

TURNING BARRIERS INTO ALLEYWAYS: Unsolved transitions from Old Barcelona to the Post- Cerdà city

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Abstract

The evolution of Barcelona up to its present state brings to light quite diverse logics of performance, started with the destruction of the old walls and ramparts and subsequent expansion on the plain, up to its natural Northern limit -the Collserolla mountain range. Such growth incorporated villages in its vicinity requiring deeper articulation, to form a new entity explained in basic processes read and measured with Depth-Map:

- *Proposals to put to good use the space left by walls demolition, stitching the tissues that existed on both sides. Old Barcelona had to be reinterpreted; quite particularly, the varied projects –even those never realized- that provided new visions. In order to know their impact on the present city –had they been implemented-, a simulation of such layouts are included in today's urban fabric;*
- *The expansion of the Ensanche and how it inserted or repelled existing fabrics and historical thorough ways;*
- *Configurations propitiated by the annexation to Barcelona's layout of little villages in the vicinity of Collserola, to which new growths did follow, as emergent models between the Ring Roads.*

These processes are useful, without disregard of the role fulfilled by the Ring roads, to understand present Barcelona and the causes of its heterogeneous functioning.

The object of the study is to read the behaviour and logics of these fabrics of transition, isolating the elements/ streets/ patchworks that link and make the coexistence of local and global logics possible; throwing light on a hybrid system that heightens still operating dynamics. For this purpose, Step Depth Analysis and Normalized measures are obtained and applied to isolate fuzzy boundaries and to know the contribution of elements to the system.

Keywords: Urban morphology; Space Syntax; Spatial Sustainability; Urban performance; Urban Heritage

Theme: Historical Evolution of Built Form

Introduction

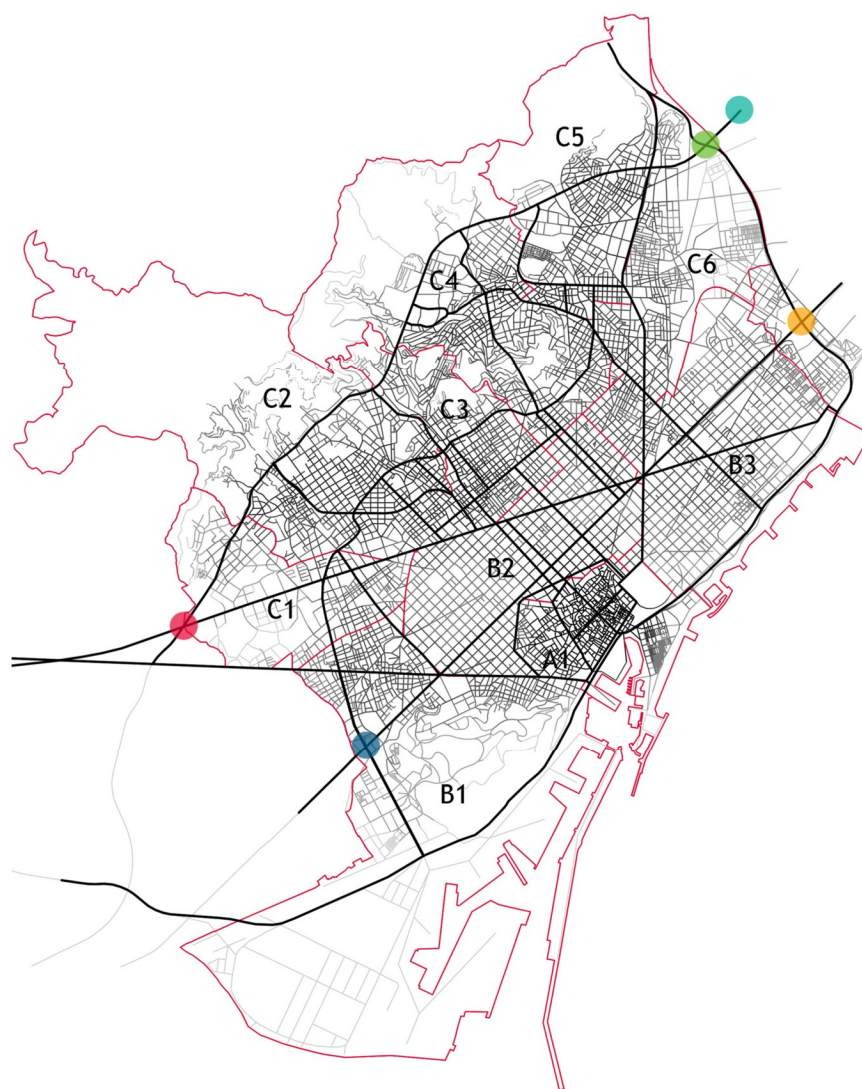
Out of the divergent growth processes that took place in Barcelona leading to its present state, recent ones interest us here, relating them to continuities built as well as to opportunities, which left its imprint in the evolution of ideas about the city, though never built. Digital Urbanism operations, as the evaluation of plans before disrepair and the visualization of not implemented proposals suggest questions: what if... such projects had been built?, how relations within urban configurations, concerning continuity or to links with movement economies in a changing context are affected?

We refer the reader to fig 01 for a description of Barcelona's actual foreground, as it relates to its ten administrative districts. Within this layout we can perceive three Ring roads, surrounding in turn three intermediate coronas: the oldest formed by Ciutat Vella or Old City (A1); a second corona adding the districts of Sants-Montjuïc (B1), Eixample (B2) and Sant Martí (B3); and the last peripheral corona, formed out of the more complex districts of Les Corts (C1), Sarrià-Sant Gervasi (C2), Gràcia (C3), Horta -Guinardó (C4), Nou Barris (C5) and Sant Andreu (C6). If the names are cumbersome for the reader, please, follow the text by means of the letter plus number that indicates the corona and a relative number, chosen from old centre to periphery in clockwise sense.

The presence of Ensanche is strong by its perfect grid character exactly oriented (NE- SW axes parallel to the sea and NW-SE axes perpendicular to the sea), extended as far as St. Martí district (B3), and conferring the system order and structure. Indeed, the Cerdà lattice acts as centripetal/ centrifugal exchange mechanism, collecting arriving flows and redirecting them quickly to the periphery, now enhanced by the activity of Ring Roads. The Ensanche is an exchange area of through-movement, with high values of integration at its very core. At the same time, some natural routes channel to-movement from origin to destination and back, along specific ways linked for centuries to rainwater courses and fords or bridges built to pass over them. Thus, a symbiotic relation between centre and periphery is established, already streamlined at the core and with emerging phenomena at the periphery.

Relative vehicular weight acquired by Ring Roads (Upper, Middle and Coast Ring Roads) is indicated in the scheme of Foreground vs. Background, at the bottom of Fig. 01, provided by the Town Council of Barcelona. Bypasses between great infrastructures to re-direct movements are located at the Third Ring road –close to the natural limit of Collserola Mountain Range- indicated as small colour circles (the red and yellow dots are most hectic, the dark blue has lost traffic recently, and the NE couple -green and light blue- are evidence of continued movement. Perpendicular ways to these rings act as links between primary and secondary flows, increasing important choice and integrating lines; but, most especially, providing quick access to a series of small worlds where old summer houses were built, now sought-after as permanent homes or to locate educational institutions and small clinics, etc., a variety still operative that is causing emergent patchworks.

The reader is most likely acquainted with the diagrammatic nature of Barcelona structuring lines; nevertheless, orientation is included to navigate easily through the city. Fig. 01 is tilted, a professional habit when dealing with Cerdà's Ensanche, designed to have the diagonal of its plots oriented North-South for adequate exposure to sunshine, especially if one or two sides had been left un-built; North- South is the sense of Meridian Avenue, main line of access from NE in the old days and still operative (you can notice it at the right side of Figure 01, with one side between districts C6 and B3 and the other between C5 and B2). Its perpendicular – horizontal in Fig 01- is Avenue Parallel, a source of unsolved patchworks, owing to the petty tracing that could otherwise bind naturally the edge of the Old City and the historic settlement of Sants, Montjuic and Hostafrancs/ B1, especially the latter, as a simulation explained in the text lets know. Other conspicuous streets are well known by Space Syntax researchers: Diagonal and Gran Via meet Meridian at a square (Glories), thought as a new centre. The rest can be followed as a succession of interfaces showing the metropolitan vocation of the city.



		2010	2011	Variation 2011-2010
Ronda de Dalt (Diagonal)	●	140208	138329	-1,30%
Ronda de Dalt (Pota Nord)	●	81773	81570	-0,20%
Gran Vía (Plaça Cerdà)	●	105774	102235	-3,30%
Gran Vía (Besòs)	●	115398	110939	-3,90%
Nus de la Trinitat	●	109987	107033	-2,70%

Table 01_Vehicle flow/day for BCN rings.

The ten districts:
A1_Ciutat Vella (First Ring), B1_Sants-Montjuïc, B2_Eixample and B3_Sant Martí (Second Ring), C1_Les Corts, C2_Sarrià-Sant Gervasi, C3_Gràcia, C4_Horta-Guinardó, C5_Nou Barris and C6_Sant Andreu (Third Ring)

Figure 1: The administrative division in districts of Barcelona and its foreground.

Spatial analysis of urban grids and historical variations

Studies of Barcelona grids contrasting background and foreground showed that “distinguished constancies appear in angular segment integration analysis; within 500 meter radius; the Old

City maintains the highest local integration values as the spatial system grows. Some distinct local centres start to appear in the heart of the suburban areas which once were scattered villages in the vicinity of the Old City”(Al Sayyed K., Turner A. and Hanna S. 2009; Hillier B., Turner A., Yang T. and Park H.T. 2007). The global effect of the collective behaviour of segment spatial elements is reflected within 2000 meters radius. High values of integration are spread to the area between Old City and its immediate context, when the organic tissue of the Old city is changed by a uniform grid, but with a decrease in the original values within its nucleus. Interestingly, high integration values “spread to the cores of the suburban town centres creating a network which connects all parts of the urban grid” (our stress). Consequently, it made sense to enlarge historical thorough-ways to increase depth. The above-mentioned authors simulated some Study Cases to reveal the embedded properties of Barcelona urban structure in search of emerging models that followed three stages (Old Barcelona, Ensanche and recent patchworks). Three stages help to understand Barcelona’s current state and its growth processes.

1. The Old City preserves relatively high integration values and so do the cores of the suburban town centres, which emerged in later stages of the city growth. This old core first kept our attention, related to unbuilt Plans (Baixeras and GATCPAC), plus a network derived from the extension of historical thorough ways, owing to the emphasis on “smoothness” and themes from segment angular analysis. Baixeras plan operates in a similar way as continuity maps, and the GATCPAC proposal deals with the global geometric/ topologic structure of the grid and with metric depth to identify characteristic patchworks (Turner A. 2001; Figueiredo L. 2005; Hillier B., Turner A., Yang T. and Park H.T. 2007), though neglecting the potential of structuring lines.

2. High global integration values are mostly seen in the uniform grid, owing to its connective attributes, fading away as we move outwards from the uniform grid. We do not elaborate on intensifying the uniform grid, since we considered the observations by Al Sayyed K., Turner A. and Hanna S. 2009 well grounded (it “*destroys the organic distribution of integration values and draws all the high global integration values to the uniform grid centre*”), but also because of its unlikely realization. Instead, the extension of old entrance lines has effects on the surrounding villages, evidencing the phenomenon of pervasive centrality and neglected potential, still existing in the layout.

3. A third stage accumulates the last evolution of initiatives started in 1901, with peaks caused partially by international events and by endowing existing settlements with new cohesion. Angular depth highlights a network of diagonal and perpendicular long lines, which along with their semi continuous extensions define the global network pattern that connects all the city parts. This point drew us to search historical evidence (abundant: the access to and departure from the Old City were treated by Roman Centurions, the Junta Roads in the 18th and 19th century, Jaussely’s Plan in 1901, etc...). The background analysis defines clusters of short lines forming patchworks in recent organic portions of the grid.

Consequently, changes in the emergent behaviour of the city grid and potential rules can work in combination with Hillier's "centrality and extension": “*don't block a longer local alignment if a shorter one can be blocked*”, to which parallel or perpendicular alignments to the coast are relevant to unveil their connectivity values. “Horizontal” lines (i.e. parallel to the coast) carry most of the traffic and are the faster sectors of traffic belts; whilst “vertical” lines (i.e. perpendicular to the coast) fulfill a distributive function; both of them, plus underground links, let us know why some sectors are neglected or emerging, with a simple procedure:

First; rules might be extracted from the edges of the growing system; in fact, from the range of angles to form new lines out of the older ones.

Second; change in the foreground versus the background structures might show distinctive generators, where serious damage was produced in old times.

Third and most important; some generative rules could be extracted if a measure of change is

introduced with which the forces of directional growth can be isolated in the network. Enhancing the properties of the growing networks by *optimizing spatial depth* might aid strategic spatial planning.

A quick glance at Fig 02a provides a clear contrast between Node Count local values for present Barcelona quite intense in the First Ring/ Old City district, from which the city sprung. It seems an overstatement of the evident lack of inter-relation and mutual understanding that the Choice Graph shows, where a spatial structure, born out of very different interventions and not completely superseded. Even thus, some patchworks produced out of old grids and originally segregated villages are distinctively marked.

The GATCPAC- Le Corbusier intervention brought improvements to the first ring and a simple modification of diagonals that ordered the city's spatial structure.

But the really bold proposal by architect Baixeras proposal, seen as a morphological and costly whim, might have had far-reaching consequences in connection with today's connectors. As the Choice Graph clearly shows, we face a model where both pervasive centralities and fuzzy boundaries would be acting from inception. The historical approach connecting Hostafranchs and the Old City marks Parallel Avenue (between C1+ B2 and B1 in Fig 01) and a blurring continuity of the Old City boundary, whose perimeter is cohesively linked to patterns outside and its performance relates several centres (quite enhanced in the image of Node Counts), as counterpart of cores differentiated in districts configured by the uniform grid.

This proposal led us, in turn, to the role played by diagonals and long lines, which stitch and solidify two parts of a single reality. If we connect these partially existing ways in what we call Diagonals Modified Barcelona, Depth-Map shows a cohesive result on the perimeter fabrics close to Old City, and an incipient grid diagonalization is perceived in Choice maps for radius 1000.

Discussion has two stages: A first part in which we attend these facts from graphs and data obtained with Depth-Map and Syntax Analysis, in search of regularities for the three main interfaces operating in Barcelona. And a second part, inseparable from the former, where critical issues as the treatment of density, the stitching of destroyed fabrics or the forms appearing as result of urban dynamics. The first analysis cannot be prejudiced and serves the purpose of understanding the basis for the second analysis, where previous discussions are seen with a new light.

Our point of departure is the diversity of layouts shown (as seen in Depth-Map graphs, Figs 02a and 02b). Relevant to our approach is the contrasting performance of diverse areas limited by Ring Roads that shape the globality of the urban fabric as growing interfaces. Inspecting Tables 02 and 03 we can compare these Graphs, to make a first study of different proposals within the frame of the Old City /A1, paying attention to the most general measures –local and global-, proceeding later to study the different rings as they configure Barcelona, to evaluate the contribution of NC and depth and derived values. Normalized values show a poor dispersion; so, it is interesting to compare each situation analyzed. We knew that the current urban system and that proposed by GATCPAC are quite close in the Old City/A1, as seen in Tables 02 and 03 and as it appears in NC values. It is not a surprise that integration and especially NAINT have similar values; and the same happens with NA Choice.

Following this argument, we can compare models simulated to reinterpret the role of Old Barcelona (today's Old City District and the first interface), to throw some light on the present city. Depth-Map Graphs included in Figs. 02a and 02b let us see some proposals contrasted with present Barcelona:

- That developed by the Catalan functionalist architects GATCPAC with Le Corbusier proposed a clearing and improvement of hygienic conditions in the Old district, with a

link – Gran Via- to a leisure city at the far SW, relating all parts; to a great extent, the cause of its high integration;

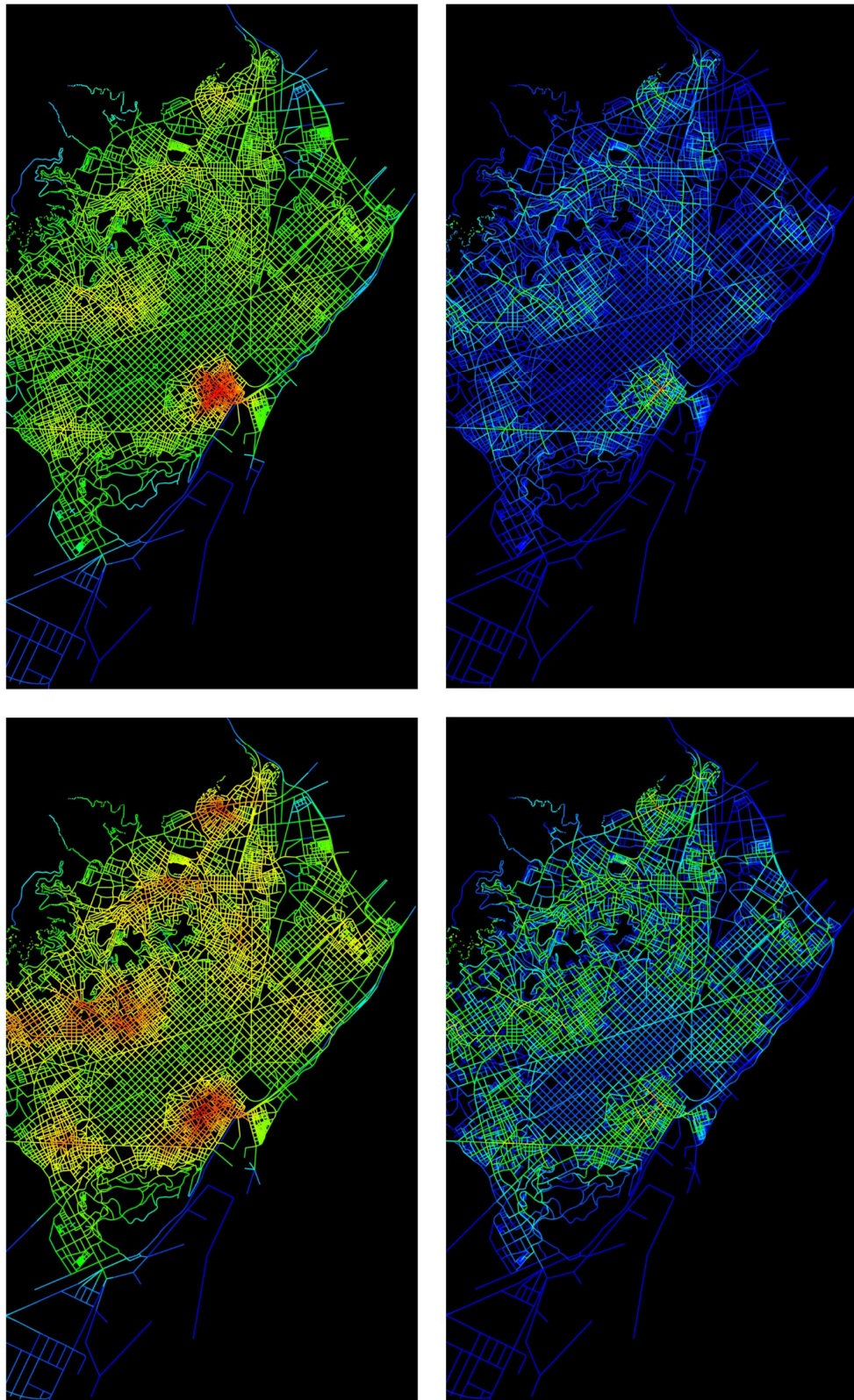
- The shocking proposal by Baixeras does not influence so directly the immediate context, as much as distant city sectors, a fact revealing increased connectivity; and finally,
- A recollection of diagonals - historical and from previous Plans that enrich the city fabric, as we know it today- is enlarged, endowing them with new connections in the layout, so that they acquire a role in the spatial structure of the present model. No great proposals seemed required, after all.

BCN&DISTRICTS	CH_2	NC_2	TD_2	NACH_2	NAINT_2
CURRENT	15604.1	461.034	689.301	1.48	2.29
BAIXERAS	16066.2	482.542	724.478	1.47	2.30
GATCPAC	15427.2	458.414	685.325	1.48	2.29
MODIFIED DIAGS.	16710.0	488.046	729.838	1.47	2.32

Table 2 Local readings of Historic layouts in Barcelona (R 2).

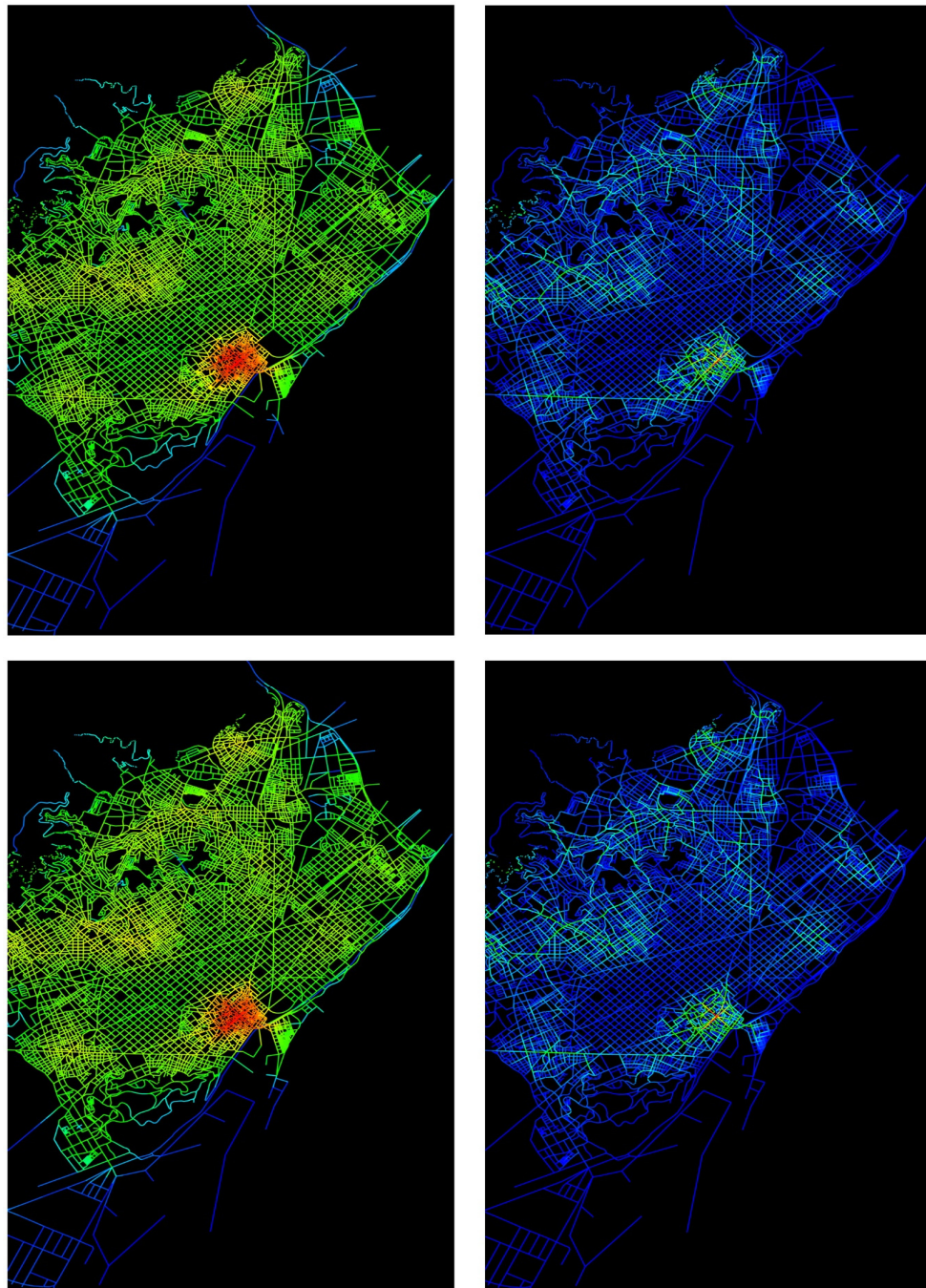
BCN&DISTRICTS	CH_10	NC_10	TD_10	NACH_10	NAINT_10
CURRENT	1.18E+06	16746.6	9.50E+04	1.22	1.23
BAIXERAS	1.15E+06	16175.8	9.07E+04	1.22	1.24
GATCPAC	1.19E+06	16919.3	9.61E+04	1.22	1.23
MODIFIED DIAGS.	1.18E+06	16846.6	9.48E+04	1.22	1.24

Table 3 Global readings of Historic layouts in Barcelona (R 10).



From top to bottom:
01_Current Barcelona Node Count radius 1000, 02_Current Barcelona Choice radius 1000, 03_Baixeras Barcelona layout Node Count radius 1000, 04_Baixeras Barcelona layout Choice radius 1000.

Figure 02a: Local Node Count and Choice in different layouts of Barcelona.



From top to bottom:
 01_GATCPAC Barcelona Node Count radius 1000, 02_GATCPAC Barcelona Choice radius 1000, 03_Diagonals Modified Barcelona layout Node Count radius 1000, 04_Diagonals Modified Barcelona layout Choice radius 1000.

Figure 02b: Local Node Count and Choice in different layouts of Barcelona.

The dismantling designed by Baixeras is more viable locally in Angular Analysis than in historical reality; after all, taking care of the main structuring lines, modifying some diagonal lines, we may have an increase in TD and higher NC. *“The distinctive diagonal lines in the uniform grid play an important role in connecting all the city parts”. And “the exclusion of the diagonal lines in the grid does leave some impact on the spatial configurations of the segment map. This applies to both the local and global radiuses”* (Al Sayyed K., Turner A. and Hanna S. 2009). With new connections provided by modern Ring Roads, such proposal affects the whole city, especially the already established villages in the second corona, –the reading for radius R 1000 in Fig 02, and the modification of historic diagonals heightens the foreground, another proof of

the “paradox of centrality”.

Some remains in the urban pattern seem to turn into effect the entropic expenditure produced in previous generations: going against the rules of the prevailing configuration is expensive and it should be duly justified. A form of understanding and interpreting the city can be unveiled, by paying attention to data appearing in the successive coronas (Tables 04, 05 and 06):

The fabric included within the first Ring has the lowest NC, coexisting with high connectivity and a considerable depth when compared with its increase in the expanding city: in such conditions, its local integration –relatively low- is indicative of exhaustion, after decades of intervention, renewal, even bombardments, pointing to the necessity of readjustment. This is also reflected on a local choice that could well be higher, being a district crossed by alternative ways: here the point is whether or not this tracing is the correct one. Equally, local integration has a poor value, the remains of a hectic area, when detailed performance is consulted (Garcia-Espuche A. 2009).

Furthermore, we are facing here an issue of optimization, discussed by Park H-T. 2005: *“although entropy is a concept often emphasized more than that of multiplicity, the former is no more than a logarithm of the latter. Yet, the logarithmic measure becomes vital when N –the number of edges- is large”... Entropy cannot exist without distance, but at the same time distance cannot make any real sense without entropy*”. The above-mentioned author illustrates correlations between ITS (intensity) and CTR (centrality), as well as centrality and integration, with a concluding synthesis: *“there is therefore an appealing duality: we can actually retrieve from real observations and experiences a priori ideal or theoretical models we already have. This is also the way CTR, not ITG, can be verified a posteriori”* (Park H-T. 2005: 571). Indeed, such is the case in the proposal by Baixeras and that of Modified diagonals, when increased depth is provided.

The second Ring, on the contrary, exhibits high local integration, owing to its grid condition, although a reduction of such values and its singular character can be observed at a global scale, which can be explained by the deformation and adaptation to the grid of pre-existing organic tissues.

The third Ring shows low global integration, derived from its heterogeneous fabric, and formed out of diverse nuclei with singular identities, opposed to the 1st corona, an organic unitary configuration persisting through centuries despite all problems.

RINGS	NC	MN CONN.	MN DEPTH	MN INT. HH R_3	MN INT. HH R_n	MN CHOICE R_3
1st RING	1376	2.94549	12.0529	1.39206	0.74464	31.3808
2nd RING	3537	3.13175	23.3821	1.51481	0.49905	58.3992
3rd RING	5968	2.96347	26.5839	1.39644	0.41322	31.1887
AVERAGE	3627	3.01357	20.6730	1.43444	0.55230	40.3229

Table 4: General data for BCN rings

RINGS	CH_10	NC_10	TD_10	NACH_10	NAINT_10
1st RING	60560.8	2290.02	11937.4	1.17	0.90
2nd RING	365615.0	6833.01	27796.5	1.25	1.44
3rd RING	586359.0	9070.66	56134.1	1.21	1.00
AVERAGE	337511.6	6064.56	31956.0	1.21	1.11

Table 5: Global normalized measures for BCN rings (R10).

RINGS	CH_2	NC_2	TD_2	NACH_2	NAINT_2
1st RING	892.156	99.241	136.481	1.37	1.87
2nd RING	22604.900	734.364	1091.290	1.43	2.52
3rd RING	2951.510	179.739	254.775	1.44	1.99
AVERAGE	8816.188	337.781	494.182	1.41	2.13

Table 6: Local normalized measures for BCN rings (R2).

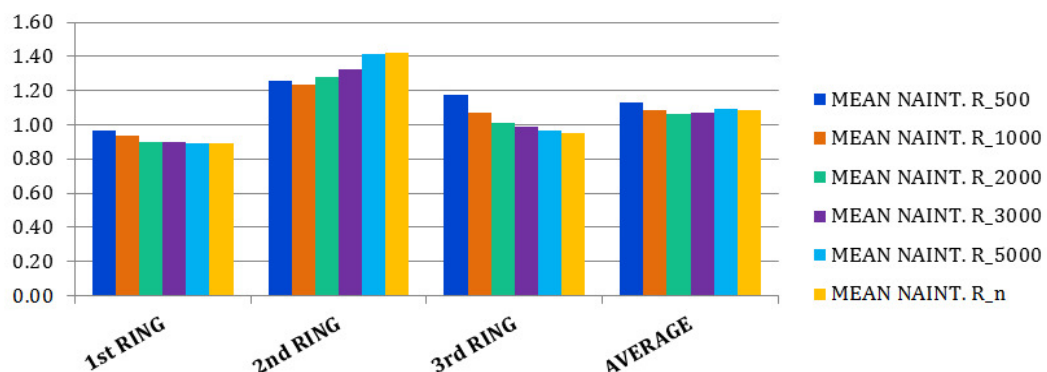
Tables 05 and 06 vouchsafe that it is within the second Ring that maximum values of integration, local and global, are to be found (NAINT_10 = 1.44 and NAINT_2 = 2.52), owing to its particular grid network condition, even with chances of improvement. The foreground of an organic system still in process cannot compete with the clear schema of an almost perfect grid within the second Ring.

Contrasting with these facts, the grid exhibits a rigid pattern of choice values when it meets some pre-Cerdà pseudo-grids (Gracia/C3 and Sarrià-St. Gervasi/ C2), without the flexibility shown by Ensanche/ B2. This phenomenon is solved with ease by the organic patterns, at the cost of some segregation generated in the system. The results point to the need to establish lateral connections, since topographic conditions and human activity have produced synergies to have minimum risks in areas with likelihood of rainwater floods, choosing alternative ways and increasing choice.

The variation of normalized integration values as radii increase offer a consistent picture, as can be seen in Table 07, where the 2ond Ring exhibits the highest values, and the 1st Ring the lowest. But the patterns of variation seem more relevant, as shown in Table 07 and Graph 01; they are similar to those in the progression of NA IN as radii are increased for a comparison of the different districts of Barcelona. We can assimilate both cases, remarking that both are reciprocal proof of their acting in consonance: A. continuous increase with higher radius; B. small variation as in a plateau; C. continuous decrease –slow or sharp–.

	MN NAIN R_500	MN NAIN R_1000	MN NAIN R_2000	MN NAIN R_3000	MN NAIN R_5000	MN NAIN R_n
1st RING	0.96626	0.93903	0.90227	0.90118	0.89392	0.89388
2nd RING	1.25396	1.23834	1.27702	1.32791	1.41588	1.41946
3rd RING	1.17754	1.07086	1.01159	0.98983	0.96487	0.94803
AVERAGE	1.13259	1.08274	1.06363	1.07297	1.09156	1.08712

Table 07: Variation of Normalized measures for Barcelona districts between local and global scale.



Graph 1: Mean NA IN for Barcelona rings at radius 500, 1000, 2000, 3000, 5000 and n.

The first case is particularly relevant, since it is linked to the high values of integration at Ensanche/B2, beyond the values perceived in other grid cities. It is a phenomenon sufficiently

interesting as to devote it further research, where integration, entropy, informational gain and fuzzyness must be linked. Since we are dealing with radii of different scales, a comparison of how intelligibility varies seems necessary to analyze the operations of the spatial system, locally and globally, and especially how these two levels are interrelated, through synergy.

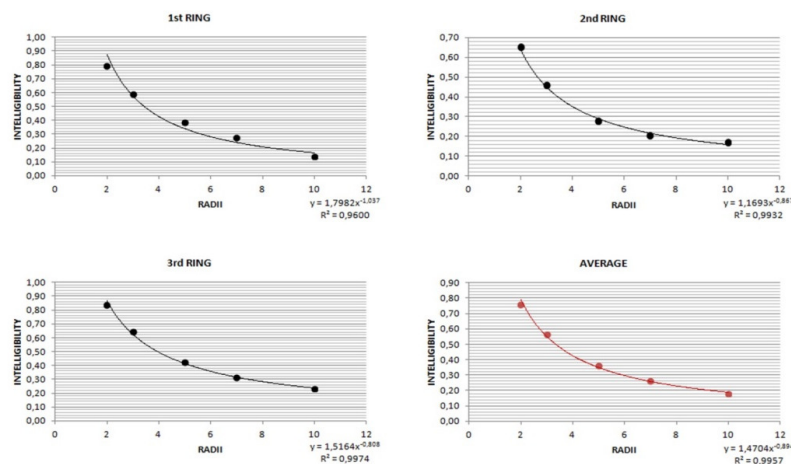
	INTEL. R_2	INTEL. R_3	INTEL. R_5	INTEL. R_7	INTEL. R_10	INTEL. R_n	SYNERGY
1st RING	0.794109	0.587889	0.384389	0.272185	0.138296	0.062583	0.218634
2nd RING	0.651893	0.459353	0.276916	0.206041	0.168521	0.110331	0.472303
3rd RING	0.838467	0.645324	0.421479	0.314378	0.231923	0.131313	0.352604
AVERAGE	0.761490	0.564189	0.360928	0.264201	0.179580	0.101409	0.347847

Table 8: Intelligibility progression of Barcelona Ring Roads/ interfaces.

The intelligibility shown by the Third Ring Road is higher (its value of R^2 equals 0.9974, against 0.9932 for the 2nd Ring road and 0.9600 for the First Ring, when we check their synergy scattergrams). The average value 0.9957 lets see a higher contribution of the first two mentioned (2nd and Third), rather than the latter one (first Ring road). Several organic tissues are in process of consolidation in last urban expansions; there the relation of scales in urban fabrics is closer when we approach the Second Ring, owing to its homogeneous condition and the influence of nearby grids, whether it is Gracia/C3 or Ensanche/B2; this influences in noticeable form the fabrics close to its deployment.

Growth processes in the three stages mentioned can be seen as a sequence of interfaces between the old fabric and the emergent ones, underlined by a Ring Road that contributed to settle new constructions. Each with its own character.

The first ring bounds the first Barcelona, today the Old City district (A1). It has received detailed research that points unsolved problems, especially at its Eastern Sector and in the petty dimensions of the surrounding avenues designed by the architect Garriga. The second ring is equivalent to Cerdà's Ensanche and has a transformation of its own, providing coherence to others sectors at the moment, whilst its quantitative and qualitative relevance demands approaching it with care. This binding led to emergent models in the natural growth of suburbs, close to the Third ring road, coexisting with patterns derived from the pre-planned city (Busquets J. et al. 2004; Al Sayyed K., Turner A. and Hanna S. 2009; Millan A., Lazo F. and López D. 2012). In any case we can follow the evolution of interfaces.



From left to right the three rings:
01_First ring, 02_Second ring, 03_Third ring, 04_Average

Graph 02: Progression of intelligibility versus radius Bracelona rings.

The first interface and Ring Road, or the expensive cost of pettiness

Alçamora's engraving (Fig 03) illustrates the challenge of continuity between the Old City and its inclusion in the new fabric: Raval to your right (SW) packed with convent conglomerates at its Northern areas and separated from the oldest city by the conspicuous Ramblas; a central area full of institutions in the middle, and a damaged Eastern Sector, still under the surveillance of the Ciutadella Fortress, implanted upon the Ribera quarter, the people's buried city. Two headings contain several themes: solutions for density and the continuity of patterns.

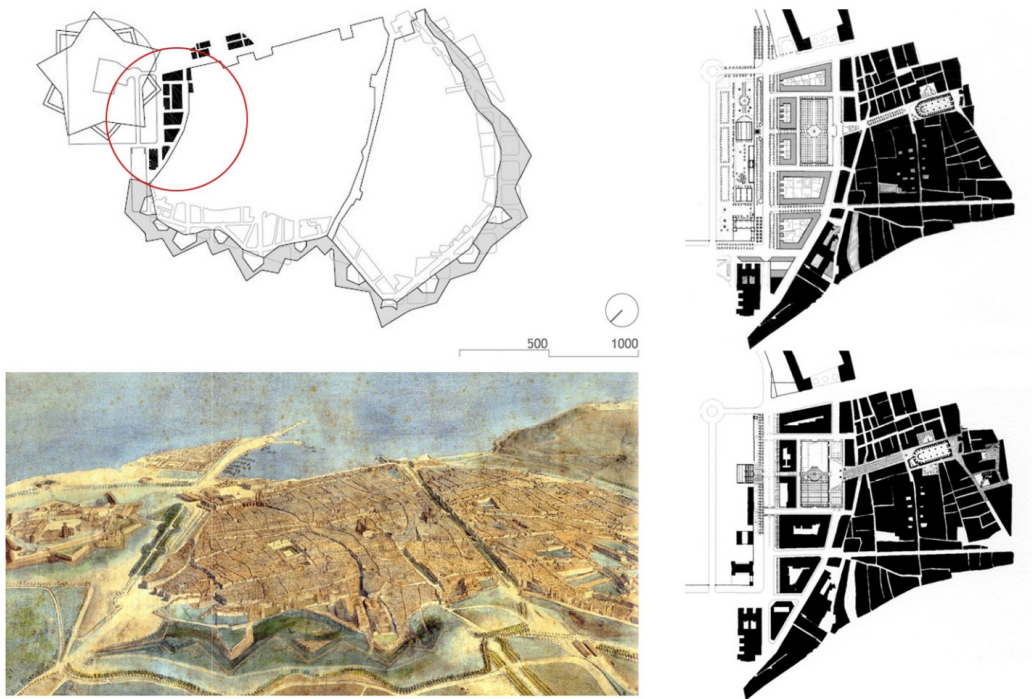
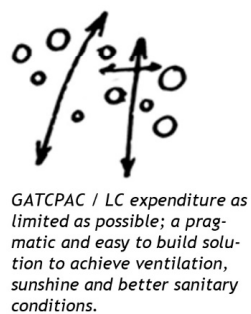
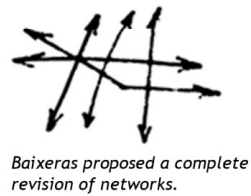
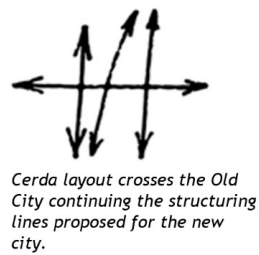
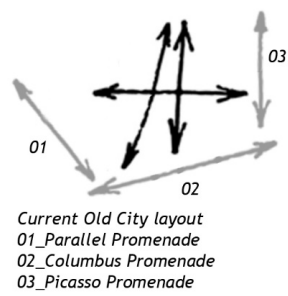


Figure 3: Demolition of Ramparts, engraving by Alçamora, 1860, next to an inverted plan of Old City, where three treatments of edges can be observed: transformed into boulevards, into Catalonia square, and the Eastern side, still unsolved. Two proposals by Amadó& Domenech and Barba, Bellingén & Wade for Picasso Promenade are added.



From top to bottom:
01_Current Old City layout, 02_Cerda layout, 03_Baixeras layout, 04_GATCPAC layout

Figure 04: Current Old City layout; Cerda, Baixeras and GATCPAC layouts for Old City.

Cerdà's inspired himself in the existing city correlating analogies of plan and elevation: the first configured the duality streets/ inter-streets, acting as graph duality between streets and constellations of built forms (Steadman P. 1983); the second would take care of services, plus a redistribution of density and movement, in buildings five storeys high, still a sustainable model, even without lifts. A hectic operation could proceed from the newly born city towards consolidated neighbourhoods to renew them, as happened with the ramparts empty space. These areas were the natural location of boulevards and Ring Roads spanning from the Old City Western Sector working eastwards towards remains in the area of St. Peter's, north of Old City Eastern Sector. The reader will understand these cryptic names when informed that lack of space in that Old City was extreme; so, convents were secularized or transformed into squares/ hospitals, simply burnt or turned into a square, a market or an Opera house.

The edges changed in a hurry still admit regeneration (indicated as diagrams in Fig 04): Parallel Promenade (Fig. 07-01), that close to the Sea (Fig. 06-03) and their elongations, as well as the Picasso Promenade close to the Citadel Park (Fig. 03), were supposed to have ordering value.

- Parallel Promenade is a direct way, transformed into a traffic way, where the initial porticoes and pedestrian sideways were destroyed; it should be the link between the Old City/ A1 and Montjuïc- Poble Sec/ B1, changing the peripheral character of the area. Patchworks on both sides of this way are different, showing the lack of continuity between them, especially noticed in the development of segment maps.

- Columbus Promenade (Fig 06-03), next to the coast, was a first episode to transform the port into an urban area, filled with constructions of disparate character, different from the clear appearance shown before the 1992 Olympics, for a short while.

- Picasso Promenade was meant to connect the old Ribera neighbourhood and the blocks designed by J. Fontseré to foster new uses in the area close to the Old market of Born; its recent transformation into a cultural centre brought to light the old quarter destroyed at the beginning of 18th century; it is in fact one of the biggest archaeological urban sites in Europe.

Either this part of the city is considered gone forever or an attempt is made to restore its dignity, as the readings in Fig. 03 show. This issue is significant in a Space Syntax treatment, not as a formalistic alternative, but as a decision to keep the genetic data of the underlying configuration. In doing so, the approach suggested by Cerdà is an option, reinterpreting the smoothness of a continuity line that crosses the whole Old city. We have simulated the extension of such a line; the angular analysis shows an increase of integration in an area that already has high values.

Edges turned into alleyways are still inseparable from the treatment of density.

A. Renovation went ahead with the Cerdà Plan passed in 1860. New and old were mapped alike, a new grid with a clear structure, integrating services and aiming to solve Barcelona's health conditions. Old City was to be integrated into the new one with streets from the Ensanche in it, forming a characteristic H shape (fig. 04): Carrer Muntaner and Via Laietana perpendicular to the coast, and a parallel axis (Plaça Nova and Santa Caterina), where the position of the cathedral fixed the exact position of axes. Despite differences of morphology, and paradoxically, most of the main lines in the Cerdà Plan are related to the position of the Old City. Different proposals for its treatment were different forms of dealing with its density (Fig. 04).

B. A first dealing with the interface was Garriga i Roca's proposal, originally a plan for the entire walled city, drafted with outstanding cartography and visibility emphasis on the network of streets and public spaces (widths and irregularities to define a precise layout). His survey still remains a good companion for Heritage researchers and served as municipal control, reflecting the need of physical planning, with "division of zones, districts, neighbourhoods, street blocks and public buildings". Two sectors needed renovation: the Eastern Sector (where the streets had insufficient hygienic conditions and the area suffered high levels of mortality), and the Western

Raval, packed with a conglomerate of buildings. When the Ensanche started, Garriga segregated from his plan the project for a boulevard at the edge of Ciutat Vella, inspired in Paris and the Vienna Ring. It was based on a 60-metre-wide tree-lined boulevard, later limited to 45, and again reduced to 30 meters in yet another project including the University and a square in front of it. A controversy with two sides: the continuity of the urban layout and the restraint of "grandeur" ideas, with a conflict between common sense and pettiness, still suffered. Gran Via gained visibility and value as integrating axis.

C. Back to the urban pattern, the architect Baixeras presented his 1879 Barcelona Renovation Project, based on three major thoroughfares crossing the Old City centre (Figs. 04 and 06):

- Gran Via A, today Via Laietana, shortened some 5-metre arcades on each side, to reach its present state.

- Gran Via B, linking Plaça Universitat and the Old Shipyard (Drassanes), distorting Cerdà's proposal. Rather than establishing continuity with street Muntaner and the grid, Baixeras traced a parallel to Rambla to adapt the existing layout and end with a large square as entrance to Barcelona by sea.

- Gran Via C ran crosswise as Cerdà proposed, but with 5-metre arcades. Its construction implied the destruction of many historical buildings and total transformation of the whole. With Baixeras Renovation the city recovered control over some popular sectors and increased the value of real estate property in key areas of the Old City layout. Its radical intervention has been evaluated with Depth-Map in the previous section, showing a homogeneous pattern, with effects in the upper sectors of the city.

D. The group of rationalist architects, GATCPAC, included a Sanitation Plan for District V in the "Macia Plan" of 1932, by Le Corbusier and his GATCPAC colleagues as idea for the new 20th century city. They proposed the opening of some spaces to provide sun lighting and ventilation in crowded areas. Avoiding costly building, they had as priority housing and services rather than traffic, suggesting that widening streets was expensive, affected properties and postponed action. Rather, the design of long blocks for cheaper building and effective sanitation became an urgent issue. With hindsight, the Macia Plan for the Old City was far reaching and compares well with most recent proposals. Angular analysis shows a certain disdain for the underlying street network, which inevitably shows on the analysis with higher radii.

Finally, other approaches include A. Florensa's reconstruction of the Old City with a medievalist approach that still provides enlightened ideas. He became known for a possible layout of the Gothic Quarter and the old Ribera neighbourhood and his common sense: the difference between driving motor cars around sectors of the Old City or straight through it was indifferent and such expenditure unjustified. Using open spaces to "air" the district would not disrupt the original scale of streets and houses. His proposal also intended rapid communication between Diagonal and the sea, reaching the railway station to France.

And a Partial Plan for the old town proposed in 1956 in the context of the Regional plan. Although the 19th century proposals of demolition to build a new continued, growth had to be ensured, and important infrastructures were proposed: "ronda" ring roads, and a railway network related to industrial and port activities. The aim to maintain the Old City left this area waiting until the transformations of the 1980s.

Consequently, the relations of the main structuring lines within the First Ring with its closer context are analyzed by means of StepDepth Analysis in Fig 06, to perceive their role to know if the emphasis put on them is a correct interpretation. The streets Ferran and Via Laietana (Fig. 06, 02 and 04) added connectivity to this layout.

Second Interface and Ring Road: from theory to practice

A second ring is formed out of the Ensanche/ B2 and Sant Martí/ B3 districts, affecting also to Sants-Montjuich/ B1 through morphology acquired with new infrastructures.

The classification of ways and squares into five groups realized by Cerda, according to their connecting relevance and economic importance, was made to calculate the land value and the possible rent accurately. Old meandering streets offered resistance in the analysis. Such confusing patterns in the city destroyed and buried in 1714 (Garcia-Espuche 2009: 31-105) were turned into a square grid model, according to movement flows (either parallel to the coast – structuring lines- or perpendicular to it –most serving streets). In this ordering, surfaces equivalent to streets and plots were calculated as a square insula whose surface could be compared with the average insula.

This thinking became a habit to describe the city-as-built, with an underlying principle: *"All that has as object ways and movement is referred to the street, and all that belongs to room and habitability, is referred to the insula (manzana), island or inter-ways"* (Cerda I. 1867: II- 7). Such subtleties lead to interpretations: when dealing with ways, the sidewalk was part of the way; but, when dealing with inter-ways, it was an isolating zone of inter-ways. This proposal met resistance in an inherited or alien urban domain, as in the boundaries of the Old City and the ways crossing it. Precisions of other times are still relevant today. An example was and is the exchange of ideas on the nature of the grid, in an old debate between De Solà-Morales with Leo Krier:

"Your proposal for blocks of 22x22, with a 3x3 grid, and pedestrian ways (8.50 wide by 22 high) seems to me a typological choice to solve above all the problem of tower blocks. 22x22 is OK for an isolated tower: four fronts, independent architecture etc. Here you are suggesting a new urban idea of coordinated towers (a "Rational-Pavilion" idea, if you like).

(...) The high density results in the doubling of the building, which calls in question many of the principles of residential hygiene that were the starting point of the typology. And this is the common model for the block as perimeter building in a line with a central court, repeatedly applied.

But up to what point are the central courtyard and the perimeter the models on which Cerda's Ensanche must base itself? This is the point of confusion that normally obscures arguments and operational intentions concerning the Ensanche. Perhaps the block closed on four sides: is not the unit-model for the Ensanche...

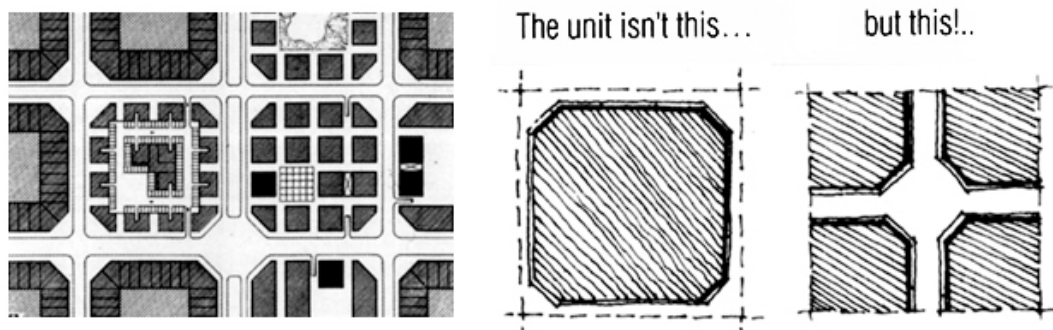


Figure 5: Leo Krier with notes by Sola-Morales. 19th century closed city block revision.

(...) This is a cardinal point. Everything changes a great deal if we recognize it. What define the Ensanche are the street intersections, and its building is determined by the four corners. The cut-off corners constitute the fundamental urban spaces and also the strongest and most characteristic image of Barcelona.

(...) we find in Barcelona the most perfect and complete development of the idea of the intersection and the crossroads as generator of the plan.

It is precisely the architectural invention of the "corner house" which made possible the enlargement of the minor grid in contact with linear building that was becoming increasingly irrational precisely because of its waste of the corner

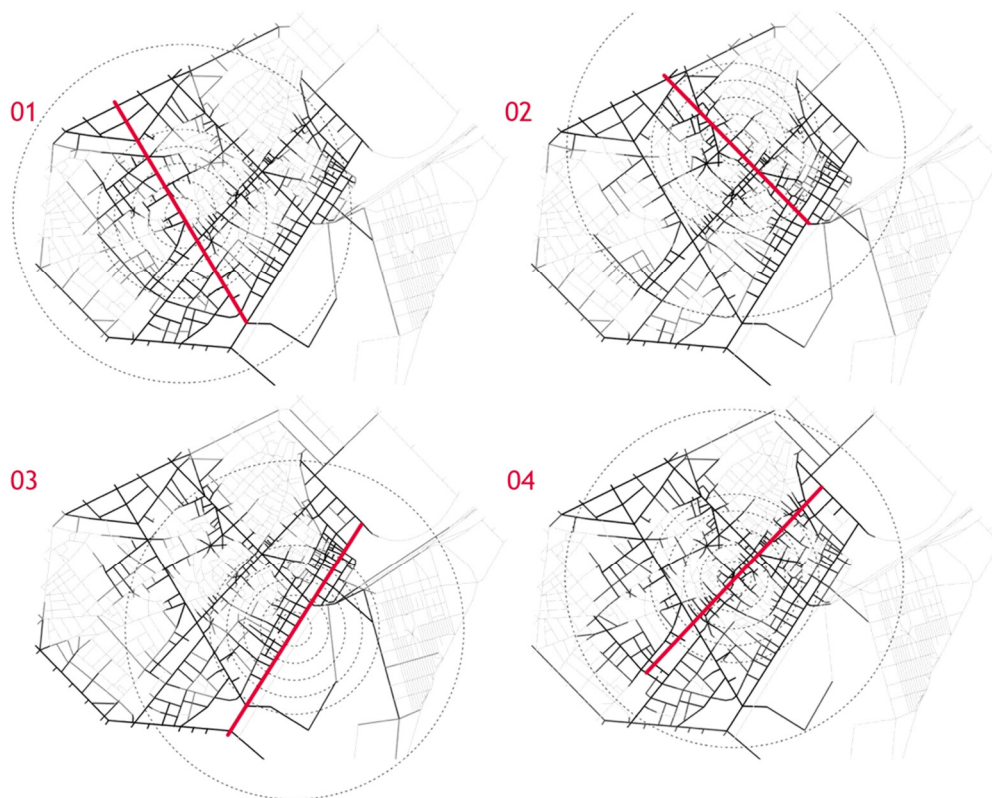
(...) If we recognise the importance of the corner in the Ensanche of Barcelona we see that, apart from its reflection of real- estate values and its loyalty to conservative camouflage, its most genuine fascination is in the logic of the division and re-stitching of the texture of the city. This texture, as elsewhere, has its geometry: it is not just composed by abstract pieces. It offers us culturally-significant laws of urban composition" (De Solà-Morales M. 2010: 59-65).

Interestingly, some grids with high-normalized values (Santiago and Chicago) are mentioned after this text. It seems that the aim of us all is to reach concrete solutions out of abstract reasoning, for a deeper understanding of exchanges between networks and the systems involved.

The Cerdà Plan started urgently with Plaça de Catalunya and the Ring Roads. Either the limits of the Old City were faced as a priority to promote deep transformations, or the city had to grow according to a homogeneous plan. The argument has two parts:

- the rearrangement of the old internal structure in keeping with the general transformation (explained in Fig. 04 and Fig. 06),
- and the new treatment of edges, to provide continuity.

A syntactic translation of this situation could be expressed as the detailed analysis of local structure, and the global consideration of structuring ways for radius n (in this case, radii do not vary much: from 500 to 2000). These were sides of just one problem: the central-periphery tension were interfaces between two structures that had to operate as one. In fact, *"the almost spontaneous creation of Catalonia Square and the projects for boulevards by Miquel Garriga i Roca and Josep Fontseré in 1862 were symptoms expressing that the need to provide a solution for the nucleus was implied in the solution of limits Barcelona was not lucky... Catalonia Square is an empty and formless place and the Ring roads show a physical and social pettyness when compared, not with the Viennese Ring, but with the closer barcelonense Rambla that went through a similar process a few centuries earlier"* (Bohigas O. 1985: 48).



*The analyzed lines of the first ring:
01_Rambla, 02_Via Laietana, 03_Columbus Promenade, 04_Ferran-Princesa-Unió*

Figure 06: Step depth analysis of the first ring.

Interfaces between successive systems had to be solved after the ramparts elimination. Dysfunctions in a no-man's land were a risk, also an opportunity for improvement, where components can be evaluated today as correlations within a model. The Ensanche illustrates this need: already an aged district, the historical centre of a Metropolitan city provides astonishing performance when their data are compared with other areas; then, a new visualization emerges: centralities point to possible movements, inseparable from an idea of the whole –of universal distance–, pointing in turn towards integrated domains coexisting with a partly segregated totality. This would be the case of its more Eastern sector where the lines with highest values of choice show several diagonalizations of the grid.

A Third interface and Ring Road: or metropolitan connectivity

When the city seemed almost defined, compromises had to be taken with a heterogeneous fabric, formed by old nuclei and villages in the vicinity of the city that witnessed a quick growth, derived from the annexation of municipalities and the intense migration to these outwardly areas propitiated by an emergent economy. Migrations were produced in massive waves, entailing phenomena such as self-built housing and precarious building; they lasted until the 1950's and 1980's, when quick urban interventions had to be taken as an emergency. This might explain the multi-centred character shown by these areas when the fabrics are consolidated out of the fusion of several foci. Fig 08 shows a comparative study of peripheral areas carried out with DepthMap (Step-Depth analysis and NC values). Some patchworks detected allow recognizing old historic centres, next to some emergent centrality cores, to which the phenomenon of pervasive centrality has been extended.

When the Ring Roads/ Rondas were built in the 1990s, as well as some metropolitan connectors, these nuclei direct their activity towards the new infrastructure (Ronda de Dalt) that links them

together and each of them with Barcelona. The Step-Depth axes shown at Figure 08 develop varying roles, according to their function within the expanding urban domain:

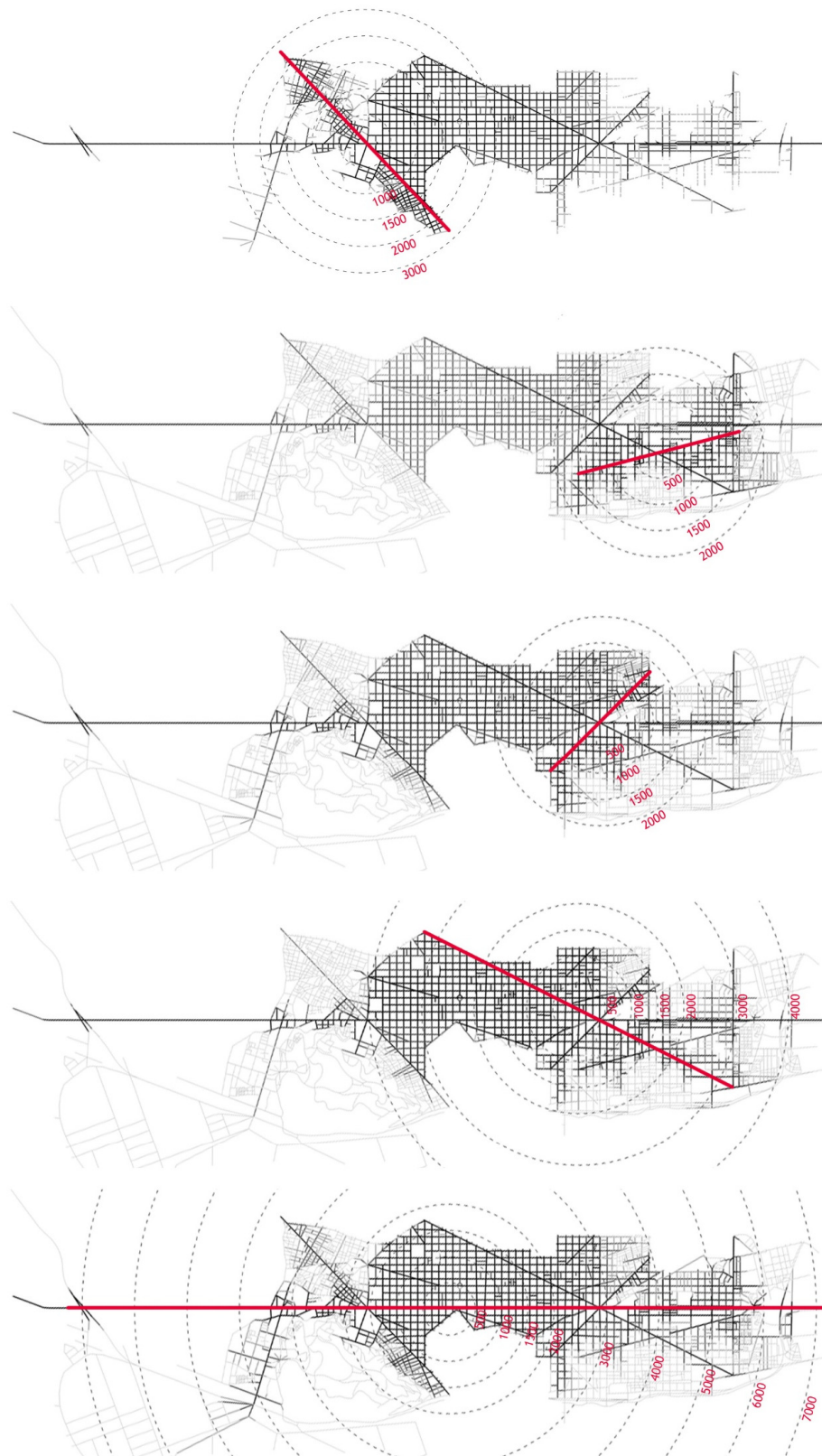
- A. Connections between great infrastructures/.
- B. Relations between the great infrastructure and its immediate context, with a dual global/ local role that binds foreground and background/.
- C. Stitching of close fabrics belonging originally to different patchworks

clearly defined structures, as in the succession of nuclei of Coll and Horta (A3 and A4 Centrality Nodes in Figure 08); also in the nuclei of Can Peguera and Nou Barris (B1 and B2 Centrality Nodes in Figure 08). Though forming a dense tissue, the lack of agreement between different patchworks forces the whole to operate as a collection of small autonomous units, functioning as micro-economic structures that collaborate between them and whose further dynamics is still in process of development.

In these cases the study of NC together with the similarity of radii provides a good image to compare them. The StepDepth Graph in Fig. 08 adds further information to describe the foreground.

Therefore, the third corona has a strategic role within the configurative scheme of Barcelona scheme, as we can deduce from data included in the study (Tables 04, 06 and 08; Figs 02a, 05b); but, furthermore, its potential in relation with the metropolitan region should be stressed. The skirts of Collserola park and mountain range appear as an insurmountable limit, confined between the Second and third Ring roads and a key element to stabilize metropolitan developments and to connect the city with the Vallès plain, thus configuring a key economic region, providing local and global exchanges and innovation in varied sectors.

Some initiatives, such as the “Barcelona doors” competition, organized by the City Council, aimed to define the links at the outer Northern corona, so that its relations (in fact, fuzzy boundaries) with the natural park limiting the city could be understood. This third corona has a high strategic value that can be detected at global and local scale, as it can be seen in those districts that coexist with important by-passes between large infrastructures.



From up to bottom the step depth analysis of important streets in the second ring:
 01_Avinguda Paral.lel, 02_Pere IV, 03_Avinguda Meridiana, 04_Avinguda Diagonal, 05_Gran Via de les Corts Catalanes

Figure 07: Step depth analysis of the second ring.



The analyzed lines of the third ring by Step Depth:
01_Passeig de Fabra i Puig, 02_Avinguda de l'Estatut, 03_Carrer de l'Escorial, 04_Carrer de Muntaner

T1024 Node Count R500 metric_Centrality nodes in the third ring:

Historic centrality nodes (A):

A1_Sarrià village, A2_Gracia village, A3_El Coll core, A4_Horta village, A5_Sant Andreu village, A6_Trinitat settlement, A7_Camp del Arpa settlement.

New centrality nodes (B):

B1_Can Peguera core, B2_Nou Barris core, B3_Bon Pastor core.

Figure 08: Step depth analysis of the third ring. T1024 Node Count R500 metric

CONCLUSIONS

- Despite its reputation as a perfect grid, regularly configured city, Barcelona shows a heterogeneous collection of urban fabrics readapting mutually in accordance with changing dynamics. An analysis of its growth processes provides clues to detect strategic areas that may benefit from structural interventions. Tensions between centre and periphery require adequate reading: fine grain is increasingly disappearing fine in Old sectors (partially derived from the oblivion of previous proposals –from Cerdà to the Modern Movement), global scale is gaining relevance at the central core and new organic patterns close to peripheral areas between the Second and Third Ring Roads are emerging, demanding a solution of their fuzzy boundaries.
- New connectivity enhanced in the last three decades endows the city with an added sense of scale to its metropolitan dimension. The mathematical duality between topo-geometric and metric measures applied to the urban network captures high values of structure-function measures, such as integration and choice, bringing to light a consistent foreground that persists during consecutive historical periods and emergent patchworks upon a background, where metric measures detect a cohesion still evolving.
- The fabrics within the second ring offer the highest values of synergy between global and local integration and increasing intelligibility and normalized measures as the radius is increased. The reasons for such increase and the values shown, together with other cities, such as Santiago and Chicago, suggest a revision of models and a deeper understanding of centripetal/ centrifugal urban exchanges, reconsidering the roles of centrality and integration measures when the entropy of the urban system is considered.

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