Tittle

Embedded resilience in the built stock. Lessons from socio-spatial interpretation. The case of CanFugarolas (Mataro-Barcelona)

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Abstract

The concept of resilience remains vague as it pertains to the buildings' scale and the architectural dimension, particularly when dealing with the recovery and reuse of former industrial premises. This study advocates for socio-ecological (bounding-forward) resilience and the use of Panarchy heuristics to analyze the embedded resilience of building stock. This research is based on a case study of CanFugarolas, in Mataró (Barcelona), a former workshop converted into a socio-cultural center. Here, the building becomes a repository for latent urban dynamism, where spatial transformation is the mechanism by which embedded resilience is released in the form of social dynamism. Adaptive spatial capability (potential) translates into social dynamism (performance) because of socio-spatial interactions. The quantitative and qualitative analysis of the spatial and social parallel evolution of the case study reveals that i) a strong correlation exists between spatial transformation and social participation; ii) spatio-functional tactics and spatial adaptive capabilities are social and formal complementary mechanisms for spatial appropriation during social progression; iii) spatial diversification and hierarchization are evidence of spatial specialization, resulting from said socio-spatial interactions. Eventually, iv) indications of thresholds appear in the form of spatial over-fragmentation and hyper-specialization, denoting spatial exhaustion and embedded resilience limitations.

Keywords

Embedded Urban Resilience, Built Stock, Spatial Adaptability, Urban Regeneration, Self-organization, Brownfield’s recovery

INTRODUCTION

This study investigates regenerative social-driven processes for the reactivation of former industrial spaces (brownfields). Said urban premises have the potential to become niches for self-organized community-led activities to optimally marshal available resources (derelict built stock) for urban reactivation, especially under conditions of urban shrinkage, as in the case study of Mataró (Barcelona - Spain).

The research is based on the following premises. First, the city is considered an evolving dynamic system. Second, urban systems are made up of interacting subsystems, such as social and infrastructural subsystems. Third, the built stock—specifically derelict former industrial buildings—as a repository of latent (embedded) urban resilience. Finally, self-organized initiatives, as emergent urban processes, enable the release of embedded resilience in the form of social dynamism, resulting from socio-spatial interpretation.

Hence, the aim of this study is to demonstrate the potential of built stock as a latent reservoir of embedded urban resilience, released in the form of social dynamism resulting created by the interaction between physical support and social momentum. Here, socio-spatial interpretation is the process through which space transforms and adapts to users' demands while fostering social progression.

THEORETICAL BACKGROUND: URBAN RESILIENCE

Resilience and Panarchy

The term resilience was first introduced by Holling (1973) to describe the models of change in the structures of ecological systems. First, resilience was defined by Holling as the persistence of relationships within a system, and it is a measure of the ability of those systems to absorb changes in state variables, driving variables, and parameters, yet continue to persist. As a result, most research on urban resilience has focused on the capacity to absorb "shocks" while maintaining functions and returning to the initial state (engineering resilience). In contrast, the concept of socio-ecological resilience is related to the capacities for change, renewal, and reorganization and development, which are fundamental to the discourse on sustainability (Gunderson and Holling 2002).

Adaptive management is one of the results of this new way of understanding socio-ecological systems (Holling 1986). For the first time, the *Adaptive Cycle* was defined, where nonlinearities are essential, multi-stable states are inevitable, and surprise is the consequence of the interaction of processes at different time and space scales. The adaptive cycle was conceived as a representation of the never-ending *exploitation(r)–conservation(K)–release(Ω)–reorganization(α)* path any system runs. These systems are characterized by the capacity for self-organization, diversity, the individuality of their components, the interaction between components, and the autonomous processes capable of selectively choosing some of the results of these processes as feedback for the system itself (Levin, 1999). Borrowed from the ecological realm, the emergence of the resilient perspective represented a leap in policies to control changes in supposedly stable systems. This made it possible to manage the capacity of socio-ecological systems to cope, adapt, and shape change (Berkes *et al.* 2003, Smit and Wandel 2006).

Similarly, the concept of *Panarchy* aims to represent the hierarchy between a set of adaptive cycles, whereby sustainability is the result of the operation of these cycles and communication between them (Holling 2001). It is a place to capture the nature of adaptive and evolutionary cycles, including adaptive interlinked cycles, across temporal and spatial scales. The *Panarchy* therefore is the representation of how a system benefit from invention and experimentation, generating opportunities, while remaining safe from those processes that could be destabilizing (Holling 2001). *Revolt* and r*emember* are defined as the main interactions occurring between different temporal and spatial scales. Thus, when a panarchy level enters the phase of creative destruction (*Ω-phase*), it can span to higher levels, especially if they (higher levels) are at conservation stage (*K-phase*), when vulnerability is maximum. This is known as the *revolt*. In the opposite direction, when upper levels at a conservative stage (*K-phase*) act as the repository of capital needed for reorganization (*α-phase*)—after collapse of the levels immediately beneath, *remember* takes place.

Resilience and urban systems

Socio-ecological resilience offers a means of addressing the evolution of the long-term built environment and exploring the implications of changing conditions on the effectiveness of different approaches to planning, design, management, valuation, and governability. Sustainability and resilience are processes that are strongly dependent on the concept of time (Moffat and Kohler 2008). Whereas sustainability corresponds to a static vision of the future and is often expressed as a utopia, resilience represents a more dynamic vision of the future. Considering its changing nature, many scholars (Shane 2005, Warner and Whittemore 2012) have understood the process of constant (urban) change. In some ways, the built environment can be considered a document of long-term adaptation. That is, the built environment is a record of the ability to overcome catastrophes throughout history and to adapt in response (Pickett *et al.* 2014). According to Davoudi (2012), urban resilience is understood not as a fixed asset, but as a continually changing process, not as a being but as a becoming. Here, resilience is not about bouncing back, but about the capacity for adaptation and, crucially, for transformation. Moreover, for Chelleri (2012), socio-ecological-resilience identifies, understands, and provides clear and useful insights from system dynamics, constituting substantial potential for urban systems. It is this *Panarchy* model of the *Adaptive Cycle* that underpins the evolutionary meaning of resilience (Davoudi 2012). Resilience in this perspective is understood not as a fixed asset, but as a continually changing process, not as a being but as a becoming. For Pickett (Pickett *et al.* 2014) resilience is a key concept in the operationalization of city-level sustainability. Hassler and Kohler (2014) consider resilience in the context of long-term sustainable management of the urban environment, understanding it as a set of diverse capitals (natural, physical, economic, social, and cultural) and highlighting the distinction between designed components that structure the action arena and self-organizing processes playing out in that arena. The built environment serves both to ensure the continuity of day-to-day activities and to reflect society's cultural notions of time. Cities have a cyclical existence of production, growth, waste, and shrinkage. Thus, the appearance of vacant land signals that the city is in one stage of this natural cycle (Németh and Langhorst 2014). This implicitly accepts the dynamic nature of cities. In addition, for Davoudi (2018), complexity theory is the epistemological basis of evolutionary resilience, with the possibility of ruptures and transformations, whereby small-scale changes can amplify and cascade up into major disruptions of the perceived stability of normality. For de Balanzo and Rodríguez-Planas (2018), the panarchy model offers a powerful narrative with practical implications for better understanding the vulnerabilities and windows of opportunity of real estate dynamics.

However, few studies have considered this evolutionary socio-ecological dynamic perspective to address urban regeneration. Schlappa and Neil's (2013) study on the evolution of shrinking cities embraces the adaptive cycle approach to draw future trajectories for the recovery of shrinkage through which their future can be re-imagined. Marcus and Colding (2014) also apply the adaptive cycle theory to analyze urban morphology as a new research frontier, addressing design for resilient urban social-ecological systems by linking some key morphological aspects in relation to four key attributes of resilience: “change,” “diversity,” “self-organization,” and “learning.” For Herrmann, Shuster, Mayer, and Garmestani (2016), *Panarchy* is one way to approach the dynamics of shrinking cities because it conceptualizes social-ecological systems, such as urban systems, as a hierarchy of adaptive cycles in which changes in lower-order cycles can create circumstances for change (a “revolt”) in a higher-order cycle. Urban form and urban scale, along with self-organization and diversity, arise as relevant issues in thinking on urban resilience. Feliciotti et al. (2016) also embraces five *proxies*—diversity, connectivity, redundancy, modularity, and efficiency—to assess resilience at different urban scales (plot, façade, block, street, and district), which subsequently allowed the incorporation of resilient principles in regeneration masterplans in the city of Glasgow (Feliciotti *et al.* 2017). The city form affects its capacity to survive and thrive in the face of adverse events. A better understanding of the concept of the “resilient urban form” and “resilient urban form typologies” is therefore essential to achieving further advances in urban resilience (Sharifi and Yamagata 2018). Sharifi successively proposed the concepts of streets and street networks (Sharifi 2019a) as well as the meso (Sharifi 2019b) and macro (Sharifi 2019c) scales to analyze urban resilience in the face of climate change events.

Self-organization and resilience in the urban system

As one of the main characteristics of complex systems, the city's capacity for self-organization is also highlighted. Scott (1998) adopted the concept of “*command and control pathology,*” referring to failed top-down attempts to manage natural systems (Holling and Meffe 1996), for direct transposition into the world of urban planning as "*seeing-like-a-state pathology*.” This characterizes urban and political planners who do not consider the self-organizing processes that direct the "*bottom-up*" movements of human settlements, from housing to the city, through the neighborhood and district.

From the perspective of socio-ecological systems (SES), Folke et al. (2004) state that the capacity to respond to and shape change in productive ways is a function of “self-organization.” Holling and Goldberg (1971) first suggested that urban systems and ecological systems share some common properties, including resilience, and that cities are prime examples of self-organizing complex adaptive systems. Social systems that have the ability to respond to change and reorganize (...) are likely to have flexible institutions that allow for adaptation to changing circumstances (Ostrom 1990) and a social organization that allows for knowledge exchange among different stakeholders and actors to facilitate appropriate responses to changing conditions and avoid cultural inertia (Colding *et al.* 2003). According to Berkes *et al.* (1998) and Folke, (2004), as cited in Wilkinson (2010), self-organization and participation are some of the key factors for building adaptive capacity in SES. Both the socio-ecological and self-organized approach to the urban realm resound in recent research by du Plessis and Brandon on the ecological worldview as the basis for a regenerative sustainability paradigm for the built environment (Du Plessis and Brandon 2015), where motivating social transformation in the built environment through stakeholder engagement becomes crucial (Du Plessis and Cole 2011). The ecological worldview sees the phenomenal world as constantly regenerated through interactions within systems at all scales and levels of existence (…). These interactions result in and from flows (…) as well as processes of adaptation and self-organization, which in turn allow these systems to evolve. While multilevel management is very attractive, it is difficult to implement for two basic reasons. First, how can system management processes that are not fully known be designed? Second, because the management process itself can affect the development of the management system, design and planning must include self-organization processes in the built environment (Anderies 2014).

Brownfields as a research object

The built stock is one of the components of the built environment, a term first coined by social scientists to jointly refer to manmade building and infrastructure stock that constitute physical, natural, economic, social, and cultural capital (Rapoport 2011). Urban fabric is a complex socio-technical system that encompasses different scales—buildings, building stock, neighborhoods, cities, and regions—each with different time constants, actors, and institutional regimes (Hassler and Kohler 2014). In this regard, empty buildings can be considered reserves for present and future needs, and these reserves seem to be considerable (Kohler Hassler 2002). Schön (1984) anticipated resilience as an implicit part of traditional constructive design knowledge before the nineteenth century. Over-dimensioning, repetition, and repair are forms of tacit constructive knowledge. However, research on the German built stock (Kohler *et al.* 1999) highlights the lack of information on non-housing stock and the need for better knowledge about the industrial heritage as it constitutes an enormous physical and cultural potential (Hassler *et al.* 2000).

Recent works highlight both the urgency and potential for the recovery of derelict and depressed urban areas, particularly the potential of brownfields (Dixon 2001; Franz *et al*. 2006; Ganser and Williams 2007; Heberle and Wernstedt 2011; Frantál *et al.* 2015) as a trigger for urban resilience (Eraydin 2013; Petrescu *et al.* 2016; Stevenson and Petrescu 2016; Cenci 2018; Wilkinson 2018) . Recent scholarship has also emphasized the role of self-organized community-led initiatives in the reactivation of these urban premises (Abu Zayed and Al-Kurdi 2019; Kim *et al.* 2020; Virani 2020) through urban tactics, in the form of temporary use or take overs in the face of inability or stagnation on the part of planned strategies (Haydn and Temel 2006). In this regard, artistic-led initiatives stand out for their revitalization of depressed urban environments, serving as fonts for creativity and innovation (Florida 2003; Bosák *et al*. 2019) and underscoring the relevance of derelict built stock as a research object.

Socio-ecological resilience at the architectural scale: A matter of adaptability

However, there is a gap at the architectural scale and its constructive and spatial dimensions. This is of crucial importance given that self-organized and social-driven initiatives take place within the city. In this regard, this study aims to fill this gap by providing evidence of socio-ecological urban resilience resulting from the interplay between spatial adaptability and social performance at the architectural scale.

Only a few studies have recently embraced the socio-ecological resilience approach to the analysis of architectural design by linking resilient adaptive capacity to adaptability. Although social-ecological resilience is a new concept within the discipline of architecture, the themes that emerge suggest that this broad concept can effectively engage and reorganize the extensive and sometimes marginalized discourse that explores changing concepts, changing contexts, and changing artifacts of architecture over time (Laboy and Fannon 2016). In this regard, the need to overcome the engineering vision of the term bouncing back, which is predominant in urban and architectural studies, is also highlighted. A building's adaptive capacity should be considered in relation to the changing conditions of the environment, specifically, of users' changing demands. According to Laboy and Fannon (2016), adaptable buildings incorporate both technical transformability and social resilience, recognizing adaptability at both the technical and social levels. This relates to the built environment (built stock) as a changing artifact over time. As Kahn (1955) envisaged, all future uses (of a building) could not possibly be anticipated. A building tightly fulfilling the present requirements would quickly become obsolete. *Served* and *servant* space distinctions were defined as the components of his "*hierarchy of spaces*" principle for adaptability. Thus, while Kahn did not explicitly discuss resilience, his theory and built work manifest these principles (Laboy 2016). For Hertzberger, spatial interpretation becomes the way users adapt to space and form. Functions or activities do not make specific demands on the spaces that are designated for them; it is the different individuals who make their own specific demands because they want to interpret the same function in different ways according to their own natures (Hertzberger 1962). Brand (1995) also noted that buildings were something started rather than finished. Adaptability, as a design principle for adaptive capacity enhancement, has been widely assessed as the interaction between use and form. In this regard, Brand (1994) and Schmidt (2010) provide a theoretical framework and analytical matrix in which the adaptive capacity of buildings (*ables*) chronologically relates to the type of change, decision level, scale, and built *layer* where such adaptation takes place. This reinforces Hertzberger's (1991) idea that architecture should offer an incentive to its users to influence it wherever possible, not merely to reinforce its identity but more specifically to enhance and affirm the identity of its users. In the same vein, the capacity and potential for adaptation, in the form of spatial transformation of derelict built stock, in hosting social activity matches Schmidt's provisions for under-design rather than over-design and unfinished space as a mechanism for social engagement. In addition, seminal approaches to adaptability design in buildings did so as a mathematical expression of probability and combinatory issues (where an optimal relation between space and functions must be reached (Fawcett 1979). Conversely, this study conceives adaptability as a socio-functional expression of change. Thus, the embedded adaptive capacity of built stock, in terms of socio-ecological resilience, is assessed not as a mere statistical future probability but as the ongoing transformation process of space while accommodating and favoring social dynamism.

CASE STUDY – CANFUGAROLAS, MATARO, BARCELONA

As in other cities in the industrial periphery of Barcelona (Spain), Mataro experienced a large population increase because of the migratory waves of people moving from other regions of Spain during the 1950s to 1990s. In fact, it more than doubled its population from 1950 (40,000 inhabitants) to 1990 (more than 90,000 inhabitants). Between 1962 and 1992, there was strong urban growth and expansion owing to its important industrial activity. However, during the 1990s, symptoms of stagnation and obsolescence arose, with an industry greatly affected by the post-Olympics crisis and the closure of textile companies and the few remaining metallurgical companies (Brullet 1993). Regarding urban planning, PlaMat77 acted as the regulatory framework at that time, and it was characterized by the extensive growth measures typical of that time along with the densification of the existing urban fabric (Hosta and Jornet 1995). Thirty years of growth (60s–90s) had formed an incoherent, very dense, disconnected, and non-organic city (Salicru 1993). Subsequently, the city (especially some inner areas) experienced a progressive abandonment together with, or due to, the relocation of the industrial enclaves of the twentieth century, leading to the proliferation of underutilized factory environments within the consolidated urban fabric.

According to Saez (2014) on the urban gaps in Mataro, three main conclusions emerge. First, the prevalence of three distinct types of urban gaps: empty plots, empty ground floor premises, and empty buildings. Second, the geographical concentration of "empty buildings" in three specific areas of the city. Third, the geographical correspondence of such areas with three former industrial areas within the city: *Balanzó* *i Boter*, *Entorns Biada*, and the *Eixample de Llevant* area where the case study is located. These areas are located on the outer perimeter of the *Eixample* Master Plan of Mataró (1878) (see Figure 1_Left), far from the old city. Over time, these areas have integrated into the urban fabric, constituting spaces of enormous potential given their current centrality.

The *CanFugarolas* sector (see Figure 1_Right) comprises a former 4,500m² industrial building and a 2155m² inner yard. It was defined as a "*Remodeling Sector / 5-04_Colón-Toló*" by the current Master Plan (1996) to "*encourage urban improvement (...)or transformation of decayed buildings*" through the delimitation of "*development sectors soil"* and its replacement by new residential sectors. The building was vacated in 2002 after 33 years in operation as a car-repair workshop, which it has been since it was built in 1969. The building consists of a multi-story (basement, ground floor, mezzanine, and first floor) structure. Subsequently, almost 11 years of inactivity (2002–2013) until it was entered to run the *CanFugarolas* project—borrowing the name of the sector. Irregular use and vandalism resulted in formal and functional degradation of the building as it did not receive any interventions pending the development of planning provisions.

In social terms, The *CanFugarolas* project is a continuation of the socio-cultural community-led project led by *Cronopis* (circus company), *Taller d'Idees*, *Estudi I Mig,* and *Co-Working* (local entities), based upon the reuse of obsolete industrial spaces. Three former industrial buildings in Mataró—*La Fibra* (2006–2008), *Can Fàbregas I Caralt* (2008–9), and *Fàbregas de Paper* (2009–2013)—had previously witnessed the project's birth and evolution before being either demolished or refurbished for other uses. Thus, in 2013, due to the urgent need to abandon its former site in the industrial warehouse of *Can Fàbregas de Paper*, a new location was needed. Thus, the *CanFugarolas* project (hereafter, "the Project"), in its current emplacement, was born. What makes this case study so relevant to those concerned with urban planning and urban regeneration, is its demonstration of the potential of available built stock, thereby contributing to urban resilience thought at a regulatory, managerial, and research level. Thus, under the urban stagnation (urban shrinkage) described above and crystallized in the proliferation of urban voids, the Project emerges as an urban resilience mechanism based on the reuse of derelict industrial buildings to meet social demands.

Figure 1. Urban context and emplacement. Left: Urban gaps in Mataró at the time (2013–2014) the Project moved to the CanFugarolas location (4), indicating former locations (1. *La Fibra* / 2. *Can Fabregas i Caralt* / 3. *Can Fabregas de Paper*); *Casc Antic* (Old Town) area and *Plan de Ensanche* (*Eixample* Plan, 1878) extension are identified. Right: Delimitation of seminal *CanFugarolas* Planning Sector (Red line) and subsequent extension (Dotted Red line), with identification of the main building (A) and the playground (B).

METHOD

This paper is based on mixed research methodologies, comprising quantitative forms and surveys, along with qualitative semi-structured interviews. This provided quantitative information on both spatial transformation and social engagement, and qualitative data on how and why socio-spatial interactions occur. The approach to qualitative research consisted of grounded research as the theory on socio-spatial interaction was developed from the data collected during the interviews.

Figure 2 summarizes the research process, from the qualitative and quantitative data collection stages to the assessment of socio-spatial correlation.

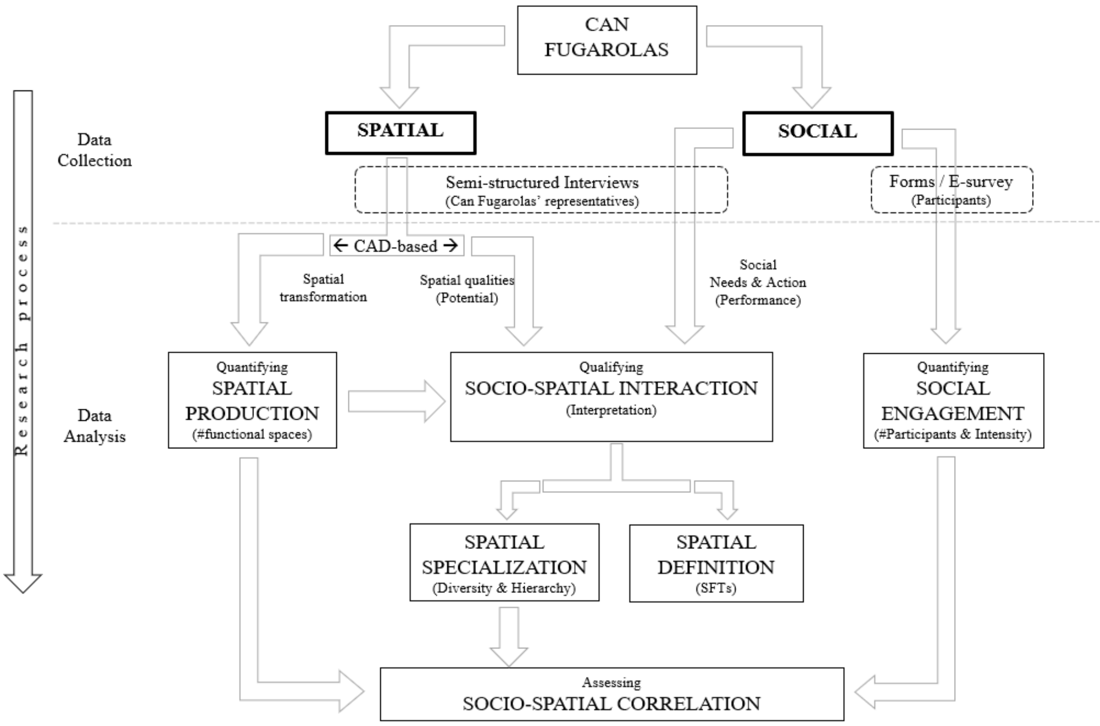

Figure 2. Research scheme

Data collection

Data collection took place during the corresponding author's two-month stay as a member of one of the Project's collectives (Co-Working). Inevitably, this could imply some bias in the qualitative methodologies. We attempted to minimize this by interviewing multiple people and using multiple people to code the data and by triangulating this data with the quantitative evolution of spatial and social data discussed in the "*Socio-spatial interpretation*" section.

The data collected covered the six-year period (2013–2019) since the Project was set up in its current location in the CanFugarolas Sector. This time frame was given by the very validity of the Project, so no other consideration was given at the outset. However, it fits the user-driven strategies period, according to the previous work by Schmidt *et al.* (2010) and Brand's (1994) on architectural adaptability, providing relevant complementary contributions to adaptability at the architectural scale.

The spatial issue

Data on spatial transformation were gleaned from the information provided by the representatives of the leader entities of the Project, during semi-structured interviews. These interviews covered several issues regarding the evolution of the spatial layout and utilization of the inner spaces, allowing the story of the spatial and functional transformation to be CAD-based and chronologically drawn. This, in turn, shed light on the spatial evolution of the building, from its seminal "open" layout to its current compartmentalization, along with the functional reactivation of space.

The social issue

Quantitative analysis of the social dimension was based on an analysis of participation (#participants and intensity of participation) in the Project. Two data collection procedures were performed to this end. First, an Excel-based form covering the current (year 6) #participants (individuals) was sent to and filled in by each of the entities (all persons participating in the project are obliged to do so by joining one of the entities) currently involved. The remaining data was then completed using historical data on #participants (#individuals and #entities) provided by the Project. Second, data on intensity of participation were gathered via an electronic survey (Google Forms), which was carried out from October 1–15, 2019 (year 6) to collect information from "current" users, upon their year of involvement. This allowed us to track the evolution of user's intensity of participation according to the year of enrollment. Unfortunately, it was not possible to collect information on the intensity of participation of former users.

All current Project participants were invited to take part in the survey (e-mailed). A total of 170 responses out of 400 were recorded, corresponding to 35% of the total current (year 6) users. However, excluding the 145 children who attended the Cronopis training courses, the response rate actually reached 66% of those surveyed. The questionnaire covered several aspects such as geographical origin, age, year of enrolment, type of linkage (User/Member/Both), activities attended/participated in, time slot information, frequency of attendance, and duration of attendance. However, for the purpose of this study, only data on activities attended and frequency of attendance are shown.

At the qualitative level, semi-structured interviews provided information on the evolution of social-spatial interactions. In this regard, semi-structured interviews focused on social issues, such as spatial needs, internal social network variability, or the need for more privacy, which have subsequently had an impact on the spatial layout and formal evolution of the building. As stated above, this implies some level of bias as the questions asked were aimed at validating the interviewer's (corresponding author) research hypothesis on the alleged relationship between spatial transformation and social dynamics.

Data analysis

The data analysis is structured into three subsections. The first, spatial and social evolution, is devoted to the independent quantification of spatial and social evolution. Thus, spatial production (#spaces) and social engagement (#participants and intensity of participation) were tracked. The second, devoted to socio-spatial interpretation, qualitatively analyzes the spatial transformation resulting from the interaction between spatial potential and social performance. This provides information on the mechanisms for spatial appropriation in the face of functional needs, along with spatial specialization. Finally, socio-spatial correlation statistically assesses the correlation between spatial and social evolution.

Spatial and social evolution

On the spatial side, data collected during the interviews and transferred to CAD afterwards, provided crucial information regarding spatial production (#spaces). Here, spaces are counted to the extent that, irrespective of temporality, they host a specific defined activity/function. The time series of the number of spaces (#spaces), the area (m^2/year) these spaces annually involve, and the evolution of the "in use" (m^2) area within the building are tracked.

Regarding social evolution, the data collected provided a temporal series of social participation (engagement), both in terms of participants (#participants) and intensity of participation (#activities attended and frequency of attendance). The results were obtained directly from the Excel-based survey and *Google Forms* e-survey, respectively. Regarding participants, during the data collection campaigns, a distinction between *users* (individuals) and *entities* (organizations) was made. In addition, to quantitatively translate the qualitative data on frequency of attendance, responses

(*Sporadic/Monthly/Weekly/Regularly/Daily*) provided through the e-survey were assigned a corresponding numeric value (1, 2, 3, 4, 5).

Socio-spatial interpretation

This analysis is based on the combination of qualitative data on spatial potential and social needs collected during the interviews, which was subsequently transferred to CAD, and the quantitative spatial transformation data discussed in the "Spatial and social evolution" section.

First, as user-led mechanisms for spatial definition and functional appropriation, Spatio-functional tactics (SFTs) are identified and classified according to their degree of formal definition. This provides relevant results on why and how spatial appropriation takes place in relation to spatial production and availability.

Second, spatial diversity and spatial hierarchy are tracked as main issues (proxies) for the socio-ecological approach, at a meeting point between quantitative and qualitative analysis. Thus, whereas diversity is based on seminal ecology and planning (spatial) similarities (Holling and Goldberg 1971) regarding the richness of biological and social communities, the space to subspace distinction is based on the "*hierarchy of spaces*" as an adaptive strategy at the architectural scale. Thus, the *Shannon diversity index* was used to evaluate the spatial diversity. This implies the assimilation of spatial diversity into biological species diversity. Similarly, research on artificial reef design (Sherman *et al.* 2002) links structural complexity (of artificial reefs) to greater fish abundance, species richness, and biomass. According to the *Guidelines for the placement of artificial reefs* (PNUMA 2009), there is a direct relationship between the (spatial) complexity of a reef and the diversity of species. Here, spaces are counted to the extent that they have distinct formal surface area and/or functional characteristics with respect to each other. As a result, a temporal series of spatial diversity was obtained. In addition, spatial hierarchy is also addressed based on the evolution of the ratio of subspace/space over the years. Here, regardless of formal considerations, the analysis of spatial hierarchization identifies spaces devoted to independent functions, whereas subspaces are those hosting subsidiary uses from the principal one. Thus, a temporal (yearly) series of subspace/space production rates was also obtained.

Socio-spatial correlation

As a validation tool, this section analyzes the statistical correlation between spatial and social evolution. This lies in the consideration of spatial transformation as a necessary mechanism for social dynamization. To this end, scatter plots and *Pearson correlation coefficients* (*PCCs*) were graphically and analytically performed. Here, spatial variables are deemed independent, whereas social variables are deemed dependent. The results section provides the correlation analysis between the spatial quantitative (#spaces) and qualitative variables (diversity and hierarchy) as well as the social engagement, in terms of both participants (#individuals and #entities) and intensity of participation (#activities attended and frequency of attendance). This analysis is derived from the results obtained in the first and second sections.

RESULTS

Social and spatial co-evolution

The social evolution (Figure 3) reveals an increase in participation from years 1 to 4 and a subsequent stagnation/decrease phase from years 4 to 6, both in terms of participants (individuals) and entities involved. Thus, whereas participants increased from 100 in year 1 to 345 in year 4 (+245%), the number decreased to 323 (-6.38%) by the end of year 6. Similarly, the number of entities grew from 5 to 21 (+ 320%), falling to just 19 (-9.5%).

In relation to the intensity of participation, both total activities attended, and total frequency of attendance showed a slowdown trend from years 4 to 6 after the initial growth (years 1– 4).

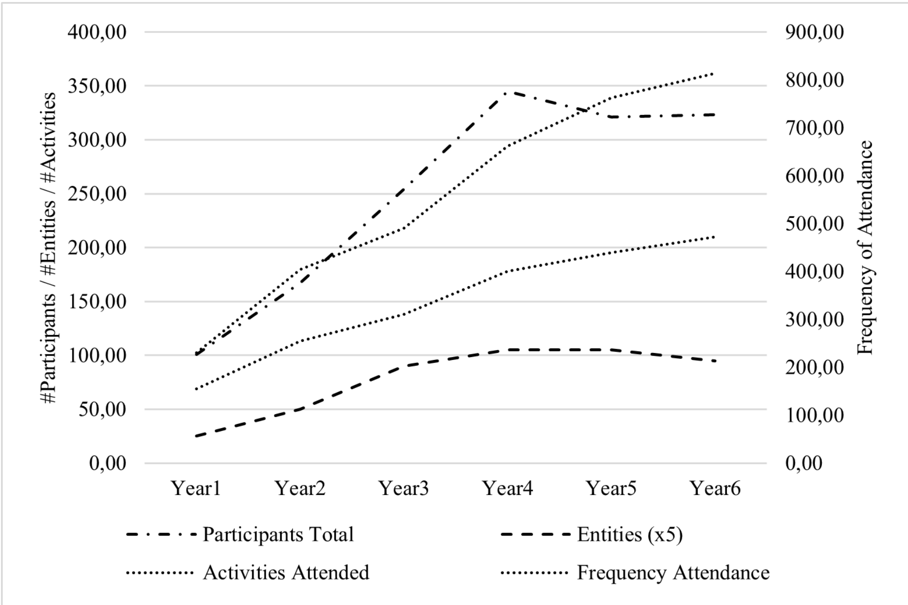

Figure 3. Social evolution

In relation to spatial evolution, the spaces show a progressive increase over the years. This is evidenced by the progression from just 6 functional spaces in year 1 to 50 by the end of year 6. Relevant parallel considerations emerge as a result of quantitative spatial production, such as spatial differentiation, in terms of area (m^2) and spatial depletion, for both the annual total and mean area affected by the new spaces. First, contrasting areas of space are revealed by the end of year 6, ranging from barely 10m^2 (Individual Workshop_*Fugart*_L1) to over 1250m^2 (*Cronopis*_L0) (see Figure 5). In addition, the annual total area of new spaces downs from almost 5000m^2 in year 1 to less than 500m^2 by year 6 (-90%), whereas the mean area reaches 225m^2 in year 1 and falls to just 22m^2 (-90%) by year 6. Finally, the results also provide information on the evolution of the “in use” area over the years. Thus, whereas it increases from year 1 (2430m²) to year 4 (3930m²/almost 100% of the inner space), it subsequently decreases by year 6 (3610m²), despite the growing spatial production rate. Figure 4 graphically shows the evolution of spatial production in terms of #spaces, the area (m²) these involve, and the “in use” area. Surprisingly, from year 4 on, the continuous rise in spatial production (#spaces) does not translate into major reactivation ("in use" space) of the inner space or into an increase in the area involved annually

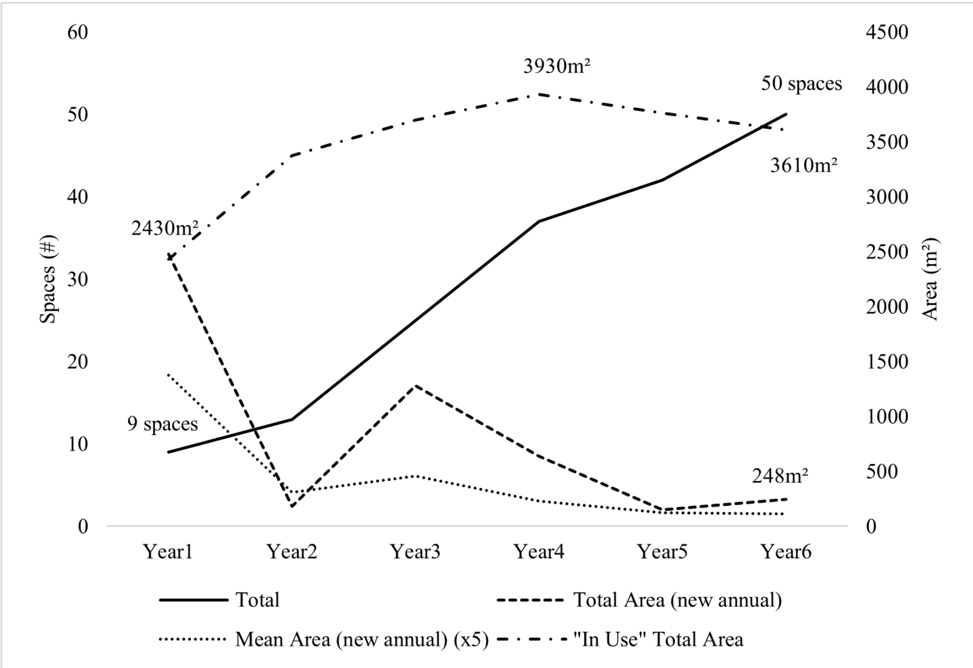

Figure 4. Spatial production

At the architectural dimension, Figure 5 graphically displays the spatial production process along with the evolution of the total “in use” area (shaded in gray).

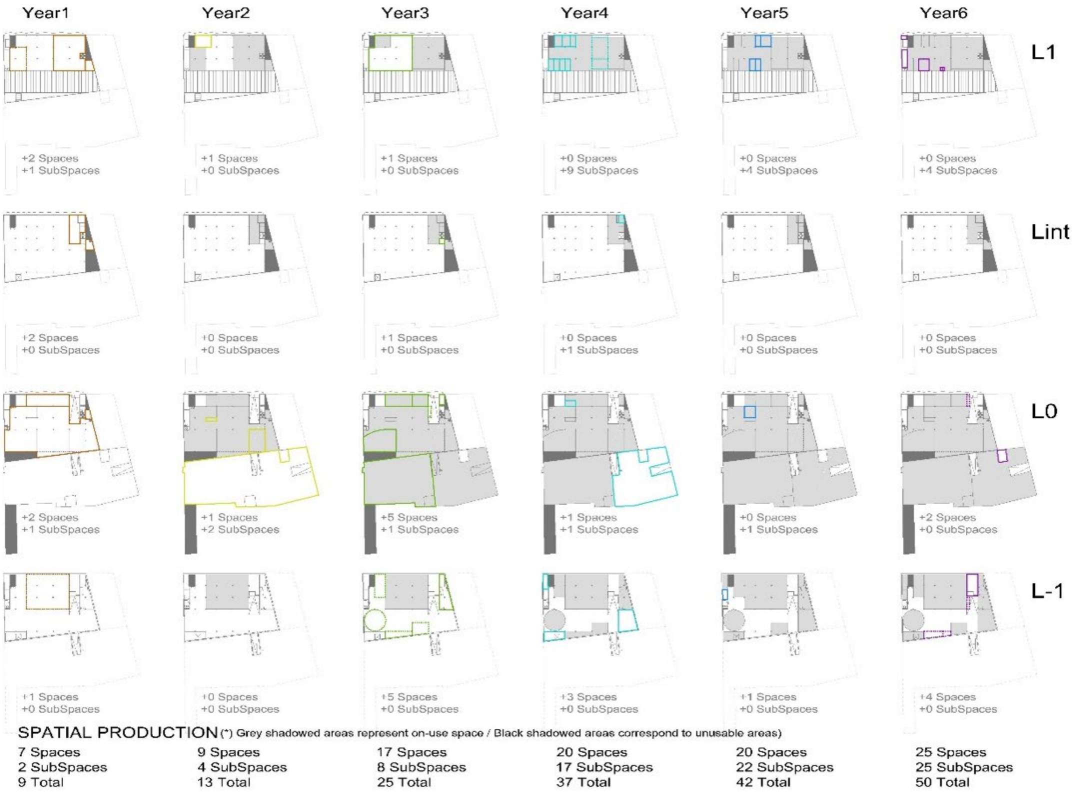

Figure 5. Cartographies of change*:* Spatial production

As shown Figure 5, the creation of new functional spaces (spatial production) is based on leveraging the pre-existing construction elements, regardless of the area, year, or floor. Thus, existing interior partitions and screens, the grid of pillars, and the façade openings appear as key elements where to rest the new spatial defining devices.

Analyzing socio-spatial interpretation

As a result of the qualitative analysis of socio-spatial interaction, the study explored how new spaces are appropriated and how space specialize over the years.

SFTs toward spatial definition

As a result of the analysis, SFTs are classified by their degree of formal definition. Thus, *formally defined* (*FoD*) refers to new functional formally defined spaces; *functionally adapted* (*FuA*) refers to those functional spaces accommodated to pre-existing formal boundaries and pre-existing elements of the building (walls, partitions, pillars, columns, etc.) on which they rest, and *functionally defined* (*FuD*) refers to those spaces which appropriation is based on their use, without defining any formal boundary or delimitation.

Figure 6 shows the evolution of the SFTs over time. Thus, initially (year 1) spatial definition mainly lies on adaptation strategies (*FuA*), both in terms of number (7) and area (> 1850m²). Subsequently, year 2 is characterized by quietness (*FoD*: 3 Area?), whereas year 3 is characterized by simultaneous strategy coexistence (*FoD*: 5; *FuD*: 5; *FuA*: 4). Years 4 and 5 show the prevalence of formally defined strategies (*FoD*; 10 in year 4; 0 and 5 in year 5). In contrast, year 6 is characterized by the prevalence of non-formally defined spaces: *FuD* (4) and *FuA* (4). This suggests accommodative strategies prevail during the first stage of the project (years 1–3), when use mainly adapt to former spatial conditions without formal modifications. Subsequently, as the Project progresses (and the inner space is activated), formal definition strategies take the lead (years 3–5). In addition, *FuD* appears as a wildcard tactic over time, despite its impact in terms of surface area, although continuous, is relatively low.

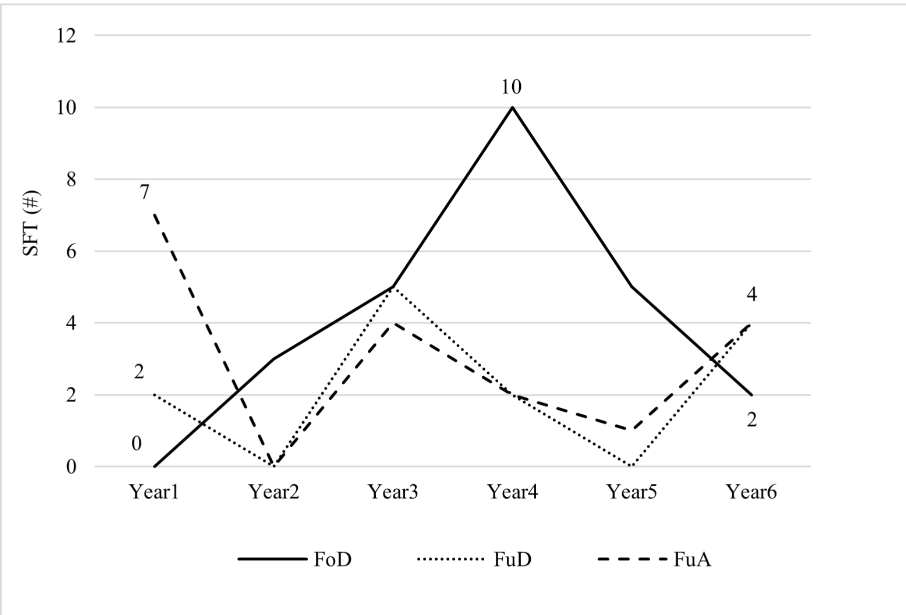

Figure 6. Spatio-functional tactics (SFT)

Figure 7 graphically displays the SFTs undergone within the building over the years, along with the evolution of the total "in use" area (shaded in gray).

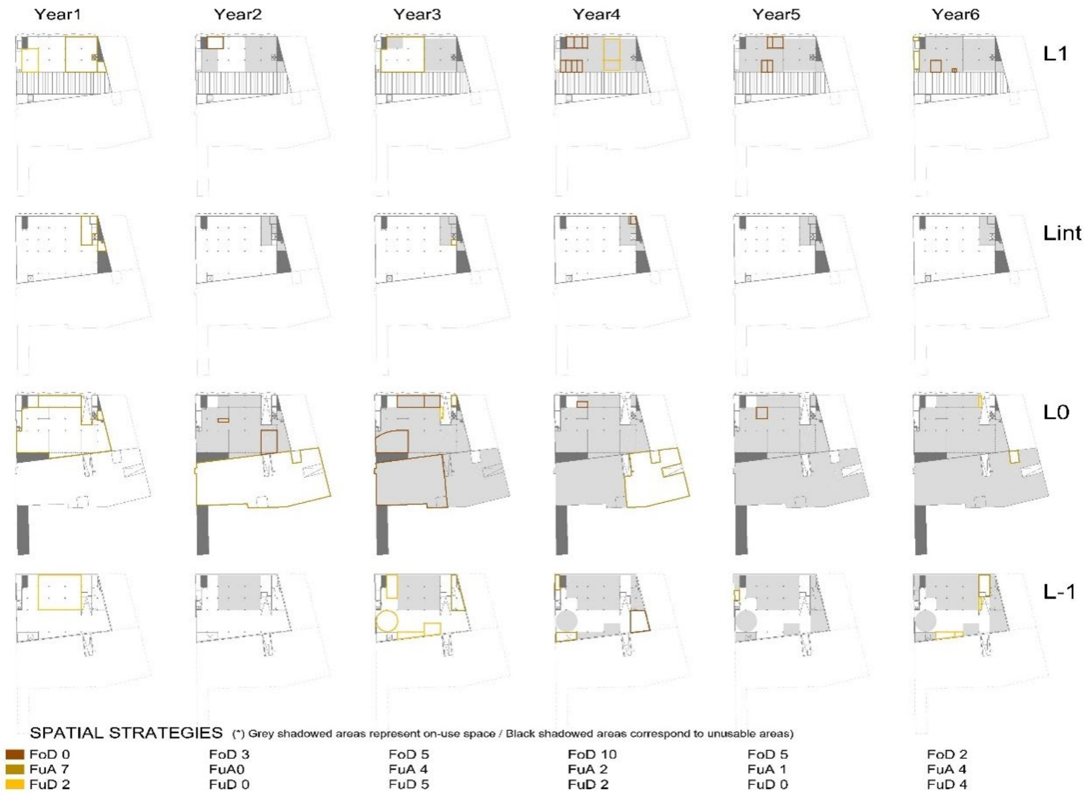

Figure 7. Cartographies of change*:* Spatial definition

This, in turn, provided significant findings regarding the evolution of spatial definition in relation to spatial availability and the evolution of the "in use" area (see Figure 4). Functionally adapted spaces (accommodative) prevail during the first stage (years 1–4) parallel to the increase of "in use" area. Subsequently, formal mechanisms take over as the space fills up and the "in use" area decreases. This is especially evident when looking at the behavior at each level independently. Thus, whereas in L1, FoD tactics take the lead once the space is filled (year 4), L-1 is wholly characterized by non-formal definition tactics because there is still space available.

Contributions on spatial adaptability

The findings provide complementary contributions to the theoretical framework of spatial adaptability. Specifically, this paper sheds light on the analysis of the user-driven stage of architectural adaptability. Thus, Table 1 summarizes the results on the buildings' new *ables* and *layers* involved during each SFT's predominant stage, chronologically (years 1–6) complementing Schmidt's and Brand's research.

Schmidt's (2010)					Brand's (1994)
Able	Type of change (*Predominant*)	Decision-level	B-E scale	Time (cycle speed)	*Layers*
Occupiable	Functional Adaptation (FuA)	User	Inner Spaces & Subspaces	Years 1-3	Spatio-functional Boundaries
Appropriable	Formal Definition (FoD)	User	Inner Spaces & Subspaces	Years 3-5	Spatio-functional Boundaries
Usable	Functional Definition (FuD)	User	Inner Spaces & Subspaces	Years 1-6	Spatio-functional Boundaries

Table 1. New Building's Ables for Adaptability. Adapted from Schmidt (2010)

Here, *occupiable* refers to a spatial (un)definition that makes a piece of (inner) space suitable for a permanent functional purpose without formal implications. *Appropriable* refers to a spatial (un)definition that allow the space to be formally bounded for a permanent specific function. Finally, *Usable* refers to a portion of space in which formal (un)definition makes it suitable for non-formally defined temporary uses.

Diversity and hierarchy toward spatial specialization

The assessment of the *Shannon diversity index* (see Appendix 1) reveals the global *increase* in diversity (Figure 8) from 3.71 in year 1 to 5.21 by year 6. However, some remarks can be made insofar as a first stage of growth can be observed (years 1–3), followed by another of stagnation/decrease (years 3–5) and, finally, a new increase (year 6).

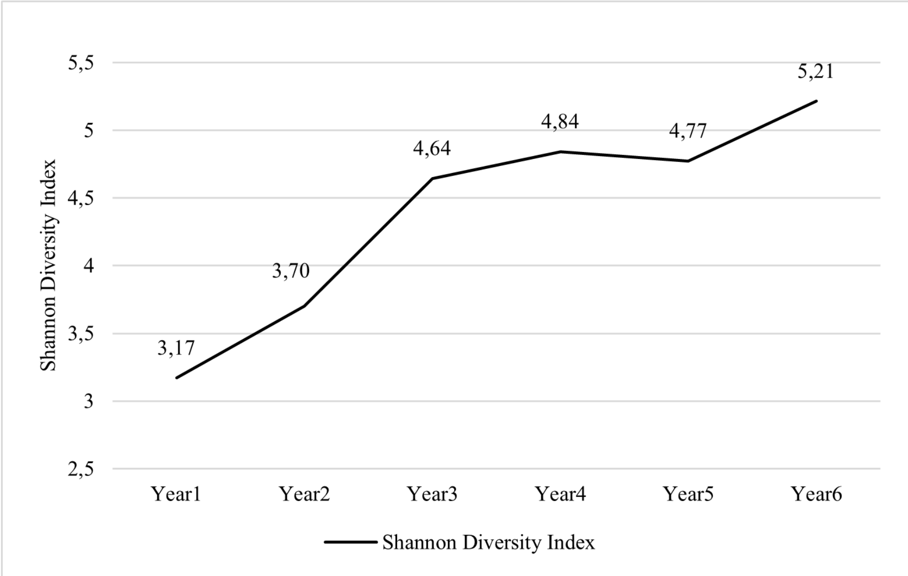

Figure 8. Spatial diversity

Spatial hierarchization was also revealed because of socio-spatial interactions. The results show uneven, albeit complementary, evolution of spaces and subspaces. Thus, whereas spaces increased from 7 in year 1 to 25 by the end of year 6 (+357%), subspaces experienced even greater growth from just 2 in year 1 to 25 by the end of year 6 (+1250%). In addition, relevant differences and complementarity when comparing annual series appear. Thus, while the first stage (years 1–4) is characterized by the predominance of space (+25) production, the following stage (years 4–5) is characterized by the production of subspaces (+16). Finally, year 6 shows a convergent trend as the space rate slightly increases and subspaces stabilize. Eventually, the evolution of the ratio between the two was tracked. Thus, the proportion (subspaces/spaces) increased from 0.29 in year 1 to 1.00 in year 6, after a correction point in year 5 (peak of 1.1).

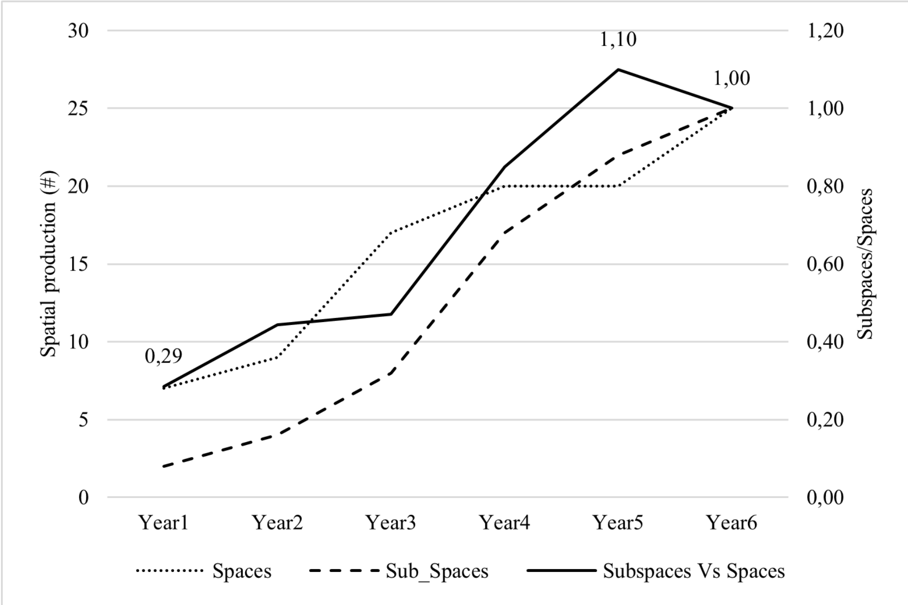

Figure 9. Spatial hierarchy

The processes of diversification and hierarchization are also linked to spatial production (#spaces). Figure 10 shows the relationship between diversity and hierarchy (dependent variables) and the independent spatial variable.

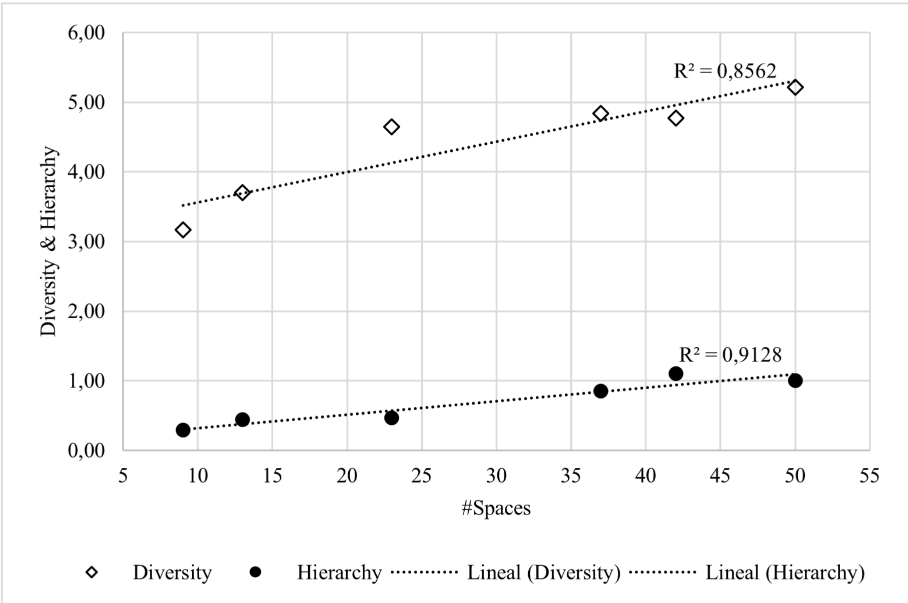

Figure 10. Diversity and hierarchy versus spatial production

Statistical analysis reveals a strong direct correlation to spatial evolution for both hierarchy (ρ = 0.95) and diversity (ρ = 0.92).

Assessing socio-spatial correlation

As a validation process, this section focuses on socio-spatial correlation. Thus, beyond absolute values (some series have been scaled up for illustration purposes), Figure11 reveals similarities between the spatial (continuous lines) and social (dotted lines) trajectories over the years. This seems to confirm the authors' hypothesis regarding the linkage between spatial transformation and social dynamism.

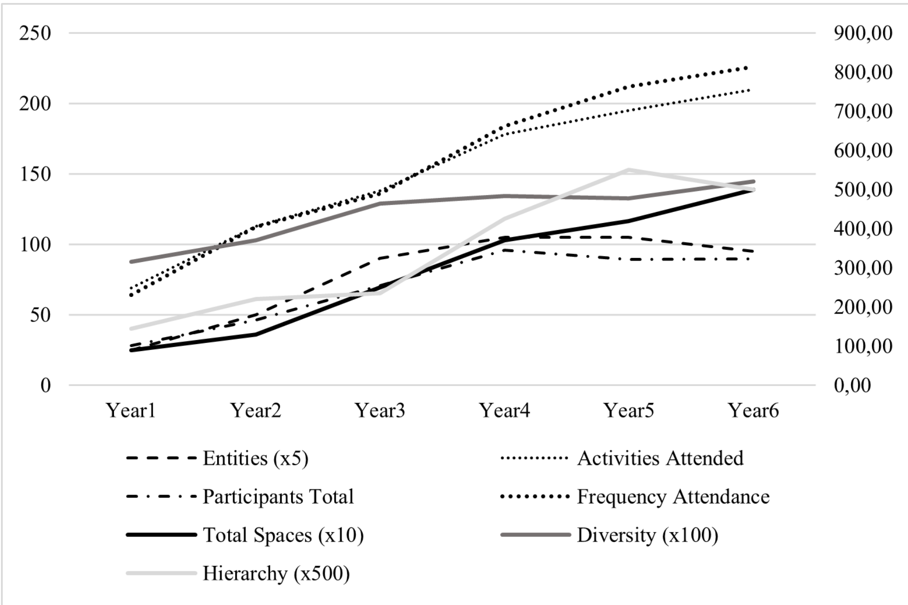

Figure 11. Social and spatial trajectories

However, some symptoms of partial socio-spatial dissociation between the two (spatial and social) arise. Thus, after a period of parallel growth (years 1–4), a turning point (year 4) is reached, when a process of slowdown, stagnation, or even decline (years

4–6) in participants occurs, despite the progressive increase in quantitative (#total spaces) and qualitative (diversity) spatial terms. In contrast, intensity of participation (#activities attended and frequency of attendance) does follow the rise in spatial production.

Social evolution vs quantitative spatial transformation

The scatter plot (Figure 12) clearly shows a correlation between spatial production (#spaces) and engagement (#participants and intensity of participation). The Pearson correlation index reveals a very strong positive correlation among total participants (ρ = 0,92), activities attended (ρ = 0,98), and frequency of attendance (ρ= 0,98), whereas there is a strong positive correlation for #entities (ρ = 0,86).

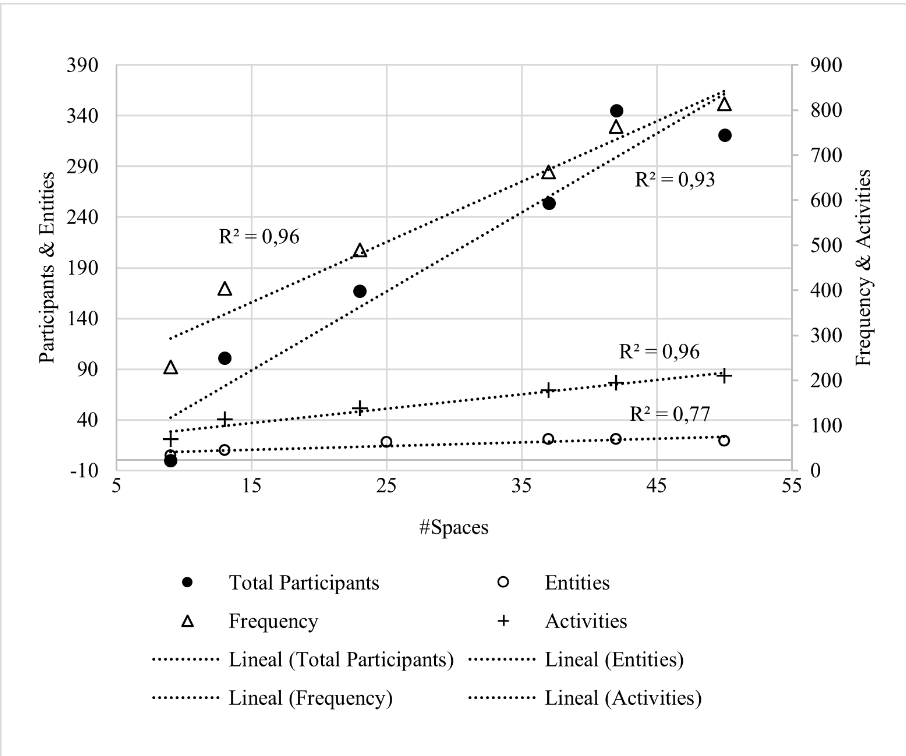

Figure 12. Participation versus spatial production

However, considering the bifurcation point observed in year 4 between spaces and participation (see Figure 11), the correlation for years 1 to 4 was even higher for both total participants/individuals (ρ = 0,99) and entities (ρ = 0,94). From year 4, the growth of spaces does not translate into an increase in the number of participants.

Social evolution vs qualitative spatial transformation

Finally, the correlation between spatial specialization (diversification and hierarchization) and social engagement is also assessed (Figure 13).

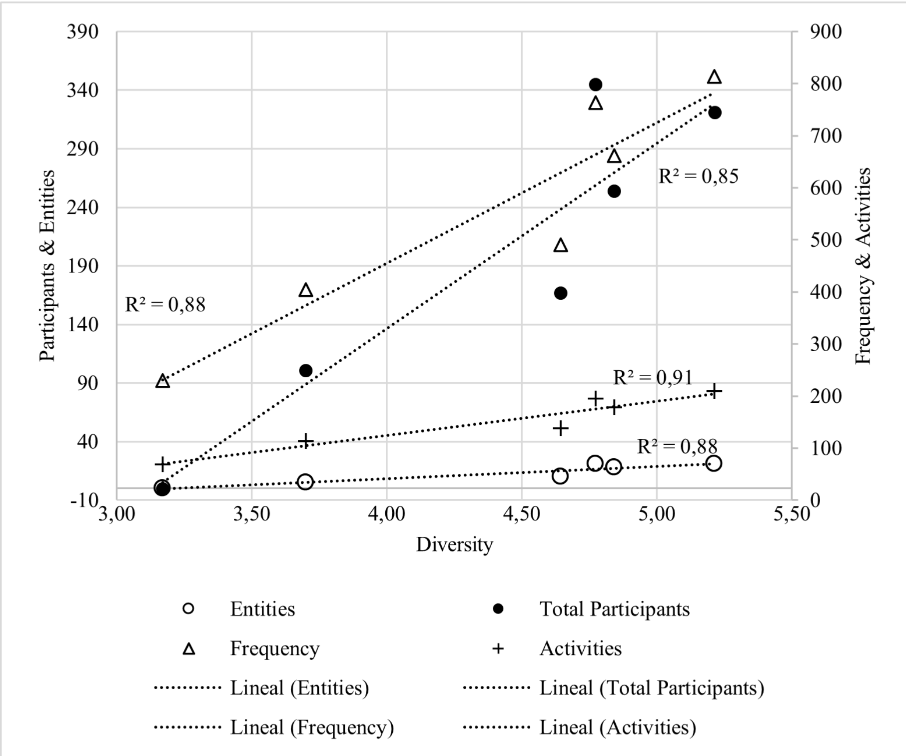

Figure 13. Participation versus spatial diversification

Participants, both individuals (ρ = 0,96) and entities (ρ = 0,95), the and frequency (ρ = 0,97) and intensity of activities (ρ = 0,94) portray a very strong positive correlation with spatial diversification (Figure 13).

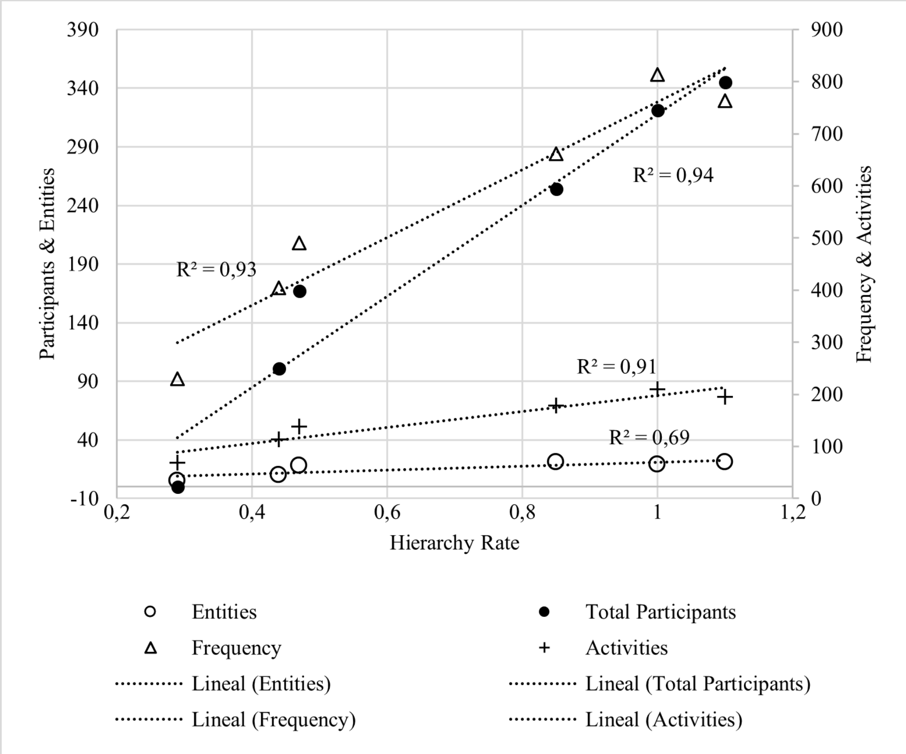

Figure 14. Participation versus spatial hierarchization

Similarly, participants, both individuals (ρ = 0,89) and entities (ρ = 0,83) show a strong positive correlation with spatial hierarchization. Further, frequency (ρ = 0,97) and activities (ρ = 0,95) portray even stronger positive correlations in terms of intensity of participation (Figure 14).

DISCUSSION AND CONCLUSIONS

In contrast to the predominant engineering (bouncing back) approach to resilient thinking at the urban scale, this study investigates a socio-ecological (bouncing forward) urban resilience attempt at the architectural scale, based on a self-organized case study on the recovery of a former industrial structure. The building (built stock) represents a formal repository accumulated during stagnation (*K phase*) of the infrastructural subsystem. This capital is leveraged (*remember*) by community-led processes at lower scales (social subsystem) for their own reorganization (α-phase) and growth (*r-phase*) during the *backloop*. At the same time, this promotes the reactivation (*revolt*) of the former infrastructural subsystem. Thus, embedded resilience is released in the form of social dynamism as the space transforms, enabling the urban system to progress. Quoting and adapting Holling (2001), urban resilience, at the architectural scale, is the result of the operation and communication of these cycles (*Panarchy*), enabling the system to navigate itself. Here, community-led initiatives present a new paradigm for stakeholder engagement and motivation in the built environment. In relation to co-responsibility approaches (Du Plessis and Cole 2011), social self-organization stands as a leverage point to change the system while overcoming the rigid distinction between direct and undirect stakeholders.

Space undergoes quantitative and qualitative transformations over the years. At a quantitative level, this transformation leads to spatial production in the form of functional spaces rising, whereas at the qualitative, spatial specialization, in terms of diversification and hierarchization, emerges. Such specialization appears because of socio-spatial interpretation. In addition, social progression is strongly correlated to said quantitative and qualitative spatial transformation because an increase in both the number of participants and intensity of participation runs in parallel to the increase in spaces, diversification, and hierarchization.

This study also provides significant implications regarding adaptability, diversity, and hierarchy as core principles of resilient architecture. Based on the peak of social engagement, optimal resilience at the architectural scale appears at a meeting point between spatial production (functional spaces), at the quantitative level, and spatial diversity and hierarchy (servant and served spaces), at the qualitative one.

However, considering urban resilience not as a fixed asset, but as a continually changing process (Davoudi, 2012), adaptability, diversity, and hierarchy are required to the extent that they progressively allow space to accommodate social dynamism. Therefore, it is not a fixed preliminary design issue, but rather a result of the socio-spatial process. Not as being, but as becoming. It is the very process of adaptation, diversification, and hierarchization that makes it possible for social progression and, hence, for urban resilience.

The socio-spatial interpretation indicates that SFSs arise as emergent mechanisms for spatial definition at the architectural scale. In Hertzberger's terms, SFTs appear because of users' interpretation (performance) of spatial possibilities (potential) under social needs. Based on their degree of formal implementation, SFTs alternatively take the lead for spatial appropriation, contingent on spatial availability. As noted, the progressive spatial infill, translated into a larger "in use" surface area, leads to an increase in formal SFTs. This contrasts with accommodation-based strategies employed when first entering the building, when leveraging pre-existing built elements is required. The terms occupiable, appropriable, and usable characterize spatial adaptive capacities (*ables*) during each SFT's dominant period, enhancing adaptability at the building scale through users-driven actions.

This confirms Kohler and Hassler (2002, 2014), who argued empty buildings should be considered reserves for present and future needs and for the continuity of day-to-day activities. These results may push urban planners and policy makers to consider built stock as an asset in regeneration plans going forward.

This study has several limitations that should be addressed in future research. Unsurmountable bias in the qualitative approach must be minimized to ensure greater trustworthiness and relevance of the results. Here, the concern is whether the researcher has been transparent and reflexive, that is, critically self-reflective about their own preconceptions, relationship dynamics, and analytic focus (Polit and Beck 2009), about the processes by which data were collected, analyzed, and presented (Galdas 2017). Thus, some indications seem to point to socio-spatial exhaustion, indicating thresholds for the progression of urban resilience. In this regard, social stagnation, or even decline, appears once the building is almost fully operational ("in use") by year 4, despite spatial production, diversity, and hierarchy rising. This is followed by a surprising decrease of "in use" areas till year 6. Similarly, the progressive annual decrease in total and mean areas seems to confirm this. This raises questions concerning fragmentation, in terms of over-division, hyper-specialization, over-diversification, and over-hierarchization as symptoms of spatial depletion. Further, the study also highlights the limitations of the Project in terms of overcoming the physical boundaries of the building. The formal implications of the socio-spatial interpretation are restricted to the interior space of the building, without investigating the impact on the urban surroundings. As such, this study serves just as a starting point; more research will be needed on the temporality (meanwhile), pre-existing constructive layout conditions, potential for expansion, and impact of such projects at the urban scale, to determine whether industrial urban areas (brownfields) are, and to what extent, true repositories of embedded urban resilience.

Declaration of Interest Statement

No conflicts of interest exist.

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