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The role of synergy, intelligibility and permeability in structuring polycentric development in Doha

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ABSTRACT

In matured cities, there is a subtle transition between major centres, minor centres, and other non-central areas. The configurational grid is shallow, and one experiences the city as a whole, transitioning from area to area without noticing an edge condition. In emerging cities, on the other hand, urban centres are often spatially deep and disintegrated, meaning one experiences the city as destinations, often disconnected from each other. Some of the major implications of such spatial qualities, as many studies have shown, are the patchy distribution of ground-floor revenue-generating land use, dependent on flows of through-movement; a more disorientating urban experience; and a poor appeal for knowledge economies, dependent on face-to-face interactions and random street encounters.

Here we investigate the role of synergy, intelligibility and permeability as variables that can assist in understanding the difference in experience and spatial quality of two of Doha's main central areas – West Bay and the historic centre. The first observation we make is that between the two, the West Bay area – which is planned as the Central Business District - is less spatially integrated and hence has lower values for all three measured variables. A big part of the reason is the way that the grid is planned, which gives primacy to edge conditions and second- and third-step hierarchy, rather than first-step one, coupled with an inversely configured road hierarchy. In other words, because it lacks an easy reach from the edges into the interior, it is far less permeable; hence, it is a deeper system. In the historic centre, there is far greater permeability, the system is shallower and more consistently hierarchical in its through-movement. The results help explain the differences in spatial experience and support the proposition of the importance of synergy, intelligibility and permeability in measuring the spatial performance of urban in the context of the growing polycentric development in emerging cities.

KEYWORDS

Synergy, intelligibility, permeability, spatial laws, polycentric development

1 INTRODUCTION

We now have an understanding that cities mature from bottom up, as complex and dynamic systems, via continuously evolving processes that are mostly sociological in nature; contrary to what post-war planners had thought, which was that cities were in some sort of a planned equilibrium (Batty, 2010). This understanding has led to many investigations on the nature of these processes and how they relate to our urban experiences. One area of profuse interest within current urban planning is the formation of centres and sub-centres and the access to them. In mature cities one seems to be experiencing the city in a seamless, connected way, transitioning between centres without noticing edge conditions. What is noticeable instead is a densification of the grid and of the non-residential land use, as well as the increased density of people. Outside of a central area, on the other hand, one often experiences shorter street segments, more residential units and less people on the streets. Such observations have also tied the nature of the urban grid to the type and quantity of land uses found along its segments. Hillier's theories on natural movement (Hillier *et al.*, 1993) and movement economy (Hillier, 1996) have explained the socio-spatial logic of cities and provided a clearer understanding of the underlying complexities in the reciprocal relationship between people and spaces and how essential it is to achieving good urban planning and placemaking.

Such an understanding is of particularly importance in the case of emergent cities – such as the ones in the Middle East - where often rapid provision of essential infrastructure and building mass misses on opportunities for placemaking and the enhancement of the urban street experience. In Doha, for example, one observes multiple configurational templates that are stitched together in an urban quilt of various shapes and sizes, often with very hard spatial edges, such as wide uncrossable streets. Some patterns include short lines (streets) meeting at acute angles in a seemingly un-organized way; others include more looping patterns, and yet others are composed of long lines in orthogonal grids. Usually, the first type of pattern is that of a historic centre - albeit disappearing in most cases – which hosts more responsive geometrical patterns, shaped by paced maturation of socio-economic processes; and usually, the more orthogonal or clearly geometrical patterns are a result of modern planning. While current spatial strategies provide a series of best-practice guidelines to ameliorate the urban experience - by establishing, for instance a hierarchy of major and minor centres with good connections between them - they are largely missing an overarching analytical dimension that is useful and applicable to all disciplines and leaps from the visionary spirit to the practical application.

Space syntax provides several theories which explain the formation of the city's street grid and how it relates to our urban experience. In this paper, we are particularly interested in

investigating the configurational measures of synergy, intelligibility and permeability, and we find that they best explain the contrasting nature and behaviour of two of Doha's main central areas – West Bay, which is the top-down planned large-scale development, and the historic centre. We argue that understanding these three urban variables as tools for analysing the urban configurational pattern provides an analytical basis for explaining the urban experience in the emerging city and suggests ways of improving it. We are particularly stressing on these three variables because they have both a global and local impact on urban spatial qualities as they all explain the relationship between parts and the whole and hence, explain how to achieve consistency in a polycentric development.

Our analysis is in three steps. First, we investigate the measure of synergy and explain the differences via a transect investigation, following methods established by Hillier in his definition of *centrality* (Hillier 1999). Both urban centres lie at the coastline, hence at the end of the transect. By sectioning off along the transect, we are able to argue on how some of the foundational spatial laws, established by Hillier and others, play out in the case of our two chosen urban areas, along the transect from local to global conditions.

The second step of the analysis focuses on the measure of intelligibility, which is closely related to synergy and gives us an idea of where the two centres lie in terms of the urban average and in relation to each other. The results from this analysis are very interesting since they identify that intelligibility in Doha – measured by the connectivity vs global integration relationship – is low for the city as a whole as well as for the two centres in question. This sets up an inquiry on how this could be explained and turns our attention to the measure of permeability.

Finally, we break the two urban areas into their constituent parts along hard edges and look forensically into their configurational patterns. The permeability analysis is supported by statistical and comparative exercise among four variables - Choice R3, Average Line Length, Length Sum, and Average Connectivity; and via a step-depth analysis to the 2nd degree.
We find that although the non-historical West Bay holds above-average synergy, it suffers from poor intelligibility and permeability, which might be explained by its reverse metrics of its 1st and 2nd deep urban corridors. This also explains the lack of global pervasive centrality (Hillier 2009), caused by the presence of suburban typologies that impede natural movement through the system.

We conclude on the collective value of the three variables as analytical tools for understanding the quality of urban experience by analysing the configurational nature of the urban grid.

2 UNDERSTANDING SYNERGY, INTELLIGIBILITY AND PERMEABILITY THROUGH A DISCOURSE ON CENTRALITY

In *Space is the Machine* (2007), Hillier structures the discourse of poly-centricity around a scientific framework and explores methods of measuring it. He identifies the paradox of the principles of *centrality* and *linearity* at work in the evolution of urban form, the resolution of which served to maintain the existing spatial structure of settlements shallow to their ever-expanding edges during growth. The linearity exhibits the way centres – identified with the *grid intensification* conditions occurring at these locations – are integrated within the urban whole, based on the formation of a steeper regression line on the scatter plot of local to global integration (Ibid.). The concept of linearity is important as it also consistently applies to the relationships between space and function, i.e. land use. (Hillier *et al.*, 1993).
How well the spatial linearity plays out globally is what is termed as the degree of synergy. *'Research has shown that the critical thing about urban sub-areas is how their internal structures relate to the larger-scale system in which they are embedded. The best way to bring this out is to analyse the system for its integration at two levels. First we do ordinary integration, which counts how deep or shallow each line in is from every other line. Second we count how deep or shallow each line in is from all lines up to three steps away. The latter we call radius-3 integration, since it looks at each line up to a radius of 3. The former we can call radius-n integration. Radius-3 integration presents a localised picture of integration, and we can therefore think of it also as local integration, while radius-n integration presents a picture of integration at the largest scale, and we can therefore call it global integration.'*(Hillier 2007, pp 99-100).

The concept of synergy - as a determinant of the parts-to-whole relationship and an underlying principle of an intelligible polycentric profile - is an important one, as it embeds one's perception and navigability of a local system, in relation to the whole city. This is crucial for planning of centres and the transitions between them. A highly synergized urban system would be shallow, permeable, legible and without edge conditions that impede natural movement or the understanding of one's place in the urban system.

The property of 'intelligibility' is similar. It measures '*the degree to which what we can see from the spaces that make up the system - that is, how many other spaces are connected to it - is a good guide to what we cannot see, that is, the integration of each space into the system as a whole. An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces.'* (Hillier 2007, p.94). In other words, how well is the local area seamlessly connected within the global urban structure so one can easily read the local conditions and understand one's position within the global environment.

The variables of intelligibility and synergy are an important discovery and explain the distinction between historical or organically grown cities and emerging cities, as in the case of Doha where intense top-down intervention seems to have discontinued the process of maintaining a consistent parts-to-whole relationship. Further, if we link synergy and intelligibility as foundational principles to the theory of *pervasive centrality* - where the persistence and reliability of highly integrated urban segments to not only afford a diversity of uses, but also extend, engender and spill into connecting segments, thus forming local centres (Hillier, 1999) – we find that missing on maintaining high intelligibility and synergy in the planning of the emerging city, also misses on pervading the centrality from major urban centres to other urban areas. The resulting spatial structure is less readable and in fact, poly-syntactical in nature, where configurationally varying parts are struggling to connect in an urban whole and to make a consistent urban experience.

The process of centrality – which embeds the concepts of intelligibility and synergy – is how cities grow and break from the initial mono-centric growth into socio-economic sub-centres. In order to maintain a good parts-to-whole relationship during that process, the spatial growth needs to abide to the laws of *spatial emergence* and *convergence* (Hillier, 1996). The first is predictable "global spatial effects" that arise from purely "local physical moves" in the design of the urban grid (Ibid., p.5). The second is 'processes whose rules… converge on particular global types which may vary in detail but at least some of whose most general properties will be invariant" in an ortho-radial grid (Ibid., p.245). This is to say that local spatial moves tend to replicate themselves *ad infinitum* in terms of their formal order in order to conserve their existing spatial structure in the absence of intervention, especially in maintaining the shallowness of the centre to its expanding edges as a subsequent of growth (Major et. al, 2021). In naturally-paced urban growth, new sub-centres tend to extend and replicate the local conditions of previous centres, in order to maintain certain thresholds of synergy and intelligibility and hence, a good part-to-whole relationship.

Hillier's identification of these principles appears to be a validation of the rudimentary models of city growth developed until that point, since they capture fundamental characteristics about these principles at work in city form during urban development. Over the subsequent twenty years, many researchers have confirmed the validity of these laws and the instrumental power of the principles of *centrality, linearity, intelligibility and synergy* at work in shaping and consolidating spatial structure during urban growth in cities of the United States, Europe, and elsewhere in the world (Hillier, 1999; Chang and Penn, 1998; Hillier et al., 2007; Hillier and Iida, 2005; Vaughan et al., 2009; Major, 2018; Peponis et al., 2007, Dalton 2011).

We build up on the understanding of spatial growth, parts-to-whole relationship, intelligibility and synergy, with the concept of permeability. We borrow Hillier's explanation of the relationship between them to help illustrate the local grid conditions in the two centres we have chosen: '*the permeability structure of a complex is essentially a matter of how the relations of*

spaces to their immediate neighbours builds into a system of possible routes. It defines where you can go and how to get there'(Hillier et al. 1987, p.383). Permeability is essentially the founding principle of the through- and to- movement (Hillier et al. 1993) – the measures that sum up the way we experience the urban grid; as a journey from point a to point b, through a chosen path. The theory of *natural movement*, measured via to- and through-movement variables, is tested with the studies of King's Cross, or City of London, where highly integrated parts of the system afford the biggest movement rates, whereas areas in isolation, such as housing estates, are low-movement areas (Ibid). It follows that, in the more integrated shallower systems, the to- and through- movements (captured by the measures of *integration* and *choice*) have high values both globally and locally; whereas in deeper systems (such as the housing estate), they would have lower values. According to Hillier (1996), commercial activities distribute along streets with high accessibility values which afford higher movement rates, in what is known as the *movement economy*; whereas residential components distribute in more segregated streets. This is also an important distinction to be made in relation to emerging cities, where, as we will see, deep systems in central areas (the West Bay) challenge the *through*- movement and hence, the footfall-dependent land use, characteristic of main urban centres.

In summary then, one could say that the natural movement and movement economy would be greatly facilitated by increased permeability; or that the degree of permeability can be a predictive measure for the accretion of natural movement and footfall-dependent land use. As a consequence of an increased permeability, the quality of the urban experience would be elevated, catalysed by increased ground-floor activation and by the increased footfall which brings about a myriad of social benefits – increased walkability, random or planned encounters, urban awareness and sense of belonging, discovery, well-being and outdoor activity.

3 OBSERVATIONS ON DOHA'S SPATIAL CONFIGURATION AND EMERGING HIERARCHY OF CENTRES

In Figure 1, we illustrate the axial integration analysis of Doha at R8 and our two chosen urban centres, West Bay on the North and the historic centre on the South of the coastline. The global axial model is taken at R8, which eliminates the edge effect by corresponding to the maximum mean depth of the overall system, which is observed on the most integrated line, Salwa Road (Figure 1). Because the historic centre is located at the tip of Salwa Road (or rather, Salwa road has historically extended outwards from the historic centre), it is worth investigating whether the *pervasive centrality* (Hillier, 1999) is at play along Salwa Road and into that area. Transect analysis with step depth is used to account for the condition, which then lays out the expectation for the analysis of the local conditions and varied grid configurations between the West Bay and the historic centre.

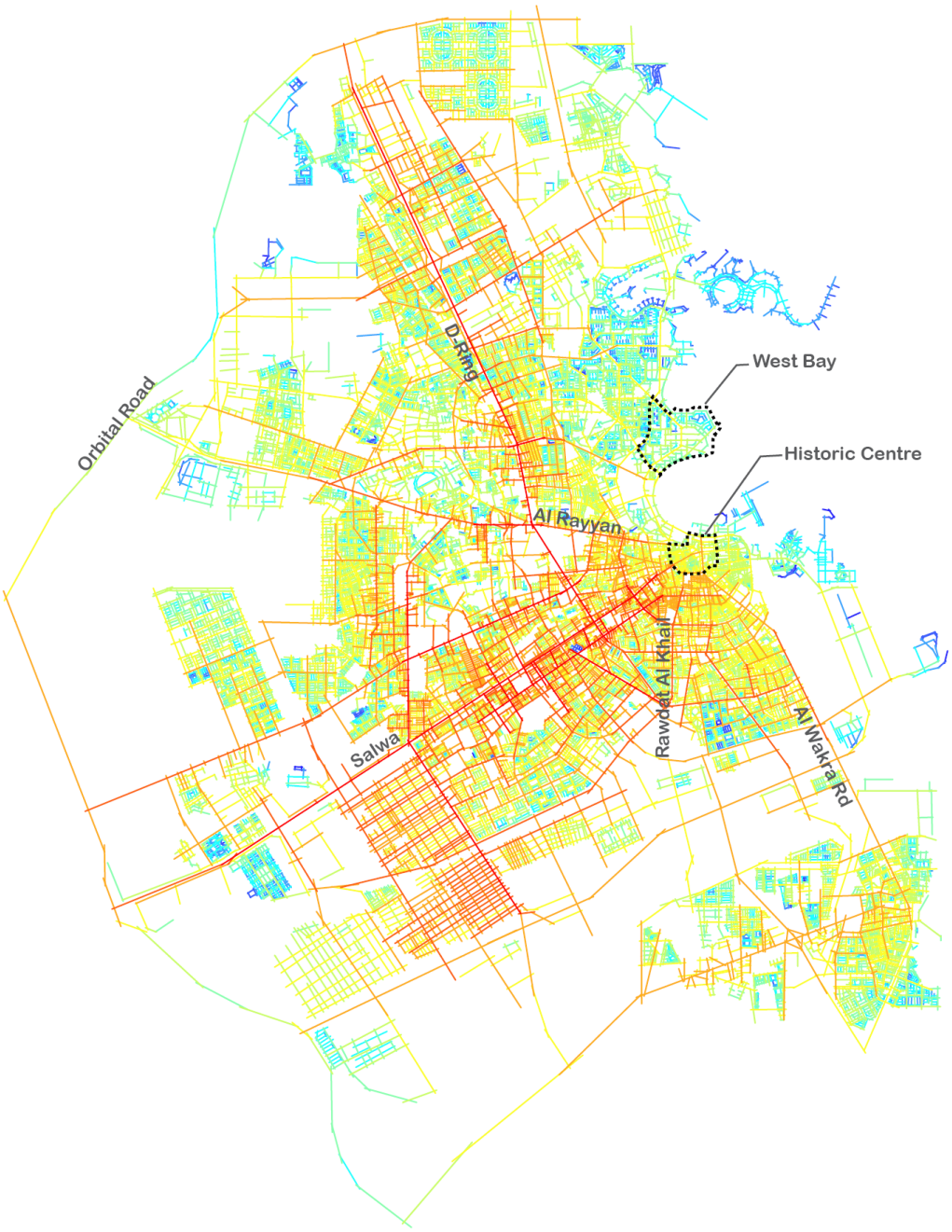

Figure 1 A syntactical analysis taken at R8 to eliminate edge effect. Two things are evident: a shifted centre, picked up in earlier studies - from the historic centre outwards, towards the intersection of D-ring and Salwa Road; and the strength and persistence of Salwa Road, extending from the Orbital Road all the way into historic centre, clearly with evidence of local centralities beginning to form on the way.

The first observation is the shifting of the syntactical centre from the historic centre westward along major vehicular corridors, who seem to spill out axially into adjacent areas in what could be prematurely perceived as a *pervasive centrality* phenomenon, before a closer look is taken at the local pattern later in the paper. The shift in centrality is not uncommon during the process of urban growth. Hillier (1999) states that that the most common displacement is from the historic centre outward, towards what was once an edge, as found in historical small hill towns of France and Italy. Hence, Hillier continues, the '*edge city is one of the elementary processes of urban*

growth' (p.108). What is important, however, is to recognise the pressure this shift puts on creating new and on maintaining old local centralities, through structuring dense local grids with smaller block sizes that facilitate *to-* and *through-* movements (Ibid.). Indeed, in Mirincheva et al., (2013), it was argued that one of the spatial failures of the West Bay was its large centrally-located block sizes – a planning move in stark opposition to the Siksna's (1997)processes and definitions for downtown areas. A recommendation was put in place to intensify the urban grid, which would result in increasing the area's local and global integration.

A second important spatial law for the process of shifting urban centres – especially in the case of spatial conservation of the historical centre - is the structure of long axials that while extend the city outward, also maintain a strong integrative relationship to the core (most often the CBD), thus maintaining a shallow system depth and keeping the core as an integrated and intelligible part of the whole. A familiar case is Chicago, where Major (2018) illustrates a shift in global centrality from the CBD westward to the intersections of two of the longest and most integrated streets – Western Avenue and North Avenue. In a 1-deep step depth analysis, however, it is clearly evident that the CBD (with its movement-privileged Michigan Avenue) although spatially offset, is still highly connected to the global syntactical centre, making it highly intelligible *and* consistent with Intelligibility of the Chicago urban spatial network (Ibid., p.191) (Figure 2). Similarly, in Doha, as shown in Fig. 1, the historic centre, although has lessened its integration hold globally, seems highly connected to at least four radials (Al Rayyan Rd, Salwa Rd, Rawdat Al Khail St and Al Wakra Rd.); i.e., there seems to be a reciprocal relationship of pervasive centrality outward and strengthening the core inward by the increased integration values of the radials. Contrary to it, the West Bay, albeit now part of a matured northern expansion, is still not connected by potent arterial integrators and is more spatially isolated.

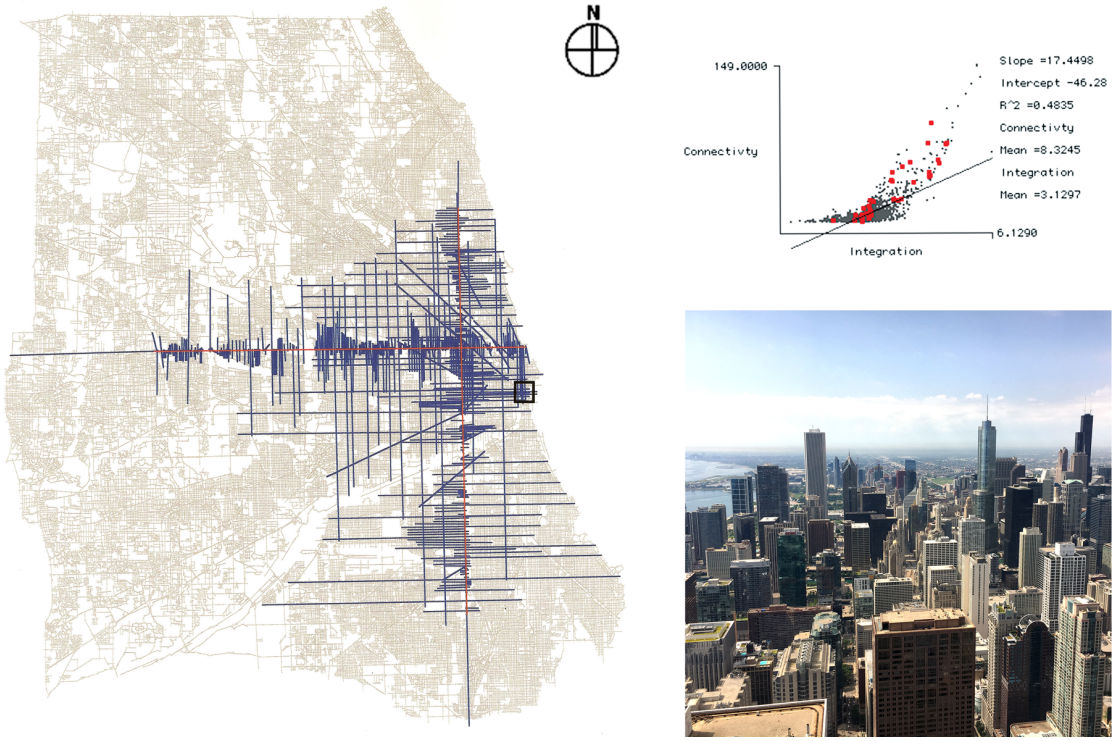

Figure 2. Conserving the centre in Chicago, Illinois USA showing (left) Western Avenue/North Avenue (in red) and all immediate connections (in blue) with The Loop (outlined in black), (top right) intelligibility of The Loop (in red) within Chicago as a whole (in grey), and (right bottom) aerial view of The Loop in 2018 (Source: Major, 2018; 191/Authors).

The two major points made above – firstly, the pressure of shifting centralities on local grid densification; and second, the *pervasive centrality* that maintains integration with main centres - are important observations and the basis of our subsequent analysis.

4 SYNERGY AND HOW IT DEFINES THE PARTS-TO-WHOLE RELATIONSHIP

The hypothesis just posited above about maintaining a shallow system via pervasive centrality is first tested by looking at the degree of synergy that each of the chosen centres has between their local and global integration; or the relative strength or weakness of the parts-to-whole relationship. A comparative analysis of the synergy in each centre illustrates the higher values of the historic centre compared to West Bay, in Figure 3.

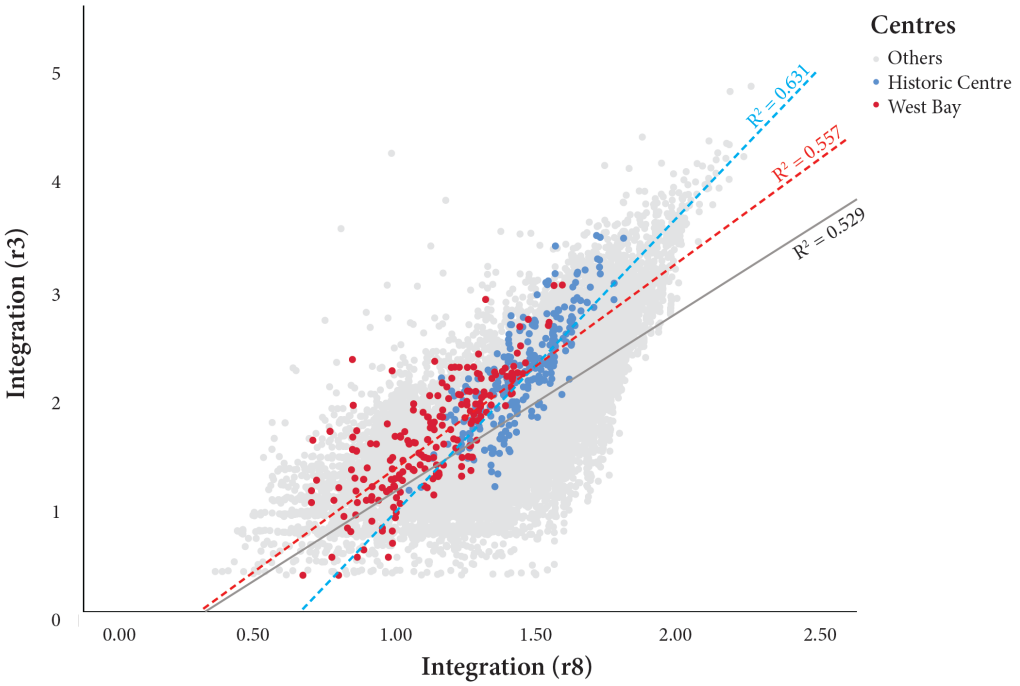

Figure 3 Axial Synergy scatter plot – between local integration at radius 3 and global integration at radius 8, show the high synergy between local and global integration for the historic centre (r^2=0.631), compared to West Bay (r^2=0.557). The steeper fit line for the historic centre indicates the increased synergy in this case.

We begin interpreting this finding by firstly investigating the transect conditions for the historic centre. An axial 2-deep model – 'the minimum conditions for creating an orthogonal grid' (Hillier 1999, p.110) - is used to account for the changing grid conditions, in a direction from Souq Waqif outward and along Salwa Road (Figure 4a). A 2-deep model measures 2 steps away from an origin, in this case Salwa Road. The R3 vs. R8, which is the measure of synergy – measures how well integration within these 3 steps (origin and 2 steps) is a predictor for the global condition, here taken as R8, eliminating edge effects, as stated previously. The method follows closely Hillier's investigations on centrality and pervasive centrality within London's neighbourhoods (Hillier 1999).

On the same transect (Figure 4a), Sector A (taken up to A-Ring Rd.) falls within the historical centre, currently hosting two of the most visited zones – Msheireb and Souq Waqif. In 2 steps from the main axis, the system permeates deep into the premises of the historic centre – touching the outermost edges - and especially into the Msheireb area, forming distinct local centralities. A proof of that is the grid intensification, i.e., the greater number of lines that shape orthogonal spaces and outline smaller block sizes. The changing local grid conditions and centre to edge conditions are well recorded in *Centrality as a Process* (Hillier, 1999). Also here, even without a statistical proof, one can see significantly more and shorter lines in Sector A, less lines and longer length in Sectors B and C, and some quite drastically longer lines in Sector D. What does this tell us? It supports the spatial laws that describe the natural growth of a city outwards, the

shifting of the centre, and the reaching out to keep the urban system shallow along main axes that connect the more distant areas into an urban whole.

It also demonstrates the persistence of the synergy of the system as one moves out of the historic areas and along Salwa Road, captured by the regression scatterplot (Figure 4a). Sector A in Downtown Doha (in purple) is followed by Sector B (in green), which is followed by Sector C (in blue), which starts to overlap with Sector D (in orange) but is also surpassed by it in value. What is also quite interesting is that the synergy of the system is achieved with a 'unidirectional' (Major et al., 2019) sequence of spatial distribution, meaning '*the segment of the Salwa Road/ Wadi Musheirib sequence you are on forms part of an intelligible distribution system directly: in front of you if traveling east-to-west out of town; or, behind you if traveling west-to-east into old Doha (Ibid. p.7).* To explain this phenomenon, we refer to the scatterplot. Segment A0 (which denotes the Step Depth 0 – the first segment of Salwa Road - and which is illustrated with a single bigger dot), sits within the 2-deep system of Sector B; B0 sits within the 2-deep system of Sector C, and C0 sits within the 2-deep system of Sector D. The resulting sequence is progressively synergized towards the shifted syntactical centre. When one moves along Salwa Road, there is an awareness of origin and destination, as well as a systematic distribution into neighbourhood areas along longer lines, followed by shorter lines. The 'strip effect' progressively weakens outwards, with 1-deep and 2-deep lines becoming progressively longer; on several occasions, 1-deep lines reach very far in the overall network – a sign of building up or maintaining a shallow global system that would allow for polycentric aggregation at key nodes in the system, if Hillier's (1996) laws of *spatial emergence* and *converge* continue to propagate in a consistent manner (Major, 2018).

In West Bay, the conditions are drastically different. Firstly, the overall syntactical pattern of the surrounding area is more variegated than around Salwa Road, supporting the initial assessment of the poly-syntactical nature of Doha. We note a mixture of orthogeometries, looping inner developments, undeveloped areas and few more irregular patterns that seem to have emerged in a more responsive manner. The lack of consistency and sequence speaks of a more top-down approach for these northern parts. It is important to acknowledge the peninsular shape of West Bay, a result of land reclamation. This condition might seem like a cause for the lower performativity, but it is the planning response that ultimately shapes the that the West Bay is integrated both locally and globally.

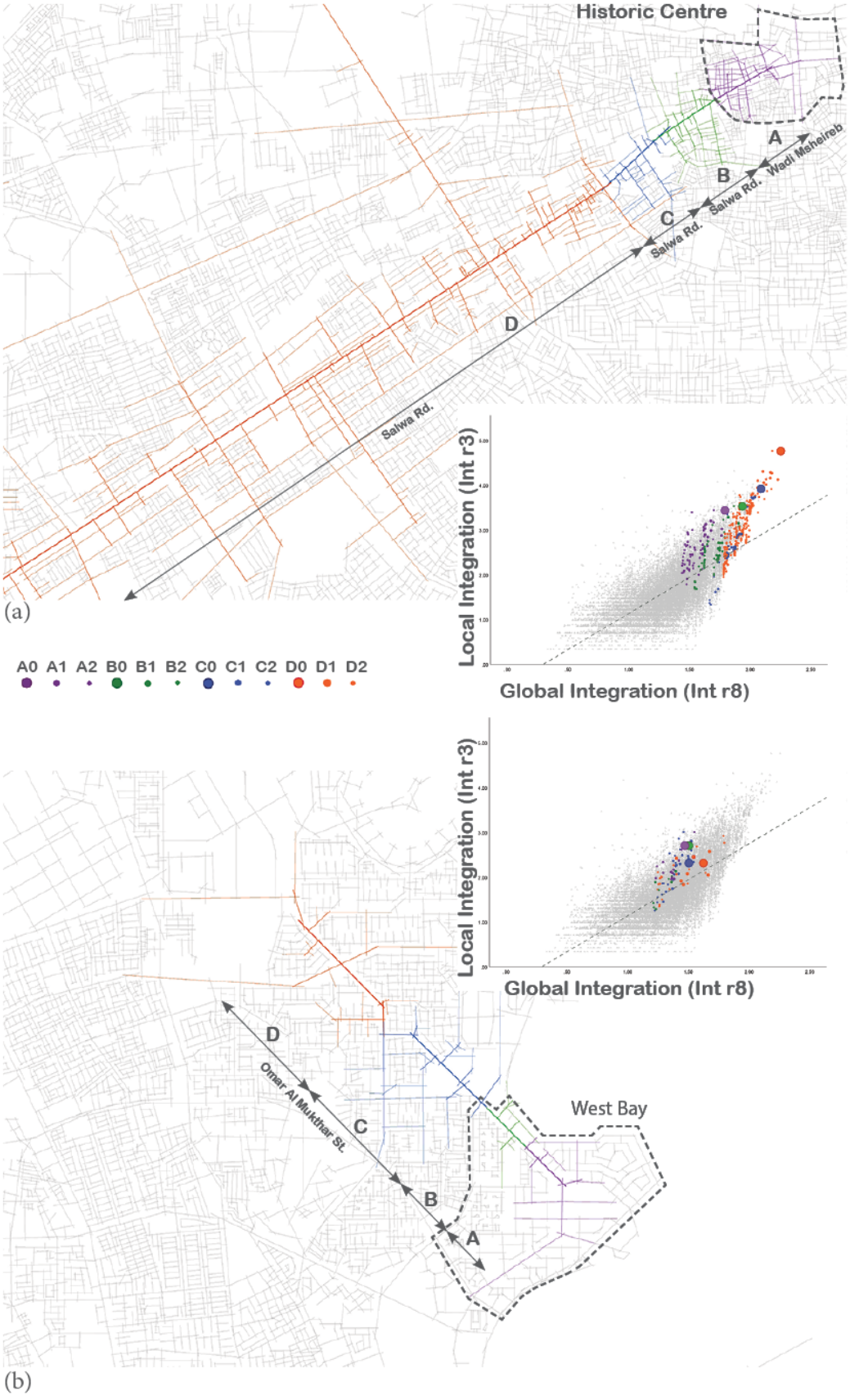

Figure 4. The 2-deep transect analysis of Salwa Road (a) is divided in segments along the ring roads. In the case of Omar al Mukthar Street (b), it is divided in segments roughly where grid conditions change. The numbering of 0-2 represents step-depth of the segment.

Observing one of the major urban corridors that leads to the heart of West Bay, Omar Al Mukhtar Street (the A0-D0 segment in Figure 4b), we notice no gradual change in line length or density. One-deep lines are shorter, more equal to the length of two-deep lines along Salwa Road. This, along with the configurational pattern around, leads to believe that the West Bay area is surrounded mostly by single-family residential developments. The primary network of A0-D0 is connected, through short lines, to a tertiary network of residential units, in a very abrupt way. This is clearly evident in the most north-western part of West Bay, where a clear residential, cul-de sac pattern contrasts the large adjacent plots and the mega-blocks at the heart of the West Bay.

The network's ability for pervading its centrality is worsened by the interruption of the observed main axis, by what seems to be a residential development (between Sectors C and D). Clearly, there is no unidirectional sequence to or from the West Bay along what is a major movement corridor, in an out of the centre. These properties are also evident on the scatterplot, where the synergy of each sector varies from the lowest values to the highest values of the assessed system. This indicates that there is a disconnect between local and global properties. The central artery – the A0-D0 segment (Omar Al Mukhtar Street) – acts like a *bridge* – if one is on it, one is globally aware of the system, whereas if one steps down from it, a person would most likely get lost.

This analysis supports our initial argument that, based on evidence and experience, the West Bay area feels disorienting and confusing to navigate and ironically, acts less central than it should. To make this argument clearer and more relatable – especially for the urban designer – we follow with an intelligibility and permeability analysis to paint a fuller picture of local conditions and their global relatedness.

5 INTELLIGIBILITY AT PLAY IN DOHA'S CENTRES

Intelligibility basically measures the relationship between the number of connections of a street to its global integration; in other words, how important an immediate connection is in terms of its global reach. It is closely related to the measure of synergy in terms of the ability of reading the whole system from experiencing or being only in one part of it.

The lower intelligibility of the West Bay (Figure 5) is predicted by the syntactical map, showing the connectivity of the streets within each centre (Figure 6). Clearly noticeable are the higher value connectors in the historical area, which span longer distances and reach the systems edges. In West Bay, on the other hand, even the most connected lines have only few connections and do not spread across the system, nor do they sufficiently reach the edges.

What the analysis shows is that the amount of local connections (number of routes that one can use to reach the edge of the system) in West Bay is limited and the system is not as connected to

the wider context, as the historic centre. As Hillier observed in *Space is the Machine* (1996), a navigable/legible system would have a high correlation between connectivity and global integration. He noted that low-value correlations are typical of housing estate or suburban typologies. As we will see later in this paper, such typologies do exist in the West Bay area, which would explain the lower levels of intelligibility, as compared to the historic centre.

Another explanation for the lower intelligibility values and how the systems can be read overall is provided later in this paper, via a statistical descriptive analysis of parts of West Bay and parts of historic centre in our discussion on permeability below.

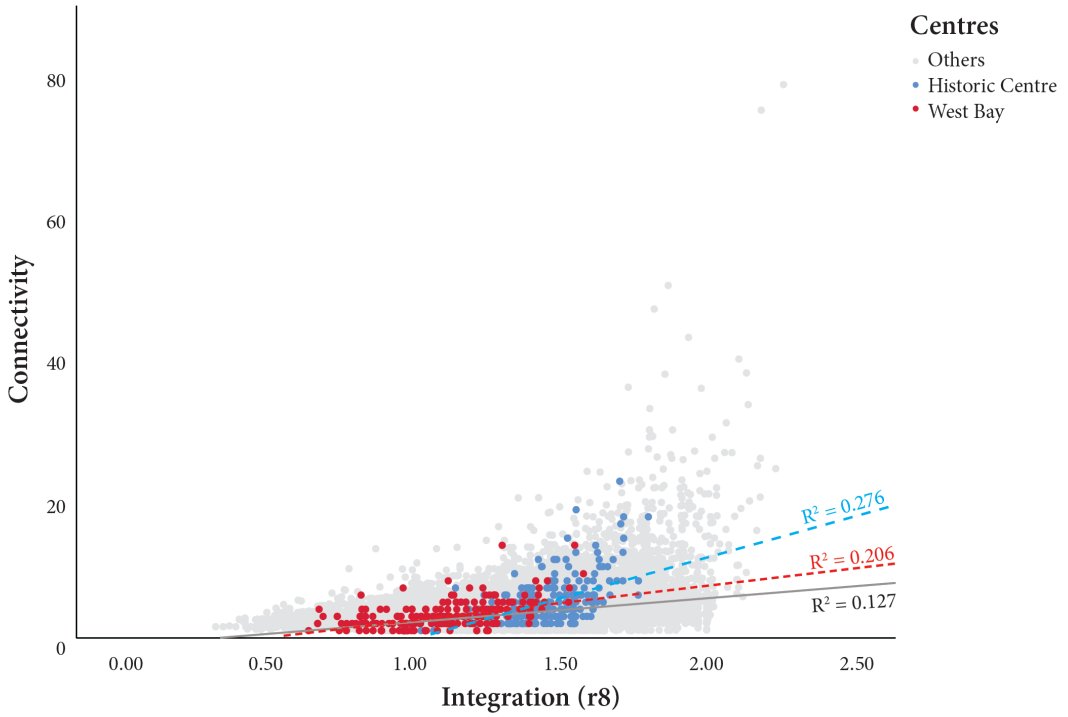

Figure 5 Axial Intelligibility scatter plot – between connectivity and global integration at radius 8, show higher intelligibility for the historic centre (r^2=0276), compared to West Bay (r^2=0.206).

6 PERMEABILITY AND ITS IMPLICATIONS ON THE URBAN EXPERIENCE

The final but central argument of the study revolves around the comparison between a part of West Bay and a part of the historic centre. The more forensic look is necessary, because it captures singular local patterns, which explain the functional and dysfunctional properties moving up the scale towards global analysis in both areas. Again, we employ step depth, coupled with statistical descriptors to shape our narrative on the urban qualities of the two centres.

A connectivity all-line analysis in Figure 7, both overall and based on sub-areas, begins to offer clues into the configurational efficiencies and deficiencies in each centre. The historic centre hosts several centralities, compared to only one in West Bay. Moreover, if we dissect each urban

centre into hard-edge parts and re-run the all-line analysis, we will notice that the historic centre retains

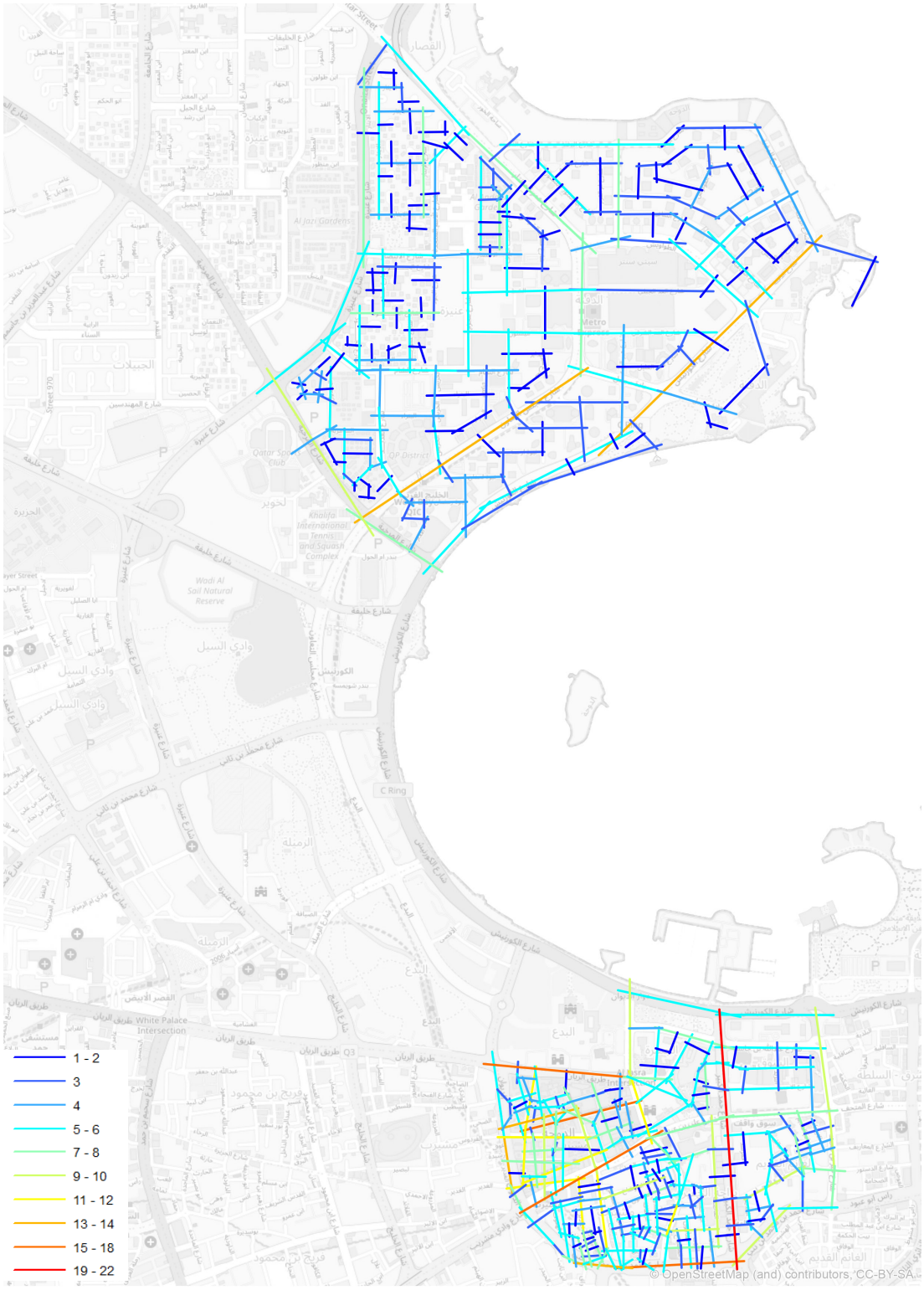

Figure 6 Connectivity map of both urban areas. West Bay on the northern side, exhibits lower values for connectivity along its major connectors and less to the edges, which impacts its parts-to-whole relationship. It also exhibits both large and small blocks sizes, adjacent to each other, which is an indicator of low-rise residential typologies sitting next to high-rise or large block typologies.

local centralities in its constituents, whereas West Bay barely does in 2 out of 4 parts; instead, it retains a high value edge condition.

Besides this overview, emphasis has been placed on two sub-areas – Msheireb and West Bay-North – outlined accordingly. The choice is guided by the fact that both Msheireb and the whole of West Bay is planned top-down; however, to relate in terms of scale we choose only the West Bay North Area. Another reason is that both sub-areas have a consistent configurational pattern and hence, make good candidates for a discussion on planning and design (unlike other parts in both areas which consist of various patterns, including empty plots, which would make it difficult to investigate consistently). It is also important to acknowledge that Msheireb's planners have explicitly maintained historic configurational patterns and have achieved an integrated solution with the wider context.

Msheireb falls within what is considered historic Doha, whereas the whole of the West Bay area is built on reclaimed land and hence, is considered a modern part of the city. They are still, however, top-down planned, with Msheireb being a significantly younger development. Another careful consideration is their common mixed-use feature and highly dense profile, measured both in terms of people per hectare and Built-Up Area. There are no large open spaces or mega-blocks that might affect the properties of the system. West Bay North is more than twice the size of Msheireb and this needs to be kept in mind when describing some of the forthcoming statistical properties of each. As we will see, this metric supports our overall argument of its shortcomings. The 'bridge' effect described earlier, is again evident in the West Bay and its sub-parts. A highly connected central artery cuts West Bay into four sectors of more disintegrated local configurations. The strength of the edges is maintained, but it seems the 1- or 2-step quickly weakens, and no local grid intensification is visible and hence, no discernible centrality. In two locations, certain internal segments seem more connected (as indicated by the arrows in Figure 7), but clearly, they do not follow any spatial laws that would allude to a possible location of a high street or an open space that acts as a local connectivity node. On the other hand, the historical centre consists of long connecting corridors, which permeate in all four directions. Even, on a local level, a more consistent configuration of long, medium and short lines create several occasions for configurational centralities.

Permeability is quite clearly the property in West Bay and historic centre that is distinctly different, resulting in the difference of overall intelligibility measures. The connectivity measure gives a fairly good indication of the amount of permeability in each zone. But even more telling is the centre-to-edge relationship within the sub-areas, illustrated in Figure 7; hence, we need to look inside-out. In all sub-areas of the historic centre, the previously indicated local centralities have a clear reach to the edges. In syntactical terms, the system that is 1 step away from the edge - is the one creating the local centrality.

Figure 7 All line axial analysis of the entire historic centre (above) and entire West Bay (below) gives evidence to the different spatial properties in each, including (besides connectivity) block sizes, configurational patterns and angles, line length and density. Two areas are picked up for further analysis and outlined here – Msheireb and West Bay-North.

In the case of the West Bay, the local centrality is 2-deep from the edge, i.e., the streets that are two steps away from the edges are the most central. This condition aligns with Major et al.'s (2019) findings of Doha's neighbourhoods, where the inner core adopts what he calls a *hierarchical separation by linear integration - 'a spatial strategy seeking to generate a distinctive spatial hierarchy between center/edge streets and interstitial streets providing immediate access to building lots (especially residential ones) without a radical loss of connectivity. This tends to result in greater overall spatial depth in the urban network but we argue this is a more sophisticated model of structured depth as opposed to an ordered one in the American model'* (Major et al. 2019, p.3). An example of this typology – which, in Major et al.'s (2019) work is taken from more suburban locations – is clearly evident in the northwest part of West Bay, in the configurations of residential 'compound-like' grid formations (Figure 8a). There, four short connecting lines link two edges to two internal distribution corridors; resulting in deepening the system through a short singular step. Similarly, West Bay North area – which is non-residential – also exhibits the same configurational pattern (Figure 8- b and c). While Major's argument of 'cultural intent' might well explain and suit the background urban residential network in an Islamic settlement, here it is

a reason for a disorienting urban experience. The existence of such suburban-like deep and segregated systems in a centre is counterproductive for its intelligibility in an obvious way – one remains imprisoned in a looping grid, worsened by one-way circulation system.

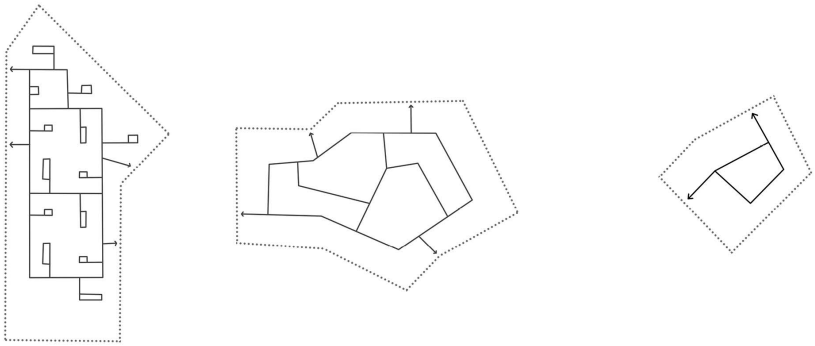

Figure 8 Examples of suburban 'pin-wheel' typologies, found in the West Bay Area. To the left (a) is a compound typology, found in the northwest parts of the West Bay. Centre (b) and right-hand side (c) are typologies, found in the West Bay-North area, which is of particular interest to this study, and which is non-residential, yet of very similar configurational pattern.

The implications of this spatial failure are far reaching. In Mirincheva et al., (2013), it was argued that spatial accessibility is a factor in the way that knowledge economies thrived in the area and the quantity of *spatial capital* – a combination of density and diversity at ground level – that was accumulated (Marcus, 2007). Due to large block sizes and low building density per unit area, coupled with front-facing parking lots or other spatial offsets, pedestrian movement is limited, which leads to struggling movement economy – one of the most inherent properties of urban centres (Hillier, 1996). Here, we strengthen this preposition by almost preceding it with measures of synergy, intelligibility and permeability, to argue that before a more layered analysis is performed on urban centres – street widths, provisions of sidewalks, nature of setbacks, land use mix and other factors – a more foundational approach needs to be adopted in the cases of emerging cities, where the 'urbanity' of parts of the city has not matured enough to adopt second and third order analytics. Hence, emerging planned hierarchy of centres and sub-centres, whose network is underdeveloped will first need to be scrutinized in terms of more founding properties - such as synergy, permeability and intelligibility – before they become subject to more advanced analysis.

To help reach that point and to quantify our argument, we revert to some statistical descriptors in the cases of West Bay North and Msheireb, which help us understand the conditions of system permeability both in a syntactical way and in plain terms. We employ again a step depth analysis, as shown in Figures 9 and 10. We use the same colours for our local centralities as in the transect analysis, for legibility purposes and we also distinguish the 1-deep and 2-deep systems in a gradient variation. This is important to note, as the relationship in the measurements jumps out immediately as a reverse one. Remembering again that the West Bay North area is twice the size of Msheireb, the first observation (Figure 9) is the number of lines it has in the 1st and 2nd steps – half as many as what Msheireb has in half the area of the West Bay. The next set of variables are quite telling. We review them together as a set of variables that indicate the degree of

permeability and intelligibility of the system. All four (Choice R3, Average Line Length, Sum of Line Length and Connectivity Average) are higher in the 1st step and lower in the 2nd in Msheireb; while lower in the 1st step and higher in the 2nd in the West Bay North. What that tell us is that West Bay North (and by comparison, all the West Bay area), is acting exactly the opposite as it should in terms of the spatial laws it must adhere to, and which are found to be essential for maintaining a good parts-to-whole relationship and lay the foundations for polycentric development.

	Msheireb 1st Step	Msheireb 2nd Step	WBN 1st Step	WBN 2nd Step
Count	23	35	12	11
Choice r3	189.95	53.33	34.66	42.36
Length Average	255.54	161.42	240.06	277.79
Length Sum	5877.606	5646.81	2880.81	3055.77
Connectivity Average	6.73	5.28	3.25	3.9
	Decreases		Increases	

	Msheireb	West Bay
Total no. of lines	61	41
No. of lines w/n 2 steps	58	23
% of lines w/n 2 steps	95.08%	56.10%
Total length of lines (m)	11747.59	9472.73
Total length of lines w/n 2 steps (m)	11524.42	5936.58
% length of lines w/n 2 steps	98.10%	62.67%
Total area of the Zones (m2)	377173.98	788690.21
Segment Length/Unit Area (m / m2)	0.031	0.012
Area / Unit length of segment (m2/m)	32.11	83.26

Figure 9 Statistical analysis of several variables that help explain the reverse relationship between edge and centre, exhibited in Msheireb and West Bay-North.

Why are these four variables significant? Firstly, local Choice (R3) is indicative of pedestrian through movement. The lower choice in the 1st step West Bay North system supports our 'bridge' theory – from a highest value system, we fall into a tertiary value system. This is indicative of the *hierarchical separation by linear integration*, intrinsic to suburban layouts (Major et al., 2019). The second variable, length average, tells us that the while Msheireb deepens in the 2nd step, West Bay North deepens right at the 1st step, where the lines are shorter; i.e., the permeability is cut at the 1st step. Length sum, the third variable, is an offspring of length average – longer lines connect to the edges, while shorter connect to the 2nd step in Msheireb; the relationship is reversed in West Bay North. Finally, and significantly, the connectivity average in West Bay

North is stronger in the 2nd step, not the first, as in Msheireb, which means more lines are connected to the 2nd step than the first, explaining again a sudden deepening of the system in favour of internal looping rather than permeability through the system.

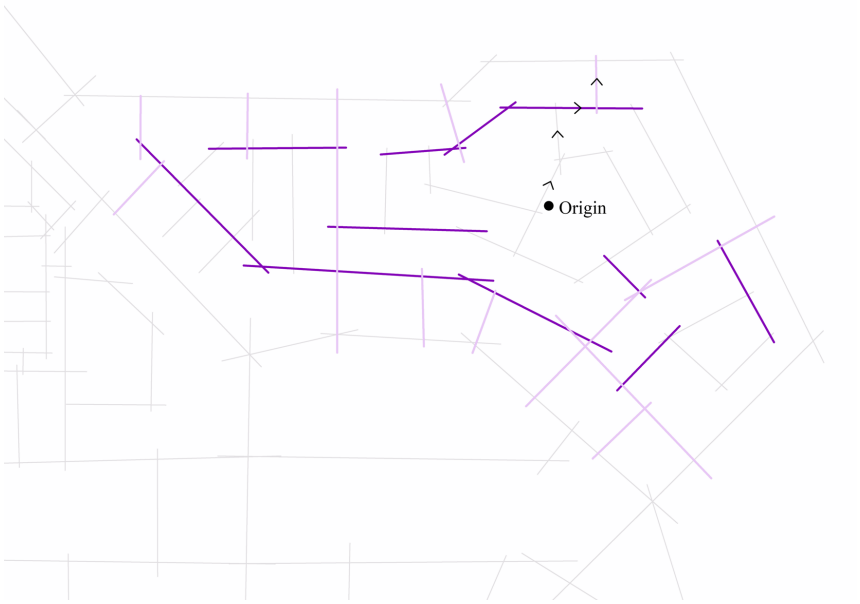

Figure 10 The multiple turns that one must take to reach very short distances in the West Bay, speaks of a looping and unintelligible system. One might see where to go but cannot reach there in a straightforward way.

The reverse relationship is clearly illustrated graphically in Figure 9. The most direct reflection of the graphical illustration is the following statistical descriptive: in maximum 2 steps in Msheireb, a person can get to at least one edge from anywhere in the system 95.08% of the time; compared to only 56.10% of the time in West Bay-North. In Figure 10 below, we illustrate this condition in its worse scenario. Because of the suburban-like spatial configuration, in the rest of the 43.9% of cases, it would take a minimum of 4 moves (sometimes with a combined 180 degree turns) to reach an edge from the inside of the system. It is not a surprise then, that the most movement in the West Bay area is along the edges and through the central artery (as seen in Figure 7), which acts more like a connector of southern parts of Doha with northern parts of Doha, than a local distributor of pervasive centrality.

7 CONCLUSIONS

We started by arguing that in mature cities, there is a more gradual transition between central and non-central areas and that there is a higher awareness of one's local position in relation to the global system; whereas in emerging cities often the urban experience is more disorienting due to less consistency in the configurational urban patterns and how they come together. We embed this argument in the discourse of polycentric development, where the relationship between the parts and the whole should be strongly maintained, resulting in a shallower urban system and smooth transitions between centres and non-centres.

We relied on the theories and methods of space syntax to investigate two central areas in Doha – the historic centre and West Bay area. Through the lenses of some founding spatial laws – centrality, linearity, laws of emergency and convergence - we analysed and measured their degree of synergy, intelligibility, and permeability, to help structure an overall discourse on the role of the network in the spatial experience of the city.

We employed two very telling methods. Firstly, a transect analysis that gave evidence to pervasive centrality, formed along Salwa Road and into the historic centre, as well as to the lack of these conditions in the case of the West Bay area. In addition, on a local scale, we employed a statistical descriptive analysis to better understand the metrics of the spatial properties in our two central areas. This second analysis was very helpful in quantifying the degree of permeability, which accounts for how one feels when navigating in the West Bay, compared to navigating in the historic centre. The drastic differences were captured in four main variables – Choice R3, Ave Line Length, Length Sum, and Connectivity Ave. Combined, these variables set out a reverse statistical relationship between the two central areas. The cause of that in the case of the West Bay area is its adoption of more suburban-like typologies that are detrimental to natural movement and hence, the accretion of movement economy.

We conclude by arguing that as much as spatial laws that result in good urbanism are invariant and universal, some are more relevant than others in relation to the kind of city one is analysing, designing, planning, or living and working in. More matured cities usually grow a clearer hierarchical distribution of centres and sub-centres, based on the repetition and maturation of local spatial moves, i.e., the emergence and convergence conditions (Hillier, 1996) mentioned earlier; as well as adherence to the rules of natural movement which keep urban centres shallow to city edges. Inevitably, they achieve a greater degree of synergy, permeability, and intelligibility in a more paced way. In emerging cities like Doha, where the urban development is rapid and proliferated, this is not the case. What this paper shows is that synergy, intelligibility, and permeability should be engaged as control mechanisms; founding spatial laws for the growth and accretion of major and minor urban centres before second order analytics start finding their role in shaping the urban experience. Understanding how these variables can be employed analytically can assist the designers' approaches to planning, in particular for their understanding of the active configurational properties of the network at play to structure movement, attract land use, reach and connect and form the basis of the urban experience.

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