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ARTICLE

THE INDOOR SPACE AS A DISTINCT ENVIRONMENTAL CATEGORY FOR SPATIAL ANALYSIS

O espaço indoor como uma categoria ambiental distinta para análise espacial

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Abstract:

The words "environment" and "space" demonstrate distinct spatial units. It must be questioned whether the internal space, seen as an analytical subcategory of space, adds specificities of this type of designation. Therefore, if indoor is a subcategory of space, then its characteristics and types of representation must be observed and analyzed considering aspects of space. The purpose of this article is to present the characteristics of the indoor space unit as a subcategory of space. The “space” terminology applied to specify the indoor spatial unit has some features of spatial analysis that allow a broader and deeper spectrum as an object of study. Compared to space, the "environment" proves to be limited to represent the characteristics of the indoor. The intern must be understood as a space within a space, inserting a subcategory of the urban space, however, it is never seen as in its entirety. The totality does not observe space as it is, but everything within it. Space, as a creation of man, allows the creation of subspaces with no connection to the outside, in the category called indoor contributing to the analysis procedures based on the understanding of their relationships.

Keywords: Indoor; Space; Environment

1. Introduction

The process of spatial production is related to the existence of men and the social role assigned to it (LACOSTE,1993; SANTOS, 2005, and PADUA, 2011). In the past years, this process has undergone a significant under-industrialization (PADUA, 2011; SCHABUS et al., 2015) thus resulting in a restructuring of its economic and residential activities to promote new modes of spatial relations (SANTOS 2002, 2005). Therefore, new segregated spaces (SCHABUS et al., 2015) within the context drawn by de-urbanization, divide inside the buildings (PADUA, 2011; SANTOS,

2005) and urbanize again the internal spaces, here called indoor environments (BIEHLER and SIMON, 2011; CHIU and LEE, 2018; SCHABUS et al., 2015; VANCLOOSTER et al., 2016). This scenario is part of a process in which Lacoste (1993) already mentioned: people have even less understanding of the external areas in which they circulate when compared to the indoor ones.

Lacoste (1993) presents his theory from the example of people, that once used to walk through the territory to a certain reference point, and met in a continuous space, in which all the elements of this space were recognized. On the other hand, he calls to attention that today people are transported from their territories to other points of reference through subway lines, thus unable to recognize the continuum space between their territories to the points of reference, being limited to count the number of subway stations.

This tendency has intensified lately after the occupation of segregated spaces closed from the outdoor environment (BARRETO, 2017; PADUA, 2011; SCHABUS et al., 2015). Therefore, the indoor environment has become more complex and the quantity of services offered in these spaces has "represented" the outdoors in which it is inserted. (BARRETO, 2017; LACOSTE, 1993). For example, there are shopping malls in which one can find aisles that simulate streets, with the fronts of stores, restaurants, banks, and other services places in a segregated space. Hence, it is observed that indoor environments are shaped for people to spend more time in them, an explicit representation of the de-urbanization process.

Although the process is not limited to the transposition of services, labor, or entertainment, it is also connected to other process commonly seen in the city, such as verticalization, which increases the complexity of these spaces (SANTOS, 2005) and the increased dimension of those spaces within the city (DE SOUZA, 2003). Consequently there is an increased interest a locational system that permits the population to guide themselves through theses spaces, to acquire spatial understanding, to set routes, to optimize travels by selecting a quicker route, such as interactive maps for outdoor urban environments (CHO 2016 and DIAKITÉ; ZLATANOVA, 2018, and VERMA et al. (2016).

The terminology indoor in this paper must be understood as a closed space in which the communication with the external areas is done through windows and doors, restricted to some type of edification, as the previously mentioned mall, or an airport, commercial center, and others. These are spaces involved in complexities, such as the distribution of various services, requiring optimized navigation, or in other words, then the user is capable of recognizing the environment and can make quick decisions.

However, it is usual that scientific literature uses the terminology "environment" in this spatial unit (DIAKITÉ and ZLATANOVA, 2018; ILKOVIČOVÁ et al., 2014; KIM and JUN, 2008; LUO et al., 2017) instead of the "space" one. The terminologies here are used to demonstrate spatial units that have distinct characteristics and definitions. Authors such as Schabus et al. (2015) and Zhou et al. (2017) prefer to use indoor as a spatial unit, or as an analytical subcategory of space, and not from the environment, thus aggregating specific characteristics of this designation.

The previous argument directs to the hypothesis that indoor is a subcategory of space, then its characteristics and means of representation must be observed and analyzed considering the elements of space. The terminology "environment" is related to an idea that does not include all specificities inherent to the spatial unit indoor, thus it is an analytical category that is more restricted than space. The later, with a wider spectrum, allows researchers to develop various topics as many as there are for external spaces, allowing the growth of new analytical categories and means of representation. The correct distinction between space and environment offers an epistemological contribution to indoor cartography, in addition to contributing to the analysis

procedures based on the understanding of their relationships. Hence, the objective of this paper is to present the characteristics of the spatial unit indoor as a subcategory of space.

2. Indoor space and environment

With the growth of population located in urban environments, there is also a growing concentration of activities performed inside edifications, which demand a crescent awareness of spatial information that may fulfill a constant need for orientation, navigation, emergency routes, among others (WANG and NIU, 2018). At this point, it is important to sort out two frequently used terminologies used to mention the interior of buildings: the indoor environment and the indoor space.

The environment can be understood as a subjective element, a system of relationships between man and the surroundings, among subjects and objects (SÁNCHES, 2013). The subject can be understood as the modifying agents, the society, and the groups of individuals, while the objects comprehend the elements of the landscape. In external environments, the objects can be listed as fauna, flora, water bodies, among others (SÁNCHES, 2013), but the concept of environment extrapolates the natural landscape and it is integrated into the urban one, therefore it can be applied into indoor environments as well. Moreover, the objects can be represented by doors, walls, aisles, and more.

Hence, when referring to an indoor environment, it essentially deals with the relationships among subjects and objects. In other words, some impacts can be caused onto the objects through actions performed by the subjects, or the opposite, such as impacts caused onto subjects due to the nature of the object (SANTOS, 2002). It is important to highlight that when in an indoor environment, the term “environment” refers to a direct relationship between subjects and objects.

When applying the terminology “indoor space” (SCHABUS et al., 2015; ZHOU et al., 2017) the researcher considers indirect relationships. At this point, it is worth mentioning the approach to the concept of space that comprises the field of our experience in its three-dimensional aspect (ROBINSON and PETCHENIK, 2011). This view, however, does not understand the relationships that make up the context of the indoor, being necessary to look for an approach the specifics of the spatial dynamism for the construction of an epistemological base for the indoor. In this sense, the space can be understood as a set of objects and relationships that occur indirectly over these objects, then the objects act as mediators of relationships generated by mankind (SANTOS, 2002, 2012; SCHABUS et al, 2015).

Space is the result of mankind's actions intermediated by objects, and that occurs over the same space (SANTOS, 2012). The concept must not be mistaken by the physical space, once the nature of human space is a result of social practices upon it. The urban space is an exponent of this analytical category and has various levels of alterations, such as physical, social, structural, and quantitative, while the society living in the studied space changes. This paper will consider Santos (2002, 2012) and Schabus et al (2015) for the conceptualization of space for dealing with aspects related to its dynamism and the indoor context.

Under the mentioned context, it is possible to consider the indoor space as an analytical subcategory (BIEHLER and SIMON, 2011; DIAKITÉ and ZLATANOVA, 2018) of the urban space, taking into account as it reproduces external areas. Then, it represents a spatial category, but not

its totality, once space would be broader and composed not by one, but by many subcategories (SANTOS, 2002, 2012; SCHABUS et al, 2015). Indoor space is a space within a space, therefore, a spatial subcategory (Figure 1).

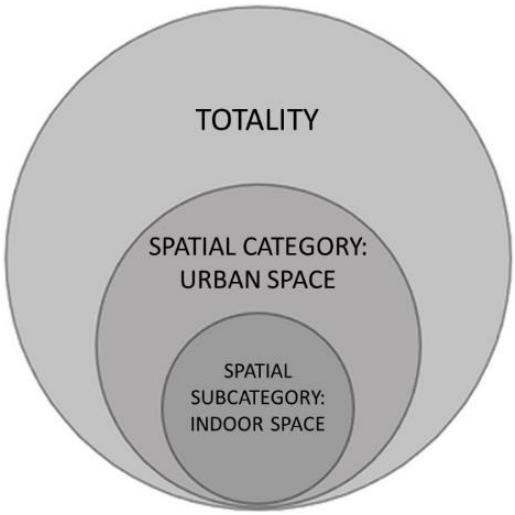

Figure 1: Spatial categories.

Source: The author.

The indoor environment is related to the concrete and fixed objects, directly linked with the individuals that coexist with them (SANTOS, 2012). Fixity does not allow dynamic human relationships to be intensified by other elements, such as social and economic changes, that promote constant renewal inside edifications (DIAKITÉ; ZLATANOVA, 2018). One example of this lack of fixity is represented by shopping malls, in which some stores open or cease to work according to the local economy, besides other changes that promote constant reorganization to better support the influx of people.

The indoor space, however, embraces the inherent subjectivity found in the interior of edifications, once it can deal with arising issues in different scales and perspectives (VANCLOOSTER et al., 2016). Because it is a characteristic that approaches indirect relationships, the fixity of objects is not a preponderant factor, as the relationships become the main element of analysis. For a cartographical study, the before-mentioned analytical category includes the objectives set in this paper, once it applies to discussions related to orientation and navigation in a dynamic environment and with different rules. It can be used, for example, in a mall as in a perspective of an indoor space, hence orientation based on the placement of stores, considering that these can switch places or even cease to exist, or even represent another phenomenon beyond the location of stores can solve. Technology, in this sense, helps in the many means of representation, as it will be detailed further in this paper.

The notions of environment and space to be used to analyze the interior of edifications must be applied according to each one's specificities and with the desired analysis. In this paper, the spatial terminology indoor was used, once the study of cartographical representations has subjective characteristics that are more related to the notion of space. The direct relationship that structures the terminology environment, among subjects and objects, does not embrace the full dynamism that can be observed in the indoor space.

3. Characteristics of the indoor space

Urbanized areas, which currently have the majority of the population (CARVALHO, 2016), experiment an increase of the flux of activities directly related to the present social dynamics, in both outdoor and indoor spaces (WANG and NIU, 2018). This fact creates a demand to acquire a series of spatial information that allows the user to understand the dynamics of both spaces, enabling orientation, navigation, register, emergency management, among other activities (WANG and NIU, 2018).

Nowadays, mankind has spent most of its time into indoor spaces than in outdoors, which the later has become even more a transitional space (BASIRI et al., 2017; BIEHLER and SIMON, 2011). This social characteristic demonstrates the importance to perform studies that better represent the indoor spaces in urban areas. With that being said, it is important to highlight the importance given to the indoor spaces in urban environments is due to a specific phenomenon inside urbanization, in which people spend most of their time inside edifications, while in rural environments, such time is mostly spent outdoors (BIEHLER and SIMON, 2011). Hence, it is worth mentioning that the characteristics of the indoor space have a higher demand in urbanized spaces.

Another important characteristic is found in the fact that a regular map user understands space from his perception, acknowledging distances, routes, and dimensions, while in the indoor spaces, this process is challenged by the existing complexity (DIAKITÉ and ZLATANOVA, 2018; SCHABUS and SCHOLZ, 2015). Therefore, it is possible to confirm that the quantity of information present in a small portion of the indoor space involves a series of complexities that many times do not allow simplification, as it occurs in the representation of outdoor spaces (SCHABUS and SCHOLZ, 2015).

The complexity of indoor spaces is also related to the three-dimensionality of those spaces (VANCLOOSTER et al., 2016), which is influenced by representation, once part of the edifications in urban spaces has more than one pavement (ZHOU et al., 2017). It is a natural characteristic of the cities, to accommodate the high number of individuals, to verticalize buildings and raise pavements, thus subdividing more the internal subspaces (DIAKITÉ and ZLATANOVA, 2018; PIPELIDIS et al. (2017).

The verticalization of buildings is a challenge for cartographers who represent these spaces on different floors, using the orthogonal and two-dimensional view of maps. Into the indoor spaces, the division in various pavements is attributed to an inherent characteristic of the represented space, which cannot be discarded or simplified. The technology available today facilitates the representation of outdoor spaces using maps. Besides that, smartphones facilitate the calculation of routes and orientation across the way. These maps can be more complex to represent buildings and transition between floors, considering the two-dimensional representation for routes calculation, neglecting the up and down movements (VANCLOOSTER et al., 2016). When the environment is three-dimensional, such applications tend to not work properly, especially regarding the representation of the space, which demands solutions that can reproduce the three-dimensional characteristic of edification in 2D or 2.5D (DIAKITÉ; ZLATANOVA, 2018).

In the indoor space, it is important to highlight the character of the transitional elements that differ from those observed in the outdoors (VANCLOOSTER et al., 2016). The access to the interior of buildings is done almost exclusively by pedestrians, which is distinguished from most of the outdoor ones, done mostly by vehicles, such as cars, motorcycles, buses, or trains. The pedestrian aspect of it does not previously establish rules such as the movement of a car, which must follow

present traffic laws. Therefore, the pedestrian access influences the level of freedoms that impact directly on navigation (VANCLOOSTER et al., 2016).

It is observed that in outdoor spaces the edifications build linear structures that facilitate navigation and allow free traffic flow according to the means used to reach its doors. The indoor space, on the other hand, is restricted by walls, windows, doors, and aisles, which challenge pedestrian traffic and it does not have established rules. Today scientists have been working to integrate such areas, then it will be possible to contemplate in a single representation both spaces.

It is possible to observe that the nature of the indoor spaces has relevant specificities that require further studies to be better represented. Mapping those environments must consider the before mentioned characteristics, which directly influence the means of production and representation of the indoor maps to be used, allowing researchers to represent the complexities inherent to this analytical category. At this point, it is important to discuss the specificities of indoor maps.

4. Indoor space maps

The indoor spaces, under the context of social reproduction, open to possibilities of representation and to theoretical and spatial studies because of issues related to the dynamics and the nature of such spaces (LACOSTE,1993; SANTOS,2002, 2005, 2012; SCHABUS et al.,2015; ZHOU et al.,2017). The study of the aspects related to the technology used to represent these spaces, scale, and symbology are present-day demands.

The means of representation adopted under this spatial subcategory must consider that the indoor space has distinct structural characteristics from the external, outdoor space, besides previously discussed specificities mentioned by Diakitée Zlatanova (2018), Vanclooster et al. (2016), and Wang; Niu (2018). Regarding the structural characteristics, it is important to mention the walls from the building, which physically limit and suggest impermeability (BIEHLER and SIMON, 2011), therefore, they are not only describable, but they also provide isolation from the external space and its totality. The isolation is only physical, once spaces are dialectical structures not only regarding the transition of individuals between spaces (DIAKITÉ and ZLATANOVA, 2018) but also because of phenomena and activities that are present in one space and may affect the other, direct or indirectly (SANTOS, 2005, 2012).

A broader analysis of the category allows subdividing the indoor space into many other different subspaces, according to the degree of permeability and isolation from the outdoors, as seen on Figure 2. Therefore, the indoor space, which is already a subspace, can be subdivided again into two more subspaces, the indoor spaces 1 and 2.

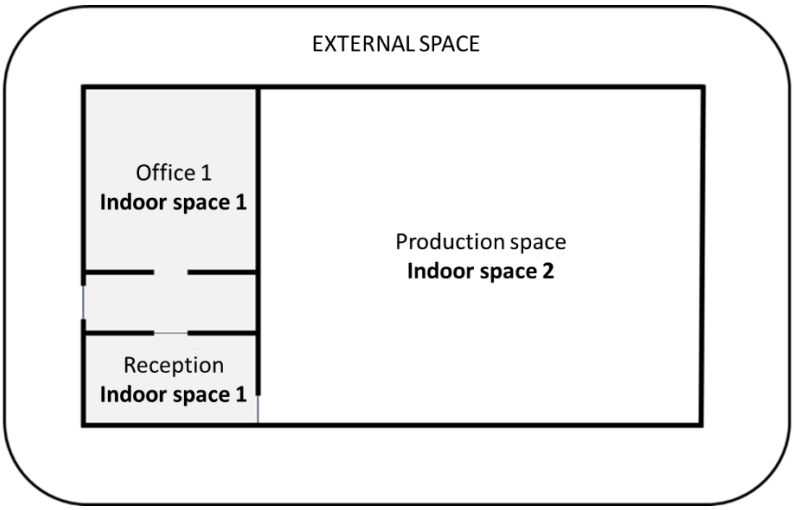

Figure 2: Subdivision of the indoor space, by isolation.

Source: Adapted from Schabus et al. (2015).

If by one side the indoor space and its subspaces are isolated from one another due to architectural structures, on the other side they are present in their totality, and then they are still connected (Figure 3). Image 4 demonstrates a flowchart of these connections according to Schabus et al. (2015). However, the author did not consider in his paper the conceptual differences between environment, space, and totality, as it is demonstrated in this paper. Hence the flowchart was adapted tanking these concepts into account.

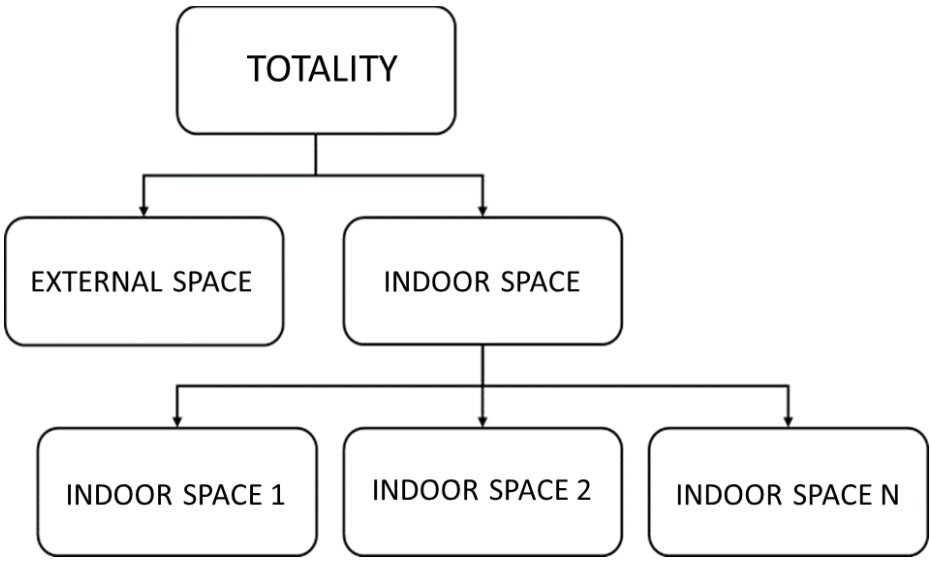

Figure 3: Spatial subcategory according to its totality.

Source: Adapted from Schabus et al. (2015).

Even if there is a physical connection that allows people to transition from one subspace to another, such as a door, the relationship is not essentially met; only if the activities from one subspace generate consequences on the other (DIAKITÉ and ZLATANOVA, 2018; SCHABUS et al., 2015). Therefore, the concept of space within a space demonstrates that, besides the configuration of a totality, both spaces may not have a relationship, thus developing to the concept of a disjointed space. Such terminology refers to space within a space, disconnected from the totality (DIAKITÉ and ZLATANOVA, 2018; SANTOS, 2012, 2002; SCHABUS et al., 2015).

Modeling the indoor space for representational purposes must deal with these characteristics, adapting solutions previously used in cartography to properly represent these spaces with differentiated design, or developing new means of representation based on new technologies. It is not only a matter of dimensions or perspectives that will impact in the representation of indoor spaces when compared to the outdoor spatial representation, but also the change in scale, not in the cartographical sense, but the geographical one (BIEHLER and SIMON, 2011). This variation in scale and spatial dimensions can be seen when moving from an outside space, which has a macroscale if compared to the indoor one, and the microscale of the indoor space when observing the outdoors (VANCLOOSTER et al., 2016).

The representation models of indoor spaces have reproduced the logics of representation from outdoor spaces that use predominantly 2D models (DIAKITÉ and ZLATANOVA, 2018). On the other hand, three-dimensional models have been used to represent the different pavements of an edification, considering its complexity. Moreover, these representation models have shown to be complex to be interpreted and manipulated (DIAKITÉ and ZLATANOVA, 2018).

Science studies these questions trying to identify the most adequate representation model for this type of space. Considering how to approach the questions regarding the connectivity of subspaces, the horizontality of aisles, such as connective agents of transition between subspaces, and the design of vertical transmission in representations, as well as for navigation. Maps have been produced and studied based on already existing models, and in regards to the format to represent many phenomena to assist navigation and orientation in these spaces, a series of solutions have been tested.

One of the solutions is the indoorGML (Geography Markup Language), a standard set by the OGC (Open Geospatial Consortium) to represent and create navigation models for indoor spaces. The main goal of these standards is to provide a design for topographic and semantic modeling of the components of an indoor navigation network that can be used as a basis for the development of further applications (LEE et al., 2016; OGC, 2016).

The representation of geometric and semantic aspects of the space established by the IndoorGML system is based on the theoretical concepts about the nature of such spaces, which is described in this paper. Then, there are two aspects of the concept of space adopted by IndoorGML that calls our attention: first, it sets that the represented space is a physical one. The description of the tool describes that the architectural components are not objects of analysis, thus giving attention to the physical space where navigation is possible. Secondly, there is an issue regarding the relationship between spaces, which is another concern with this standard. The relationship among spaces based on their connectivity and continuity is an issue to be observed.

Within this aspect, IndoorGML offers a solution to represent subspaces and their connective and disjointed aspects for navigation. According to Figure 4, the spaces and subspaces are represented graphically by cells (R1 and R2) isolated from the external areas by walls subdivided into indoor and external. B1 and B2 represent the external and internal walls of R1, respectively, and B3 and B4, the indoor and external walls of R2. The cells are connected by access D1, while D3 represents the access between the external area and the indoor space. The representation is similar to the conceptual model presented by Schabus et al. (2015), as seen on the Figure 3, however, in concept, the IndoorGML does not consider the intrinsic relationships of the social construction of the space, representing only its topologic and semantic characteristics.

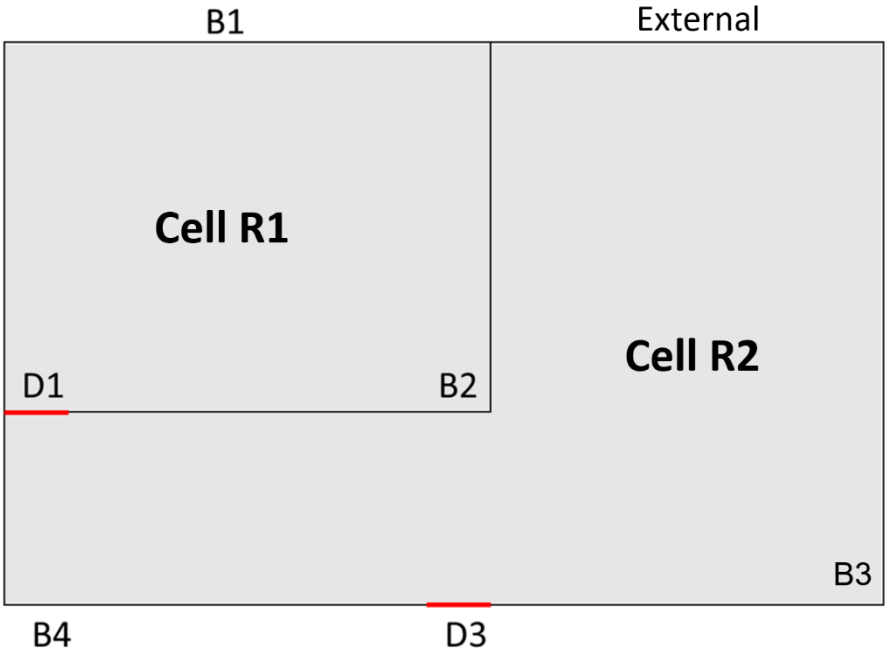

Figure 4: Topographic space.

Source: Adapted from OGC (2016).

In the space represented in Figure 5, the topological relationships can be represented by the connectivity and adjacency graphs (Figure 5). Therefore, the space represented in Figure 5 is transformed into a graph of connectivity and adjacency in Figure 5a, in which all possible connections are represented by lines, either connectivity or adjacency. Figure 5b better describes these relationships, in which the influence of semantic information is observed, in which spaces that have a connectivity relationship in D1 and D3 are considered navigable and represented by a continuous line, while the adjacency relationships in B1, B2, B3 and B4 do not allow navigation between spaces and are represented by dashed lines. Finally, Figure 5c represents the final step of building the graph with real connectivity and possible navigation between cells. These representations enable the implementation of topological relationships in navigation systems aimed at indoor environments.

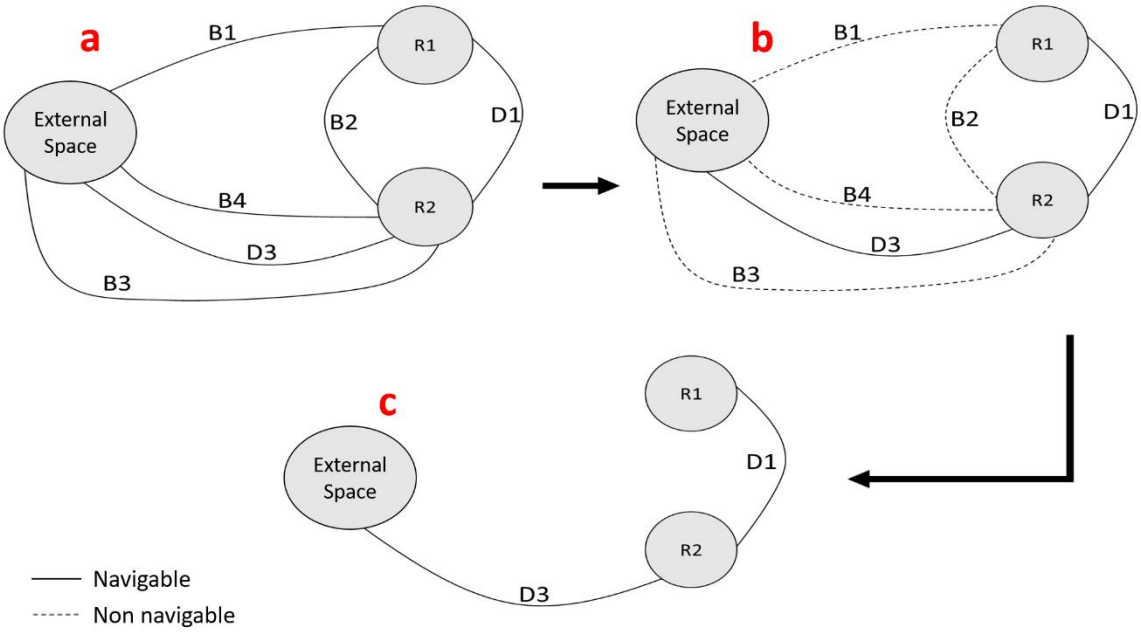

Figure 5: Adjacency and connectivity charts.

Source: Adapted from OGC (2016).

These representations highlight the space in its physical aspect only, not taking into account its geographical content. It is observed that the concern applied in the standard is the relationship among spaces, an essentially geographical phenomenon. Even though relationships here described are related to the spatial connectivity and continuity, these elements are determined by social relations (DIAKITÉ and ZLATANOVA, 2018; SCHABUS et al., 2015) in which, despite the physical connection, while there is no established social relationship, the continued process of navigation can be halted. Here we highlight the importance of analyzing indoor as a subcategory of space, open to the possibility for studies related to spatial dynamics and the production and representation of space. Yet, even if indoor space is integrated to a category present in a "confined" or "isolated" space when observing from the totality, it demonstrates the necessary characteristics to integrate itself into analysis from other areas, such as from social sciences, thus becoming the basis for more complex studies, as the ones about the formation and reproduction of space. Such studies can also lead to the development of new means of representation, and also to the constitution of new maps. Therefore, it can become a cornerstone of alternate objectives and representation of different phenomena, such as it is observed for the outdoor spaces.

5. Final remarks

The terminology "space" applied to specify the spatial unit indoor presents analytical elements that allow a wider approach and depth for a study object when compared to the terminology indoor environment. In comparing to space, the environment limits the representation of the inherent characteristics of the indoor space. It must be understood as space within a space, defined as a subcategory of the urban space, but never its totality.

Totality, in this case, does not comprehend the space as a whole, but everything within it. Space, created by man, constructed and reconstructed by him especially in urban spaces, allows the development of subspaces without connection with the outdoors, under a category called indoors. These questions must be considered so that the indoor space as an analytical category becomes integrated with all its levels of complexity.

The adequacy of indoor as a subcategory of space is not related only to a conceptual matter, but to the construction of a solid epistemology in this field of study. Besides that, the space within a space is subject to analytical methods that are applied to external spaces, especially under the spectrum of geoinformation. In this area, computer models can be applied to analyze the transformations in space based on the social elements and their abstract concepts under the construction of space. It is important to highlight that the conceptual approach based on a critical aspect, which considers the constant changes to which the space is subject, allows the understanding the dynamism of the indoor space as an object of study.

This consideration should support the analysis and spatial modeling and should not be understood as absolute representationsof indoor spaces. Based on this assumption, more studies shoud be conducted considering the indoor with its full epistemological approach to implement through computer analysis the social elements that compose this space.

The implementation of this concept of space in later analysis may reflect in new types of representation of space and new challenges for cartography. In this field of study, there is a new frontier under the development of cartographic understanding that needs to be crossed, which will contribute to the develop the same field of study in other branches of science that use space and social relations as objects of study and that can integrate the indoors into their discussions.

Therefore, studies that approach different levels of spatial relationships can provide the understanding of such spaces and the relationships that occur on there, even more, thus making these analyses more complete and becoming the basis for a more complex representation of phenomena. This paper aimed to demonstrate that this understanding involves different levels of information, from the theoretical concept of a spatial unit to its representation.

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AUTHOR´S CONTRIBUTION

João Victor Pacheco Gomes carried out the research and wrote the manuscript. Luciene Stamato Delazari and Marcio Augusto Reolon Schmidt, worked on the curatorship, research recommendations, analysis and critical review of the text.

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