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SUSTAINABILITY INDICATORS APPLIED TO NEIGHBOURHOOD SCALE

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Introduction

The widely recognized effort to define methods for the analysis of local sustainable development through the use of indicators emerged after Rio Earth Summit in 1992 (Gomes *et al.*, 2000; Haapio, 2012; Sharifi e Murayama, 2014; Sitarz, 1993). Under this context, the use of a group of indicators (indicators system) at the local contexts prompted analysis of multiple dimensions of the sustainable development (social, economic and environmental), thus helping in decision-making process (Bossel, 1999).

As quality of life depends on the quality of the urban design (Myers, 1988), the ability to plan cities that respond to individual requirements, while meeting global goals is one of the most important purposes of contemporary society. As it relates with both local and global processes, the neighbourhood is considered a suitable scale of analysis with the potential to provide an approach large enough to consider a broad range of sustainability issues while being small enough to affect people's life and facilitate the implementation of sustainability strategies (Rudlin e Falk, 1999).

Like other complex structures, cities are the result of inter-relations between its fundamental units. Indeed, neighbourhoods are building blocks of cities (Sharifi e Murayama, 2014) and as these parts become more sustainable, they will contribute to the sustainability of the city as a whole (Choguill, 2008; Sullivan *et al.*, 2014). Moreover, the prosperity of a city highly depends on the vitality of its neighbourhoods, since they promote inhabitants quality of life through its physical and social conditions (Rohe e Gates, 1985).

The aim of this study was to compare the performance of two contrasting neighbourhoods in the city of Bragança (Portugal): one traditional and one contemporary. As an analysis tool, an indicator system was developed and applied, trying to address as many sustainable development issues as possible.

Methodology

The neighbourhood sustainability assessment was based on the selection of indicators that could be applied to the neighbourhood scale, according to the procedure in Table 1.

Table 1 - Methodology stages toward the selection of indicators

Stage		**Methodology**
1	Bibliography research	Survey of indicators that could be applied to the neighbourhood scale.
2	Selection of feasible indicators	Selection of indicators based on the applicability to the studied neighbourhoods and the availability of database.
3	Assessment considering international principles	Assessment of the association between indicators and principles of sustainable development.
4	Indicators system	Selection of indicators with more principles associated.
5	Adequacy	Adequacy of the indicators system, regarding the need for integration of as many principles as possible

Stage three of the selection method considered principles for urban sustainable indicators obtained by the survey of international Charters, namely The Charter of the New Urbanism, the New Charter of Athens, the Sustainable Development Goals (Goal 11) and the New Urban Agenda (Habitat III).

Through the selection process, a framework of 14 indicators (Table 2) was achieved and applied in contrasting neighbourhoods in the city of Bragança (Portugal): the *Braguinha* Neighbourhood, representing the contemporary urbanization model, and the Old Quarter, with a traditional model. Further interpretation allowed for additional in depth analysis and was based on inner neighbourhood analysis, regarding statistical data for urban subsections available on National Statistical Institute of Portugal (INE).

Results and Discussion

The two analysed neighbourhoods are located in the city of Bragança, Portugal (Figure 1) and have different urban patterns, due to the period in which the urbanization process took place.

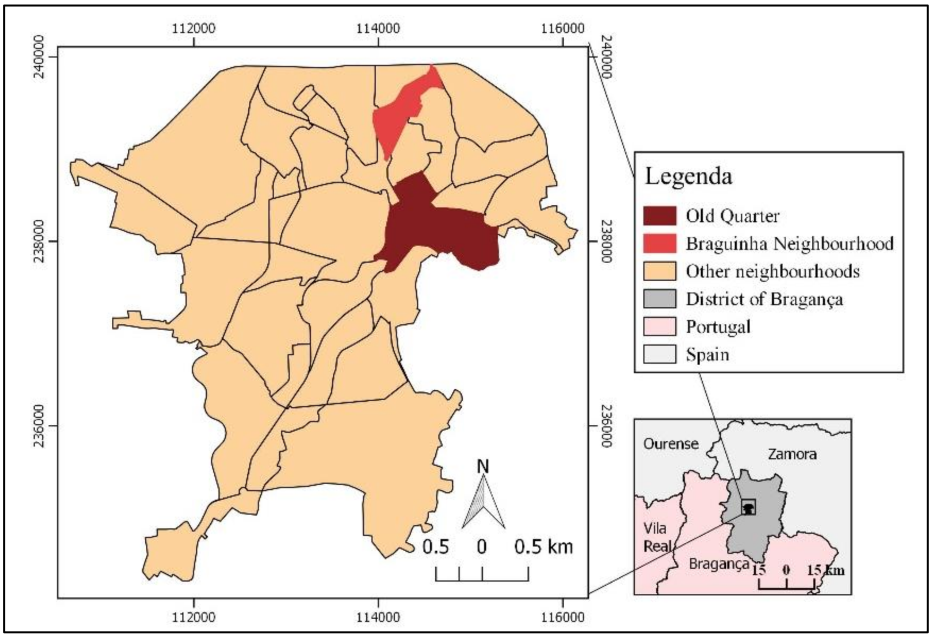

Figure 1 - Map of location of the Old Quarter and the *Braguinha* Neighbourhood in the city of Bragança, Portugal

The urbanization process of the Old Quarter has its roots on the evolution of defensive structures typical of the medieval period from XII to XV century.

This context, combined with the defensive need for compactness kept functions and activities close to each other, determining the compact and continuous pattern of this neighbourhood. The Old Quarter had approximately 1.661 inhabitants (INE, 2011), in an area of 73 ha, and presents buildings with the predominance of traditional architecture, with some preservation of the historical identity of Bragança, despite the clear signs of degradation.

The *Braguinha* neighbourhood, on the other hand, had its urbanization process initiated in the transition between XX and XXI centuries through a controlled urbanization process, through semi-formal planning mechanisms. This neighbourhood presents a diffused urbanization pattern, with multifamily dwellings (5-8 floors) and a population of approximately 1.958 inhabitants (INE, 2011) in an area of 25,6 ha.

Table 2- Selected sustainability indicators to assess neighbourhoods of the city of Braganç

	Indicators	**Measures**	**Formula**	**Reference values**
1	Urban complexity	bits	$-\sum_{i=1}^{n} Pi \times Log_2 Pi$ n: Amount of activities classes Pi: Relative abundance of each type of activity	>5 bits in more than 50% of the area
2	Corrected compactness	m	$\frac{\text{Buildings volume}(m^3)}{\text{Open spaces}(m^2)}$	10 – 50 m
3	Proximity to local facilities	% of people	$\left[\frac{\text{pop. next to five kinds of Facilities}}{\text{Total Population}}\right] \text{x } 100$	>75% of the population next to 5 kind of facilities
4	Green spaces	m²/inhabitant	$\frac{\text{Total area of public green spaces}}{\text{Total Population}}$	10m²/inhabitant
5	Proximity to soft transports	% of people	$\left[\frac{\text{pop. next to soft transports}}{\text{Total population}}\right] \times 100$	>80% of the population next to all soft transports
6	Potentially flooded zones in urbanized areas	% of area	$\left[\frac{\text{Potentially flooded zones in urbanized area}}{\text{Total flood zone}}\right] \times 100$	0%
7	Proximity to waste collection bins	% of people	$\left[\frac{\text{pop. next to waste collection bins}}{\text{Total population}}\right] \times 100$	80% of the population next to all kinds of waste collection
8	Pedestrian spaces	% of road length	$\left[\frac{\text{Pedestrian space}}{\text{Pedestrian space + Car space}}\right] \text{x } 100$	60% of the road designated to pedestrian in more than 50% of the total road
9	Housing density	housings/hectare	nº of housings/area	>100 housings/hectare
10	Population density	people/hectare	Population / area	> Housing density
11	Sky view factor	Dimensionless	Calculated with Software SAGA Gis 2.1.2	>0,63
12	Impervious surfaces	% of area	$\left[\frac{\text{Sealed surface } (m^2)}{\text{Total area } (m^2)}\right] \text{x } 100$	<50%
13	Buildings conservation	% of buildings in bad state/ruin	$\frac{\text{nº of buildings in bad state/Ruin}}{\text{Total buildings}} \times 100$	0% in bad state/ruin
14	Open spaces *per capita*	10 m²/inhabitant	$\frac{\text{Total open spaces } (m^2)}{\text{Total population}} \times 100$	10m²/inhabitant

The application of the selected indicators revealed differences and similarities between the two analysed neighbourhoods, as illustrated in Figure 2.

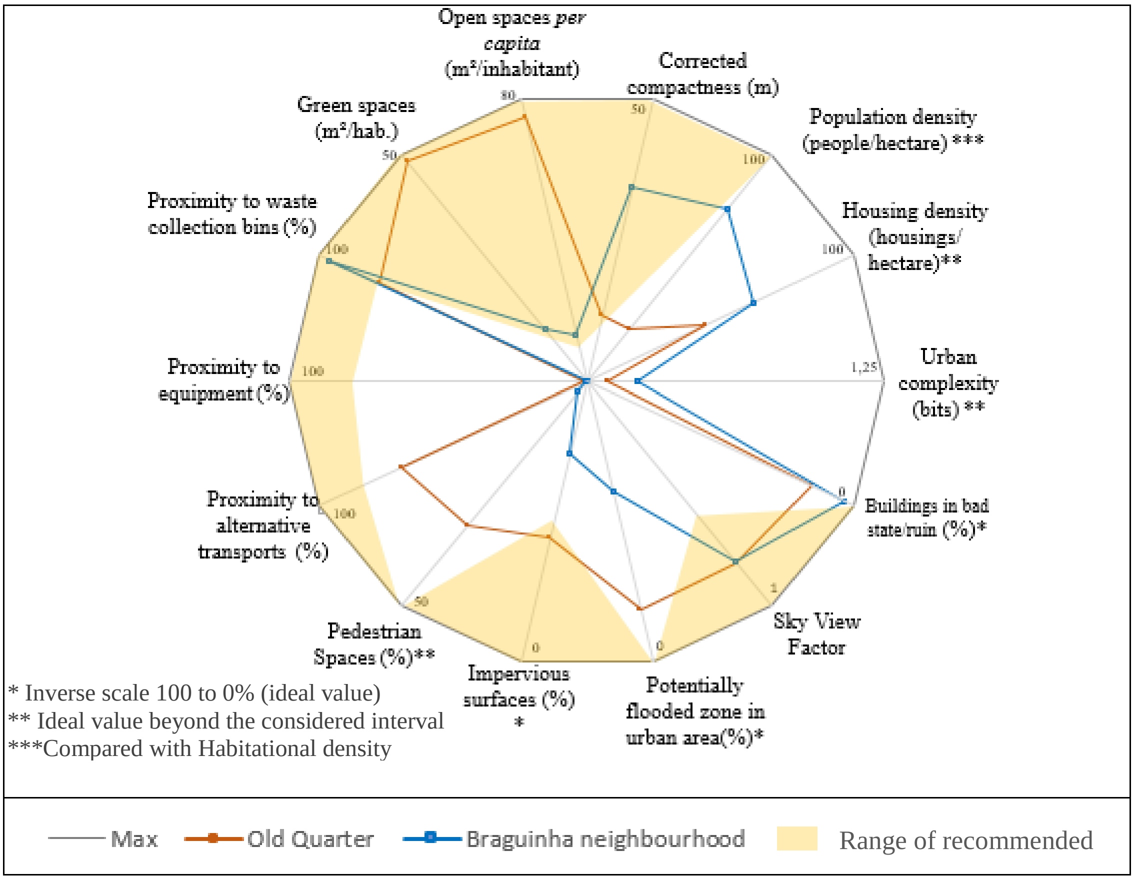

Figure 2 - General results of the indicators applied to the analysed neighbourhoods

Between the positive attributes of both neighbourhoods are the indicators: *Proximity to waste collection bins*, *Green spaces*, *Open spaces per capita*, *Corrected compactness* and *Sky View Factor*. While the most negative results were observed for the *Proximity to local facilities* and *Urban complexity*. Negative results show that the distribution of economic activities and facilities do not fully contribute to local sustainability in both neighbourhoods, since local conditions promote residents choices on the use of motorized mobility instead of walking or cycling.

The application of the indicators *Proximity to soft transports* and *Corrected compactness* also show the potential influence of both neighbourhoods attributes on the choice of means of transport by residents. *Proximity to soft transports* represents the possibility to provide access in larger distances inside and outside the neighbourhoods. Results of the application of this indicator demonstrate low results in both neighbourhoods, with a limited ability to overcome distance to key with alternative and efficient means of transport, improving mobility. The *Corrected compactness* integrates the urban space density and open spaces in a single indicator, thus providing important information on balance between compression and decompression (Rueda, 2012). Results show that the Old Quarter has a better score than the *Braguinha* neighbourhood, due to a more balanced distribution of open spaces throughout the Old Quarter, while in the *Braguinha* neighbourhood the open spaces are mostly concentrated. The open spaces availability reflected in this indicator results were however satisfactory in both neighbourhoods (>10 m²/hab.), as were the results from the indicator *Green spaces*, that also were higher than 10 m²/inhabitant. The high availability of green spaces had influenced the results of the indicators *Impervious surface* and *Potentially flooded zone* *in urban area*, although more satisfactory in the Old Quarter than in the *Braguinha* neighbourhood. To this later indicator, the predominance of pervious paving in the Old Quarter was a contributing factor.

The analysis of the results for the indicator *Pedestrian spaces* allowed for the identification of problems regarding the use of sidewalks, especially in the Old Quarter, where they were narrow or even inexistent. This situation, essentially related to the urban development pattern, should be regarded as relevant also for the indicators: *Proximity to soft transports*, *Sky View Factor* and *Proximity to waste collection bins*. The application of the indicator *Sky View Factor* presented similar values in both neighbourhoods (≈0.8), with suitable results in more the 90% of the areas. Nevertheless, the better results for the Old Quarter is highly influenced by the narrow roads and the complex terrain, opposite to the less steep terrain in the *Braguinha* Neighbourhood. Regarding the indicator *Proximity to waste collection bins*, the more satisfactory results were observed in the *Braguinha* neighbourhood and are related to its better capacity to host facilities of the collection system, including recycling bins.

Other indicators with better results in *Braguinha* neighbourhood than in the Old Quarter were: *Housing density; Population density* and *Buildings conservation*. The relation between Housing density and Population density in the Old Quarter shows its fragile vitality, due to the higher Housing than Population density, with many vacant real states. To collaborate to this analysis, the results from the indicator *Buildings conservation* show the large proportion of buildings in bad state/ruin in the Old Quarter, with many buildings unsuitable for living.

Generically, the Old Quarter had better results in indicators that are related to the existence of public open spaces, such was the case of the indicators: *Green spaces*, *Open spaces per capita*, *Corrected compactness*, *Potentially flooded zone in urban area* and *Pedestrian spaces*.

Overall, many factors may have influenced the performance of the selected indicators, with contrasting conditions in both neighbourhoods, including: the urbanization model, compactness vs openness; the location in relation to the central area of the city, centrality vs periphery; and the predominant urban function, touristic/commercial vs residential. However, the limited extension of the city of Bragança may have limited the level of contrast between the two selected neighbourhoods, not so far away from each other.

Conclusions

Generally, these analyses revealed the influence of the urbanization pattern on indicators results. Although similarities were found, both traditional neighbourhoods and new developments had differentiated performances, with no clear single benefit on one of the selected neighbourhoods. Existent contrasts are caused by many factors: urbanization model; location in relation to the central area of the city and predominant urban function.

The methodology used to select indicators proved effective for this work, once it provided a pathway to the assessment of the urban environment based on variables related to internationally accepted principles for sustainable development. The indicators were able to cover broad urban issues, including essential components of sustainability: economy, society and the environment. Nevertheless, in the future, additional and complementary activities should be included in order to validate the proposed methodology and the relevance of the indicators comparing the results with the population's perception on its influence on their quality of life.

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