed place-based studies in GIScience and performed classifications according to the respective conceptual frameworks, data, methodologies, and research objectives.

In this article we aim to review the efforts that have effectively operationalized the construct of place, and thus have contributed to translating the abstract construct into components, models, formalizations, and practices that can be incorporated into GIS or constitute the foundations of place-based GIS. Therefore, the rationale behind this review is to take a step further from the previous reviews by narrowing down the search to studies that have designed solutions to bridge places and systems through real-world, artificial, or suggested applications. Although we focus on the operationalization of place, the step of formally describing, defining, or characterizing the construct becomes imperative prior to general-purpose or domain-specific implementations. On those grounds, we outline our research question: how is place formalized and operationalized within the scope of GIScience and place-based GIS? To address this question, we conducted a mixed-method literature review in an attempt to map, organize, and synthesize the existing contributions as well as to encourage new studies in the field. The remainder of this article is structured as follows. In Section 2, we present the methodology. Section 3 presents our results and an initial discussion of our findings, which is concluded in Section 4. Section 5 presents some concluding remarks.

2. Review method

Our mixed-method literature review follows the guidelines and suggestions made by Snyder (2019), Tranfield, Denyer, and Smart (2003), and Paré, Trudel, Jaana, and Kitsiou (2015). We classify our review as mixed-method due to the fact that our methodology combines elements that characterize systematic, semi-systematic, and theoretical literature reviews. For the selection process, we followed the PRISMA methodology for a systematic search of the relevant literature on the topic (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). Our results and discussion are based on content analysis and narrative synthesis of the selected papers. The selection process of the studies reviewed is schematized in Figure 1, with information regarding each step. First, we defined a search query in order to retrieve articles that explicitly used the terms platial, placial or place-based GIS within the scope of GIS and GIScience:

SQ = ((“placial” OR “platial” OR “place-based GIS”) AND (“GISc” OR “GIScience” OR “GIS” OR “geographical information” OR “geographic information”))

The use of these terms is at the heart of research that ultimately aims to bridge the gap between places as perceived by people and their spatial footprint in the context of GIS and spatial information. We applied the query for full-text search without language or year of publication restrictions in three open academic databases on the web: Scopus (n = 107), Web of Science (n = 21) and ACM Digital Library (n = 6), retrieved on March 15, 2021. After merging the results and removing duplicates, the abstracts of the remaining papers were screened to select studies that would pass to full-text screening. We used the following rule to select the papers based on their abstracts: (a) the abstract must mention the terms *placial*, *platial* or place-based GIS in the context of GIScience, GIS, geoinformation/geoinformatics or spatial information, or must discuss the place–space dichotomy, the construct of place, or place-related concepts within GIScience. The abstract screening resulted in the selection of 38 papers, published both in journals and conference proceedings. Subsequently, we screened the full papers for eligibility using the following rule: (b) the study must outline tangible integrations of the construct of place into standards, principles, and practices of (geographic) information systems and knowledge representation. We must emphasize here that we sought papers that operationalized solely the construct of place itself, thus not including derived psychology-based concepts such as sense of place or place attachment (Acedo & Johnson, 2020; Jenkins, Croitoru, Crooks, & Stefanidis, 2016).

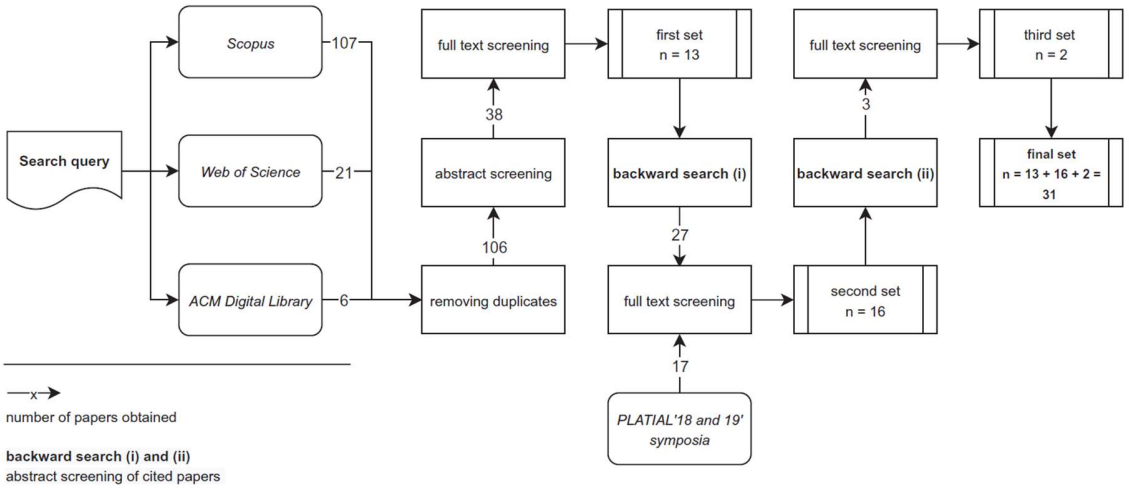

Figure 1. Steps of the selection process of papers for the literature review.

We then performed a backward search of the first set of papers that passed the full text screening (*n* = 13). The first backward search involved applying abstract screening rule (a) to all the references cited in the first set of papers, which yielded 27 papers. During the abstract screening of references, we came across the proceedings of the PLATIAL '18 symposium (Westerholt, Mocnik, & Zipf, 2018), cited in the work of Giordano and Cole (2020). Its *platial* research agenda within GIScience was found to be rather pertinent to our search criteria, consequently leading us to include the 17 papers of PLATIAL '18 and PLATIAL '19 in the following full text screening. Screening using rule (b) resulted in the second set of papers that were included in the review (*n* = 16). The last step of the selection process was to replicate the backward search using the same rules on the second set of papers, which

yielded a third set of papers (*n* = 2). Consequently, the final set of papers included in the review consisted of the first, second, and third sets, amounting to 31 pieces of research from journals and conference proceedings.

Before carrying out the review, we used the VOSviewer software to apply an exploratory text analysis of the title and abstract content of two different sets: the final set of studies (*n* = 31) and the entire data set first encountered in the search query (*n* = 106). In both cases the chosen parameters were: full counting of the words, five as the minimum number of occurrences, and the default choice of selecting the 60% most relevant terms. Our aim was to obtain some initial insights for interpretation of the landscape of the place-based GIS research. As for the review itself, the methodology was twofold: content analysis alongside initial interpretations and narrative-based discussion of the findings. This approach allowed us to combine objective and subjective interpretations which ultimately worked best for a scope that makes use of different conceptualizations and methodologies, consequently having different objectives and outputs. First, we classified and identified several aspects regarding each paper, including the research scope, places, research objectives, conceptual frameworks, formalization of the concepts, methodological frameworks and data (Figure 2). Furthermore, we identified and elucidated the ways in which the studies formalized and/or operationalized the construct of place, including their limitations and contributions. The next step was to discuss the findings, so as to try to answer the proposed research question, synthesize similarities, discrepancies, and trends, and to address potential research pathways in the field. We also framed our discussion within the place-based GIS research agenda.

3. Results and initial discussion

3.1. Bibliometrics

We performed the first network bibliometric visualization of word occurrence in both the titles and abstracts of the data set encountered in the first query after removing duplicates (106 studies). Figure 3 shows the four main clusters identified. The most frequent terms encountered together (place, space, GIS and GIScience) not only reflect our search query, but also confirm how place is frequently mentioned in conjunction with space, revealing how place-based research within GIScience is permeated by the space–place dialectics. Other terms such as object, scale, and model suggest the operationalization and formalization of the notion (also an identified term) of place. Aside from common concepts approached in GIScience, the word neogeography appeared as a recurrent term, which is indeed a field often concerned not only with the abstractions people build to make sense of their space, but also with addressing the construct of place (Adams & McKenzie, 2012; Warf & Sui, 2010). The term geography was also common, as most of the conceptual backgrounds that ground place-based studies come from the field of human geography (Wagner et al., 2020). During abstract and full-text screening, we recognized several areas of GIScience that are involved with place-based research, including volunteered geographic information (VGI), neogeography, location-based services, ontology, semantics, user-generated content analysis, public participation GIS (PPGIS), and uncertainty representation. This initial overview is in conformity with the findings of Merschdorf and Blaschke (2018), who recognized the main streams of GIScience research that have been engaged in place-based investigation. Furthermore, despite the word *platial*/*placial* being present in the search query, it did not come up as a frequent word based on the parameters we used. Lastly, the terms *human*, *social medium*, *user*, and *bottom* are interesting cues associated with the conceptual landscape of place-based research.

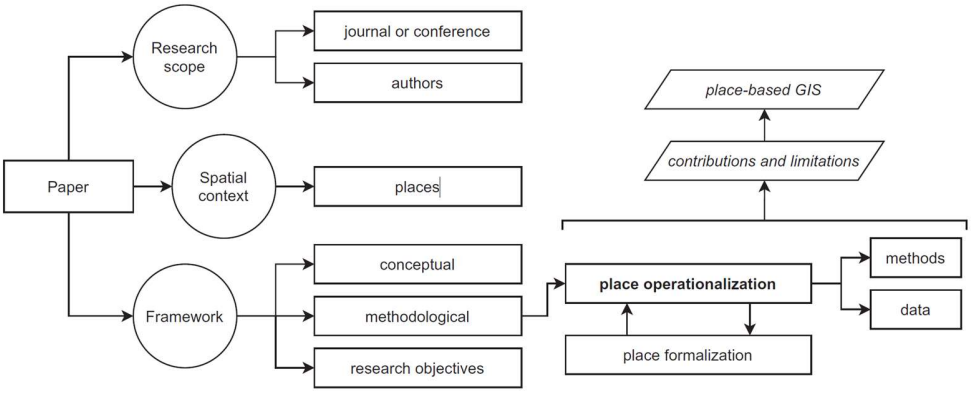

Figure 2. Diagram illustrating the categories for identification, classification, and interpretation of the review.

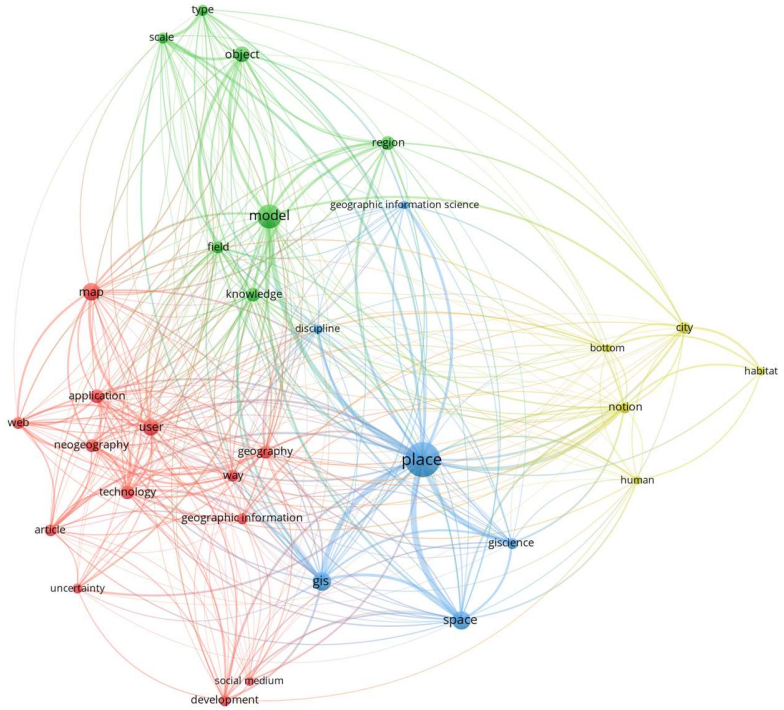

Figure 3. Network cluster map of the word occurrences found in the titles and abstracts of the papers first obtained from the search query.

Of the final set of 31 papers, 13 were published in journals and 18 in conference proceedings. We also carried out a word occurrence bibliometric analysis with the selected papers for final review (Figure 4). The term *place* appeared in the central position, surrounded by other different word clusters. In this case the word *platial* occurred in the same word cluster where the terms *location* and *information* are found. Terms such as *pattern*, *framework*, event, and *activity* suggest a shift towards works that lean toward the operationalization of the concept of place. As for the term *affordance*, one of the pioneer works on operationalizing the construct was conducted by Jordan, Raubal, Gartrell, and Egenhofer (1998) using the psychological theory of affordance, which later on was also implemented or referenced by other place-based studies. A comparison of the word occurrence network from the selected papers with the previous one (Figure 3) shows that the terms *neogeography*, *geography*, and *GIScience* are absent. This reflects a change from papers that were more focused on theory, suggestions and literature reviews of the place-based stream, but not necessarily outlining operational frameworks of the notion of place. In the next

subsection, we discuss the findings regarding the main research areas in which the selected papers for review are enclosed. Furthermore, Figure 5 displays the year of publication of the selected articles, while Figure 6 shows the journals and conferences that published at least two papers from the set of reviewed papers.

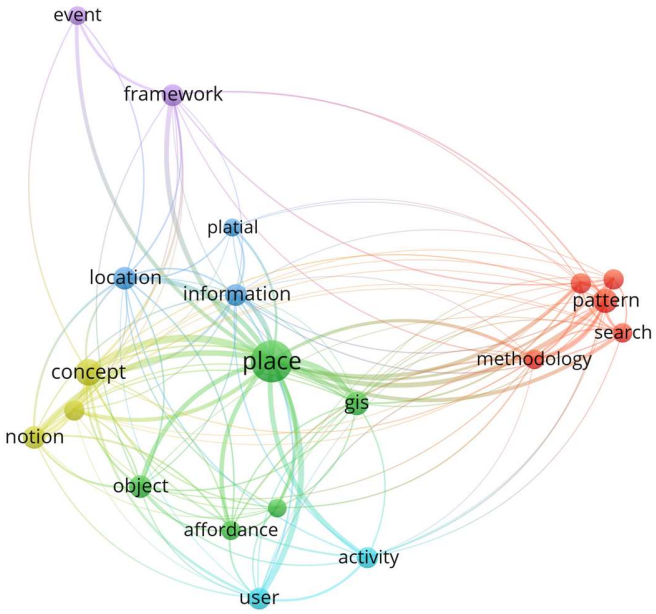

Figure 4. Network cluster map of the word occurrences found in the titles and abstracts of the papers selected for review.3.

3.2. Scope

The designated research scope within which the journals and conferences of the final set of papers fell are shown in Figure 7. From the set, 22 studies (71%) are pieces of research found in journals or conferences that are explicitly categorized within the scope of geographic information science. As for the remaining articles, their identified areas (spatial information science, information science, system science, and remote sensing) constitute rather solid disciplines, yet they intimately connect to, overlap with, or have major influence on GIScience. Hence, efforts to operationalize the notion of place within the place-based GIS stream are effectively part of the GIScience research agenda, although still not quite solidified or integrated. Furthermore, two papers (Janowicz, 2009; Plewe, 2019) are placed within the field of digital humanities, the interface between humanistic inquiry and digital technologies, and from which the subfield of spatial humanities (or geohumanities) emerges as a research agenda whose core lies on the construct of place built upon literary works, geographic narratives, personal histories, and other cultural products (Pavlovskaya, 2017). We then pinpointed the main research areas in which the authors of the selected papers are engaged (Figure 8). For each paper, one or two disciplines were identified based on the authors' publications, institutes, and departments. The top four fields of GIScience, spatial cognition, computer science, and geography reveal the disciplinary foundations of the place-based GIS stream of research. Similar to the previous list, the other fields are closely linked to GIScience or are examples of disciplines that have approached place in the context of GIScience such as urban studies and environmental psychology. As for history, although the work

developed by Giordano and Cole (2020) is published in a GIScience journal, the disciplinary context of both the study and the researchers falls within the historical sciences.

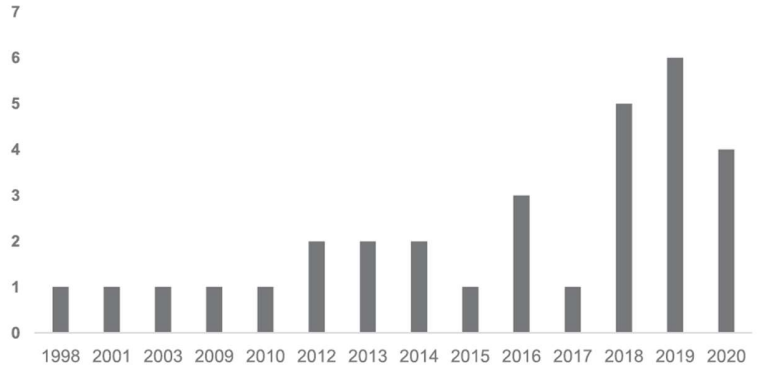

Figure 5. Year of publication of the selected studies.

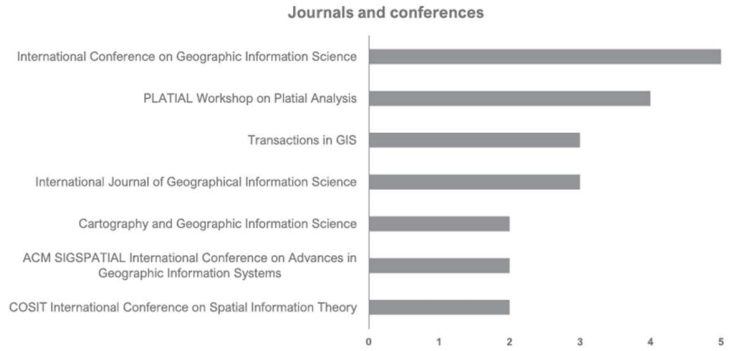

Figure 6. Journals and conferences that published at least two papers from the final set for review.

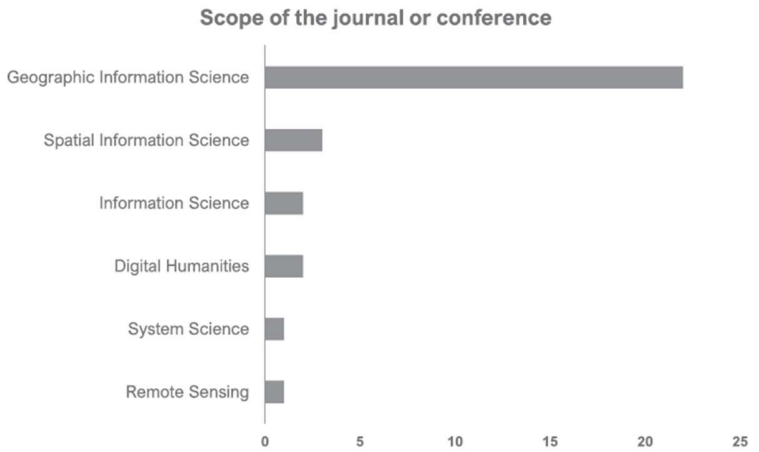

Figure 7. Research scope of the final set of papers according to their respective journal or conference.

Figure 8. Main research fields in which the authors of the selected studies are primarily engaged.

3.3. Places and context

Regardless of the methods or conceptual frameworks utilized by the authors to formalize and operationalize the construct, places are still bound to their spatial location and environmental context. Table 1 presents a brief description of the places that were used for applying, exemplifying or describing the different frameworks designed in the selected papers. We classified some papers as not applicable when the studies did not provide a concrete exemplification when formally characterizing place or when conceiving a model, for instance. In these cases, some papers provided solid formalization of the concepts as well as formal description of operations between concepts, yet the framework was not illustrated with potential examples. Other papers showed both a lack of examples as well as underdeveloped operational and formal attributes of the concept of place.

Approximately 55% of the papers worked with examples and implementations of places whose scale is embedded within the urban landscape (e.g., points of interest, landmarks, green urban areas), where finer-grained representation of phenomena is facilitated as cities are loaded with place-based information, as well as being the scenario where most of the world's population live. On the other hand, some studies applied their frameworks to place-based notions with the spatial resolutions of cities, counties, and other administrative regions (Gao et al., 2013; Janowicz, 2009; Jones et al., 2001; Vögele et al., 2003). We also found studies that operationalized places with generalized examples that were not attached to existing cities or regions, such as restaurants (Jordan et al., 1998) and airports (Papadakis, Baryannis, & Blaschke, 2018). In the works of Papadakis, Resch, and Blaschke (2016), Papadakis, Petutschnig, and Blaschke (2018), Papadakis, Baryannis, Petutschnig, and Blaschke (2019), Papadakis, Resch, and Blaschke (2020), shopping areas were the places utilized as the object of study for their function-based model, which was first published in 2016 and has been substantially developed over the years. Finally, two articles carried out studies on unusual places: dream settings and “shithole” (sic). The former is found in the paper of Enescu et al. (2020), in which the authors developed data models for analyzing and visualizing the spatial patterns of dreams. According to them, dream settings are examples of *platial* knowledge and place-making, carrying both physical and social elements of a person's surroundings. As for the place “shithole”, Comber, Butler, Malleson, and Schafran (2018) constructed a model to evaluate geotagged Twitter content and tested it in the context of place-based stigma and discourses of denigration in social media platforms.

Table 1. Places that were conceptualized, formalized, modeled, or analyzed in the studies selected.

Paper	Place	Paper	Place
Jordan et al. 1998	Restaurant	Papadakis and Blaschke, 2017	Shopping areas in Santa Barbara County (California, US)
Jones et al. 2001	Administrative regions in Scotland (Scottish Borders, West Lothian, Midlothian and City of Edinburgh)	Papadakis et al. 2018	Shopping areas in London (UK)
Vögele et al. 2003	Frankenwald region (Germany) and its supra/sub-regions	Comber et al. 2018	Places refered as "shitholes" by users of social media in the UK
Janowicz, 2009	City of York (UK)	Blaschke and Piralilou, 2018	NA
Scheider and Janowicz, 2010	Points of interest: e.g., buildings and markets	Papadakis et al. 2018	Airport
Winter and Freksa, 2012	Places in Federation Square (Melbourne, Australia): e.g., streets, train station and museum	Westerholt et al. 2018	NA
Alazzawi et al. 2012	Points of interest: e.g., cinema, art gallery, high school and cricket ground	Cho and Yuan, 2019	Primitive spatial units of criminologial places: streets and intersections in Dallas (US)
Gao et al. 2013	Cities/towns in Santa Barbara County (California, US) and Beijing Subway System (China)	Papadakis et al. 2019	Shopping areas in London (UK)
Scheider and Purves, 2013	Landscape features of mountain routes	Davies, 2019	Railway crossing
Scheider and Janowicz, 2014	Farmers Market in Santa Barbara (California, US) and Place de La Bastille (Paris, France)	Purves et al. 2019	NA
ElGindy and Abdelmoty, 2014	Points of interest and landscape features: e.g., hotel, beach, park and canyon	Wu et al. 2019	Toponyms in Haidian District (Beijing, China); e.g. Peking University, Weiming Lake and Tsinghua Garden
Quesnot and Roche, 2015	Landmarks in Paris (France): e.g. Eiffel Tower, Place de la Concorde and Jardins du Trocadéro	Plewe, 2019	Places relevant to the early (1830–1930) history of The Church of Jesus Christ of Latter-day Saints and its members
Blaschke et al. 2016	Mirabell gardens in Salzburg (Austria)	Iosifescu Enescu et al. 2020	Dream settings
Mennis and Mason, 2016	Safe places in Richmond, Virginia (US)	Giordano and Cole, 2020	Trajectories and places of the Holocaust experienced by two individuals
Papadakis et al. 2016	Shopping center	Lai et al. 2020	Points of interest in Camden Borough (London, UK): e.g., Euston Railway Station
		Papadakis et al. 2020	Shopping areas in London (UK)

Note: NA = not applicable: studies that did not specify a place or location when developing and implementing their framework.

3.4. Research objectives

We assessed the various research aspects explicitly stated on the selected papers, such as the motivation of the study, research questions, and aims and objectives. After interpreting how the authors positioned their work with regard to these research characteristics, we split the main research targets into four categories, shown in Figure 9: formalization (26%); model (48%); data (10%); and analysis (16%). We classified each paper into a single category as the main subject of the study as whole, although many articles approached, mentioned, or developed other components that fit other targets. Most of the studies did not explicitly formulate research questions mainly because of their design science-oriented methodology, in which the authors proposed knowledge-based models and frameworks in order to embed places in geographic information systems. Nonetheless, all articles showed clear motivations that in some way relate to efforts to bridge the gap between human-centered notions of place and different components of GIScience, including GIS themselves. Figure 9 displays the four categories in a circular diagram pattern in an attempt to show how the main targets are placed within a framework of dealing with phenomena in (geographic) information systems and science: formalization of the concepts is required to structure knowledge and subsequently build a model that represents the phenomenon, in which the best data structures will be chosen to carry out analysis, leading to the refinement of the theory and consequently of the formalizations and models

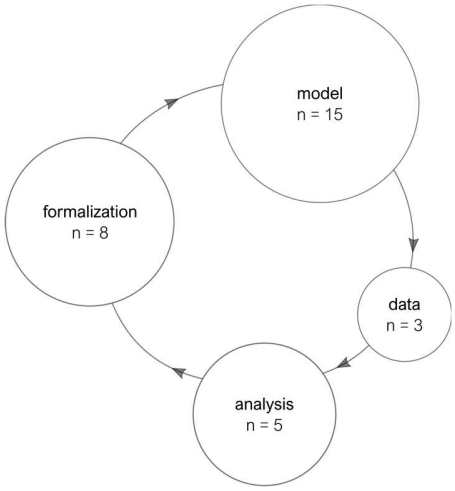

Figure 9. Main categories of the research objectives of the papers reviewed.

To elucidate our interpretation, we clarified how the categories were distinguished. The model category integrates the works that focused on building, designing, and implementing operational models of places within GIS environments. The objectives of these papers varied from designing prototypical to fully operational models within GIS, either using or not using real-world examples based on their proposed frameworks (e.g., ElGindy & Abdelmoty, 2014; Jordan et al., 1998; Papadakis et al., 2019). As for the formalization category, it includes the papers whose main stated objectives concerned formally describing place and related concepts through different methods for further integration and operationalization in geographic information systems and spatial analysis (e.g., Blaschke & Piralilou, 2018; Scheider & Janowicz, 2014). Papers that fell within the analysis category were characterized by having their main focus on switching the traditional spatial analysis to *platial* analysis, although some of them

included building a place-based model or framework as well (e.g., Gao et al., 2013; Lai, Lansley, Haworth, & Cheng, 2020). Articles whose objectives were categorized as data had as their main goals to propose new data models, classifications, or structures for specific scenarios (e.g., Plewe, 2019; Quesnot & Roche, 2015). Again, several papers did in fact fall into more than one category, but our classification considered the research focus according to the main objectives stated by the authors.

3.5. Conceptual framework

Place and related constructs are conceptually approached in the selected works through the use of relevant literature as well as through interpretation of these concepts. First, we present the most exploited sources in the literature for conceptually contextualizing the definition of place. Then we discuss how the authors shaped and framed the concepts in order to set the ground for their construct formalizations and operationalizations. The research fields from which the conceptualizations were drawn included human and critical geography, social sciences, psychology, and urban studies. Figure 10 shows the sources that were cited in at least two papers when the authors provided theoretical foundations for their conceptual interpretations and further formalizations. The two most used references were the works of Tuan (1977) and Relph (1976), both well-known examples of phenomenological approaches to theoretical studies of place, mentioned by 61% and 42% of the papers, respectively. Other important references within human and critical geography include the works of Curry (1996), Tuan (1979), Couclelis (1992), Cresswell (2004), Agnew (1987, 2011), and Seamon (1980). These books, chapters, and papers fall mostly within the fields of human geography, yet they carry confluences with social sciences and anthropology. Within the works cited at least twice, we also found examples in psychology (Gibson, 1979), architecture, and urban studies (Lynch, 1960) as well as GIScience (Winter & Freksa, 2012). The study by Winter and Freksa (2012) is one of the papers reviewed but was referenced in three different studies in their theoretical background.

Throughout the theoretical discussion on the concepts of place found in the selected papers, we came across differences concerning whether researchers developed their own conceptualizations of the construct based on the interpretation of existing studies or drew definitions directly from the literature for their conceptual framework. Of the 31 studies, 17 (55%) built their conceptual framework through explicitly discussing and interpreting the literature, while also providing additional input in how the concept is defined or characterized according to their objectives. Thirteen (42%) did not further establish particular understandings of the constructs, but used existing definitions and discussions found in the literature to support their research. Finally, one paper did not sufficiently discuss or provide conceptualizations of the construct. Vögele et al. (2003) did not put forward a conceptualization of the notion of place, but argued that place names are traditionally documented in gazetteers whose geographic reference is based on coordinate-based spatial footprints.

With regard to place in the conceptual context of GIS and GIScience, the authors of the selected studies provided different backgrounds. The earliest study from Jordan et al. (1998) argued that the concept had been neglected within GIS. Twelve years later, Scheider and Janowicz (2010) said that the ambiguity of place had only recently been explored in GIScience, developing their ideas based on the conceptualizations structured by Jordan et al. (1998). In the most recent paper, Papadakis et al. (2020) argued that existing formalizations of place within GIScience focus on semantic enrichment of spatial information, affordances, qualitative spatial relationships and

cognitive representations of space. The main topics found in the papers for contextualizing place within GIScience and GIS were the following: (a) challenges with data structures (vector and raster) and representation (object and field-view); (b) issues with place name databases such as digital gazetteers; (c) classic concepts such as ambiguity, semantics, ontology, vagueness, accuracy, topology, and precision of places in the debate of GIScience; (d) place and reference coordinate systems; (e) place in the semantic web, location-based services, VGI, geographic information retrieval, PPGIS, social media, and crowdsourced data; (f) places as points of interest or landmarks in the urban context; (g) neogeography, nave geography and critical GIS.

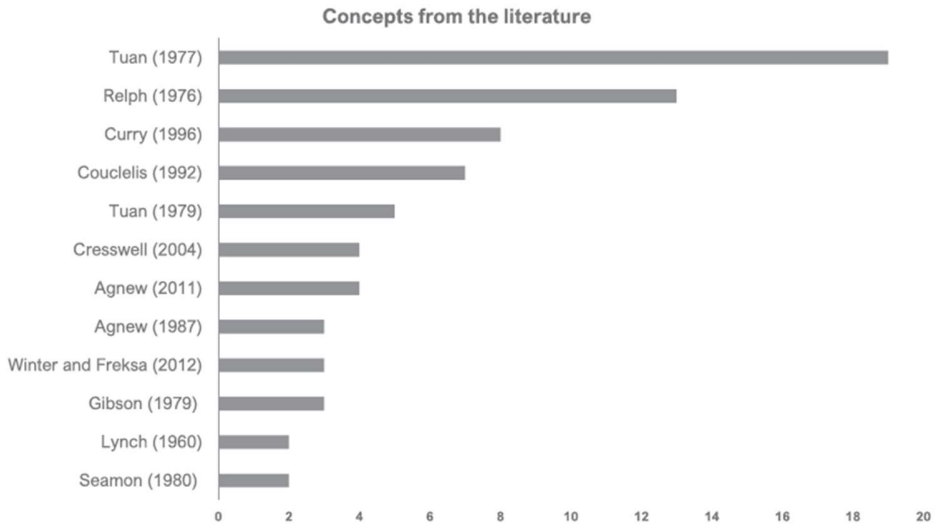

Figure 10. Works used as reference in at least two papers as part of the theoretical background.

3.6. Formalizing the concept of place

In order to translate conceptualizations of place that are framed in qualitative frameworks, one must formally characterize the concepts, enabling their integration into information systems. Here we foreground the several different approaches that the authors took when formally describing the concept of place. Table 2 provides brief descriptions of the components, models, classifications, and methods that the different papers utilized to formalize the construct. The table provides a summarized overview of each article's main conception in depicting the fundamental constituents of place according to its conceptual framework and research objectives. In some papers, the task of disconnecting formalization and operationalization of the construct was not thoroughly fulfilled because they were carried out concurrently during the construction of the models. The degree to which the concept was formalized varied greatly among the selected papers, from simple concept postulations to extensive mathematical designations that portray places in light of information theory.

The procedure to formally characterize the concept of place varied according to how detailed the implementation or suggestion of implementation was, as well as the research goals each paper proposed. Nonetheless, we found many approaches in this first step of integrating place into (geographic) information systems. Creating entity-relationship diagrams, conceptual frameworks, or models that are visually represented by different elements that characterize or make up the construct of place was one of the main ways in which researchers structured their

concepts. In this case some papers only built visual representations of their frameworks without providing formalized descriptions (Papadakis, Baryannis, & Blaschke, 2018; Quesnot & Roche, 2015). Other papers built intricate models of place with both pictorial representations and well-developed statements to explain their model, either context dependent or independent (Papadakis, Petutschnig, & Blaschke, 2018; Plewe, 2019). A few papers did not deliver solid schemes aimed at holding the concepts from the literature, providing only qualitative definitions whose operationalization was suggested further through examples, resulting in an overall poor formalization (Blaschke, Lang, Tiede, Papadakis, & Kovacs-Gyori, 2016; Davies, 2019; Janowicz, 2009).

Within the papers that utilized mathematical statements or descriptions to describe place, the level of elaboration also varied. We found papers that used set-theoretic statements to describe places, and location according to human discourse (Vögele et al., 2003; Winter & Freksa, 2012); logic-based statements that formalize the composition and functionality of a place (Papadakis et al., 2020; Scheider & Purves, 2013); equations that integrate the spatial, temporal, and semantic information of places (Lai et al., 2020); fuzzy formal concept lattices of places represented by graphs (Wu, Wang, Shi, Gao, & Liu, 2019); high-order logic statements, axioms, and definitions of place reference systems (Scheider & Janowicz, 2014); ontology-based frameworks to organize place-based knowledge for distinct implementations (Alazzawi, Abdelmoty, & Jones, 2012; ElGindy & Abdelmoty, 2014; Jones et al., 2001); and other examples where entities and relationships that make up place were portrayed through the use of different mathematical formulas, variables, and postulates. In such cases, regardless of any system or context dependency, formalization could allow better integration of the conceptual realm of place into GIS, although the procedures to carry out such operationalizations also varied in the papers. In the next subsection we present the distinct examples and methods used in the papers to transform their structured concepts into operational practices.

Irrespective of how the authors built their formalizations, we observed that some components were often explicitly described as being fundamental parts of the concept of place. First, the *where* element came up in almost every paper, demonstrating how location is regarded as an intrinsic dimension to the construct of place. In GIScience the concept of place is considered to be inherently attached to a portion of geographic space (footprint), and splitting the concepts into polar opposites does not seem to be on the research agenda of place-based GIS. The work of Relph (1976) brought up this discussion through examining the concept of place not as a separate concept from space, but as an intimate dialectical conceptual and existential dynamics between the two. In fact, the second most used conceptual reference in the selected papers is drawn from Relph (1976). Second, another fundamental part of place can be described as the *what* component, which, depending on the formalization, can represent place names (toponyms), place characteristics (functions, activities, affordances), and physical components, among others. Thirdly, not formalized as often as the *where* and the *what*, but certainly very relevant in several studies, we have the relationships between places (topological, semantic) and between people and places (sense of place, place identity). Finally, we also noted that some studies formalized their concept of place using the dimension of time, as according to the researchers, places can emerge, cease, evolve, transform, or even coexist with other places at the same location but at different times.

Table 2. Formalization: brief descriptions of the components, methods, and characteristics of place formalization for each study.

Jordan et al. 1998	Diagram of place definition: place has components of environment, actions/goals and agents (user models)	Papadakis and Blaschke, 2017	Model of place: self-contained building block containing spatial organization, composition (topological network) and function (offered activities)
Jones et al. 2001	Entity relationship diagram: place has place-type, centroid (location) and artefact. Place is a geographical concept with name, date, language and location	Papadakis et al. 2018	Composition patterns of places hold functions and components. Their composition rules hold occurence, property, hierarchy, correlation, topology, distribution, proximity and organization
Vögele et al. 2003	Regional connection calculus (RCC) is used to describe the upper and lower approximations of place name regions through units of reference in a tessellation and their topological relationships	Comber et al. 2018	Place model: user-generated content is decomposed into elements of other, own, facilities and personal
Janowicz, 2009	Places of historical facts: suggestions to use structured microtheories as conceptual reference models including thematic, spatial and temporal dimensions	Blaschke and Piralilou, 2018	Place as rule-based multi-scale objects and their relationships
Scheider and Janowicz, 2010	Entity relationship diagram of place: place has medium, surface, substance, affordance, time and location	Papadakis et al. 2018	Conceptual model: bridge space and place through a structured conceptual two-way interface. Place has location, affordance, equipment and extent
Winter and Freksa, 2012	A place P in a reference system X has boundaries specified by contrast (P against X\P)	Westerholt et al. 2018	Index sets: *platial* units are regions in a conceptual space C, which carries quality dimensions q1 x q2 x ... qn, the attributes of how people judge place similarity
Alazzawi et al. 2012	Entity relationship diagram of place: place-type class is associated with service-type class (activities, services and affordances)	Cho and Yuan, 2019	Conceptual framework: places are shaped in space and time by a event cluster, which is the uniqueness of a location and its components to afford the occurrence of these events
Gao et al. 2013	Place-based join: attributes from places (S) to the target place (T) based on their topological predicates (P). Place-based buffer: n-degree connected places based on their semantic relations	Papadakis et al. 2019	Set theory and logic-based statements: purpose, function, composition, components and data are the semantic resolutions of the place model
Scheider and Purves, 2013	Logical statements to describe inference tasks of places: place equipment (referents), place affordances (activities), place localization (space) and time	Davies, 2019	Conceptual model: diagram overlaying the mental semantic space onto the geographic space, places are the combination of location and sensory-motor properties
Scheider and Janowicz, 2014	Place reference systems: high-order logic axioms of place location, containment, affordance, equipment, identification and classification	Purves et al. 2019	Ontological commitment of place: place is an object with shared identification of a location which might be part of a network and participate in events
ElGindy and Abdelmoty, 2014	Model of place: place, place type, place activity, and their properties/interrelationships. A geographic place might be associated with multiple place-types and activities	Wu et al. 2019	Fuzzy Formal Concept Analysis (FFCA): places (c) are concepts with extent (X, footprint) and intent (Y, set of toponyms). There are part-whole hierarchies among places
Quesnot and Roche, 2015	VGI data classification: contains explicit, implicit, primary and secondary components of locational data and *platial* data	Plewe, 2019	Model of place: Qualified Assertion Model containing assertions about the place that describe existence, attributes, relationships and location
Blaschke et al. 2016	Places in geographic object-based image analysis: composite hierarchical entity that holds context, geometry, texture as well as semantic and spatial classes	Iosifescu Enescu et al. 2020	Data models: knowledge of space modeled in circles of intimacy (place cookie); 26 setting components of environmental conditions (setting spider); along with other pairs, the setting is paired with time (event spider)
Mennis and Mason, 2016	Conceptual model with three entities: place, location and subject. Place is the relationship between a subject and a location	Giordano and Cole, 2020	Model of place: place has scale, location, locale, sense of place, resolution and representation
Papadakis et al. 2016	Entity relationship diagram: place, space, functionality, functional class, spatial pattern, spatial properties, composition and functions	Lai et al. 2020	Place profile: place has toponym, location, activities and their time-based evolution
		Papadakis et al. 2020	Set theory and logic-based statements: purpose, function, composition, components and data are the semantic resolutions of the place model

3.7. Operationalizing places

3.7.1. Implementation and methods

Table 3 provides a brief summary of how the researchers implemented or exemplified their proposed frameworks. Similar to what we observed on the formalization process, operationalization was carried out with different methods and degrees of complexity. It is important to note that although some authors provided solid conceptual foundations and formalizations of place, they did not implement their model with data or more concrete real-world examples. In these cases, they suggested and discussed potential integrations of their schemes into real-world scenarios, information systems, or future applications in the context of GIScience. Within these papers, suggestions included descriptions of future operationalizations in case studies, data classification examples, illustrations, possible methodologies, and future challenges. Therefore, not all studies established both formal characterizations of the concept and their operational application, yet they all outlined tangible examples in which the boundaries between (geographic) information systems and the notion of place were merged.

The operationalization of the constructs was heavily dependent on the research objectives of the papers, as some studies only proposed the design of a model based on a specific theoretical background while others additionally wished to apply their framework to specific tasks. Such tasks included place-based queries (Papadakis et al., 2020), place-based GIS operations (Gao et al., 2013), information retrieval based on equivalent or nearby places (Jones et al., 2001; Purves et al., 2019), representation of geohistorical information (Plewe, 2019), footprint approximations to infer the hierarchy of place name regions (Vögele et al., 2003), place-based hypothesis testing (Mennis & Mason, 2016), exploratory data analysis (Cho & Yuan, 2019), data classification (Quesnot & Roche, 2015), and data representation (Iosifescu Enescu, Bär, Beilstein, & Hurni, 2020). Most of the studies followed the steps of first conceptually framing the problem, then using different methods of knowledge representation for their formalization, and finally applying their representations in a real case study or a hypothetical example. Below we present the different sources and types of data utilized in the studies to test, adjust, or demonstrate their place-based models. We also categorized the main methodological approaches used in the papers: (a) knowledge-based; (b) knowledge-based and empirical; and (c) theoretical. Most papers (71%) were characterized by the knowledge-based approach. In these papers the authors took a one-way path that involved constructing their model guided by conceptual foundations developed based on the existing literature. Depending on the paper, the model was then fully, partially, or theoretically applied to one or more places. There were studies that combined empirical and knowledge-based approaches (19%), in which researchers either built their models and then adjusted them according to the data or designed the framework itself with the aid of data. Finally, the theoretical category consists of papers that theoretically elucidated starting points, methods, and pathways toward tangible solutions aimed at incorporating the elusive notion of place into (geographic) information systems and science (Blaschke & Piralilou, 2018; Davies, 2019; Janowicz, 2009).

Table 3. Operationalization: brief descriptions of the components, methods, and characteristics of place operationalization for each study.

Jordan et al. 1998	A restaurant was theoretically modeled using its actions, purposes and intentions and three different hierarchy levels: "why", "what" and "how". The authors suggested the implementation in GIS for place-based queries	Papadakis and Blaschke, 2017	The composition pattern was built to retrieve all places that offter the functions of a shopping center in Santa Barbara County (US). The model offers the projection of functions onto space and the infusion of space with functional context.
Jones et al. 2001	Information retrieval in archaeology: example of "axes in Edinburgh" should include location and thematic similaritiy metrics between query and candidates, including distance, travel time and their topological relationships	Papadakis et al. 2018	Function-based compositions of place: empirical pattern (spatial analysis and statistics) and theoretical pattern (text analysis) of shopping malls in London (UK)
Vögele et al. 2003	The upper and lower approximations of an area in Bavaria (Germany) are projected onto a reference tessellation to obtain qualitative spatial footprints through topo-mereolopgic relations between extensionally and intensionally-defined regions	Comber et al. 2018	The model was used to predict the 4 classes (other, own, facility, personal) of the tweets containing the place term "shithole" in the UK
Janowicz, 2009	Suggestions on how to incorporate the spatial dimension of place into the framework: place and time as additional first-class ordering principles for the microtheories of historical facts	Blaschke and Piralilou, 2018	Suggestions on how to incorporate the mathematical foundations of the central limit theorem, the brownian motion and the wiener process for scale detection and space partitioning in a potential place-based GIS
Scheider and Janowicz, 2010	Suggestions on interpretations and applications of their model to describe places (buildings, market places and landmarks) in the urban scenario	Papadakis et al. 2018	They decomposed the narrative of an airport into location, affordances and equipment. Then, the components are formalized into a hierarhical ontology and their spatial projection is described based on semantic relationships and design regulations
Winter and Freksa, 2012	Survey of place descriptions: ten place descriptions of a specific area of the city of Melbourne (Australia) were qualitatively analyzed based on the paper's proposed formalization	Westerholt et al. 2018	Suggestions on the *platial* counterparts of geostatistical concepts such as autocorrelation, heterogeneity and stationarity
Alazzawi et al. 2012	The place model was represented in OWL and built using frequency-based lexical analysis of place-type descriptions to derive their services and activities from different data sources	Cho and Yuan, 2019	Streets segments and intersections were used as the primitive units: clustering events, decomposing event distributions and identifying the similarity of event clusters of criminological places in Dallas (US)
Gao et al. 2013	Place-based operations were carried out to first seek the towns that are part of the Santa Barbara County (US) and calculate their total population. Then, a place-based query was conducted to retrieve subway stations in Beijing (China) serving more than one line	Papadakis et al. 2019	Implementation of three compositional patterns of place: theoretical, empirical and probabilistic. Expansion of their theoretical pattern using modal logic and statistical relational learning to identify and locate shopping areas in London (UK)
Scheider and Purves, 2013	Implementation through reconstructing a portion of a narrative written by a mountaineer to extract landscape features as semantic references and locations based on activity relations	Davies, 2019	Suggestions on extracting sensory-motor attributes from text analysis that can be linked to a GIS and allow queries, going beyond the spatial and semantic
Scheider and Janowicz, 2014	Implementation of their formal theory in a GIS workflow to compute and model a Farmers Market in Santa Barbara (US)	Purves et al. 2019	Illustration of their conceptualization using information systems. Examples of place-based meta-data, information retrieval from online sources and extraction of place properties
ElGindy and Abdelmoty, 2014	Extracted user-generated tags are translated to concepts of interest in their model of place. The tags were used to build semantics associations and the derived ontology was evaluated against existing ontologies	Wu et al. 2019	Implementation with places obtained from user-generated content in Beijing (China). Similar place concepts in the lattice are clustered into conceptual clusters and the simplified spatial hierarchies of places are generated. Questionnaire was carried out to validate the results
Quesnot and Roche, 2015	To exemplify their data classification of VGI, they provided sources of location-based user generated content in different places and described their characteristics according to the proposed model	Plewe, 2019	A relational database was built with assertions, statements and qualifiers. The place "Ogten Utah 4th Ward" (US) was decomposed in property, relationship and qualifier assertions. A query was implemented to retrieve the attributes from the place ID
Blaschke et al. 2016	Brief suggestion on the segmentation and classification of satellite imagery: water gardens are composed of water body, grass, built-up and bushes	Iosifescu Enescu et al. 2020	The data and meta-data models are implemented for visualizing dream settings in dream cartography: the setting spider is applied on a personal dreamland map of a test person
Mennis and Mason, 2016	Case study: place-based perceptions of safety among 139 adolescents enrolled in a longitudinal, georeferenced ecological momentary assessment (EMA) study of substance use in Richmond (US)	Giordano and Cole, 2020	Model implementation using testimonies of two Holocaust survivors
Papadakis et al. 2016	Their example illustrated the decomposition of a shopping center into functions, spatial patterns and spatial properties	Lai et al. 2020	Text mining and point pattern analysis to identify place names from Twitter data and clustering for estimation of their spatial extent. Creation of the place profile of geotagged tweets from Camden, London (UK)
		Papadakis et al. 2020	Implementation of their design pattern in searching shopping areas in London (UK): detection of the regions that qualify as shopping areas and score-based evaluation of each candidate area

3.7.2. Data

Of the 31 papers, 20 papers sourced and used data in at least one step in their formalization and operationalization process (Table 4). Data were not considered when not used with these specific objectives. For instance, the work of Westerholt, Gröbe, Zipf, and Burghardt (2018) used Flickr data but for visualization of geotagged social media content, which is outside the scope of our research question. Types of data included Linked Data, text data, documents, narratives, surveyed data, and geotagged social media data. With regard to sources, data were collected from Twitter, dictionaries, Wikipedia, OpenStreetMap, online gazetteers, questionnaires, and city council portals. In most cases data were only used to demonstrate and implement the models, representations, and frameworks. As seen in Table 4, we also identified whether the studies considered the dimension of time as part of their framework as a whole. We found that commonly the temporal component was expressly incorporated in the conceptualization and formalization of the construct, but not considered when implementing the proposed models. Characteristics of the data included: text from Wikipedia pages on specific places; place descriptions from a mobile location-based game; structured Wikipedia data extracted from DBpedia; land use data and points of interest from OpenStreetMap and GeoNames; georeferenced survey data collected from mobile devices; English dictionaries; historical documents, lexical databases, mountaineering narratives, and Twitter data.

Table 4. Description of the data used in the selected studies as well as if time was considered in their framework.

Paper	Data	Time	Paper	Data	Time
Jordan et al. 1998	NA	No	Papadakis and Blaschke, 2017	OpenStreetMap data	No
Jones et al. 2001	Digital gazetteers and thesauri data: place names	No	Papadakis et al. 2018	Dictionaries, design guidelines, Wikipedia and OpenStreetMap data	No
Vögele et al. 2003	NA	No	Comber et al. 2018	Geotagged Twitter data	No
Janowicz, 2009	NA	Yes	Blaschke and Piralilou, 2018	NA	No
Scheider and Janowicz, 2010	NA	Yes	Papadakis et al. 2018	Wikipedia data	No
Winter and Freksa, 2012	Wikipedia and surveyed data: place descriptions	No	Westerholt et al. 2018	NA	No
Alazzawi et al. 2012	Digital gazetteers, ontologies, dictionaries, lexical databases, Wikipedia and surveyed data: place-type definitions	No	Cho and Yuan, 2019	Crime incident data from the Dallas Open Data portal	Yes
Gao et al. 2013	DBpedia linked data: RDF data of places	No	Papadakis et al. 2019	Dictionaries, design guidelines, Wikipedia and OpenStreetMap data	No
Scheider and Purves, 2013	Descriptive narrative of places from mountaineering texts	Yes	Davies, 2019	NA	No
Scheider and Janowicz, 2014	OpenStreetMap data	Yes	Purves et al. 2019	NA	Yes
ElGindy and Abdelmoty, 2014	Tagzania website: place instances and tags generated by users	No	Wu et al. 2019	Check-in data from Sina Weibo (Beijing) and surveyed data	No
Quesnot and Roche, 2015	NA	No	Plewe, 2019	Historical documents (1830–1930) of The Church of Jesus Christ of Latter-day Saints and its members	Yes
Blaschke et al. 2016	NA	No	Iosifescu Enescu et al. 2020	Surveyed data and random dream reports collected from online repositories	Yes
Mennis and Mason, 2016	Georeferenced surveyed data	Yes	Giordano and Cole, 2020	Two testimonies of Holocaust survivors from Italy and Hungary	Yes
Papadakis et al. 2016	NA	No	Lai et al. 2020	Geotagged Twitter data	Yes
			Papadakis et al. 2020	Dictionaries, design guidelines, Wikipedia, GeoNames and OpenStreetMap data	No

4. Discussion

4.1. Operationalizing place: Contributions and limitations

One of the goals of the place-based GIS research stream is to design ways to concretely incorporate how people perceive their surroundings into the data, operational and analytical standards of GIS. Throughout our review, we observed several methodologies and outputs that were able to contribute to bridging this gap. Nonetheless, the final outputs varied significantly in the selected papers, and in most cases the frameworks were context-specific.

Within the selected studies, the works of Purves et al. (2019) and Scheider and Janowicz (2014) were the examples whose frameworks had the lowest degree of context or application dependency. Scheider and Janowicz (2014) designed a comprehensive place reference system which was based on the cognitive capabilities to simulate activities and involvements of people in the perceived environment. Through an extensive set of mathematical axioms, definitions, and operations, the authors built the platial equivalent of reference systems. The more recent paper by Purves et al. (2019) contextualized the concept of place in information systems and science, putting forward an ontological perspective that enables a range of possibilities in computing place-based data. Limitations of the aforementioned papers include language and culture dependency of the concepts, challenges in semantic interoperability, and the lack of platial equivalents for spatial operations in GIS.

Regarding GIS operations, the only study that proposed and operationalized the place-based equivalent of classic spatial operations (*buffer* and *join*) was that of Gao et al. (2013). The authors used semantics, topology and linked data to define their *platial* operations and implement them in case studies. Another pioneer approach is the study carried out by Blaschke et al. (2016), throughout which the researchers put forward the place-based perspective of image analysis, as well as diagnosing the apparent lack of methods, methodologies, and a research framework designed to address *platial* concepts. In fact, their investigation was the only one of the selected papers that approached the viewpoint of place in the field of remote sensing. In the context of the spatial humanities, Giordano and Cole (2020) combined traditional GIScience principles, historical sciences (a field where place plays an important role), and place conceptualizations with the objective of creating a place-based model of the narratives of Holocaust survivors. Janowicz (2009) and Plewe (2019) were also examples of research within the fields of historical sciences and spatial humanities. Those and other studies lacked to some extent more generalized frameworks that aid the future construction of a true place-based GIS, mostly because they have specified research questions and objectives. Due to the fact that the place-based GIS stream of research is still not well established, it is reasonable that the attempts to bridge place and GIS are mostly exploratory, prototypical and often lack reproducibility outside of a specific context.

We observed that geotagged social media content plays a crucial role in the field. Indeed, not only within the selected papers but also in several streams of GIScience social media data have been exponentially gaining attention because they represent a new paradigm of geoinformation and bring new challenges of analysis, interpretation, and applications. In addition to social media information, we should not disregard the role of crowdsourced data in general, VGI and PPGIS. While it is true that these sources of data have provided infinite possibilities of gathering more insights on how people perceive their environment, their use in the selected papers is distinct. As we pointed out earlier, most of the papers that used user-generated content did so as part of their final steps in either implementing or adjusting a new model, classification, or framework. As for the use of user-generated content to build models in a deductive manner, the main limitation is related to the fact that although available information is attached to a location, interpreting the results in light of actual cognitive, behavioral, and affective mechanisms is not an easy task. As Papadakis et al. (2020, p. 31) highlighted, it "does not sufficiently account for the human understanding of place; instead, it indicates the association of particular space footprints with human-generated data, such as activities, opinions and others." Taking this into account in their VGI data classification, Quesnot and Roche (2015) argued that spatial and *platial* are not opposites, as spatial embeds both

locational and *platial* data. According to the authors, their classification sets a necessary perspective on future place-based GIS development.

Overall, the papers acknowledged the challenge of creating new standards or adjusting the existing ones in the complex task of representing and analyzing place-based information in GIS. As we discussed earlier, the methods in doing so were diverse, but recognizing that *platial* entities are distinct in comparison with their purely *locational* counterparts was commonplace. The formal characterizations and operationalizations of the construct in the selected papers showed how some concepts are essential in accounting for place in GIS. These include: topology, hierarchy, and networks to represent relationships between places in a non-metric domain; semantics and ontologies to structure and contextualize place-based knowledge; cognition and linguistics to frame the foundations of how people perceive and communicate about their environment; uncertainty and vagueness, to understand and define the footprints and boundaries of places; and time and scale, which are in fact transversal topics in GIScience and do play a significant role in place-based concepts and representations. Therefore, the main contributions of the selected papers consist of outlining conceptual and methodological frameworks that actively address and incorporate the aforementioned principles into their place-based research. Nonetheless, we found that the limitations of the studies concern not only the lack of exemplification and exhaustiveness of the models, but also the lack of stronger interlinking between the aforementioned concepts when describing places.

4.2. Toward place-based GIS?

The term place-based GIS is used in the literature to both characterize approaches that combine the subjective concept with GIS standards and designate a true place-based system. When discussing future directions of research, the authors frequently mentioned that their work is a step toward genuine place-based GIS. Naturally, the proposed future research paths in the papers also included extending, automating, broadening, and scaling up their formalizations, model structures, and analysis. However, what are true place-based geographic information systems? When using the term, the researchers did not provide any definition of what place-based GIS is or would be, but instead contextualized their models or future steps using the designation. The need or the potential to create a novel *platial* paradigm was discussed by some of the authors with different viewpoints. Giordano and Cole (2020) argued that we should not worry about creating new place-based ontologies and epistemologies, as the authors believe GIScience and related technologies provide enough means to answer place-based research questions. In line with this, Comber et al. (2018) also argued that shifting paradigms to what they call a "*platial turn*" is less fruitful than working with the existing tools. On the other hand, Davies (2019) acknowledged the challenges in expanding models for real applications and linking them to existing GIS; nevertheless, the researcher pointed out that the next phase in bringing us near place-based GIS is actually building a whole new system. However, the technical and conceptual standpoints necessary to conceive and design such a system seem to be rather vague and inconclusive in the selected literature. As stated by Westerholt, Mocnik, and Comber (2020), the place-based stream still remains within the spatial realm and future contributions can expand toward either designing solutions within the existing paradigms (Purves et al., 2019) or creating new place-based precedents. In our review, we described and discussed the methods researchers used to dissect place into components that can fit into systems, representations and standards, but the efforts are still linked to concepts and branches of GIScience, similar to what Merschdorf and Blaschke (2018) have identified. The heterogeneous panorama of the place-based research

in GIScience, and specially of the place-based GIS stream, suggests that we are nowhere near a novel paradigm when it comes to formal models, systems, and operations. Nonetheless, the research scenario does indicate that we have the necessary data and tools to extract place-based information.

Do we need the *platial* equivalent for the spatial or the geographic? On what formalisms would the *platial* equivalents rely? For some researchers, it is important to at least discuss the *platial* equivalents to concepts related to spatial statistics, operations, associations, uncertainty, representation, and data models. Gao et al. (2013) even mentioned the terms "*platial* information systems" and "*platial* information science" in connection with upcoming models and methods in the field. According to our review, the research landscape is far from reaching the ultimate goal of building a place-based GIS or even a place-based information system. In fact, the majority of papers reviewed implicitly or explicitly suggested that such a place-based GIS would rely not on creating a new *platial* paradigm, but on using the available resources to continue integrating, adjusting, and adapting our spatial frameworks with the goal of investigating how people conceive and perceive places. Indeed, the selected papers conducted studies on formalizing and operationalizing place utilizing core concepts of GIScience and information science, although epistemic and ontological stances were fragmented due to the transdisciplinarity and multidimensionality that the concept of place can hold (Wagner et al., 2020). Hamzei et al. (2020) identified more than 100 facets that the construct of place was attributed to in the literature, demonstrating and describing the existence of functional, emotive, spatial, and linguistic aspects of the concept throughout various disciplines. While these rich characterizations can ultimately aid context-specific formal descriptions of the construct, the countless dimensions that places can embed might hinder its generalized formalizations and further operationalization. Whereas we do have in hand comprehensive mathematical instruments to formalize and operationalize the construct (Blaschke & Piralilou, 2018; Papadakis et al., 2020; Scheider & Janowicz, 2014), researchers must define what a true so-called place-based GIS is. Future research should conceive tailored conceptual frameworks, well-developed formalizations and comprehensive models before attempting to integrate place and space in (geographic) information systems. As we examined, most of the articles did not aim toward a *platial* GIS, but rather toward designing solutions that use GIS to refine our understanding of place through the lenses of spatial and geographic information.

The future research avenues for operationalizing the construct of place lie on different questions and streams. The question "what is place?" should drive research on transdisciplinary conceptual frameworks that enable further formalization. In other words, concepts need to be comprehensively compiled, organized, and structured to enable a formal characterization of all the attributes, components, entities, relationships, and spatial projections that a place might carry. Computer science, spatial cognition, spatial information theory, geography, and information science should constitute the theoretical pillars of this task, although other disciplines must be evaluated. This effort also requires that the frameworks conceived are translatable to strict knowledge formalization methods that are ideally grounded in mathematical postulations of the concepts. We believe that operationalizing place should be carried out after having well-established knowledge representations of the concepts, regardless of context or application dependency. In other words, formalization efforts need to be encouraged to ensure that we establish ontological and epistemological commitments, further enabling the incorporation of concepts into standards, systems, and practices. We acknowledge that building a place model that is independent of system, culture, context, and language is almost an impossible mission, and therefore methods aimed at answering specific

research questions are valid and necessary. Although we encourage the progress of knowledge-based models, we should not ignore the huge amount of available data generated by different people at different places. As stated by Wagner et al. (2020), user-generated content has been playing a fundamental role within place-based studies of GIScience, and future research on translating these data into formal components of the construct of place is a promising pathway. In combination with state-of-the-art technologies and advances in data science, researchers have numerous means through which they can improve their models. Regardless of aiming at shifting paradigms or incorporating place research into the existing methodological frameworks, the selected literature showed how the diverse methods, contexts and implementations can aid the operationalization of the abstract notion of place and consequently improve our knowledge on human–environment interactions. In sum, bringing new conceptual and methodological viewpoints into the field becomes vital if we wish to expand the interface between places and GIS.

5. Final remarks

In short, there is no brief way to answer our research question. Our results and discussion have put forward the methods chosen by the researchers working with the concept of place through its concrete operationalization. Our review included 31 papers, published between 1998 and 2020, mostly in GIScience journals and conferences. The majority of the papers formalized and/or operationalized places in the urban context through knowledge-based models implemented using open sources of spatial data and grounded theoretical foundations on works from human and critical geography. In general, it was common to find the use of geotagged user-generated content as well as concepts related to cognition, semantics, topology, uncertainty, time, and scale. The gaps found in the selected literature concern the reductionist approaches that could be broadened in their conceptualizations and implementations, as well as the lack of fully operational examples of the models. Furthermore, our findings are based on a focused selection compared to other significant reviews (Merschdorf & Blaschke, 2018; Wagner et al., 2020), as we attempted to identify the ways in which place-based studies have dissected the notion of place through formal and operational components. As for the limitations of our study, while the goal was to investigate papers in the context of the *platial*, *placial* or place-based GIS terms, studies on place have such a large disciplinary breadth that other pieces of research might not be necessarily restricted to these new concepts and therefore further investigations should be conducted. In addition, future reviews should also consider quantitative methods such as text mining and topic modeling for content analysis. For a field that has been growing in various directions, more comprehensive reviews must be carried out, both holistic and reductionist. Since the studies of place-based GIS and place within GIScience are still scattered and spread in many areas, the task of continuing to map, clarify, and outline the research landscape becomes fundamental in encouraging new research, which would help us understand the complex relationship between people and their spatial settings.

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