

Street networks and street-blocks in the city centre of Tripoli

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Revised version received 18 May 2017

Abstract. *The results of an analysis of the urban form of central Tripoli, Libya are presented. Three cases from different morphological periods are compared: the Old Town (pre-modern), the Italian Quarter (colonial) and the Garden Suburb (early-Modernist). Two sets of descriptive indices that relate to street network and street-block structure are applied to measure quantitatively the urban fabric of the three selected cases and explore their distinct characteristics as well as common traits. The Old Town combines good privacy at the very local level due to the large number of culs-de-sac in the service street network: there is high interconnectedness both within the area and between it and its immediate surroundings. This appears to be related to the Old Town's high street density. Despite visible dissimilarities at the service street and plot level, the Old Town and the Italian Quarter share the same higher level structure, which the Garden Suburb does not. The Garden Suburb is a major departure from the morphological characteristics of the two earlier periods, and, arguably, their Ancient Roman precursors.*

Keywords: street density, city centre, urban morphometrics, Tripoli

The transformation of the urban fabric over time tends to follow certain patterns, which can be investigated and identified. Change does not happen randomly, but rather it evolves in a particular system of patterns (Levy, 1999). Urban designers must adopt an evidence-based approach grounded on systematic observation to understand the patterns of morphological evolution, in order to create better new developments (Batty and Marshall, 2009; Jacobs and Appleyard, 1987; Marshall, 2008; Steadman, 2008). According to Moudon (1997), the pace of change of urban form is dependent on the scale of its individual components: the larger the component

the slower the pace of change. This observation suggests a parallel between urban form and complex adaptive systems in nature and society (Gunderson and Holling, 2002). The street-block structure that is defined by the street network at the whole city scale is one of the longest-lasting components of urban form. The mutual relationship between the form of streets, street-blocks and plots has continued to be a matter of growing interest in urban morphology. The impact of the Italian school of urban morphology has been widely acknowledged (Cataldi *et al.*, 2002; Marzot, 2002), as has that of the British 'Conzenian' tradition (Slater, 1990; Whitehand, 2007).

Urban morphology includes quantitative studies that define and measure urban components such as streets, plots or building types, sometimes by means of comparative analysis (Koter, 1990; Kropf, 2001; Larkham, 2006; Whitehand, 2007). In particular, quantitative examination has been pursued in the past 3 decades from fields of research somewhat external to conventional urban morphology, such as space syntax (Hillier, 1996; Hillier and Hanson 1984; Hillier *et al.*, 1993) and the physics of complex networks (Barthelemy, 2011; Boccaletti *et al.*, 2006; Strano *et al.*, 2013). However, quantitative analysis in urban morphology remains underemployed (Carneiro *et al.*, 2010) and is rarely undertaken systematically and comprehensively enough to establish a common ground in the discipline (Venerandi *et al.*, 2016). Studies of Islamic city form are no exception. The vast majority of works on this subject to date are visual or descriptive (Akbar, 1988, 1995; Hakim, 2008a, 2008b; Mortada, 2003), with exceptions limited to individual components of urban form, in particular street centrality (Asami *et al.*, 2003; Azimzadeh and Bjur, 2007; Kubat, 1999; Kubat *et al.*, 2001; Topcu and Kubat, 2012).

Developing urban morphometric studies seems essential to the building of rigorous evidence on the evolutionary nature of urban change (Dibble *et al.*, 2015). Such an approach helps to support and expand established principles in the discipline, such as Conzen's repletion and transformation of plots in the burgrave cycle (Conzen, 1960; Koter, 1990; Kropf, 1996). Moreover, quantitative exploration of urban form is essential to identify patterns of change, and these may aid urban designers and policy makers to accomplish meaningful built environments (Chen and Romice, 2009). Urban morphology has contributed to the place-making shift in urban design since the Modernist era (Llewelyn-Davies, 2007; Panerai *et al.*, 2004; Shibley and Schneekloth, 1995; Urban Task Force, 1999) by emphasizing the link between the spatial and social dimensions of cities (Gehl 1987; Gifford, 2002; Marcus and Francis 1998; Whyte, 1988), with significant impact on urban

regeneration policies worldwide (Institute for Sustainability and Technology Policy, 2001; Urban Task Force, 1999; Western Australian Planning Commission, 2000, 2007). Urban designers, such as Evan Jones in Australia (Jones, 2006) and Allan Jacobs in California (Jacobs, 1993), and governmental initiatives such as those of Leadership in Energy and Environmental Design – Neighbourhood Pattern and Design (LEED-ND) (United States Green Building Council (USGBC), 2008), have grounded normative urban design guidelines in the quantitative analysis of urban form, while a new generation of 'form-based codes' is changing our planning systems (Duany *et al.*, 2006; Parolek *et al.*, 2008). Their rationale explicitly relates form to collective behaviour and ultimately various crucial aspects of city life, such as sociability (Gehl, 1994; Whyte, 1980), prosperity, safety and popularity (Felicetti *et al.*, 2016; Hillier and Iida, 2005).

To explore the model of change of urban form over time and distinguish the 'universal' structure from the variations from it in an evolutionary perspective, it is particularly important to focus on the passage from pre-modern times to the early-Modernist period. It is also important to look at cross-cultural cases so that we can build knowledge of patterns that may recur independently of cultural differences.

Tripoli, the current capital of Libya, offers excellent examples of traditional Islamic urban fabric, with Western colonial and post-colonial non-Islamic additions still clearly identifiable on the ground.

Comparable samples of the Old Town, the Italian Quarter and the Garden Suburb neighbourhoods of Tripoli city centre are considered in this study. Working with a wealth of literature mostly concerned with the features that make such fabric distinct (Al-Dosary, 2006; Al Naim, 2006a, 2006b; Bianca, 2000; Petruccioli, 2007), we follow the thread of those features that they share, at least to some degree, with the aim of highlighting the underlying structure that might unify seemingly different or even opposing models of urban form.

Old Town, Italian Quarter and Garden Suburb

Located where the Sahara Desert meets the Mediterranean Sea, Tripoli is presently considered the largest and busiest city in Libya. Historically, its unique protected waterfront became one of the most important trading ports on the southern coast of the Mediterranean Sea. Favoured by a strategic location and mild climate, Tripoli has been occupied by various civilizations since prehistory (Haynes, 2003). Over time, Phoenicians, Romans, Carthaginians and Muslims, and then Italians and British in the colonial and early-Modernist periods, have given the city its special cultural character. Through its long history, the city witnessed a wealth of cultural transformations, political trends and intellectual creativity, incorporating various cultures, arts and religions. It now displays a remarkable range of physical artefacts that express the different stages of its historical, cultural, economic and political status (Metz, 2004).

Currently Tripoli's city centre is made up of three distinct areas from three different morphological periods (that is, 'periods having unity in terms of the physical forms that were created' (Whitehand, 2007)): first, the Old Town, which is located at the heart of the city and is characterized by an Islamic structure; secondly, the colonial Italian Quarter, which is located south and east of the Old Town and dominates most of the city centre; and thirdly, the British Garden Suburb, which was developed during British military rule after the Second World War (Figure 1).

In the traditional Islamic Old Town a homogeneous, low-rise fabric of courtyard buildings defines a hierarchical network of narrow main streets and dead-end alleyways. Here the streetscape is characterized by unbroken walls forming the street edges, and winding intricate routes. Such an apparently labyrinthine system of public spaces corresponds to the characteristics of the plots and their uses. Main thoroughfares are home to substantial buildings and specialist land uses, secondary streets are predominantly residential, and service streets and culs-de-sac provide access to clusters of

private houses. Here, most street-blocks contain a variety of different building shapes, and most plots contain a private courtyard (Figure 2). Plot dimensions differ, depending on the building type: private houses usually occupy smaller plots than public buildings. Plots vary in size and shape, probably as a consequence of a historical and predominantly unplanned process of formation and continuous adaptation (Remali, 2014).

The Italian Quarter is the result of a metropolitan plan laid out by the Italian engineer Luigi Luiggi in 1912 (McLaren, 2006). The street network has a simple radial structure. There is a strong association between the land-use hierarchy and the street hierarchy: mixed retail units normally occupy the ground level of main street frontages, whereas private uses, especially services, occupy the upper levels; side streets are the preferred locations for houses and workplaces; and the simplest residential buildings are normally found on back streets (Remali, 2014). The street-blocks of the Italian Quarter tend to contain a single building structure and consist of a single plot. Streets, squares and alleyways are integrated in the Italian plan. The building footprints cover most of the developed land (Figure 3).

The Garden Suburb consists of very large, residential-only sectors, served by isolated retail and service units. The layout, largely informed by modern planning principles, departs from the traditional city's character: spatially isolated mono-functional 'islands' are connected only by large, car-dominated thoroughfares. In this 'archipelago' urban model, most developments are autonomously conceived as independent components. The street structure is internally interconnected and the streetscape exhibits a fairly low grade of enclosure. In this sense the Garden Suburb loses the consistent continuity and sense of enclosure that is typical, in different ways, of both the Old Town and the Italian Quarter. In terms of street-block and plot structure, the fine-grained plot pattern reflects the Old Town and, similarly, single-family units occupy each plot, but buildings are isolated within their plots and are entirely separated from the street by open private spaces, usually gardens (Figure 4).



Figure 1. The three 400 m-edged samples of urban fabric in Tripoli's city centre.

Measuring the street-block structure: indicators defined

The urban forms from the three morphological periods presented above characterize large areas of Tripoli's city centre. In this paper we examine 400 by 400 m samples, centred at main street crossings in each of those areas.

We build on a previous investigation of the same three cases conducted at the scale of the individual street rather than that of the street-block and the street network, where the intensity of urban activities and the physical quality of streets were also investigated (Remali *et al.*, 2015). In particular, use is made of this study's identification of main streets on the

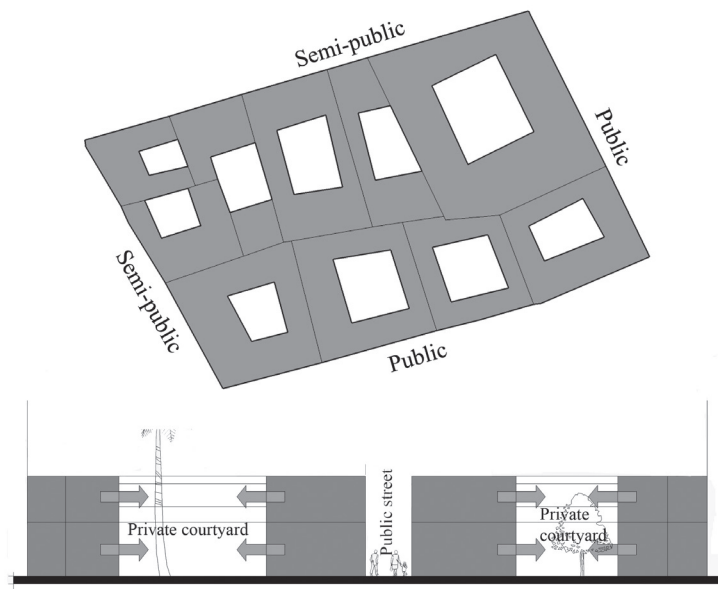


Figure 2. The street-block structure of the Old Town.

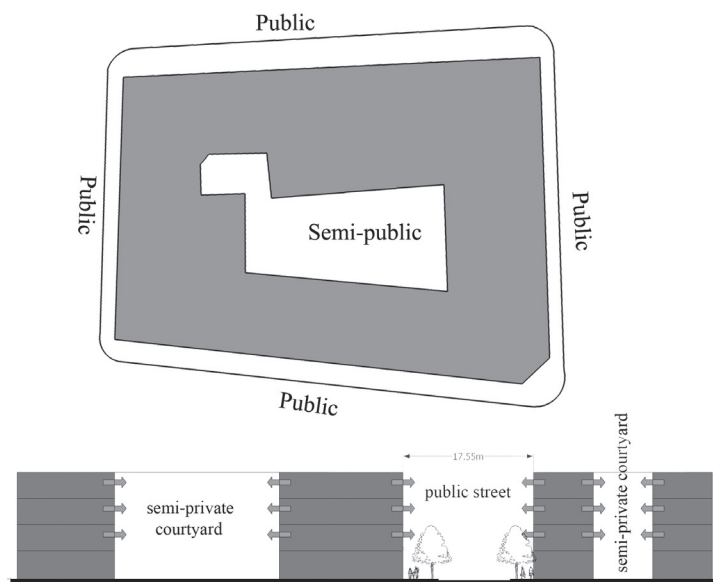


Figure 3. The street-block structure of the Italian Quarter.

basis of an extensive centrality analysis of Tripoli’s street network through a Multiple Centrality Assessment analysis (Porta *et al.*, 2006a, 2006b).

The remainder of this section defines the metrics used in the analysis. Although in many instances the mathematical definition of

the metrics is trivial, formulae are provided in the interest of clarity.

Intersection Density: ID

ID is the weighted number of intersections:

$$ID = 3N_4 + 2N_3 - 1N_1$$

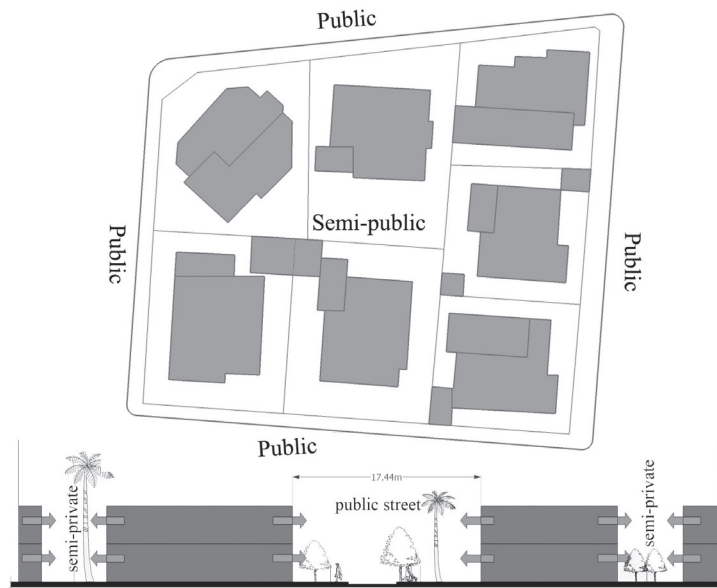


Figure 4. The street-block structure of the Garden Suburb.

Where: N_4 is the number of four (or more)-way nodes, N_3 is the number of three-way nodes and N_1 is the number of culs-de-sac. The density of intersections informs centrality measures such as ‘integration’ (Hillier, 2005) or ‘closeness’ (Porta *et al.*, 2010). In Jones (2001) and LEED-ND (USGB, 2014) intersections are weighted according to their type under the name of ‘permeability’, with four-way = 1, three-way = 0 and one-way (that is, cul-de-sac) = -1. However, in this study intersections are weighted differently with four-way = 3, three-way = 2 and one-way = -1, in order to emphasize the gap in connectivity between four- or three-way and culs-de-sac (Cervero and Radisch, 1995; Dill, 2004; Reilly and Landis, 2002).

ID measures the ‘grain’ of the street network. In effect it is an expression of the average block size. The importance of having many small blocks in cities has been acknowledged by Jacobs (1961): fine-grained street-blocks are more navigable, offer a higher number of corners (which are considered highly attractive commercial locations) and are expected to favour more retail business, self-surveillance and pedestrian flow.

Street Density (SD)

SD is the total street length relative to the case study’s entire area:

$$SD = (SL_{tot} \times 1000) / A_{tot}$$

Where: SL_{tot} is the total length in metres of all streets included in the case study, A_{tot} is the total area of the case study (here: 400 m × 400 m = 16 ha).

SD measures the density of streets, that is their cumulative length per unit of land area. A higher value of SD corresponds to a greater length of street for the same amount of land, thereby indicating good connectivity at the neighbourhood scale. Strictly, the measure is only *potential* because the index does not measure whether the streets are *actually* interconnected. In addition, SD indicates a potential to have more people in the public realm, thus contributing to local prosperity (Dill, 2004; Mately *et al.*, 2001; UN-Habitat, 2013).

Link-Node Ratio (LNR)

LNR is the number of links (streets) divided by the number of nodes (intersections) within the study area:

$$LNR = L / N$$

Where: L is the total number of links and N is the total number of nodes (including culs-de-sac).

In terms of network structure, the lower the link/node ratio the more the street network approximates the simplest perfectly hierarchical ‘tree’ structure, while the higher the ratio the more the network approximates its superior limit of complexity (Cardillo *et al.*, 2006). According to Dill (2004) this index captures the level of street connectivity in an urban system, whereby a high value indicates a robust network that provides more route options and more direct connections between every pair of origins/destinations (Ewing, 1996; Handy *et al.*, 2003; Raghav, 2014; Tal and Handy, 2011). The ‘interconnectedness’ quality in cities has a particularly profound meaning that goes beyond the analysis of the street network and touches on the definition of an urban system’s complexity and resilience (Alexander, 1965; Feliciotti *et al.*, 2016; Martin, 1972).

Internal Connectivity (IC)

IC is the ratio between number of ‘real’ nodes (non-culs-de-sac) and number of all nodes (including culs-de-sac):

$$IC = N_{re} / N$$

Where: N_{re} is the total number of ‘real’ nodes, that is nodes with three or more converging links. In addition if N_{cul} is the total number of culs-de-sac, $N_{re} = N - N_{cul}$

IC represents the ‘non-culs-de-sacness’ of a street system, that is the ‘positive’ part of its stock of intersections, or the part that actively increases the system’s connectivity. The higher the index, the stronger the internal connectivity (Betanzo, 2009; Song, 2003). This index is particularly relevant in the analysis of the traditional Islamic urban fabric where the culs-de-sac trait is widely present, especially on secondary residential streets.

External Connectivity (EC)

EC is the density of ingress/egress points at the boundary of the case study as defined by:

$$EC = IE / PL * 100$$

Where: IE is the total number of ingress/egress points, and PL is the total perimeter length of the case study (here: $400 \text{ m} \times 4 = 1600 \text{ m}$).

Ingress/egress points are the notional intersections created where the case study area boundary crosses a street. The higher the density of ingress/egress points, the shorter the distances between them along the boundary of the case study and, therefore, the greater the external connectivity of the area with the surrounding urban fabric (Betanzo, 2009; Song, 2003).

Grid Pattern: Strong (GP_{strong}); Weak (GP_{weak}) and Not gridded (GP_{not})

The GP indices measure the extent to which blocks are defined by four-way (or more) street intersections rather than three-way. If all the intersections generated by the streets that define a block are four-way or more then that block is defined as strongly gridded; if all of them are four-way or more except one it is defined as weakly gridded. In all other circumstances the block is defined as not gridded. The index measures the amount of land that is covered by strongly/weakly/not-gridded blocks, relative to the total area of the case study (Porta and Romice, 2010), as defined by:

$$GP_{strong} = BA_{strong} / A_{tot}$$

$$GP_{weak} = BA_{weak} / A_{tot}$$

Where: BA_{strong} is the total area of blocks defined by four-ways or more intersections at all its corners, and BA_{weak} is the total area of blocks defined by four-ways or more intersections, except one.

The ratio of strong- weak- not-gridded of a case study is another proxy of internal connectivity that mixes street connectivity with the size of blocks into one overall measure of great significance for the ability of urban form to allow easy navigation, frequency of ‘100 per cent locations’, and ultimately choice and prosperity (Whyte, 1980).

Ped-shed (Accessibility): Inner Ped-shed: PS_{inn} and Outer Ped-shed: PS_{out}

PS is the amount of plot land that is accessible within a given distance from the centre of

the case study if one walked along the street network, relative to the whole area that would be accessible as the crow flies. The term 'plot land' refers to the land that is occupied by plots after excluding streets, large parks, rivers and all other undeveloped areas. *Inner* and *Outer PS* are measured here according to two different distances from the centre, resulting in diameters of 200 m and 400 m respectively (Western Australian Planning Commission, 2000), as defined by:

$$PS_{inn} = PA_{200} / A_{200}$$

$$PS_{out} = PA_{400} / A_{400}$$

Where: PA_{200} and A_{200} are respectively the area of all plots accessible in 200 m from the centre of the case study along the street network, and the whole area within the circle from the same centre (that is, 12.6 ha). Analogously, PA_{400} and A_{400} are respectively the area of all plots accessible in 400 m from the centre of the case study along the street network, and the whole area within the circle of 400 m of radius from the same centre (50.2 ha) (Handy, 2011; Jones, 2001; Land Transport New Zealand, 2005).

Several of the previous indices, such as *IC* or *GP*, measure accessibility indirectly. The *Ped-shed* is a direct quantification of the degree of accessibility of developed land from the centre of the case study as a result of the geometry of the street layout (Porta and Renne, 2005). *Ped-sheds* calculate the catchment areas within conventionally accepted 2 or 5 minutes' walk (respectively *inner* and *outer* circle).

Street-Block Structure: Density: BD; Area Ratio: BA_{ra}; and Mean Area: BA_{mean}

Street-Block Density (BD) is the number of street-blocks relative to the area of the case study. Only street-blocks that are fully included within the case study's boundary are counted. The measure is defined by:

$$BD = B / A_{tot}$$

Where: B is the number of street-blocks completely included in the case study (Cervero and Radisch, 1995; Song, 2003).

Street-Block Area ratio (BA_{ra}) is the total area of all street-blocks, relative to the area of the case study, as defined by:

$$BA_{ra} = BA_{tot} / A_{tot}$$

Where: BA_{tot} is the total area of all street-blocks, excluding streets, squares, parks, rivers and all undeveloped land.

Mean Street-Block Area (BA_{mean}) is simply the total area of street-blocks divided by the number of street-blocks:

$$BA_{mean} = BA_{tot} / B$$

These are very simple indices that nevertheless express crucial information on the scale of street-blocks and the urban fabric's 'grain' and the extent to which the land is developed, that is, the intensity of land utilization (Moudon, 1994).

Street-Block to Street Ratio (BS)

BS measures the ratio between the area of street-blocks and the area of streets and squares, as defined by:

$$BS = BA_{tot} / SA$$

Where: SA is the total area of all streets and squares.

BS gives an indication of the 'importance' of the public scene of the city relative to the developed land.

The lower the *BS*, the more 'public' the urban scene is, where not only the street length offers a great contribution but also its width and the presence of squares.

Street-Block Perimeter (BP)

BP is simply the total length of all street-block edges on streets. Boundaries not abutting streets (for example, directly facing parks, shore lines or the geographical limits of the study area) are not taken into consideration. BP_{mean} is the total perimeter of street-blocks divided by the total number of street-blocks fully contained within the case study's boundary.

$$BP_{mean} = BP / B$$

The length of street-block façade that defines the streetscape is a simple but nevertheless

very meaningful way of expressing the urban form's ability to ensure business opportunities and general activities settle, which contributes to the cohesion and prosperity of the urban community (Cervero and Kockelman, 1997; Dill, 2004; Llewelyn-Davies, 2007; USGBC, 2014).

Quantitative analysis of the street network and street-block structure

In this section the urban form of the three case areas are compared according to a set of indices (Table 1) relating to their street networks and street-block structures as presented overleaf (Tables 2 and 3). On that basis, the main findings can be summarized in terms of six emerging patterns. Most of the streets in the Italian Quarter are used by both people and cars and few streets are reserved for pedestrians only. However, no streets in the Old Town are accessible by car and all streets in the Garden Suburb accommodate both cars and people.

Decay in street density: Old Town high internal navigability despite culs-de-sac

The passage from the traditional Islamic (Old Town) to the pre-Modernist colonial (Italian Quarter) to the early-Modernist (British Garden Suburb) is characterized by a progressive decrease in street density (SD : 376, 281 and 249 m/ha respectively) (Figure 5). Street density decay naturally goes together with weighted intersections. It turns out, however, that the gap between Old Town and Garden Suburb in terms of weighted intersections is significantly larger, to the point that in the former we observe more than twice as many weighted intersections as in the latter (ID : 194 compared with 88). This finding is counter-intuitive, as we should have expected that the high number of culs-de-sac typical of the Islamic traditional structure would have reduced the density of weighted intersections in the Old Town. The reality is that in the Old Town the higher street density largely outweighs the 'negative' effect of the many culs-de-sac, resulting in a remarkable value of internal connectivity.

Table 1. Variables

A_{tot} = Total Area of the case study (16 ha)	BS = Street-Block/Street Ratio	N = Total number of Nodes (street intersections)
B = Total number of Street-Blocks	EC = External Connectivity	N_i = Number of i -way Nodes (street intersections)
BA_{mean} = Mean Street-Block Area	GP = Grid Pattern	N_{re} = Number of 'real' Nodes (3-way or more)
BA_{ra} = Street-Block Area ratio	GP_{strong} = Strong Grid Pattern	N_{cul} = Number of culs-de-sac (1-way)
BA_{strong} = Total Area of strongly-gridded Street-Blocks	GP_{weak} = Weak Grid Pattern	PL = Perimeter Length of the case study (1600 m)
BA_{weak} = Total Area of weakly-gridded Street-Blocks	GP_{not} = Not Gridded Pattern	PS = Ped-Shed
BA_{not} = Total Area of not gridded Street-Blocks	IC = Internal Connectivity	PS_{in} = Ped-Shed inner ($r=200$ m)
BA_{tot} = Total Area of Street-Blocks	ID = Intersection Density	PS_{out} = Ped-Shed outer ($r=400$ m)
BD = Street-Block Density	IE = Number of Ingress/Egress points	SA = Total Area of Streets and squares
BP = Total Perimeter of Street-Blocks	LNR = Link/Node Ratio	SD = Street Density
BP_{mean} = Mean Perimeter of Street-Blocks	L = Total number of Links (streets)	SL_{tot} = Total Length of Streets

Table 2. Results: street network

Character	Index	Unit	Old Town		Italian Quarter		Garden Suburb	
			Absolute Value	%	Absolute Value	%	Absolute Value	%
Intersection Density	N_1	no.	72	37	5	8	1	3
	N_3	no.	106	54	53	79	19	51
	N_4	no.	18	9	9	13	17	46
	N	no.	196	100	67	100	37	100
	ID	%	194		128		88	
Street Density	SD	m/ha	376		281		249	
Link-Node Ratio	LNR	l/n	1.24		1.73		1.97	
Internal Connectivity	IC	$\frac{(n_{total}) - (n_{cal})}{(n_{total})}$	0.63		0.92		0.97	
External Connectivity	EC	m	1.50		1.00		1.06	
Grid Pattern	GP_{Strong}	ha	0.65	7	0.0	0	2.35	30
	GP_{Weak}	ha	0.54	6	0.89	10	0.86	11
Ped-Shed	PS_{Inn}	%		58		59		80
	PS_{Out}	%		57		68		58

Table 3. Results: street-block structure

Character	Index	Unit	Old Town	Italian Quarter	Garden Suburb
Street-Block Density	BD	no.	22	29	19
Street-Block Area	BA_{tot}	ha	8.9 ha	9.3 ha	7.9 ha
Mean Street-Block Area	BA_{mean}	m_2	4052.9 m ²	3200.2 m ²	4161.5 m ²
Street-Block to Street Ratio	BS	%	6.6 : 1	3.2 : 1	3.9 : 1
Street-Block Perimeter	BP	km	8.3 km	7.1 km	4.9 km
Mean Street-Block Perimeter	BP_{mean}	m	337 m	245 m	259 m

Old Town: highest integration with surroundings

The remarkable density of streets that characterizes the Old Town also makes it by far the most effectively interconnected externally with its immediate surroundings, if compared to the Italian Quarter and Garden Suburb (EC : 1.50, 1.00 and 1.06). Interestingly, the street structure of the Old Town provides, on the one hand, the highest privacy at the lowest grade of the street hierarchy by the abundance of culs-de-sac. However, it has the highest connectivity with the adjacent neighbourhoods resulting from the frequent

intersections along the boundaries of the study area.

Griddedness of the Old Town

Despite the popular ‘labyrinthine’ image of the traditional Islamic urban fabric, our observations reveal that the Old Town offers a remarkably consistent level of strong griddedness, which is actually higher than that of the Italian Quarter (Table 2). This is surprising given that culs-de-sac account for 37 per cent of all intersections in the Old Town and only 5 per cent in the Italian

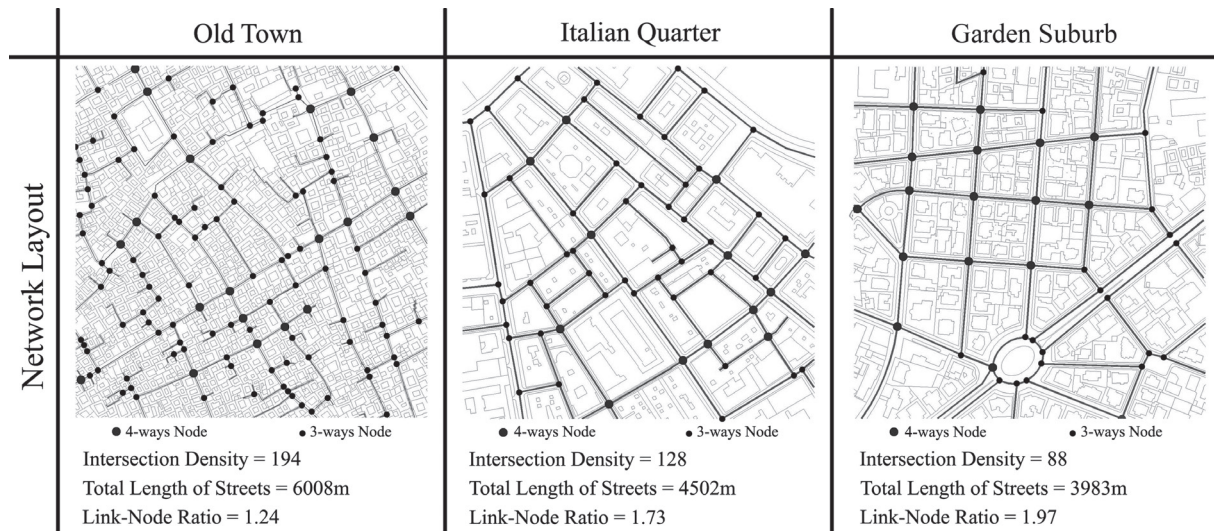


Figure 5. Street network layouts of the three case studies.

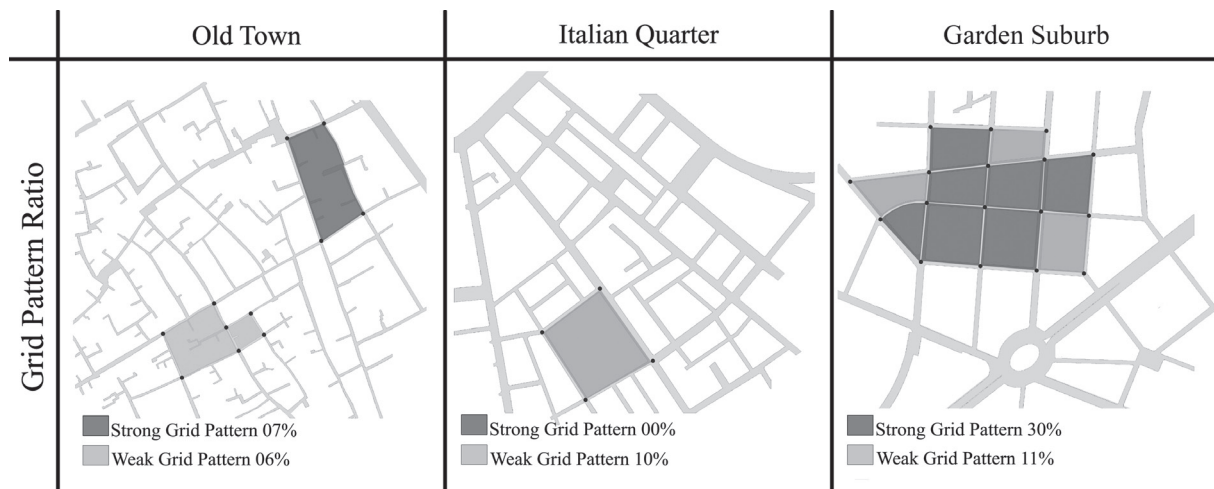


Figure 6. Strong and weak grid patterns.

Quarter. However, both the Old Town and the Italian Quarter are well below the Garden Suburb in both strong and weak griddedness (Figure 6).

Garden Suburb: high gap in accessibility between centre and periphery of the neighbourhood

Ped-shed analysis (Figure 7) shows that the Old Town and the Italian Quarter exhibit similar results across the inner and outer circle,

whereas the Garden Suburb presents a larger gap. It is important to note that the centre of the neighbourhood was located conventionally on major thoroughfares as identified through a Multiple Centrality Assessment (MCA) analysis of the street network (Porta *et al.*, 2010; Remali *et al.*, 2015). The gap clearly highlights a pattern in the Garden Suburb whereby large specialist plots emerge and consolidate just on the main roads in very accessible positions, but the plot edges act as ‘barriers’ separating the residential areas behind them.

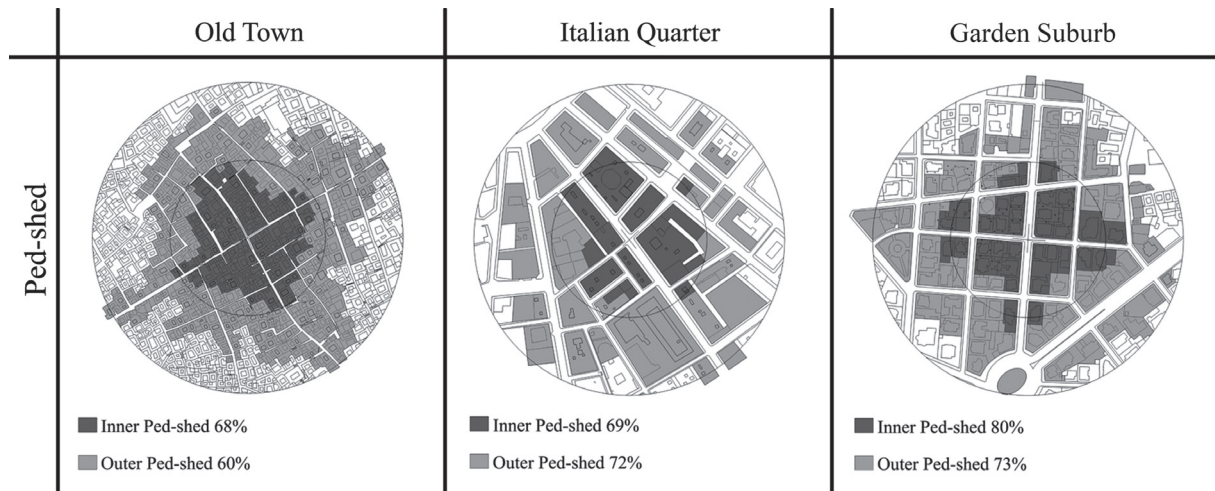


Figure 7. Ped-sheds of the selected cases.

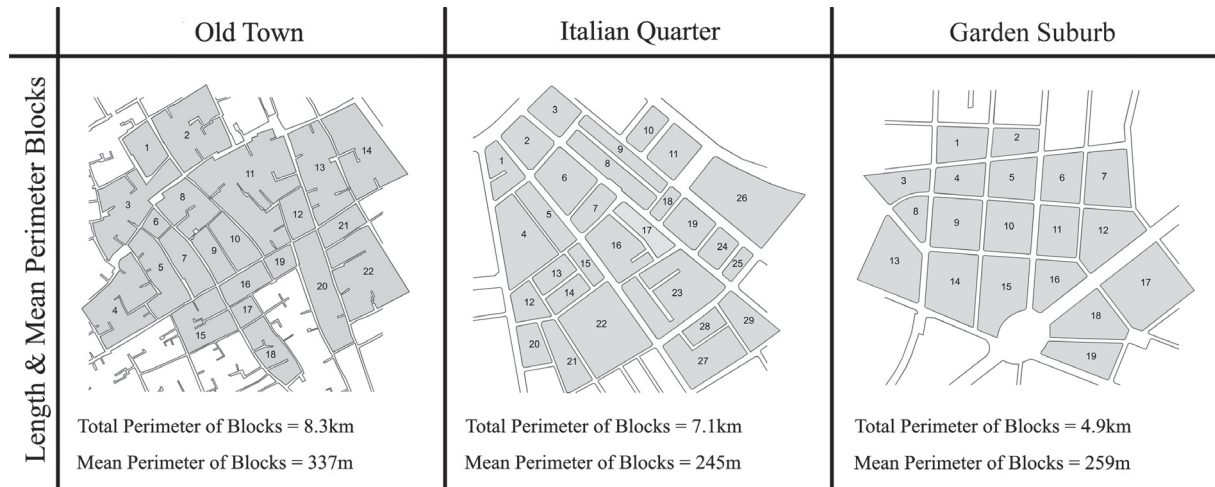


Figure 8. The street-block frontages of the cases.

Old Town and Garden Suburb: the different nature of seemingly similar street-block structures

At first glance it may be surprising that the street-block structure of the Old Town and that of the Garden Suburb have significant similarities. While a fine grain of small compact street-blocks was expected in the Old Town, the analysis demonstrates that block density, mean block area and total block area are fairly similar across both the Old Town and Garden Suburb ($BD: 22$ vs 19 ; $BA_{mean}: 4052.9$ vs 4161.5 m²; $BA_{tot}:$

8.9 vs 7.9 ha). In contrast, the Italian Quarter has a considerably smaller mean street-block area ($BA_{mean}: 3200.2$ m²; Table 3). However, the similarity of the Old Town and Garden Suburb is not consistent across measures. The overall street-block perimeter length in the Old Town is almost twice that of the Garden Suburb ($BP: 8.3$ km vs 4.9 km). The reason is that the shape of the street-block perimeter in the Old Town is convoluted by the presence of cul-de-sac service streets (Figure 8). This particular pattern needs to be understood within the historical context of its evolution.

Old Town's higher diversity

The Old Town is characterized by a high diversity in street-block size (Figure 9, left). The Italian Quarter and the Garden Suburb are more homogeneous. It is also evident that the street edges are less defined by buildings and the separations between buildings are greater in the Garden Suburb than in the other two areas (Figure 9, right).

Continuity and discontinuity in the evolution of central Tripoli: an interpretative model

An interpretative model of the evolution of Tripoli's urban fabric is suggested. Such a model (Figure 10) shows main and service streets, plots, building footprints and street-blocks, from the original Roman structure to

the early-Modernism of the British Garden Suburb. The traditional Islamic urban fabric can be seen as the direct evolution of the previous ancient Roman one, which is also archetypical of much of the Western world (Caniggia and Maffei, 2001). Even seemingly labyrinthine fabrics such as Tripoli's Old Town actually inherited the fundamental structure of main streets and street-blocks from older layouts that were extensively planned. Successive alterations were made to suit Muslims' needs and Islamic principles (Mortada, 2003), though these have generally only affected the lower level of service streets, leaving the main structure fundamentally unchanged. The introduction of *culs-de-sac* in the traditional Islamic city is conceptually, and most often also physically, just the modification of former service streets, which

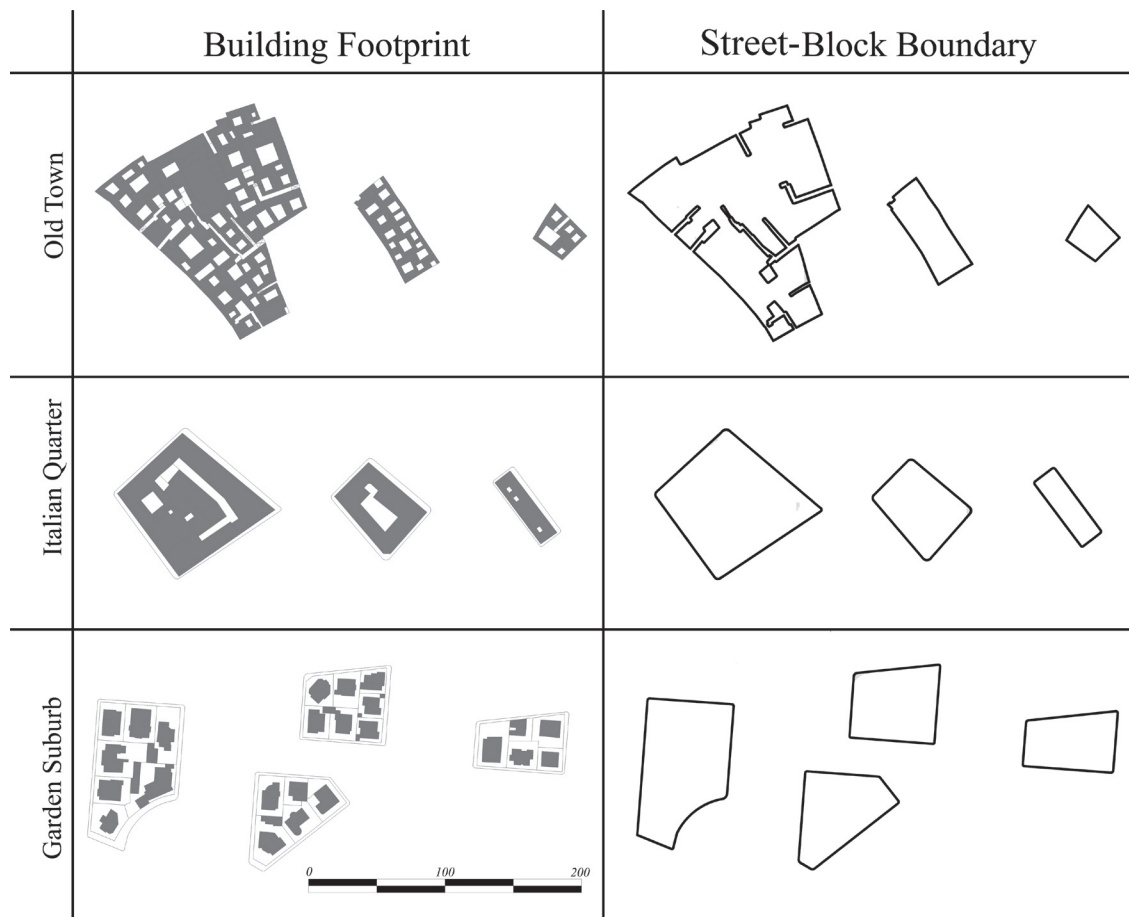


Figure 9. Street-block boundaries and building coverages: same-scale visual comparison of cases in the three historical periods.

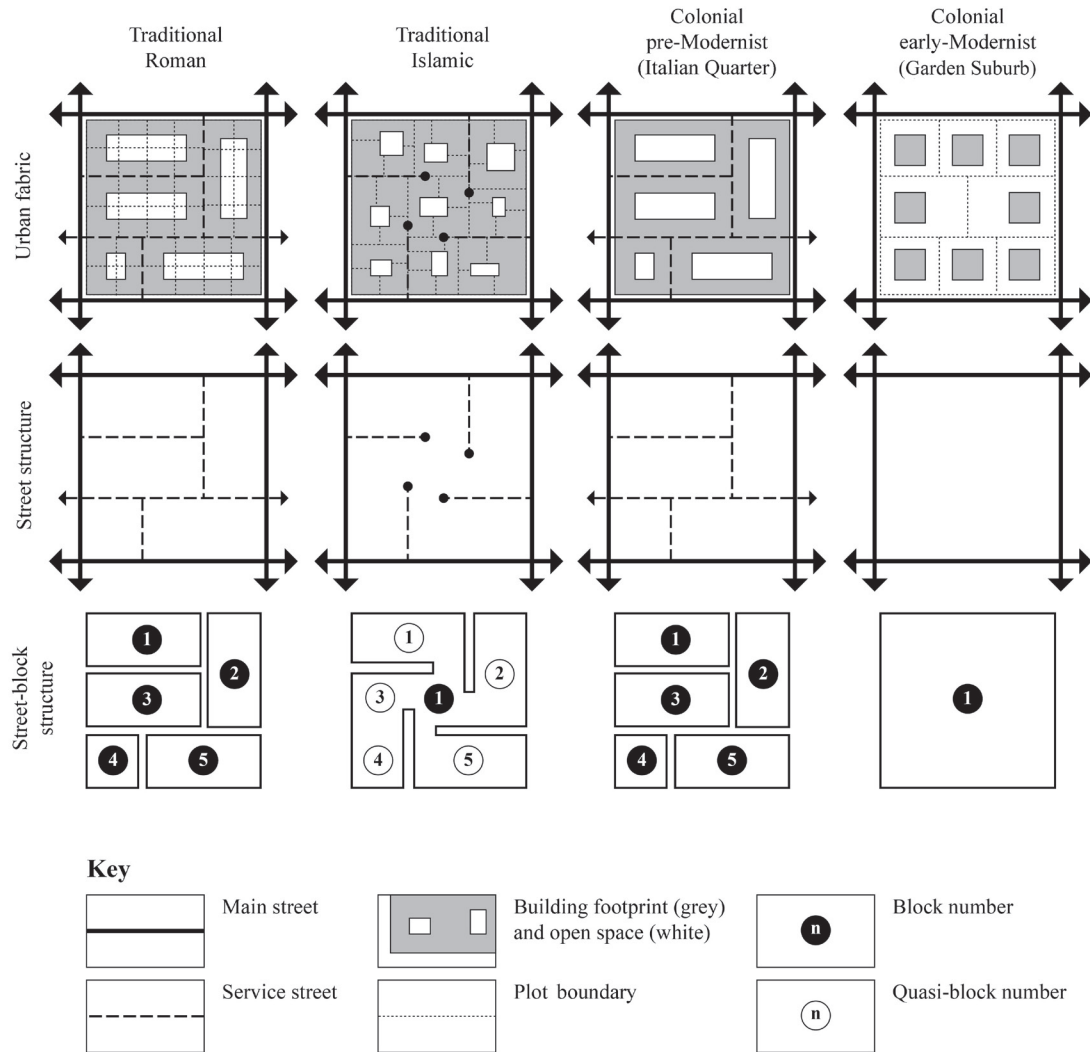


Figure 10. Interpretative general model of change across historical periods in central Tripoli.

came about as an adaptation of the older structure to the Islamic society and its cultural norms, for example regarding privacy and the extended family. Importantly, although the transformation of the service streets technically generates a much larger street-block, it does not necessarily create a coarser spatial structure in practice. In fact, the cul-de-sac system exhibits a fine structure of plots and street-blocks which is typical of many traditional urban environments, effectively generating a ‘quasi-block’ structure which is spatially and socially as fine-grained as its precursor.

Such a traditional higher-level structure, which is common to many different cultural and religious norms and values, persists well into the Italian colonial model. The urban fabric of the Italian Quarter does not change the original Roman higher-level structure in any visible way. It does, however, have a remarkable increase in the size of plots, which tends to coincide with the whole street-block (Remali *et al.*, 2015). It is important to note that the Italian Quarter was generated in the late pre-Modernist period, when the forces leading to the modern ‘bifurcation’ in the evolution of the urban structure (Dibble *et al.*, 2015; Porta

et al., 2014), including the large public and private developers operating on the city at an unprecedented scale, were already beginning to have a discernible impact on the ground.

The British Garden Suburb, drawing heavily on Ebenezer Howard's seminal model (Howard, 1902), substantially departs from the traditional spatial structure in one very important aspect. With the disappearance of the internal service streets, the street-blocks become much larger than the original Roman street-blocks. The result is a coarse inner structure of large plots along with a substantially lower utilization of land. This pattern, coupled with the change to the traditional building/street relationship illustrated previously, is effectively an anticipation of the Modernist conceptions of the super-block and isolated tower that were developed in the inter-war period and after the Second World War became the dominant model for urbanization up to the late 1980s. The evolutionary model proposed here helps to make sense of the fact that the Old Town and the Garden Suburb show similar street-block size but very dissimilar perimeter lengths. The first is the result of the modification of previous principles, in particular the creation of culs-de-sac that in turn create the meandering shape of the street-block boundary. The second is the result of applying abstract principles of an idealized form in response to a distinct cultural context. The evolutionary model also helps in reconciling two seemingly contradictory facts. First, that the Old Town has a smaller number of much larger street-blocks than the Italian Quarter; and secondly, that the Old Town appears much finer in scale. Again, the difference in the number of street-blocks and their sizes arises from the creation of the 'quasi-block' structure by a modification of the earlier Roman principles: the 'common ancestor' of both the Old Town and the Italian Quarter.

What seems to emerge here is that the sharp difference between the visible manifestation of the Islamic and Western cities does not hold if we look at their deeper spatial structures. Like living organisms belonging to the same species, traditional Islamic and Western

urban forms appear to have substantial continuity with each other and their common Roman model. The more distinct discontinuity seems to occur, at the structural level, with the advent of the modern city after the Second World War, and continues to happen across both the Islamic and Western worlds alike.

Conclusion

This quantitative analysis of central Tripoli through a set of indices indicates that the structure of the Old Town at the scale of the street-block and service street has a convoluted, clustered and labyrinthine configuration, largely owing to its frequent culs-de-sac. This structure leads to low relative internal connectivity and an urban environment orientated towards the preservation of privacy in residential areas. However, the higher density of streets and intersections largely outweighs the 'negative' influence of the culs-de-sac. Moreover, the Old Town exhibits a remarkably high connectivity with the surrounding neighbourhoods owing to the many street intersections with the study area's boundary – a further outcome of the high density of streets.

Although the Old Town appears at first glance to differ substantially from the other two cases, in fact it and the Italian Quarter share a fundamentally similar structure. The more distinct difference is with the Garden Suburb, which features a substantially different layout in terms of street-block scale as well as building/street relationship.

A point that is worth noting and investigating further is that the differences in the structure of the urban fabric partially reflect local conditions in terms of street quality and life as examined in a previous analysis of the same case studies (Remali *et al.*, 2015). For example, while the Old Town today, with the labyrinthine configuration of its street-block structure, is a place mainly used locally, the highly interconnected layout of the Garden Suburb appears to be insufficient to overcome the larger scale of the structure to generate an acceptable level of social life and public

realm quality. The results of the morphometric analysis presented in this paper provide a solid foundation for specifying variables in further research to investigate the role and relationships of other factors such as building density and centrality of location, along with the impact of planning ideology in supporting the dynamics of a prosperous urban life.

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- R. L. Rego, A. Hollatz, G. Cardoso, and M. Tavares, 'Estratégia projetual e configuração urbana: estudo morfológico de duas cidades novas no Brasil de meados do século XX' ('Design strategy and urban configuration: morphological study of two new towns in mid-twentieth century Brazil').
- R. M. Almeida, 'Uma Cidade Industrial' de Tony Garnier: repensando a gênese do urbanismo progressista, no centenário de sua publicação' ('The Industrial City' by Tony Garnier: rethinking the genesis of progressive urbanism, in the centenary of its publication').
- E. Z. Monteiro, 'A tipologia dos traçados urbanos como indicador de poderes concentrados ou dispersos' ('The typology of urban layouts as an indicator of concentrated or dispersed power').
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- O. Oliveira, 'Morfologia urbana e ambiente' ('Urban morphology and environment').
- R. Fernandes, 'A influência da forma urbana na eficiência metabólica das cidades: uma reflexão à microescala urbana' ('The influence of urban form on the metabolic efficiency of cities: a reflection at the urban microscale').
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