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Vulnerable Neighbourhoods, Disaffiliated Populations? A Comprehensive Index of Social Capital and Social Infrastructure in Barcelona

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Abstract: This article aims to understand the probable links between social capital and social infrastructure. The inclusion of these two dimensions into urban analysis may help to better understand the nature and characteristics of the relationships between the built environment and the level of organisation of the residents, and whether these have an impact on the vulnerability of the territories. Through use of statistical techniques (visual grouping and cluster analysis, among others), this article seeks to construct a comprehensive measure of social capital, as well as a comprehensive index of social infrastructure. These two in combination show, as the main results, that the characteristics of the built environment may promote higher levels of social interaction, also leading to higher levels of civic engagement and participation. However, the results also suggest that this relationship may be bidirectional. Finally, the mapping of the two indices applied in the city of Barcelona is presented and these results are compared with a previously constructed index of vulnerability for the same territory, allowing an overall better understanding of Barcelona's socio-urban behaviour.

Keywords: social capital; social infrastructure; urban vulnerability; vulnerable neighbourhoods; urban regeneration

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1. Introduction

Previous studies [1–3] have focused on the organisational component when comparing the level of cohesion and the organisational capacity of different neighbourhoods. According to these studies, the number of organisations, as well as their ability to promote encounters and address collective struggles, will have direct implications in terms of the ability of the territories to adapt to external threats, in turn influencing their resilience. In this sense, it is essential to study the social infrastructure component as a facilitator or inhibitor of potential social interaction and encounters that may have impacts on social capital.

The context of a crisis like the current one—amplified by the effects of COVID-19—forces us to rethink the design and planning of our cities in relation to the possibilities they offer, in terms of their social infrastructure [4], towards the development of civic engagement networks and actions and in terms of social capital.

In this context, one of the main hypotheses is that social infrastructure may serve as a booster for social capital creation. However, at the same time, this relationship may be bidirectional, meaning that greater organisation could also result in the improvement of the built environment (it is well established that public interventions are sometimes a result of an organised movement's struggles). Thus, this article discusses, theoretically and empirically, the limits and opportunities of two key concepts in urban planning: social infrastructure (contemplating the design and characteristics of public and private spaces) and social capital (including social interactions that may lead to the generation of networks and/or struggles towards the improvement of neighbourhoods, consequently promoting

greater resilience to crises such as the current one). This research took place in Barcelona, following the same case study as the RE-INHABIT project [5] and the first author's PhD thesis.

As has been established, recent research [6] argues that although areas with better access to social infrastructure should support higher social capital, this may still be a theoretical argument that has not been tested properly by quantitative frameworks. This represents one of the main motivations of the work presented here: to suggest a framework for the study of some of these concepts, through the construction of robust indices that may help shed some light on these urban phenomena.

Within this framework, the main objective of this article is to analyse the relations between social capital and social infrastructure. In order to accomplish this, a comprehensive index of social capital and a comprehensive index of social infrastructure were created, following quantitative statistical analysis techniques. The results of the application of these indices in the Barcelona case were mapped using geographic information systems (GIS) software. This allowed us to identify and compare areas with a lower or higher concentration of these indices' values that required special attention. A comparison with a previously constructed index, which focused on the levels of vulnerability in Barcelona's neighbourhoods, was also carried out. The results are presented in a synthetic way, offering some discussion concerning the implications of the results in terms of urban planning and policy making.

This paper is organised as follows: First, a theoretical discussion of the main concepts of social infrastructure, social capital and vulnerability is presented. Secondly, the methodology of the study is presented. A quantitative strategy was followed, which was aimed at establishing links between the concepts analysed in the case study. Finally, the main conclusions derived from the study are presented.

2. Theoretical Framework

Are there more and less organised neighbourhoods? What do these entail? During interviews conducted within the framework of the RE-INHABIT project—which focused on the urban regeneration of vulnerable neighbourhoods—some technicians from the public administration stated they could identify neighbourhoods that were more organised than others. Not only this, but they were absolutely sure—although they had no empirical data to support this idea—that places that were 'more organised', in their opinion, were areas of the city where it was possible to 'do more'. This 'doing' was related to public intervention at different levels, from a specific rehabilitation of a building to a bigger participative process that could entail the improvement of a park or the installation of escalators in areas with a steep slope. The idea was that where there was a pre-existing engaged citizenship, better implementation of policies was possible. Conversely, in those areas that were, in their own terms, more 'disaffiliated,' most interventions were impractical (sometimes impossible) to accomplish. This situation has, in fact, forced the administration of Barcelona to sometimes have to incorporate specific devices or mechanisms into their policies in the form of community mediation that could result in the 'creation' of this more organised urban tissue or fabric where it was not possible to find it. However, this means dealing with more investments and more time, and it is sometimes impractical. The result is that sometimes money is spent where it can be spent, not necessarily where it is most needed. Especially in terms of housing, a city like Barcelona has significant issues in terms of access, rehabilitation, accessibility and affordability, among others, and so needs to have a very proactive attitude in order to make informed decisions that have a truly positive impact.

In this sense, more organised territories seemed to experience more intervention. But what does 'more organised' mean? Is it a question of the quantity of local entities and associations? Is it related to political participation? On the other hand, what does 'more intervened' mean? Is it a question of the amount of public investment? Is it related to the quality of interventions undertaken? Throughout this article, we discuss some of these

questions. But first, some debates around the key concepts of this research, mostly related to urban vulnerability, social capital and social infrastructure, are presented.

2.1. What Is Urban Vulnerability?

The United Nations defines vulnerability as a state of high exposure to risks and uncertainties, in combination with a reduced ability to protect or defend oneself against these [7]. When the concept of vulnerability emerged in the literature, it allowed scholars to move beyond the concept of poverty, which was proved to be insufficient to explain social differences in a changing world [8]. Castel [9], followed by many others [10,11], was the first to explain how vulnerability was related to a certain state of being 'at risk', overcoming previous theorisations that centred around the binary relationship of social integration–disintegration. The end of a salary-centred society enabled the possibility of people becoming actors at risk: of losing jobs, of becoming disaffiliated or of losing their social networks. These 'grey areas' better account for the different situations experienced by a vast population in the post-industrial societies, characterised by probable situations of defencelessness, insecurity, risk, shock and stress. Within this framework, it is easier to understand what vulnerability actually entails: an increased risk, fracture or weakening of the known protection instruments—associated with a previous salary-centred situation—and/or the difficulty to overcome structural poverty [12].

Eventually, the application of this concept to understand the urban phenomenon would lead to a vast production of research that would focus on understanding the different populations at risk, the distribution of vulnerability among different areas, as well as the creation of different indices that would shed some light on its causes and effects. Because the concept of urban vulnerability is fundamentally multidimensional, scholars focusing on its social, economic or physical dimensions have provided different definitions that complement it. As is clear, the concept of urban vulnerability alludes to a dynamic and complex process that combines different residential, economic and social dimensions that lead to situations of exclusion [7,13].

The study of urban differentiation, specifically the use of indices, is very well established in urban sociology. In this regard, it is possible to mention some very relevant efforts to operationalise the urban vulnerability concept, and at the same time identify its territorial distribution at different scales [14–19]. The results obtained by the integrated vulnerability index (IVI) applied to the city of Barcelona [20] are presented later in an attempt to compare the maps made within this research with that previous index and try to understand the relations between vulnerability, social capital and social infrastructure.

2.2. What Is Social Capital?

Social capital (SC) is a polysemic concept: it can imply the collective construction of trust, the level of associativity or social integration, even the membership to social networks or organisations [21]. It was first described by Pierre Bourdieu [22] who, based on a theory that explains social differences and social reproduction through the existence of different forms of capital, offered a definition of SC as the structure and content of an actor's social relations, implying a durable network of more or less recognised and institutionalised relationships. More recently, the OECD [23] defined social capital as one of the factors that contributes to people's wellbeing, related to the quality of our relationships that have an impact on our levels of happiness and health [24]. These definitions share the idea that ties and trust between friends and neighbours seem to have a direct impact on one's happiness and/or satisfaction [25].

A very important work [26] points towards the difference between the bonding and bridging forms of SC and finds that, although the former entails stronger relationships between individuals, these may not necessarily lead to civic engagement, while the latter tends to result in collective action. There is an underlying question as to whether the level of vulnerability of a neighbourhood conditions its ability to transform bonding into bridging. Thus, extensive research has analysed both the individual [27] and neighbourhood effects

on the formation of SC. This article will focus mainly on the latter since our focus lies in the bridging component of SC, mostly related to the participation and implication of citizens in the production of their environment. As will be seen later, when creating the SC index, the main variables incorporated in the analysis are related to the presence and typology of local entities and civic engagement.

Moreover, a recurrent question has been identifying how the different attributes of a neighbourhood's urban design and the built environment may influence the probability of generating social interaction and building trust between residents [28]. The author demonstrates how people who live in more walkable environments are also more likely to know their neighbours better, engage in political activities, generate trust and become more socially involved, all leading to higher levels of SC, compared to people who live in car-oriented neighbourhoods. Similarly, Glanz [29] studied the positive effects of walkable neighbourhoods, besides the obvious health advantages, showing a very important increase in the number of social interactions between residents.

Thus, if higher levels of SC are desirable, with the aim of these leading to more resilient environments, there may be ways to boost and promote social interaction in order to build stronger bonds and more durable links between citizens. Urban design can become, in this sense, a facilitator of human interaction and SC [30,31]. This idea stems from Hanifan's [32] theory, which claims that certain intangible elements impact people's daily lives, goodwill and camaraderie to a great extent. A recent study examines the connections between the quality of built infrastructure and social capital, with a special focus on ethno-racially diverse and/or low-income populations [33], and its contributions are also of interest here. The following subsection analyses the concept of social infrastructure [34] in its relations with social capital. Can some socio-urban characteristics of the neighbourhoods explain why they experience higher levels of social interaction? How can we measure both phenomena?

2.3. What Is Social Infrastructure?

When analysing the very dissimilar response to a climate-related threat of two apparently similar neighbourhoods (in demographic terms), Klinenberg [34] realised that the key difference between them was their social infrastructure (SI): the physical places and organisations that shape the way people interact. Neighbourhoods with better social infrastructure tended to promote more socialisation, resulting in a better adaptation to external threats and higher levels of resilience. In this sense, social infrastructure is not the same as social capital (associated with people's relationships and interpersonal networks in terms of bonding or bridging, as was presented in the previous section), but is, rather, the physical/material conditions that play a role in whether or not these relationships can develop. According to this author, people tend to forge stronger bonds in places with healthy social infrastructures, turning local, face-to-face interactions—at the school, the playground and the corner diner—into 'the building blocks of all public life' [34]. A few years later, Layton and Latham [35] identified six different registers of sociality which are, in their words, afforded by social infrastructure. These are co-presence, sociability, care, physical activities, collective experiences and civic engagement.

In societies that are becoming more and more fragmented, Klinenberg [34] suggests a focus on a different kind of infrastructure (in opposition to the typical intervention in hard infrastructure): building places like libraries, where all kinds of people can gather. In this sense, apart from the hard infrastructures already being built, soft or social infrastructure deserves more attention, very much similar to Oldenburg's [36] proposal of 'third places' that work as community builders. Apart from a seawall or a bridge, building infrastructure should also focus on the places that shape our interactions and make our societies work [37].

A SI typology was proposed by Layton and Latham [35] where public institutions, commerce, recreational activities, religion and transit organisation serve as representative spheres of social infrastructure. As follows from this work, urban design becomes a key question, since SI materialises in libraries, museums, markets, shops, gyms and churches,

but also parks, playgrounds, street vendors, walking trails, bike lanes and others. Some questions related to their publicness, their social benefits, as well as the necessary attention on the politics of their provision are of importance at this point [35].

What is most important about the concept of SI is that it directs attention 'to a series of spaces and facilities—often overlooked and underfunded—that supports a robust public collective life in cities, and helps build into urban neighbourhoods the capacity for all sorts of ways of being with others' [38]. In contexts of a crisis, as the COVID-19 pandemic has shown, social infrastructure becomes especially important [39], acting as a sort of 'social air-conditioning' during a heat wave, to take Klinenberg's metaphor. According to Stender and Nordberg [40], this has been made especially clear by the 'pandemic pop-ups' which included quick and sometimes informal solutions to the reorganisation of traffic systems towards more walking and biking, the expansion of restaurants into street spaces, and the relocation of people to temporary accommodations. These have become altogether truly creative temporary projects that gave answers to very real problematics that, due to their positive effects, could influence future urban development policy and agendas, becoming more and more permanent solutions [41,42]. At the same time, it has become more important than ever to highlight the importance of ensuring a higher architectural quality in these shared spaces or SI, especially when certain urban areas—usually vulnerable ones—are being regenerated [40]. Fraser et al. [43] analyse the distribution of these infrastructures using mapping systems. In our case study, attributes related to public and private spaces are included when selecting the variables and constructing the SI index, all of which will be explained in the following sections.

In this article, we examine alternatives to measure the level of association or social capital of Barcelona's residents (specifically as a measure of organisation or SC in its bridging form) and at the same time try to find out whether the development of stronger links could respond to certain socio-urban attributes related to the SI of the neighbourhoods under study. Later, we map the results of the two created indices of SC and SI, which are finally put into relation to each other.

3. Materials and Methods

In order to address the main goals of this research, a quantitative strategy was followed. The data collected correspond to the year 2021 and were obtained from different open-source official websites (mainly the municipal open data platform [44] and the municipal statistical department platform [45]). The overall methodological strategy explained in this section is also presented in Figure 1.

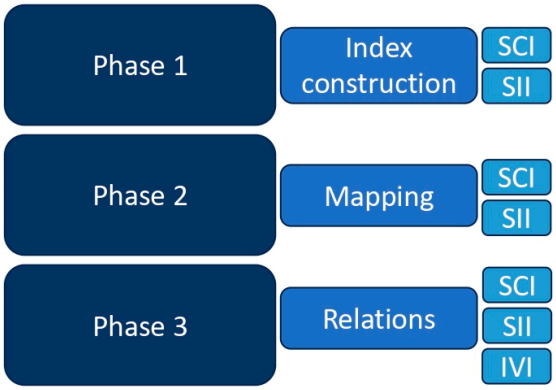


Figure 1. Methodological strategy (where SCI: social capital index; SII: social infrastructure index; IVI: integrated vulnerability index). Developed by the authors.

Firstly, we intended to create a social capital index (SCI), which incorporated certain indicators related to the level of organisation of the different neighbourhoods by adding their sub-values and conforming a new variable, which was transformed into a scalar index. The methodology followed was a numerical variable recoding and a visual grouping.

The results obtained at a neighbourhood level were later mapped in order to identify the distribution of this index in the city of Barcelona (phase 1 and phase 2 in Figure 1).

Then, we created another index that would measure the quality of the social infrastructure in each territory: the social infrastructure index (SII). This index included many different variables concerning the characteristics of the built environment that could serve as possible boosters of social interaction. The selection of indicators that comprised this index was made following the most recent literature on the subject. The technique chosen was a two-step cluster analysis. These results were also mapped (phase 1 and phase 2 in Figure 1).

Both the SCI and the SII were constructed using secondary information from open data sources, as can be seen in Table 1. The information at a neighbourhood level allowed us to build a robust database that was introduced into the IBM SPSS software (version 29.0) [46]. This program, which offers advanced statistical analysis and is commonly used when working with quantitative methodologies, allowed us to treat the data and carry out different statistical tests.

Table 1. Construction process of the two indices.

Index	Statistical Technique	Indicators	Source
Social capital index (SCI)	Numerical variable recoding and visual grouping	Quantity of Entities (n)	Municipality's open data
		Entities' typology (n)	Municipality's open data
		Participation: local elections (%)	Municipality's statistical department
		Participation: general elections (%)	Municipality's statistical department
		Virtual participation: decision making (%)	Municipality's registry of surveys
		Virtual participation: complaints (%)	Municipality's registry of surveys
Social infrastructure index (SII)	Two-step cluster analysis	Restaurants and bar (n)	Municipality's open data
		Climate refugees (n)	Municipality's open data
		Cultural equipment (n)	Municipality's open data
		Parks and green areas (m^2)	Municipality's open data
		Civic centres (n)	Municipality's open data
		Places of participation (n)	Municipality's open data
		Museums (n)	Municipality's open data
		Libraries (n)	Municipality's open data
		Association's equipment (n)	Municipality's open data
		Education centres (n)	Municipality's open data
		Places of worship (n)	Municipality's open data
		Markets and fairs (n)	Municipality's open data
		Children's playgrounds (n)	Municipality's open data
		Pet-adapted public areas (n)	Municipality's open data
		Elderly day centres (n)	Municipality's open data
		Teenager's leisure centres (n)	Municipality's open data
		Children's leisure centres (n)	Municipality's open data
		Fab Labs (n)	Municipality's open data
		Cinema, theatre, auditorium (n)	Municipality's open data
		Open-space gym areas (n)	Municipality's open data
		Urban vegetable patches (m^2)	Municipality's open data
		Music establishments (n)	Municipality's open data
		Sports facilities (n)	Municipality's open data
		Pacified or walkable streets (m^2)	Municipality's open data
		Inner block courtyard (n)	Municipality's open data

Source: Prepared by the authors.

After generating the two indices and validating them statistically, their distributions for the Barcelona case were mapped using geographic information systems (GIS). The maps were created using GIS QGIS 3.22 Bialowieza version [47]. This program offers the possibility to conduct free and open-source geographic-information-system-related tasks. The obtained results will be presented in depth in the following section.

Finally, statistical tests were conducted in order to examine the relationship and/or association between these two created measurements. At the same time, the territorial distribution of the indices was compared to a previously created integrated vulnerability index (IVI) [20] (phase 3 in Figure 1). This allowed us to generate new information about Barcelona's neighbourhoods in multi-dimensional aspects, allowing some comparison between areas and a deeper socio-spatial understanding of the city.

Although social capital could be operationalised using many indicators related to civic engagement and interaction in public spaces, among other strategies, for this paper, the social capital index was built starting from a set of variables that are most closely related to the organisational component of the territory. This is mainly supported by the definition presented in the previous section, focusing on the bridging dimension of SC, mostly related to the ability to organise and generate stronger links that may lead to taking action towards the improvement of the environment. Thus, indicators related to the presence and typology of local entities and the participatory dimension were incorporated in the construction of this index:

- The first two indicators (entities present in the territory and their typologies) were built by adding every category of entity present in each neighbourhood. The first variable refers to the institutionalised local associations that hold a legal form and have a territorial presence in the neighbourhoods where they carry out their activities on a daily basis. As for the second variable, it refers to the local association's typology (discriminating by its main activity or activities such as cultural, social, migrant-related, focused on the elderly, on children, educational, communicational and so on). These two variables were relativised according to each neighbourhood's population, obtaining a measurement that accounts for the importance of the local entities in each area.
- The third and fourth indicators (related to political participation) were built from calculating the residents' participation in local and national elections relativised by the total population in each territory.
- The two last 'virtual' participation variables were constructed by adding the values obtained from different surveys that account for citizens' engagement in online public administration's platforms for residents' participation like surveys and others, also relativised by the total population.

As for the social infrastructure index, the selection of variables includes the availability of public and other semiprivate or private establishments that serve as probable boosters of social interaction. It is important to mention that the equipment or spaces used by local entities are also incorporated (not the quantity of organisations or associations—some of which may not use a specific place—that were included as a variable in the SCI). Even though it is arguable that these could also entail (immaterial) forms of SI, this work considers mainly the material characteristics of the built environment that may play a role in the formation of bonds. Thus, indicators included here were:

- All education-related establishments and their characteristics;
- The quantity and quality of outdoor public spaces;
- The quantity and typology of cultural establishments;
- All sports and leisure establishments, public and/or private;
- All local economy and proximity businesses.

For the creation of both indices (this process will be explained in the following section) all indicators' values were normalised, allowing a better comparison of the relative importance of each variable in the total. This was performed by following the typical formula (where X can be exchanged for each indicator):

$$Xnormalized = \frac{(X - Xminimum)}{Xrange}$$

One last methodological question that is worth mentioning is the fact that all indicators and indices constructed are based on a neighbourhood level. This decision was made taking into account the fact that the local administration has been promoting the study and intervention at this scale, especially since the Neighbourhood Act of 2004. This decision responds, at the same time, to the fact that a great deal of Barcelona's history is that of its neighbourhoods, since the city as we know it today is the result of a conjunction of different and separated towns that would be united, following the inspiration of the Cerdà Plan of 1860. Thus, most neighbourhoods still hold self-representations as small towns in terms of their identity, altogether comprising the city of Barcelona as a sum. This situation still influences the way in which residents act and represent their territories, which some authors explain as the neighbourhood or territorial effect [48]. Although the decision to work at this scale is susceptible to some criticism—mainly due to the ecological fallacy suggesting the importance of analysing micro-differences—still, the results obtained in this work can serve as a big picture or representation of the city's characteristics, which is intended to help us select case studies where an extensive qualitative study is expected shortly, and which may validate or help us reconfigure parts of the work presented here.

4. Results

This section details the main results of this study. Firstly, an index of social capital was constructed, starting from secondary data related to the level of organisation of the different neighbourhoods. Then, an index of social infrastructure was constructed from statistical data related to the characteristics of the built environment. These two indices were put into relation in an attempt to understand whether social infrastructure could help explain the level of organisation and/or vice versa. Finally, these two indices were contrasted with a previously created index of vulnerability, in order to understand the nature and relationship of all three dimensions.

4.1. Recoding Variables: Towards an Organisation Index?

During the fieldwork carried out within the framework of the RE-INHABIT competitive project that also supports this paper, most consulted representatives of the public administration, as well as social leaders, agreed that it was possible to identify more organised and less organised neighbourhoods. In their own words, this had a very palpable effect: those areas with a more engaged and active citizenship were 'easier' to work in, meaning most help and programs would be implemented in such areas. In a recent paper [49], it was made quite clear that certain gaps can be identified when it comes to implementing urban-regeneration-related programs in some vulnerable neighbourhoods and that this is partly a result of the management and/or development of such policies that on occasion take for granted the fact that they needed some social fabric to serve as a material basis for (and usually before) their implementation. The result is that most investments are made in areas and buildings not because they are necessarily the ones that need it the most, but because they were 'easier' to work in, in the sense that they were 'more organised' and because a conversation between residents and administration was possible. This realisation actually made the public administration implement specific strategies to promote social links and interaction between residents where these did not already exist, giving birth to new policies such as the High Complexity Buildings [50,51] that includes a specific—and initial—phase that has institutionalised the constitution of neighbourhood communities as a first step towards a later renovation of complex buildings.

Thus, we intended to understand what a more and a less organised neighbourhood actually meant and, at the same time, validate whether the opinions of the interviewees had an actual correlation with the realities under study. Therefore, we selected some variables related to the organisation of residents conceptualised as bridging SC (some related to the participation in elections; some related to the degree of participation, quantity and area of work of local entities; some related to the participation of residents in virtual environments) and, with the support of statistical techniques (variable recoding and visual grouping), we

created a social capital index at a neighbourhood level. After having the relativised value of each indicator, this index was constructed by adding the normalised values of the selected variables. Thus, the formula for constructing the index is:

$$SCI = ent_{ln} + typ_{ln} + part1_{ln} + part2_{ln} + virtpart1_{ln} + virtpart2_{ln}$$

In this formula, *ent* is the quantity of entities, *typ* corresponds to their typology, *part*1 and *part*2 refer to the participation in local and general elections and *virtpart*1 and *virtpart*2 represent residents' participation in virtual formats, as explained in the methodology section. These all refer to local neighbourhoods (*ln*) and all variables are in their normalised values. The obtained results were later mapped using GIS (see Figure 2). The results show that some neighbourhoods seem to indeed be 'more organised' than others. More interaction and civic engagement are especially clear in areas like the Sant Andreu neighbourhood, Gràcia and la Dreta de l'Eixample. The first two neighbourhoods have a history of strong links, probably due to the fact that they used to be small towns, and that closeness which entails specific ways of interacting among residents may still be present today. On the other hand, the third neighbourhood has been experiencing significant pressure from tourism and renovation, putting this area at risk of gentrification [52] amidst the arrival of new migrants [53]. Whatever the actual reasons, it is very interesting to see that these areas of the city were the ones that both technicians and representatives of the entities assumed to be more organised, even though they could not explain why this happened. This index may help shed some light on this question.

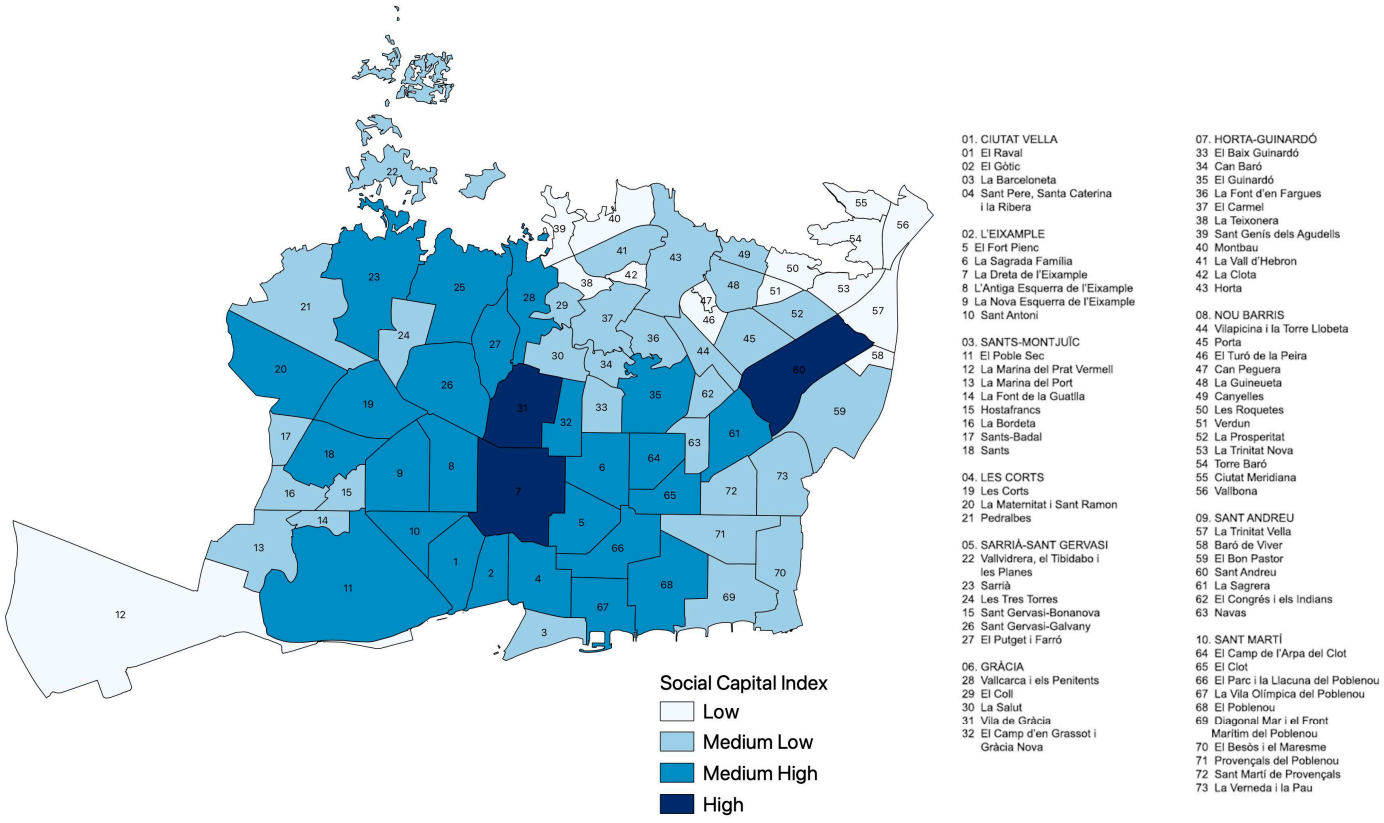


Figure 2. Social capital index (SCI). Developed by the authors.

The organisational development in Barcelona has been studied for a long time, with Alabart [54] being one of the most cited references on the subject. Diverse studies have established a differentiation of phases of the organisational movement that are identifiable [55–57], starting from a defensive attitude of the newly created associations in the middle of the last century, towards the apparition of new social movements with more

modern and proactive attitudes in recent years. Of course, the end of the dictatorship is a breaking point. Most studies agree on the importance of the year 2008, when a series of public manifestations occurred around the 15M (an anti-austerity movement, also associated with the indignados (outraged) series of public manifestations that took place in Spain between 2011 and 2012 as a result of an economic, social and political crisis that had been shaking the country). These changes may have modified the type of organisation and participation of most entities and movements, especially those at a neighbourhood scale [58]. However, COVID-19 has disrupted the 'known' ways of socialising and participating, bringing a degree of uncertainty to how the city's organisational movement will evolve [59]. Thus, it is especially important to study and have a clear vision of the subject, especially at this time, when we have been witnessing a recovery from COVID-19 that at the same time has exacerbated some of the problems existing pre-COVID-19. The SCI and its mapping could help shed some light on the issue of organisation and, later, put into relation with the SII, can help see how some urban characteristics influence socialisation and whether this has a consequence on the formation of social capital.

4.2. Two-Step Cluster towards a Social Infrastructure Index

It is not only important to measure social capital and the degree of organisation of the different neighbourhoods in the city, but also the availability of time and space that promote social encounters and civic engagement. In this sense, analysing the quality of the built environment and of the available places of proximity (such as schools, stores, parks or libraries) that promote or hinder social gathering—and/or determine the quality of such encounters—deserves some attention. Thus, at this point we intended to study which of these spaces were the most important ones in terms of socialisation and which neighbourhoods of the city were apparently better equipped in this sense.

A first model portraying social infrastructure was made incorporating each and every one of the variables proposed in the methodology section, following the literature on the subject (see the methodology section for the variable selection and their sources). Thus, a two-step cluster analysis in SPSS was performed. Cluster analysis is one of the main methodologies for analysing multivariate data [60]. More specifically, the two-step cluster analysis procedure is an exploratory tool designed to reveal natural groupings (or clusters) within a dataset that would otherwise not be apparent [61].

The results obtained from a first model generated two differentiated clusters with only a 'fair' quality of the model (see Figure 3).

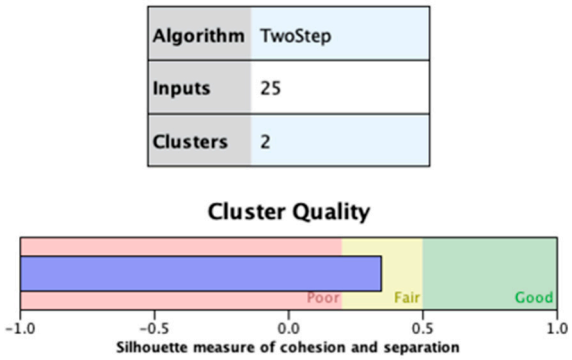
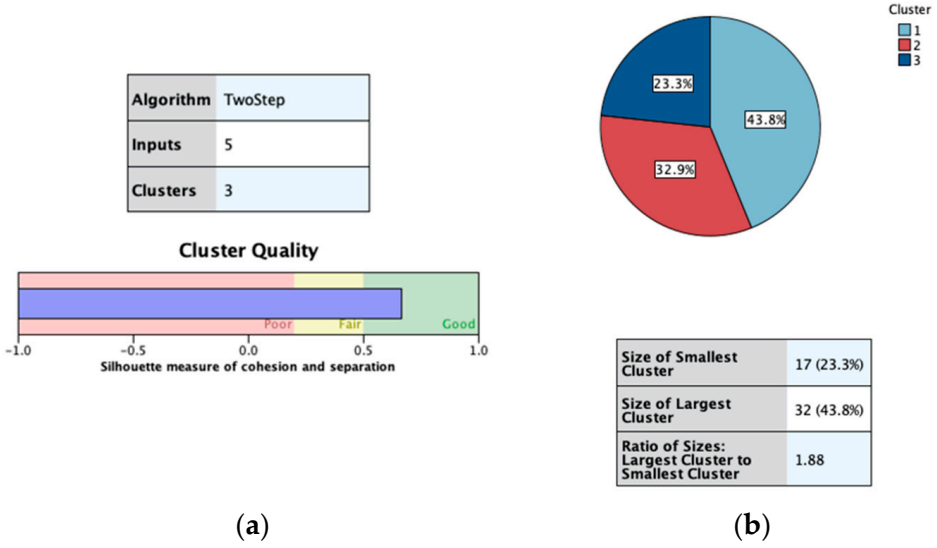


Figure 3. Results of the social infrastructure index (SII), first model. Developed by the authors.

Although the model was not a very good one, when analysing the relative importance of each of the selected variables—and their explanatory power—it was made clear that some indicators were stronger than others. Thus, a new model was carried out in which only the main variables were incorporated: cultural establishments, restaurants and bars, spaces used by local entities for gathering and educational establishments. Based on the literature [34], libraries appeared to be a very important indicator of social infrastructure, so a variable portraying these (their existence, their square meters and other characteristics

such as the use given by the communities around them) was also incorporated in this second model.

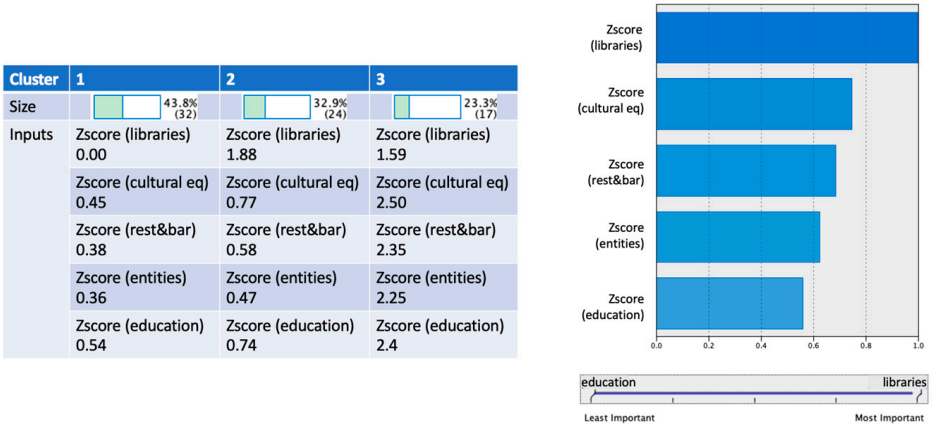
The results of this new model show the generation of three differentiated clusters with strong explanatory power. Figure 4 shows the results of the two-step cluster analysis with five inputs, generating three differentiated clusters with an overall very good quality. The ratio of sizes is also quite good (1.88), meaning that no cluster is twice as big as the other one.



(**a**) (**b**)

Figure 4. Results of second model (SII). Developed by the authors. (**a**) Model summary showing the quality of the cluster model. (**b**) Cluster sizes showing relation between different clusters.

One of the most interesting things about the cluster analysis is that it identifies the relative importance of each indicator in the total. As can be seen in Figure 5, the presence of libraries is the most important factor in terms of its explanatory power with regard to the social infrastructure in the case of Barcelona. This confirms Klinenberg's theory, suggesting the importance of libraries as generators of social interaction.



Cluster	1	2	3
Size	43.8% (32)	32.9% (24)	23.3% (17)
Inputs	Zscore (libraries) 0.00	Zscore (libraries) 1.88	Zscore (libraries) 1.59
	Zscore (cultural eq) 0.45	Zscore (cultural eq) 0.77	Zscore (cultural eq) 2.50
	Zscore (rest&bar) 0.38	Zscore (rest&bar) 0.58	Zscore (rest&bar) 2.35
	Zscore (entities) 0.36	Zscore (entities) 0.47	Zscore (entities) 2.25
	Zscore (education) 0.54	Zscore (education) 0.74	Zscore (education) 2.4

(**a**) (**b**)

Figure 5. Results of second model (SII). Developed by the authors. (**a**) Predictor importance of variables incorporated in the model. (**b**) Clusters' inputs.

Figure 5a shows the size of each cluster (how many cases each cluster gathers) as well as the relative explanatory power of each of the variables. Figure 5b depicts the relative importance of each variable: the presence of libraries is the most important one within the definition of the SII, followed by the presence of cultural equipment, restaurants and bars,

areas dedicated to local entities and finally, education establishments. These are presented by their Z-score, representing their normalised values. The Z-score of each variable was calculated from the raw score minus the population mean, divided by the population standard deviation (the formula that was explained in the previous section). This simple action allows the addition, subtraction and/or comparison of variables with very different scales and scores.

At this point, it is possible to present Figure 6, which depicts the distribution of the neighbourhood's clusters in relation to their characteristics, composition and degree of social infrastructure. Cluster number 3 shows higher values of all variables included, meaning that these are probably areas of the city that, due to the quality of common spaces, promote more and better social interaction between residents. This map was made using GIS and shows that areas of the central part of the city, as well as the Eixample district (which is currently undergoing a very important transformation such as developing the green axes and superblocks) and some areas of the richer districts of Sarrià and Les Corts, seem to be better prepared in terms of their social infrastructure. It is also very interesting to see that the Vila de Gràcia and Sant Andreu neighbourhoods also seem to be associated with better infrastructure quality. At this point, it may be interesting to test and analyse the relationship between both indices, trying to understand whether one influences the other.

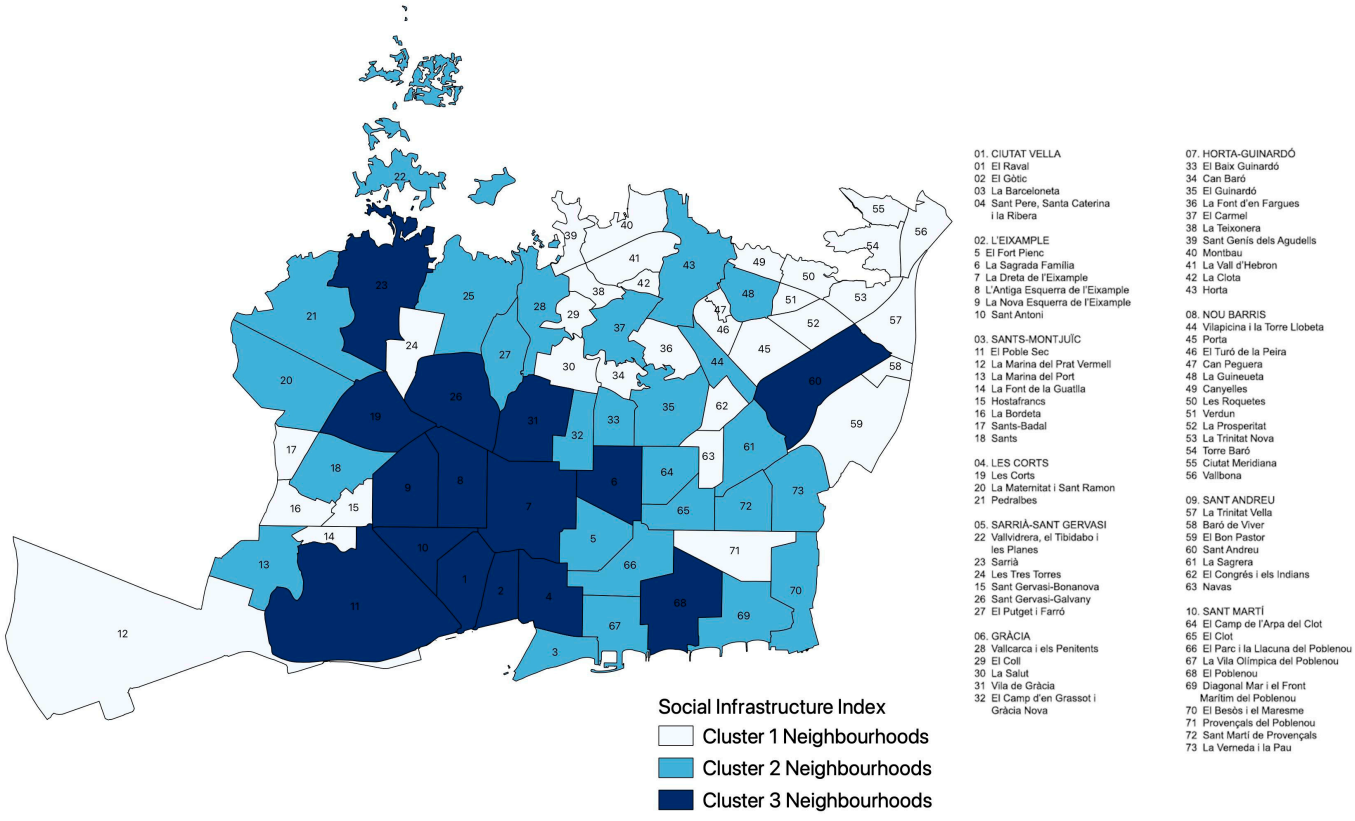


Figure 6. Social infrastructure index. Developed by the authors.

5. Discussion

The aim of this section is to statistically analyse the relationship between the two recently created indices. Consequently, it is important to establish the level of association between the two created measures, in order to test whether better social infrastructure conditions might explain higher levels of SC. However, and at the same time, it may be possible to establish whether higher levels of organisation lead to more investment (and interventions) in the form of social infrastructure. This quantitative work is not defining and is intended to provide a picture which is expected to be completed by future qualitative research.

Thus, using statistical techniques to measure the correlation of the two indices, Tables 2 and 3 show that they are indeed highly correlated. Both the parametric Pearson test, as well as the non-parametric Spearman test, show high levels of correlation, as well as very low levels of significance, suggesting that the relationship is strong.

Table 2. Pearson correlation testing.

		SII	SCI
Social Infrastructure Index (SII)	Pearson Correlation	1	0.803 **
	Sig. (two-tailed)		<0.001
	N	73	73
Social Capital Index (SCI)	Pearson Correlation	0.803 **	1
	Sig. (two-tailed)	<0.001	
	N	73	73

** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

Table 3. Spearman correlation testing.

		SII	SCI
Social Infrastructure Index (SII)	Spearman Corr. Coef.	1.000	0.754 **
	Sig. (two-tailed)		<0.001
	N	73	73
Social Capital Index (SCI)	Spearman Corr. Coef.	0.754 **	1.000
	Sig. (two-tailed)	<0.001	
	N	73	73

** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

At this point, it would be necessary to compare and contrast the relations established here within a certain time frame, so as to rule out any spurious relation. However, this has not been possible, mainly due to the lack of information on specific time series: we are not able at this point to reconstruct the indices on regular timeframes and test their correlation throughout time. This limitation means that we cannot take these results as definitive, as there is a need to repeat them in order to capture the nature of the relations more thoroughly. The local administration is making an effort to make access to open data easier by the day, suggesting this is indeed something that would be possible in the near future. However, it is possible to show whether there is correlation between temporal changes in some indicators. Thus, a simplified version of the SCI (containing two variables related to participation in elections and quantity of local entities) and the SII (containing indicators of the quantity of libraries, education centres, cultural equipment, restaurants and bars and places for associations) were constructed in order to test for correlation throughout time (5 years in the past). Tables 4 and 5 show that these new versions of the indices are still correlated, serving as partial proof for robustness that—as has been said—should still be validated in the near future with more available and updated data. Table 6 reports the correlation of the 5-year change in SCI ($SCI_t - SCI_{t-5}$) and the 5-year change in SII ($SII_t - SII_{t-5}$).

Table 4. Pearson correlation testing (simplified versions of SCI and SII).

		SII	SCI
SII_simplified	Pearson Correlation	1	0.672 **
	Sig. (two-tailed)		<0.001
	N	73	73
SCI_simplified	Pearson Correlation	0.672 **	1
	Sig. (two-tailed)	<0.001	
	N	73	73

** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

Table 5. Spearman correlation testing (simplified versions of SCI and SII).

		SII	SCI
SII_simplified	Spearman Corr. Coef.	1.000	0.682 **
	Sig. (two-tailed)		<0.001
	N	73	73
SCI_simplified	Spearman Corr. Coef.	0.682 **	1.000
	Sig. (two-tailed)	<0.001	
	N	73	73

** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

Table 6. Pearson and Spearman correlation testing between SII and SCI (5-year change).

		SII_Change	SCI_Change
SII_change	Pearson Correlation	1	0.811 **
	Sig. (two-tailed)		<0.001
	N	73	73
SII_change	Spearman Corr. Coef.	1.000	0.787 **
	Sig. (two-tailed)		<0.001
	N	73	73

** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

Then, in order to analyse the nature of the relation (meaning its directionality), a linear regression was carried out. Linear regression is a technique used to predict the value of a variable based on the value of another one [62]. The obtained results are shown in Figure 7 and Table 7.

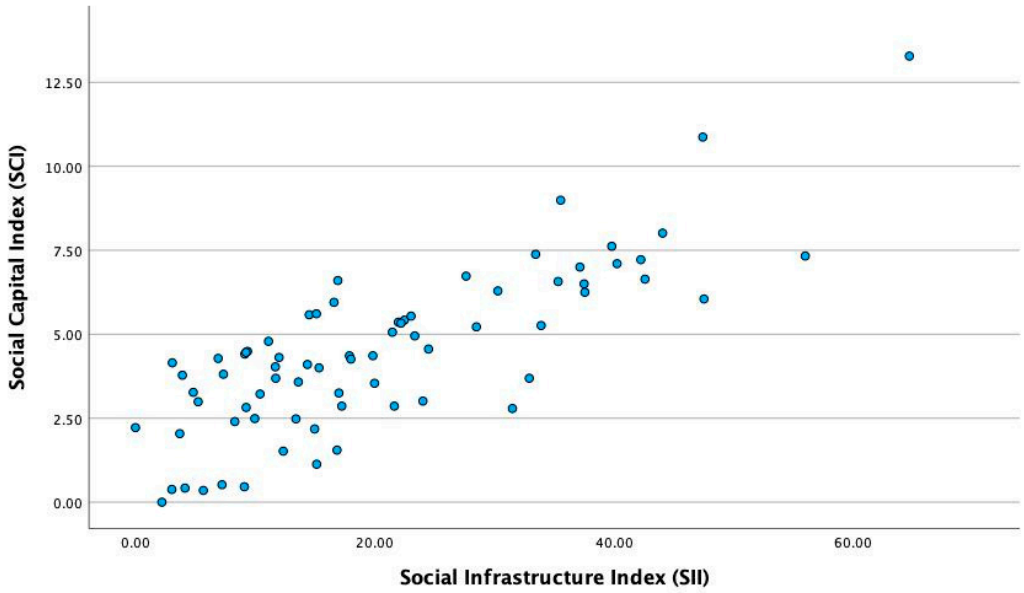


Figure 7. Linear regression 1: Social capital level by social infrastructure. Developed by the authors.

Table 7. Linear regression model summary.

Model	R	R Square	Adj R Sq	Sig F Change
1	0.803 *	0.644	0.639	<0.001

* Correlation is significant at the 0.05 level (two-tailed). Source: made by the authors.

These results show the relation between the two indices. Due to the regression's positive slope, as can be seen in Figure 7, it follows that better quality of social infrastructure may serve as a partial explanation of a territory's higher levels of social capital. This

supports our hypothesis that better planned environments promote social interaction, having a positive effect in terms of the creation of social networks. At this point, it needs to be clarified that the scale of both indices responds to their moment of construction and the statistical tool used in each of them (visual grouping and cluster analysis). So as to not to simplify any information, the values in each variable were normalised and taken as given by the model (this is the reason why the SCI's scale goes from 0 to 13.28 and the SII's scale goes from 0 to more than 64.67).

In order to statistically test the validity of our findings, some control variables were incorporated into the model (mainly sociodemographic and socioeconomic indicators). The results for the controlled model which also included a variable of income and a variable of population—by focusing on the changes in the Beta value, the R square and the change in R square—are shown in Table 8. These results compare model 1 (with only the two control variables; one focused on the demographics of the population and another one on the income level) and model 2 (including the control variables as well as the SII), showing that SI is in fact quite a good predictor of SC. Table 9 shows the SII and control variable's coefficients, where model 2 reduces the error (although still high). The significance tends to zero in all cases.

Table 8. Linear regression results with and without control variables.

Model	B	R	R Sq Change	Std Err of Est	Sig.
1		0.324		2.021	<0.001
2	0.36	0.795	0.501	1.122	<0.001

Source: made by the authors.

Table 9. Coefficients of control variables and SII.

Model	Variable	Std Err	Sig.
1	Per capita income	0.000	<0.001
	Age distribution	1.952	0.143
2	Per capita income	0.000	<0.001
	Age distribution	1.242	0.003
	SII	0.011	<0.001

Source: made by the authors.

At the same time, it could be said that the relation may work the other way round: higher levels of social interaction could help explain the neighbourhood's quality of social infrastructure. Do more organised territories have a higher capacity of attracting public investment that has an impact on the quality of the built environment? To test this relation, a new variable was included: the level of public investment by residents at a neighbourhood level. The idea was to better understand whether higher levels of social capital would entail higher levels of public investment that would, in turn, have an impact on the characteristics of the built environment, reflecting higher quality of the social infrastructure.

Table 10 shows that the two variables (the Social Capital Index and public investment), although not very strongly, are in fact correlated. It is also shown that this correlation is positive, meaning that more organisation in fact attracts public investment. Nevertheless, since this association is not very strong, probably other factors should be considered when studying this relation in future work.

At this point, it may be interesting to provide some examples, presenting more qualitative information on some neighbourhoods which can help illustrate what has been said throughout this section. In the central district of Ciutat Vella, the el Raval neighbourhood is well known for its interculturality, as well as its very old and—due to their historical value—usually protected buildings, some of which are being rehabilitated, usually for short-term rentals for tourists. At the same time, is seems to be a quite socially active neighbourhood (with a SCI value of 7.33) and has a fairly well-established urban structure

(in relation to its SII value of 55.97). These particular characteristics are probable explanations for the fact that this area of the city has seen a great deal of urban interventions with the aim of improving the quality of life for its residents, some of which have been a result of residents' struggles. On the other hand, a neighbourhood with similar social and economic characteristics to el Raval is el Besòs-Maresme, which nevertheless shows lower levels of SCI and SII (2.86 and 21.63, respectively). This area of the city is newer (1950s and 1960s) and its origin responded to a need for constructing big buildings very quickly, mainly due to national immigration at a moment of high demand for workers from the industries, and some of its current problematics relate to its lack of connectivity, accessibility and social integration since its origins. The many luxury buildings being built in its surrounding area are probably having a significant impact on this area, due to the fact that its lower levels of social infrastructure and weaker social capital bonds do not create an environment for resistance and/or collective action, which is aggravated by the vulnerability of most residents, as will be seen in the following paragraphs. When comparing attributes like the amount and typology of entities, it is possible to find one local association for every 115.46 people in el Raval. Meanwhile, in Besòs-Mareseme there is one for every 404.78 persons. This obviously has an impact on social capital and hints at the degree of social interaction that both areas witness on a daily basis. Furthermore, in el Raval there are more than 2590 square metres for outdoor dining whilst there are only 772 in Besòs-Maresme, meaning there are probably fewers residents present in the streets in the latter. These attributes are only examples that help provide a clearer image and allow a more qualitative comparison which supports this paper's findings.

Table 10. Correlation between investment and the SCI.

		SCI
Public Investment	Pearson Correlation	0.337 **
	Sig. (two-tailed)	0.004
	N	73
	Spearman's rho	0.243 *
	Sig. (two-tailed)	0.038
	N	73

* Correlation is significant at the 0.05 level (two-tailed). ** Correlation is significant at the 0.01 level (two-tailed). Source: prepared by the authors.

Finally, it is also important to compare the results of the mapped indices with a previously constructed integrated vulnerability index (IVI) [20]. For this purpose, Table 11 is presented, depicting the neighbourhoods that appeared as more vulnerable by this index, those inside cluster 1 in terms of their social infrastructure, as well as those with lower levels of social capital.

What is most interesting about Table 11 is, firstly, the fact that only seven cases coincide in the three indices (of a total of 73 neighbourhoods). This may be speaking to higher levels of overall vulnerability with weaker social links and a lower quality of social infrastructure. A focus on these cases and the reasons for this situation requires a deeper understanding, which is expected to be achieved in the near future. At the same time, it would be very interesting at this point to incorporate a discussion on the concept of resilience, mainly due to the fact that we are working on a neighbourhood level (not household), and a micro-level study at this point could help shed some light on the fact that probably not all neighbourhoods' residents and areas are the same, act as a whole or have the same characteristics. This is quite a clear limitation of this work which requires further analysis, especially centred around one or more of the seven neighbourhoods that appear to be in 'worse' condition. Thirdly, it is interesting to notice how many more neighbourhoods are put onto the scene once the SI index is presented. Research based on this not-so-studied phenomenon—that is, the social infrastructure and the characteristics of the built environment—is also to be explored in future research.

Table 11. Comparison between IVI, SCI and SII among Barcelona's neighbourhoods.

Neighbourhood	IVI	SCI	SII
La Barceloneta	X		
El Born	X		
El Gòtic	X		
El Raval	X		
Poblesec	X		
El Turò de la Peira	X	X	X
Verdum	X	X	X
Les Roquetes	X	X	
La Trinitat Nova	X	X	X
Torre Baró	X	X	
Ciutat Meridiana	X	X	X
La Trinitat Vella	X	X	
Besòs-Maresme	X		
Vallbona	X	X	X
Can Peguera	X	X	X
Marina	X		
Baró de Viver	X	X	X
La Teixonera		X	X
St Genís dels Ag		X	X
Montbau		X	
La Clota		X	X
La Marinad el P V		X	X
La Font de la G			X
Hostafrancs			X
La Bordeta			X
Sants-Badal			X
Pedralbes			X
El Putget i F			X
El Coll			X
La Salut			X
El Camp d'en G			X
Can Baró			X
El Guinardò			X
La Font d'en F			X
La Vall d'Hebron			X
Porta			X
La Prosperitat			X
El Congrés i els I			X
Navas			X
El Clot			X
Diagonal Mar i FM			X
Provençals del P			X

The X shows which neighbourhoods were included by the indices. Source: prepared by the authors.

6. Conclusions

As was presented in the introduction, the main objective of this article was to test and analyse the probable relations between two key concepts related to the study of urban vulnerability: social capital and social infrastructure. In order to achieve this, a comprehensive index of social capital and a comprehensive index of social infrastructure were created, following quantitative statistical analysis techniques from an open-source database that was built ad hoc. The first result of this research has been the construction and validation of these two measurements which allow us to shed some light on and better understand the socio-urban behaviour of the city of Barcelona in terms of its organisational potential, as well as the characteristics of the built environment that promote or obstruct social interaction. The replication of these indices is encouraged in other contexts. However, these findings should also be contrasted in the near future with the voice and views of the main actors that produce the city on a daily basis.

After mapping the territorial distribution of both indices applied in the city of Barcelona using GIS, the relations between the two measures were established. The statistical tests demonstrated correlation between the two, as well as directionality in their relationship. As the results showed, neighbourhoods with higher quality of social infrastructure tend to generate higher levels of interaction in the form of civic engagement or organisation (measured here as higher levels of social capital). However, and at the same time, although the values were lower, more organised territories also appear to be the ones that attract more investment towards the improvement of the built environment. Of course, the relationships mapped here are not linear and reality is not as simple, so we cannot establish any kind of directionality between variables as a given thing, without taking into account many other factors that may be influencing the quality of the environment, as well as the level of social interaction and civic engagement. Such complex variables are not susceptible to being captured by this quantitative statistical exercise we are introducing, but we expect to have contributed with a broader discussion that is not intended to end with this work.

In conclusion, this research has tried to contribute to the understanding of urban phenomena. At the same time, it has contributed to shedding some light on some often ignored or disregarded dimensions of the subject, providing new questions that require researchers' and planners' attention. This article has contributed the two indices of SC and SI and has, at the same time, allowed us to measure and identify areas with concentrations of higher and lower levels of SC and SI in Barcelona. Still, a limitation of this work has been that it does not provide any evidence on how these processes operate, how they are generated and how they are being represented by residents, entities and policy makers. A more qualitative discussion focused on this same subject and starting from some of this paper's contributions—probably focused on the case studies that due to their overlapping of SC, SI and vulnerability are of interest—is expected at some point.

Author Contributions: Conceptualisation, G.P. and P.G.-A.; methodology, G.P.; software G.P.; validation, G.P. and P.G.-A.; formal analysis, G.P.; investigation, G.P.; resources, P.G.-A.; data curation, G.P.; writing—original draft preparation, G.P.; writing—review and editing, G.P.; visualisation, G.P.; supervision, P.G.-A.; project administration, P.G.-A.; funding acquisition, P.G.-A. and G.P. All authors have read and agreed to the published version of the manuscript.

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