Original Article

Morphological logic in historical settlements: Space syntax analyses of residential districts at Mohenjo-Daro, Kahun and Ur

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Abstract The degree of 'planning' in historical sites has been always dominated by measures of geometry and has, therefore, always oscillated between geometric, as 'planned', and organic, as 'unplanned'. In this article, the spatial formation of four residential districts in three contemporaneous historical settlements, *Mohenjo-Daro, Kahun* and *Ur*, is examined to show that their patterns were governed not only by geometrical possibilities, but rather by certain needs of access and visibility. The article considers the application of Space Syntax methods to provide an evidence for the correspondences between the geometrical properties and certain considerations in each society, coming to the conclusion that the organic patterns of the site of Ur do not necessarily refer to lack of planning, but were possibly intended to meet certain defensive, social or climatic considerations.
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Introduction

Space Syntax is a theory of architecture and urban design that originated in the 1970s, where a family of qualitative theories with quantitative techniques (or methods) had been developed to better understand the relation between cognitive phenomena and properties of the environment (Hillier, 1996). The term 'Space Syntax' betrays its early analogies to linguistic theories; it was felt that, just as there is certain combination of words that can be assembled into a meaningful sentence, only certain configurations of spaces would actually make sense. The assumption here is that configurations of spaces do not only have a grammar, but also 'syntax' that permits configurations to be meaningful. For this purpose, Space Syntax experts developed a set of thematic maps, algorithms and software that is utilized for the representation, quantification, analysis and interpretation of spatial configuration.

While Space Syntax techniques are mostly applied in modern architectural design and urban planning, there are few attempts to use them in analyzing archeological and historical remains to extract the logic of their emergence. In this study, it is suggested that such quantifiable syntactic approach may provide historians with an extra tool to illuminate new dimensions of the life within historical communities that were not otherwise available through traditional archeological or cognitive approaches. Some of these new dimensions and possibilities are reviewed in a survey by Griffiths (2012) in his study *The Use Of Space Syntax In Historical Research*, where he gives a full record of the researches, where Space Syntax have been chosen to explore historical themes, and classified them into four categories:

Presenting some historical background to a case study is the first one of these categories; Desyllas's (1997) historical account of Berlin's morphological development since 1650 and Raman's (2003) study into spatial cultures of religious communities in the walled city of Ahmedabad are the most notable examples of it.

The second category draws on syntactical modeling to understand more about urban growth processes. Studies of this category

include: Shupza's examinations of the historical growth patterns of Adriatic cities; the studies by Pinho and Oliveira (2009) and Serra and Pinho (2011), in which GIS and Space Syntax methodologies were used for the analysis of historical urban areas; Kigawa and Furuyama (2005) study, where a model based on entropy was developed to examine the grid properties of Kyoto and its relation with the spatial culture of the city; and Spence-Morrow's (2009) study about the syntactic interpretation of archeological remains through Geophysical Prospection.

The third category is 'syntactical morphological histories', where the focus is more on understanding the history of a particular settlement or configurational object than with the modeling process. This is illustrated by several works by Medeiros and Holanda (2005) that present rich comparative morphological histories of the growth of Brazilian cities and the work of Al Sayed *et al* (2009), which draw on a detailed longitudinal analysis of Barcelona and Manhattan, using segment angular analysis to identify the syntactic rules of their urban growth. The works of Azimzadeh (2003) on Iranian and Swedish cities have also explicitly drawn on the idea of the urban configuration with a focus on understanding the urban historic cores in the modern city. A similar historical approach is also adopted by Karimi (2000) in identifying the spatial spirit of traditional English and Iranian towns; Kubat (2012) in the study of the historical evolution of Anatolian settlement; Jason Shapiro (2005) in a study about the Cultural Evolution in the Arroyo Hondo Pueblo site in North Rio Grande; and Stöger's (2007) examination of the historical city of Ostia.

The fourth category is about drawing on syntactical ideas to inform historical questions. Examples of this category include the use of Space Syntax tools to: understand the spatial symbolic constitution of imperial Beijing by Zhu (2011); interpret the spatial transformations of selected heritage cities, that is, Jerusalem, Venice and Mardin by Tokol (2003); the investigation of the logic and characteristics of the urban evolution of Fatimid Cairo by Galal (2003); understand why the historical centers in two cities (Manama and Muharraq) within the same region and the same culture have developed differently by Al-Ghatam (2003); and investigate the grid dynamics of the Iranian city of Isfahan in the past and present by Karimi (2003).

This study presents a further step in this direction, where Space Syntax analysis is used in an attempt to obtain a quantitative justification to interpret the message that is contained in the historical remains of the sites under study, with reference to their spatial qualities that are usually deemed to be immeasurable. Using the theoretical assumptions and mathematical techniques of Space Syntax analysis, this study is meant to explore what these remains reveal about people's lives in those sites and demonstrate that arrangements of spaces may illuminate certain cultural or sociological differences that were not accompanied by differences in artifacts or technologies.

Space Syntax *methodologies* will be applied here on four residential districts in three historical cities/settlements that emerged, as far as possible, within the same archeological epoch and under comparable topographic/climatic conditions; these are: *Mohenjo-Daro* site in Indus Valley (2600 BC), the Ancient Egyptian workers' village of *Kahun* (2500 BC) and the Mesopotamian city of *Ur* (2100 BC). The first two settlements are meant to represent 'well planned' historical sites with rather linier patterns, while the third settlement (from which two neighborhoods are chosen) has always been considered to be 'unplanned' because of its organic patterns. The analysis aims to define certain shifts in the space organization of those districts toward certain organizational properties; particularly complexity, enclosure, spaciousness, order and defensibility. The choice of these qualities as basis for evaluation was based upon previous studies by Franz and Wiener, Appleton and Newman, which consider these qualities as the most basic qualities of space (Franz and Wiener, 2008). Syntactic analyses and comparisons are used here to shed light on the cultural implications in the districts at the city of Ur to show that their organic configuration might have been purposefully meant to meet certain conditions. The two 'planned' districts included in the comparison were chosen to represent different cultural backgrounds that had occurred in different places of the ancient world almost within the same historical era. The *objective* of this study is, thus, to prove that such organic arrangements were possibly associated with other consideration that led to 'deform' the rigidity of the orthogonal lines and create an adaptive model of 'planning'. Based on that, it is *concluded* that, since the earliest times, human settlements needed to rely on variety of qualities in their core morphologies other than geometrical issues. These qualities are probably why people look so positively to the urban fabrics with narrow winding streets and unexpected piazzas in the historical parts of cities. It gives evidence that what

might be seen as 'un-urban' pattern might not be less 'planned' than the orthogonal 'urban' pattern.

With this in mind, the research pursues a two-fold approach, combining complementary components: a historical study of the built environment in the sites under study and a syntactical spatial analysis for their spatial configuration. This will be performed in four steps. First step is to overview the historical conditions under which the three sites evolved, where in the second step the special qualities that had been chosen to evaluate the sites, together with the syntactical and mathematical formulas to quantify these qualities, are defined. The tools of Space Syntax analysis that are used in the analysis are also indicated in this step. In step three a comparative study is performed on the selected sites, seeking similarities and differences among them. Finally, the fourth step presents the conclusions of the study.

Historical Background of the Three Sites

Around 3000 BC, people chose to live in cities – regardless of their inherent disadvantages such as: overcrowding, epidemics, separation from natural resources, … and so on – because cities offered more possibilities for amusement, occupational choice, enrichment and above all defense, than that offered by villages. The choice of sites for founding new cities depended, therefore, on: proximity to waterways and natural resources, climatic considerations and defensibility.

This part of the study presents a historical background of the chosen sites, in order to convey some ideas about the basic considerations, under which they evolved.

Mohenjo-Daro, Indus valley

Mohenjo-Daro was established around 2600 BC. It was one of the largest settlements of the Ancient Indus Valley Civilization, and one of the world's earliest major urban settlements, contemporaneous with the civilizations of Ancient Egypt, Mesopotamia and Crete (Beck *et al*, 1999). *Mohenjo-Daro* flourished for about 800 years during the 3rd and 2nd millennia BC, abandoned in the nineteenth-century BC and was not rediscovered until 1922 (Morris, 1972). It was about 1 square mile in size and had population as high as around 40 000.[1]

The site comprises two sectors: a *stupa*[2] mound that rises in the West and, to the East, the lower city ruins spread out along the banks of the Indus. The acropolis accommodated the *Citadel* and the *Great Bath*, a giant granary, a large residential building and several assembly halls, with all this upper part surrounded by a veranda. Other large buildings include a *Pillared Hall*, which is thought to be an assembly hall, and the so-called *College Hall*, which is a complex of buildings comprising 78 rooms and it is thought to have been a priestly residence.

The lower part (Figure 1a) was a complex of private and public houses, wells, shops and commercial buildings laid out along straight streets intersecting each other at right angles in a highly ordered form of planning that also incorporated a systems of drainage. Thus, it is firmly believed that *Mohenjo-Daro* was indeed a well planned city (Marshall, 1931; Morris, 1972).

With no evidence of kings or queens, *Mohenjo-Daro* was likely governed as a city-state, perhaps by elected officials or elites from each of the mounds (Morris, 1972). The city had no circuit of city walls, but was only fortified with guard towers to the West and defensive fortifications to the South. Considering these fortifications and the structure of other major Indus Valley cities like *Harappa*, which had relatively the same layout and was also not heavily fortified like other Indus Valley sites, it is postulated that *Mohenjo-Daro* was an administrative center (Raza, 2010).

Between 1800 and 1700 BC, civilization on the Indus Plain all but vanished; what befell these people is unknown, but military attack is not a suspicion. One suspected cause is a shift in the Indus River. Another is that people dammed the water along the lower portion of the river resulting in a flood, which would explain the thick layers of silt 10 m above the level of the river. Another suspected cause is a decline in rainfall (WEB_1).

Kahun or El-Lahun, Egypt

Located in *Faiyum*, Egypt, *Kahun* or *El-Lahun* is the workers' village associated with the pyramid of *Senusret II* (also called *Sesostris II*). It was excavated by Flinders Petrie in 1888–1890 and again in 1914. The site was occupied into the late Thirteenth Dynasty, and then again in the New Kingdom (Petrie, 1891). The village is about 800 m from the pyramid and lies in the desert a short distance from the edge of cultivation. However, all the buildings found were demolished in the process of excavation itself, which proceeded in long strips down the length of the village. When the first strip had been

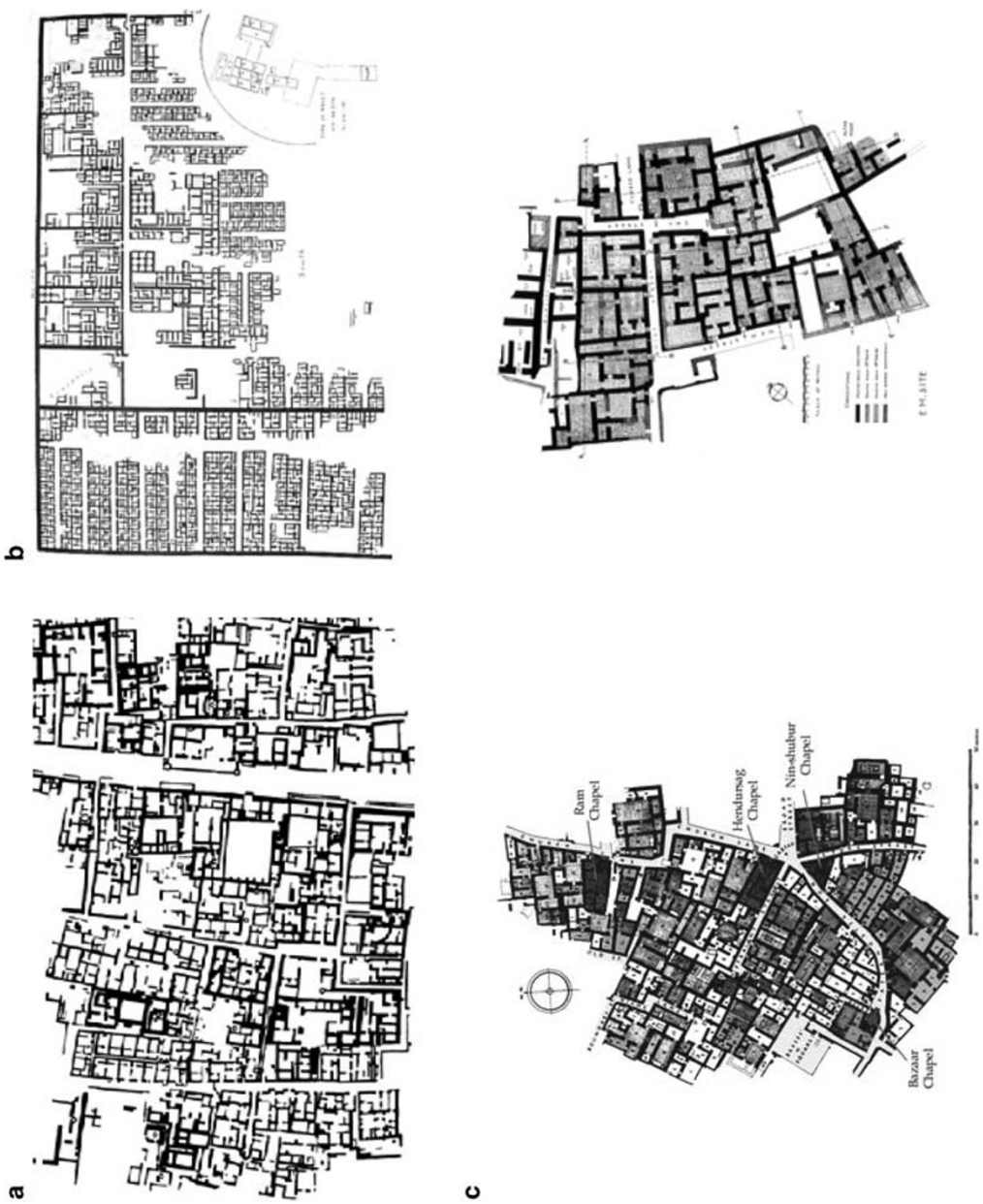


Figure 1: Plans of the studied area. (**a**) The residential district at *Mohenjo-Daro* 2600 BC (WEB_2); (**b**) The workers' village of Kahun (2570–2500 BC) (WEB_6); (**c**) Residential districts at Ur (2100 BC): Area AH, the financial district *left* and Area EM, temple workers' district *right* (WEB_1).

cleared, mapped and drawn, the next strip was excavated and the soil dumped in the previous strip. As a result, there is very little to be seen on the site today.

The town was laid out in a regular plan, with mud-brick walls on three sides. No evidence was found of a fourth wall, which may have either collapsed and been washed away during the annual inundation, or just never existed. In Ancient Egypt, different social classes did not generally live in separate city quarters as seen here (Figure 1b), where the city was divided internally by a mud brick wall, as large and strong as the exterior walls, which divided about one-third of the area of the town. In the smaller area, houses consisted of rows of back-to-back, side-by-side, single to two room houses, with access to the roof that was used as living and storing space. While the larger area, which was higher up the slope, and thus benefited from whatever breeze was blowing, contained a handful of palatial 60-room-residences with a wide street leading to the palace. The size of the houses ranged from 2520 m^2 for the elite houses to 120 m^2 for the small houses (Petrie, 1891).

A major feature of this town was the so-called *Acropolis* building. This was an important building as indicated by the presence of column bases. Petrie suggested that this may have been the king's residence while he was visiting the construction work. The building seems to have been out of use and derelict before the end of occupation (Petrie, 1891).

The streets all over the city were laid out in approximately straight lines. The main street was 9 m wide, as opposed to the alleys and streets in the workers' districts, which were sometimes as narrow as 1.5 m. The streets had shallow stone channels, running down the middle for drainage. Despite the love Egyptians had for gardens, there was no space left for them inside the walls at this village.

It is interesting that some of the villas were constructed of layers of mud brick separated by layers of reed matting – a technique that was used in Mesopotamia. Furthermore, burial beneath the living quarters of a house, as was found in some houses, was a custom noted at Ur. So, it is sometimes suggested that the workers, who were so carefully guarded by the village wall and separated from the overseers by an equally strong wall, were Asiatic slaves. About this, in his book, 'Egypt of the Pharaohs', Gardiner refers to increasingly mentioned Asiatic slaves on Stelae and in Papyrii, though there is no means of telling whether they were prisoners of war or had infiltrated into Egypt of their own accord (Gardiner, 1966).

Ur, Mesopotamia

The earliest known occupations at the city of Ur date to the Ubaid period of the late 6th-millennium BC. But, it reached its maximum size of 54 acres during the Early Dynastic Period of the early 3rd millennium (Oates *et al*, 2007). The city stood strategically on a promontory between an arm of the Euphrates River and a navigable canal and had two harbors. It continued as a capital for Sumer and succeeding civilizations. But, during the fourth-century BC, the Euphrates changed course and the city was abandoned (Rothman, 2004).

The constant wars among the Sumerian city-states for 2000 years helped to develop the military techniques of Sumer to a high level. Sumerian cities were surrounded by defensive walls as Sumerians engaged in siege warfare between their cities. The Stele of the Vultures from ca. 2525 BC implies that chariots and professional soldiers were also used (Winter, 1985). Likewise, Ur, where a large portion of the population lived for protection (WEB_4), was surrounded by a huge wall. Henry Frankfort estimated that there were 120–200 people per acre – a very dense population for this era (Oates *et al*, 2007). The city had four gates, one in the eastern wall, where the road from Larsa bridges the canal, and three can be entered only by boats.

The houses described by Charles Leonard Woolley in Ur date to the Isin-Larsa period (ca. 2000 BC), when those two cities struggled to unite the Mesopotamian city states under one king – a feat realized only briefly by Hammurabi of Babylon. They were arranged in four residential areas along narrow winding streets and alleyways, forming a maze of alleys and dead-ends that is usually considered to be 'totally lacking any sort of plan' (Oates *et al*, 2007). The blocks enclosed by this street system are very large and the houses in the middle had to be approached from blind alleys or extremely narrow passageways (WEB_4). For a fleeing enemy any attempt to cut his flight short by taking a side street would encounter a dead end. Besides, it would take weeks to explore the city and get an idea of its layout, and that will still not be enough in a panic situation (WEB_5). Moving around the city was made even more difficult by the canal that cuts through the middle of it. Furthermore, there are certain quarters of the city

that had an option to be closed off with heavy wooden gate barring entry into the street, along which the houses are aligned, and the alleys that run off them.

One or two stories tall, houses have generally no windows, through which a passer-by can peer into. Protected thus from wind and sun, the houses got light either through the inner courtyard, or simply when their reed-mat door was left open. The streets are, so, a monotony of blank, whitewashed mud-brick walls, broken only by the lintels and jambs of a doorway painted in red to ward off demons, by a shops or workshop opening out onto the street or by a little chapel on the corner of two intersecting streets (Oates *et al*, 2007). Shops were found to be connected to adjacent residences by small passage ways, while public chapels were found near big intersections (WEB_4).

Of the four residential quarters, the best documented are Area EM and Area AH as named by Woolley[3] (Figure 1c). Area EM probably housed temple workers, as evidenced by texts found in the buildings. Area AH, however, may have been a kind of financial district. It was by far the largest exposure of houses at the site, revealing more than 50 structures over an area in the range of 8000 m^2. Exact numbers are hard to determine since there are partial houses on the edges of excavation.

Woolley felt that the wandering streets with frequent blind alleys meant there was no municipal planning. Still, there was some concern for overall access and Woolley noted that when streets met, the buildings at the corner tended to have rounded edges. He believed this was in concern for pack animals that might be going through the streets – if a loaded donkey caught its wares on a sharp corner of a building, it could be disastrous (Woolley, 1929).

Formulas and tools of analysis

Syntactic analysis is an analytical tool that has been shown to be reliable in perceiving and understanding how a network of space within buildings or open spaces relates to social phenomena (Hillier and Hanson, 1984). A related theme in Space Syntax research is to understand configured space itself, particularly its formative process and its cultural meaning (Bafna, 2003). Configuration here is the relation between, at least, two spaces in a complex taking into account a third and, at most, all other spaces in the complex. It is, therefore, a more complex idea than spatial relation, which invokes no more than a pair of related spaces (Ratti, 2004). Space Syntax analysis, thereby, considers spatial systems on the basis of patterns of relationships, rather than the traditional basis of metric distance.

Space Syntax approach basically employs two methods to represent urban environments: *convex polygons* and *axial lines*. A later development was popularized by Michael Benedikt, which is the *Isovists*; a convex polygon is a polygon, in which all the points are inter-visible (Bada and Farhi, 2009). In places where the isovists tend to be larger and spread in different directions, the observer is permitted a better evaluation of the space. This means that in Space Syntax analysis, spaces are analyzed in terms of how much one may see but not what one sees – quantity rather than quality of seeing (Antonakaki, 2006).

In this direction, Space Syntax researchers developed software tools that mostly deal with space in two dimensions, focusing on the physical configuration of the space more than on qualitative issues. The most important software in this regard is *Depthmap* software, which was developed by Alasdair Turner and his colleagues. It produces the 'Visibility Graph Analysis' (VGA), which is based on a two-dimensional grid of points that fills the whole space to be considered, creating a dense array of lines that are used in two levels of measurements: *local properties*, such as connectivity, clustering coefficient (CC) and visual control (VC) values; and *global properties* such as integration and Relativized Entropy (RE) values (Bada and Farhi, 2009). Visibility Graph Analysis also generates *isovists*, the geometrical properties of which are used to measure visibility (eye level *isovists*) or accessibility (floor level *isovists*) from each of these locations.

Spatial measures to quantify the three sites

In their article titled 'From Space Syntax to space semantics', Franz and Wiener (2008) appointed four basic spatial qualities of architectural space that make the space preferable by people. These are *spaciousness, enclosure, complexity and order.* They suggested some calculations and measures to quantify these four qualities in relation to isovists' properties as the following (Franz and Wiener, 2008):

- (Isovist area/Number of vertices) as a measure of *Spaciousness*

- *Jaggedness* (Isovist perimeter^2/area) and *Revelation* ((Σ area adjacent isovists−isovist area)/isovist area) as factors of *Enclosure* and *Openness* (the length of open edge/the length of closed edge) as an opposition to it.
- *Vertices* (number of vertices), *Density* (number of vertices/area) and *Roundness* (Isovist area/perimeter^2) as factors of *Complexity*.
- *Symmetry* (number of symmetry axes) and *Redundancy/regularity* (number of unique polygon sections/number of symmetry axes+1) as factors of *Order*

Other theories such as 'prospect and refuge' by Appleton (1988) and 'defensible space' by Newman (1996) tried to explain human experience as contingent upon certain features of the environment. In their works, one finds many aspects in common with the ideas of Franz and Wiener. However, they considered another quality of space as being crucial in making a space preferable by people, which is *defensibility*. Even more than now, in such historical eras as in the sites under study, this quality was the most important feature that determined the inhabitant or the abandonment of a certain site. So, in the cases under study, this quality is deemed to be essential.

As for the space characteristics suggested to measure this quality, *Aristotle* writings in the mid-fourth-century BC in criticizing the *Hippodamian* grid system in planning give the key that governs them. He said that: '… for security in war, it is more useful if it is planned in the opposite manner, as it used to be in ancient times, for it is difficult for foreign troops to enter and find their way about when attacking' (Aristotle, 1962). So, in Aristotle's opinion, orthogonal or geometrical configuration is harder to defend than organic configuration.

To quantify this quality using Space Syntax tools, Hillier's (2006) study 'Studying cities to learn about minds' gives the key, which he calls *intelligibility*. For Hillier, intelligibility of a spatial network depends almost entirely on its linear structure – the kind of configuration that usually represents the urban type of structure with high degree of intervisibility. By applying an Agent-based analysis employing 10 000 forward looking agents on a linier layouts, he proves that by slightly breaking the linear structure (reducing intelligibility), the layout became labyrinthine and agents could not perform the same way-finding task (Hillier, 2006). On the basis ofthat, it is argued that one way to plausibly measure defensibility is by measuring intelligibility, which was measured by Hillier as the correlation between connectivity and integration. It means that in a layout of high intelligibility, information about local connectivity allows a person moving through the system to comprehend the overall structure of the configuration (Hillier, 2006). In the same study, Hillier brings in another concept that he calls 'Natural Movement', proposing that the spatial configuration of the urban grid itself produces 'attraction inequalities' that privileges some urban spaces over others (Hillier *et al*, 1993), which suggests *Control Value* as further measurements to quantify the morphological properties that determine the easy navigation of a certain space.

Depthmap software offers a further measure, which is the *Gate Counts* or the number of individuals that can pass through a particular cell (gate), which is suggested in this study as an extra helpful measure in this regard

Tools of space syntax analysis

From a variety of Space Syntax techniques a number of tools have been selected to be used in this study. The selection of these tools depended on the data sets needed for the analysis as previously discussed.

Visibility graph analysis

Integration describes the way in which each small-scale space is overall linked to all other small-scale spaces (Bafna, 2003). In Space Syntax analysis, the integration value of a line is proportional to its depth from all other lines in the network (Ratti, 2004). 'The most integrated lines are those from which all others are shallowest on average, and the most segregated are those from which they are deepest' (Hillier *et al*, 1993).

Another major Space Syntax parameter is *connectivity*, which is the measure of how well a certain path is intersected by others. In this, the length of the path has some correlation to connectivity indexes; that is, there are more possibilities for lengthy paths to be intersected by others; the higher the connectivity value the more accessible is the path or the space.

A modification of connectivity is the *control value* (CV), which measures the degree of control of certain space over its immediate neighbors. The more neighboring spaces a certain space has, the more control it will exert. To calculate this value, each space is assigned a score of 1, the score of 1 is then divided by the number of the neighboring

spaces (1/n) to which it is connected. The scores received by each space from its surrounding spaces are totaled. The higher the CV, the more controlling the space is; if a space ends up with a CV in excess of 1, it can be considered a controlling space; if control values move toward 0, it will be a controlled space (Hillier and Hanson, 1984).

Isovists

Benedikt (1979) proposed *isovists* as objectively determinable basic elements that capture local spatial properties by collapsing the space directly visible from a single observation point to its two-dimensional abstraction (Franz and Wiener, 2008). He considered isovists as 'regions of space', which can be described by the shapes obtained from people's vision if they rotate through 360 degrees. He proposed some measures to assess isovists' shapes such as area, perimeter, compactness, skewness and variance, all of which inform the degree to which these polygons are self contained or dispersed in space. All of them refers to a given observation point 'x', which is understood as the isovist's origin (Benedikt, 1979; Benedikt and Burnham, 1985).

Agent-based analysis

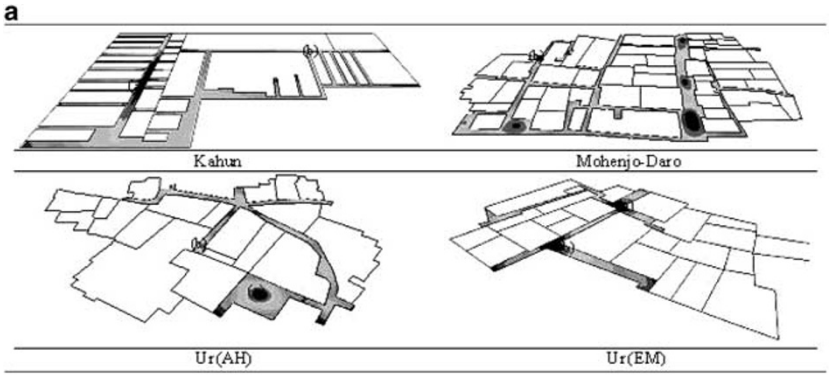
Another possibility that is offered by Depthmap software is the Agent-based analysis. This tool might be particularly useful to archeological research since it allows insights into the relationship between the built environment and spatial behavior. The impetus for this method of analysis is Gibson's (1979) theory of 'natural vision', in which the subject is drawn through a configuration not by planned decisions, but by the available affordances of objects within it. Space Syntax researches made it possible to simulate human movement by encoding Gibson's principle of natural movement, providing researcher with a further measure, which is the *Gate Counts* or the number of individuals that pass through a particular cell within the established grid. It consists of releasing a number of human-like agents at a certain radius and tracing their movement trajectories to predict how a certain space was (or would be) navigated (Bada and Farhi, 2009).

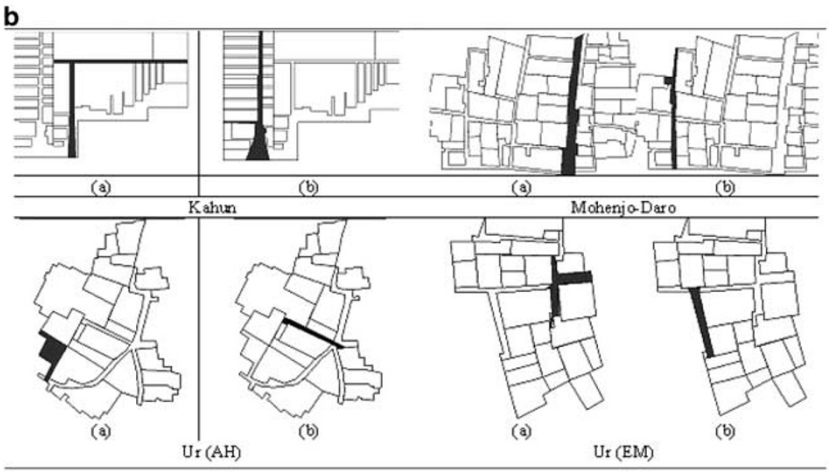
Findings and discussion

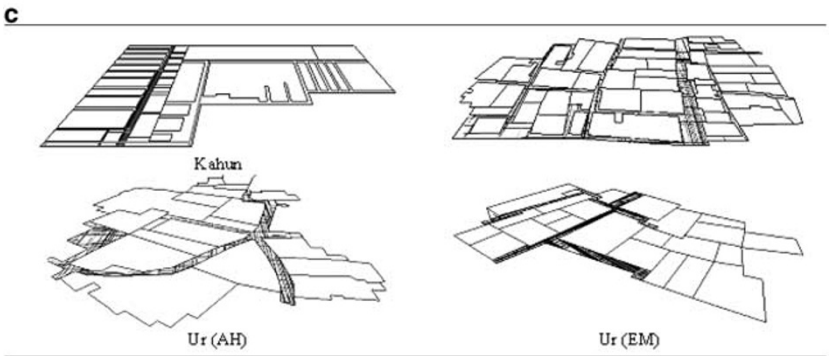
The most basic distinction that is usually made about different urban fabrics is between geometric and organic; geometric is defined in terms of straight lines and 90-degree angles, organic in terms of the lack of either. The former is thought to be planned, while the later is not, or seem not to be. Geometric is seen to be the outcome of reason, as their patterns are easily grasped 'all at once', while organic is seen to be the outcome of unplanned practicalities of everyday living rather than the ordering of human minds and their patterns are not easily grasped 'all at once'. In his study 'Studying cities to learn about minds' Hillier (2006, p. 11) demonstrated how organic patterns are just as much a 'geometric product of human minds' as orthogonal patterns. He asserts that by walking about in organic 'un-urban' fabrics, the very differentiation of their parts can make them easier to navigate than the orthogonal 'urban' fabrics. 'From inside', he says, 'we often find the organic easier to understand, from outside the geometric' (Hillier, 2006, p. 12). For him there is a hidden geometry in organic patterns, which he calls 'deformed grids' (Hillier, 2006, p. 13).

In the same sense, Al Sayed *et al* in their study 'Cities as emergent models: The morphological logic of Manhattan and Barcelona' observed that in both cases (Manhattan and Barcelona), the most integrated parts of the fabric were that of emergent model, not the planned grid. Moreover, the parts of the grids that are better integrated are in fact the ones that are broken by irregularities. They attributed Barcelona's success to its adaptive qualities; the flexibility of the grid as well as the diagonal lines even within the parts with uniform grid. This goes to show that the emergent 'organic' systems, in contrast to the orthogonal 'urban' typologies, have a quality to them that is more in tune with the residents, and make for better 'urban' systems (Al Sayed *et al*, 2009).

As for the four districts under study here, the two districts in *Kahun* and *Mohenjo-Daro* are commonly known to be well-planned sites with orthogonal urban-like patterns, while the districts in Ur are well known for their organic fabric that had been always deemed to be unplanned. In this part of the study, a comparative syntactic analysis is performed on the four districts to acquire numerical measures of the aforementioned five spatial qualities using the formulas previously discussed, in order to realize how much 'logic' is included in the districts of Ur in comparison with the other two districts. To apply these methodologies on the four districts, two sets of analytical process were performed on them: the first set concerns the district as a whole to obtain both global and local







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Attribute	Minimum	Average	Maximum
Connectivity	1	3.06772	4
Gate Counts	1	237.908	1866
Point First Moment	3	9.20317	12
Point Second Moment	9	27.6095	36
Visual Entropy R99	6.268	6.5259	6.60682
Visual Integration [HH] R99	0.111324	0.146824	0.179653
Visual Integration [P-value] R99	0.0154058	0.0191751	0.023733
Visual Integration [Tekl] R99	0.545723	0.576331	0.590154
Visual Mean Depth R99	42.74	53.0591	65.2618

Kahun

Attribute	Minimum	Average	Maximum
Connectivity	1	3.88376	4
Gate Counts	1	0.968311	21
Point First Moment	0.25	0.970941	1
Point Second Moment	0.0625	0.242735	0.25
Visual Entropy R99	6.2691	6.53137	6.61585
Visual Integration [HH] R99	0.130731	0.180465	0.232831
Visual Integration [P-value] R99	0.0151028	0.0190237	0.0262502
Visual Integration [Tekl] R99	0.582905	0.62181	0.649982
Visual Mean Depth R99	38.8533	53.9546	67.0186

Ur (AH)

Attribute	Minimum	Average	Maximum
Connectivity	1	3.7289	4
Gate Counts	1	10.9041	154
Point First Moment	0.25	0.932226	1
Point Second Moment	0.0625	0.233056	0.25
Visual Entropy R99	6.16743	6.50793	6.61898
Visual Integration [HH] R99	0.122556	0.169927	0.239382
Visual Integration [P-value] R99	0.015486	0.0207125	0.032284
Visual Integration [Tekl] R99	0.565881	0.595593	0.618709
Visual Mean Depth R99	31.6523	50.3652	65.3175

Mohenjo-Daro

Attribute	Minimum	Average	Maximum
Connectivity	1	3.94226	4
Gate Counts	1	0.978859	22
Point First Moment	0.25	0.960564	1
Point Second Moment	0.0625	0.240141	0.25
Visual Entropy R99	6.11954	6.53103	6.62024
Visual Integration [HH] R99	0.121473	0.169821	0.20399
Visual Integration [P-value] R99	0.0143296	0.0183341	0.0244551
Visual Integration [Tekl] R99	0.561513	0.61478	0.638516
Visual Mean Depth R99	41.5507	55.8225	70.585

Ur (EM)

Figure 2: Space Syntax analysis of the three sites. Analyses were performed on maps from the following sources: *Kahun:* Petrie (1891). *Mohejo-Daro:* Morris (1972). *Ur:* Joint Expedition of the British Museum and of the Museum of the University of Pennsylvania to Mesopotamia (1976). (**a**) Visual integration diagrams; (**b**) Shapes of Isovists; (**c**) Agent-based analysis; (**d**) Statistics of the analysis.

Table 1: Isovist measurements in the three sites

Isovist	*Area*	*Perimeter*	*O. edge*	*C. edge*	*Vertices*	*Area of adjacent isovists*	*S. Axes*
Kahun (a)	3904	1023	240.405	728.595	8	576+480+448+505+442+1782+272+368+1632=6505	2
Kahun (b)	4384	765.71	275.655	490.054	17	432+576+496+640+656+624+512+288+160+368+1216=5968	6
Mohenjo-Daro (a)	800	329	28	301	16	61+118+34+138.5+91+212=866.5	7
Mohenjo-Daro (b)	307.57	331.2	22.24	295.73	12	138.4+77.3+42.4+279.4=519.5	4
Ur (AH) (a)	586.19	143.46	57.384	86.076	8	194.7	3
Ur (AH) (b)	249.22	208.4	34.73	173.67	6	497.91	2
Ur (EM) (a)	92.954	83.837	10.9	72.937	10	65.655+28.4=94.055	4
Ur (EM) (b)	71.5	61.02	4.27	56.7	6	63.8	2

measures, such as integration, control value and connectivity values, while the second set concerns the properties of the isovists in each district. To select the observation points that would produce the most representing isovists in each of the four districts, the two points with the highest integration values in each district were appointed.

Figure 2 illustrates the results of Space Syntax analysis of the four districts using Depthmap software, while Tables 1 and 2 show the numerical results that had been obtained from the analysis of the diagrams in the figure.

The *interpretation* of the numerical results in Table 1 and Table 2 reveals that in terms of *spaciousness*, the site of *Kahun* has the most spacious system. The analysis shows that it presents the highest degree of visual access with the largest areas of isovists, which means more visual information available for people moving in the streets – a quality that copes with the notion of workers watched by overseers. However, in both *Kahun* and *Mohenjo-Daro*, the isovists are 'linear' (Figure 2b), which, to some extent, limits the visual access. As for the two districts of *Ur*, the least values for spaciousness and the narrowest isoveits are obtained, except for these at the point (AH-a) (Figure 2a). The reason behind this is probably that this area is the main square of the city. The values in this square are, even so, by far less than those in the two main streets in *Kahun*.

In terms of *enclosure*, the results (Table 2) show that the site in *Kahun* has also the most 'open' system, while the site of *Mohenjo-Daro* has the most 'enclosed' system. Particularly interesting are the revelation values, which indicate the 'visual stability' and the exposure to neighboring isovists (Franz and Wiener, 2008), as in two points at *Ur*, (AH-a) and (EM-b) (Figure 2a), these measures come in negative values, indicating a very high visual stability and very low exposure to neighboring areas. In her investigations in the historical site of Ostia, Stöger (2007) identifies a similar arrangement, where private domestic spaces were located in the deeper, less integrated portion of the Insula, which in her opinion ultimately makes a 'safer neighborhood'.

As for *complexity*, the district in *Mohenjo-Daro* has the most complex system as shown in Table 2. Less complex system, but still very close, is the site EM at *Ur*, with the highest values of density, which (for Franz and Wiener) is the valence indicator of pleasantness and interestingness (Franz and Wiener, 2008). Stöger (2007, p. 310) also calls this quality 'collective space structure', and says that it seems to be the key to a long period of occupation as it prevents fragmentation into individualized luxury architecture. It is also interesting that, by Franz and Wiener measures, the districts in *Ur* are more *ordered* than those in *Kahun* and *Mohenjo-Daro*, as the isovists in these sites has the least number of segments and symmetry axes (as described by Leyton, 2001).

The most noteworthy readings of the analysis are those concerning the quality of *Defensibility*. Although all results are so closed to each other, they show that the two districts of *Ur* have the best integrated systems and the highest values of connectivity, leading to a paradoxical result in terms of intelligibility, where the 'organic' pattern at the district (EM) in Ur has the highest value, and the district (AH) coming in the third place, with a very small difference from the district in *Mohenjo-Daro* in the second place, and the 'orthogonal' site of *Kahun* in the last place. The only explanation to this phenomenon is what Hiller said: 'from inside we often find the organic easier to understand, from outside the geometric'. So, higher values of intelligibility indicate spatial configurations that are easier to comprehend from inside, while hard to comprehend from outside, which means better ability for defense against 'outsiders' and easy navigation for 'insiders'. Furthermore, when considering the results of Control Values and Gate Counts (Table 2; Figure 2d) and overlapping them with the values

Table 2: The numerical results of the analysis

Spaciousness	*Isovist area/number of vertices*		
Kahun		Isovist (a) 488	Isovist (b) 257.88
Mohenjo-Daro		Isovist (a) 50	Isovist (b) 25.93
Ur (AH)		Isovist (a) 73.27	Isovist (b) 41.54
Ur (EM)		Isovist (a) 9.3	Isovist (b) 11.9
Enclosure			
Openness	length $_{\text{open edge}}$/length $_{\text{closed edge}}$		
Jaggedness	Isovist perimeter^2/area		
Revelation	(Σ area adjacent isovists−isovist area)/isovist area		

	Openness		*Jaggedness*		*Revelation*	
	Isovist (a)	*Isovist (b)*	*Isovist (a)*	*Isovist (b)*	*Isovist (a)*	*Isovist (b)*
Kahun	0.33	0.56	268.07	133.74	0.67	0.36
Mohenjo-Daro	0.09	0.07	135.3	356.65	0.08	0.67
Ur (AH)	0.32	0.2	35.1	174.26	−0.66	0.99
Ur (EM)	0.14	0.07	75.61	52.08	0.01	−0.11

Complexity	
Vertices	Number of vertices
Density	Number of vertices/area
Roundness	Isovist area/perimeter^2

	Vertices		*Density*		*Roundness*	
	Isovist (a)	*Isovist (b)*	*Isovist (a)*	*Isovist (b)*	*Isovist (a)*	*Isovist (b)*
Kahun	8	17	0.002	0.0038	0.0037	0.0075
Mohenjo-Daro	16	12	0.020	0.039	0.0073	0.0028
Ur (AH)	8	6	0.014	0.024	0.0284	0.0057
Ur (EM)	10	6	0.107	0.083	0.0132	0.0192

Order	
Symmetry	Number of symmetry axes
Redundancy/regularity	^{n} unique polygon sections/^{n}symmetry axes+1

	Symmetry		*Redundancy*	
	Isovist (a)	*Isovist (b)*	*Isovist (a)*	*Isovist (b)*
Kahun	2	6	1	1
Mohenjo-Daro	7	4	0.75	1
Ur (AH)	3	2	0.75	
				0.67
Ur (EM)	4	2	0.80	
				0.67

Defensibility	
Intelligibility	Connectivity: Integration
Control value	1/number of the surrounding spaces
Gate counts	From the agent based analysis

	Intelligibility	*Control value*		*Gate counts*
		Isovist (a)	*Isovist (b)*	
Kahun	3.07/0.15=20.5	0.38	0.55	237
Mohenjo-Daro	3.73/0.17=21.9	0.31	0.50	10
Ur (AH)	3.88/0.18=21.5	0.20	0.28	0.968
Ur (EM)	3.84/0.17=22.6	0.26	0.18	0.988

of revelation and the narrow isovists, it is also to be realized that the two districts of Ur have the best qualities for defensibility. Taking into account the constant wars among the Sumerians for 2000 years and the defensive arrangements in the city, it is very possible then that these districts were intentionally planned this way, in order to be harder to break-in by enemies.

Conclusion

Confirming the outcomes of many other studies, this article shows that Space Syntax analysis is a powerful tool that creates an alternative way to interpret and conceive spaces by making intangible aspects of space performance more tangible. Beyond that, this study is a further step toward demonstrating the correspondences between sociopolitical issues in some historical districts and the geometric properties of their spatial configuration as captured by Space Syntax tools. In this study, the role of Space Syntax analysis in comprehending these relations included: (i) presenting a new language of space that is more statistical and more tangible; (ii) constituting a new quantitative approach for 'evidence based' analysis; and (iii) giving a unique chance to evaluate historical remains, not only in terms of geometric configuration and static measurements, but rather as a social organism with convinced social characteristics that was experienced by its inhabitants.

As for the results of the analysis, they prove that the two 'organic' districts at the city of *Ur*, which had been always considered to be 'unplanned', enjoyed spatial qualities that is equal to, and sometimes even better than, those in the other two 'well-planned' districts with their orthogonal patterns. The analysis shows that the two districts in *Ur* enjoyed good qualities of enclosure as well as density, which is a valence indicator of pleasantness and interestingness (Franz and Wiener, 2008), and that, regardless of the actual geometry of the streets, their 'visual fields' were even more ordered than the two districts in *Kahun* and *Mohenjo-Daro*. It is also almost agreed upon that these narrow irregular streets and winding alleys were providing shade and keeping houses cool, as these were packed-in tightly, with their exterior walls immediately abutting each other (Oates *et al*, 2007). They provide also more shade than straight, wide lanes – an important consideration during the blistering heat of the Summer – and help to break the force of the bitter Winter winds and the sandstorms, which strike suddenly at any time of the year (Oates *et al*, 2007). In addition, they prevents fragmentation into individualized units (Stöger, 2007)

This means that the districts of *Ur* might have been intentionally planned in this specific manner for reasons of defense and protection against both man and nature. The concept of 'planning' in these districts is further supported by Woolley remark that when streets met, the buildings at the corner tended to have rounded edges, which he believed, was done in concern for pack animals going through the streets (Woolley, 1929). Residences in these districts, albeit were closely packed together, maintained private spaces in the front-to-back connections that limited access into portions of residence units. Walls, openings and pathways were arranged so as to control public encounters and maintain relative segregation – a concept that gives further support to the notion of defense.

Based on that, it could be said that orthogonal grid and organic grid in the studied cases did not indicate 'planned' or 'un-planned' configurations but rather 'open' and 'closed' networks. The earlier was found proper for the two administrative districts in *Kahun* and *Mohenjo-Daro*, in which more accessibility and supervision was required, while the latter was found more suitable for the residential districts in *Ur*, in which protection was the main issue.

The study also comes to a conclusion that, as the two districts of *Ur* have the highest values of intelligibility, this means that such 'deformations' of the grid, are probably more attractive to pedestrians, as they can enjoy other spatial qualities offered by these patterns. These qualities are probably the reason, why people look so positively to the urban fabrics with narrow winding streets and unexpected piazzas in the historical parts of cities.

The study, thereby, gives evidence that what might be seen as an emergent un-urban configuration of space might not be less planned than the orthogonal urban configuration and that by 'deforming' the rigidity of orthogonal lines, an 'adaptive model of planning' can be created.

Notes

1 The site is now threatened by groundwater salinity and improper restoration. Pakistani archeologists warned that the site may disappear by 2030.
2 A mound-like structure containing Buddhist relics.
3 Both of them are analyzed in the study.

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