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Analysing courtyards in vernacular farmhouses through space syntax analysis

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ABSTRACT

The Maltese Islands' domestic spaces have evolved over time, with each iteration aiming to reflect and respond to the cultural and social context of its era. This study examines the connection between domestic space and inhabitant behaviour through the lens of the traditional Maltese farmhouse, a key vernacular dwelling typology that embodies local architectural identity. Building on research in the literature, this study focuses on four case studies. This typology is characterised by a functional design responsive to its surroundings, featuring a central courtyard that serves as both a climate-moderating tool and a social gathering space. This space provides for natural ventilation and serves as a social hub for the residents; it is a space that serves both for gathering and communication and as a point of connection between other spaces within the domestic network. Focusing on the courtyard, this study offers insights into how this space mediates social activity, informs perceptions of the dwelling, and affects movement through it, reflecting the broader relationship between space and community life. This study reveals broader insights into how spatial arrangements and social dynamics influence and mirror one another.

Keywords: Space Syntax, Accessibility, Visibility, Connectivity, Residential Typology, Farmhouse, Malta

1. Introduction

The Maltese archipelago is comprised of a number of islands, three of which are habitable, namely, mainland Malta, the sister island of Gozo – 'Ogygia' in Homer's Odyssey (Book V) [1: 55-66], the home of Atlas's daughter, Calypso – and Comino (Fig. 1). Although a member of European Union since 2004, it is geohistorically located on the transition between North Africa and Southern Europe. The organic layout of its urban areas – vernacular towns with winding narrow streets and a Baroque church at the centre – recalls the history of the islands. Further to the palatial houses often found in the church squares, the typical residential typology ranges from townhouses to farmhouses as one moves away from the settlement's centre, recalling European and Arab influences, respectively. Until the later part of the twentieth century, vernacular farmhouses were the main type of residential unit in rural settings. Maltese farmhouse architecture has been a theme of research at the Department of Architecture and Urban Design of the University of Malta for the past half century (e.g., [2-9]). Jaccarini discusses three factors which influence the farmhouse's architecture and typology in Malta: (a) climatic considerations, (b) shelter and security, and (c) socio-economic aspects [10]. Recalling Mahoney [11: 79], he argues that "since antiquity, for reasons related to climate, Mediterranean houses were planned about a courtyard as in the Roman Villa at Rabat, Malta, and one may therefore claim that a similar house-plan could have even existed many years before the Arab conquest of Malta" [10: 9]. The objective of this paper is to apply Space Syntax Analysis (SSA) to the courtyards of vernacular farmhouses in Malta, a theme covered by one of the authors in [12]. It aims to (a) provide insight into the dynamics of the courtyard; (b) visually and quantitatively demonstrate, through graphical spatial representation and analysis, how this space influences the activities and movements of users; and (c) apply space syntax to gain a deeper understanding of the courtyard through the user's experience, perception, and movement.

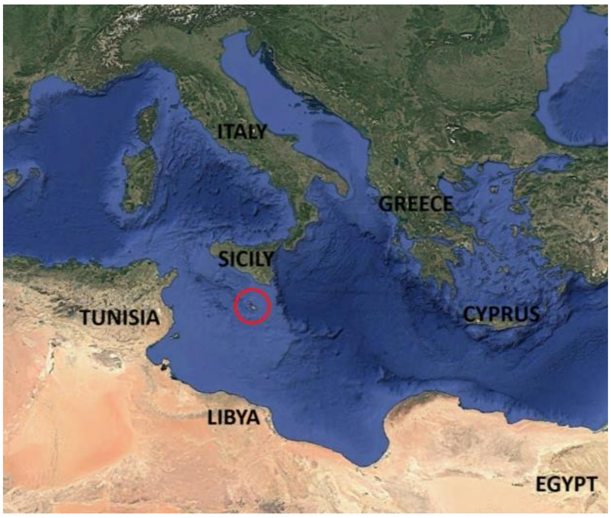

Figure 1. The Maltese Islands: (left) the location of the Maltese archipelago; (right) the islands of Malta and Gozo with the location Għasri (blue pin), Mġarr (yellow pin), and Birkirkara (red pin) respectively (© Google Earth)

2. Space syntax

Space syntax theory was originally developed to analyse urban spatial layouts and patterns of human activity by Hillier and Hanson [13]. It was subsequently developed through several journal articles (e.g., 14-19], proceedings of space syntax symposia [e,g., 20-28], and in *The Journal of Space Syntax* [e.g., 29-32]; some of these publications are cited in the recent work in [33].

Space syntax theory provides a set of analytical techniques to study architectural and urban layouts; people's location, movement, adaptation, development, and speech are all covered. In the words of Norman Foster, "these techniques work from the tough environment of practice. I love the world of analysis, observation, of research, but also passion, imprecision, the hunch. Space syntax is the testing of the interaction of these opposing worlds" (https://spacesyntax.com/the-space-syntax-approach/). Relevant space syntax parameters, as stated by Manum [26: 2] and Said-Zammit [34: 246-247], are listed in Table 1.

Table 1. Definitions of space syntax parameters

Term	Definition	Source
total depth of a node *n*	Total of the shortest distances from node *n* to the other nodes in the system.	[26:2]
mean depth for a node *n*	The average depth (or average shortest distance) from node *n* to all other nodes.	[26:2]
integration value	Parameter that describes integration by a high number when a node is highly integrated.	[26:2]
control value	Found by letting each node give the total value of 1 equally distributed to its connected nodes.	[26:2]
connectivity	A measure of the number of immediate neighbours that are directly connected to any given location.	[34:246]
entropy	The path of least disorder from a point to all other points within a system; low values indicate low disorder (which implies it is easy to move around), while high values show high disorder (it is hard to move around).	[34:246]
integration	The normalized measure of the mean shortest path from a particular point to all other points in the system, ranked from the most integrated to the most segregated.	[34:247]
mean depth	The shortest path through the graph to each other node then summed and divided by the total number minus one.	[34:247]
total depth	The total of the shortest distances from point n to other points within the spatial network of a settlement.	[34:247]

Term	Definition	Source
control	Locations which are dominant over more constrained areas.	[34:247]
controllability	Locations that are more easily dominated.	[34:247]
through-vision	The point (or points) within the spatial network of a settlement which provides the highest degree of visibility.	[34:247]
choice	Measures the quantity of movement that passes through each spatial element on shortest or simplest trips between all pairs of spatial elements in a system and so corresponds to mathematical betweenness	[34:247]

Manum [26] also includes the term ‘relative asymmetry’ (RA) – “the integration of a node by a value between (or equal to) 0 and 1, where a low value describes high integration” [26: 2] – which mathematically is defined as the reciprocal of ‘integration value’.

The point first moment and point second moment are “two metrics that relate to the shape of the isovist ..., as the first and second area moments of inertia of the isovist. They can be thought of as the potential for an isovist to spin around its generating point. More elongated isovists have more potential to spin, and those potential increases if the generating point is towards the edges of the shape. In that sense, the two metrics can be considered the inverse of compactness” [25: 6]. In the case of a residential dwelling, the visibility graph analysis (VGA graph) is generated by laying the grid over the planning layout and computing the isovists from the centres of each of the cells making up the grid. Coined by Benedikt [35], the term isovist “originated as a method to evaluate and represent the available visual field, or visual potential, at a specified point of interest, known as the isovist’s generating location. ... Two ways of moving from the instance (one isovist) to the ubiquitous (a collection of isovists) is via either Benedikt’s isovist contour maps or Turner’s [27] visibility graph analysis” [21: 2]. Yunitsyna and Shtepani define the isovist area, visual control, and visual mean depth thus: “the Isovist Area indicates the amount of space, which is visible from a specific point, and it is directly related to the Connectivity. The Visual Control of a point is the result of the comparison of the number of cells visible from it, with the same value of neighbouring cells. The Visual Mean Depth shows the average number of steps, which are necessary to make, to move to any other cell and it helps to evaluate the circulation potential in terms of accessibility and visibility” [36: 2-3].

3. Methodology

The first comprehensive study on the evolution of residential spaces in the Maltese archipelago through space syntax was the doctoral thesis of Said-Zammit [37], which was later published [34]. His research included the decoding of domestic space and village settlements [34: 228-280]. Farmhouses are among the typologies studied [34: 336, 338, 339, 341-346] (Table 2). The case studies presented in this paper – House 4 (H4), House 8 (H8), House 10 (H10), and House 11 (H11) – were selected on following two criteria: (a) their construction pre-dates the British colonial period, that is, pre-19th century, and (b) no alterations from the original have been carried out. All were constructed from load-bearing ashlar but only three were erected with two-storeys; H11 is single-storey. Where there is an upper level, it is accessed through an open staircase. H4 is in Gozo (Għasri) and the rest are in Malta: H8 in Mġarr, H10 and H11 in Birkirkara. Their respective footprints are H4: 102.0m^2, H8: 209.1m^2, H10: 219.8m^2, and H11: 686.4m^2. Analysis, based on their floor plans, is presented in Fig. 2 to Fig. 5).

Table 2. Farmhouses studied by Said-Zammit [34: 336, 339, 341-346]

Sample	Mode of access	Estimated % use of façade	Date of erection (century)	Number of windows		Number of rooms	
				external	internal	ground	first
House 1	doorway	30	19th	2	1	3	1
House 4	doorway	30	18th	2	0	3	2
House 6	siqifa	30	19th/ early 20th	0	1	5	1
House 7	multiple	20	Late 15th / early 16th, with 18th additions	3	0	5	2
House 8	doorway; flight of steps	20	late 15th/ early 16th	1	1	10	1

Sample	Mode of access	Estimated % use of façade	Date of erection (century)	Number of windows		Number of rooms	
				external	internal	ground	first
House 9	multiple	35	18th, with 19th additions	1	1	4	1
House 10	doorway	17	18th	1	0	2	1
House 11	multiple	35	18th (1714)	2	0	4	0

Access analysis, visibility graph analysis (VGA), and axial line analysis (ALA) – distinct types of SSA – were applied. Access analysis is a type of spatial representation that improves comprehension of spatial networks by translating the residential network into a plot. This is generated through *AGRAPH* software [26]; nodes are represented as circles, each of which represents a space, and the lines that connect them illustrate how one space is physically connected to another. References to spatial patterns begin to appear when spaces are visualized in this way [13]. *Depthmap* software is used for VGA to view the network's spatial hierarchy and, consequently, provide insight into its morphological structure. A grid is applied to the layouts of the houses, and the locations to be studied are selected. Point locations, each in the centre of a grid square, are used by *Depthmap* to conduct its analysis; the grid's unit size is chosen to guarantee that a particular space is thoroughly covered [38]. A graph that maps the range of values is created by analysing each plan based on the chosen parameter; warmer colours indicate higher values in a spectrum that ranges from warm red to cold blue. Alongside the graph, corresponding data are generated which include the average, minimum (min), and maximum (max) values.

ALA uses *Depthmap* and represents space as a collection of axial lines [13]. Each parameter is used to create a graph; the analysis produces accessibility and movement pattern scores that differ from the visibility and visible accessibility outcomes that the VGA produces. Consequently, ALA displays movement patterns, substantially traversed areas, and whether the courtyard directs users through the dwelling.

4. Results

4.1. Access analysis

The movement along the entrance root and the courtyard root using the justified accessibility graph for each sample were plotted and the access analysis data for the following four parameters were tabulated – (a) control value of node n, CV(n); (b) integration value, i; (c) total depth of a node n, TD(n); and (d) mean depth, MD(n) – and included in Borg [12: 70, 72, 84, 87, 90, 92, 94, 96]. Each space is assigned a consecutive integer starting with 0 as the root. Recalling Manum [26: 20],

$$\text{CV}(n) = \text{total value received by node } n \tag{1}$$

if CV > 1, then the space is a controlling one; if CV < 1, then it is a controlled space;

$$\text{i} = 1/\text{RA} \tag{2}$$

where RA = 2*(MD-1)/(k-2);

$$\text{TD}(n) = \text{the total of line } n \text{ (or column } n\text{) in the distance matrix} \tag{3}$$

if k is the total number of nodes in the system, then MD(n) = TD(n) / (k-1).
The following color notations were used:

○ entrance ● courtyard ● staircase ● transitory space ● room ● terrace/balcony

4.1.1. House H4

The justified accessibility graphs are given in Fig. 2. Sample H4 presents a deep map structure with sequentially accessible rooms with larger step depths. The access to the upper level is through the staircase located within, but not accessed through, the courtyard (5). The courtyard is accessed sequentially through rooms 1 and 2 from the main entrance but close to the public area of the dwelling. The courtyard does not exhibit the highest CV and i values; these occur within the intermediary spaces 2, 4 and 9, respectively. Integrated spaces 2 and 4 are a transitory room (2) and the staircase (4), respectively, whilst the controlling space is an upper-level corridor

(9). The deepest spaces, having the highest TD(n), are 8 and 13; the lowest depth values are with respect to the central spaces within the network, namely, the courtyard and the corridor. With the courtyard as the root space, the domestic network appears less sequential in access. The upper-level corridor (9), staircase (2), transition room (1), and the courtyard (0) exhibit the highest i values. Room organization is less centered around one space whilst many spaces are transitory rather than isolated. This signifies a lower degree of privacy and therefore separate activities cannot take place at the same time. The central space to the dwelling in terms of movement, having the lowest depth values, is transition space 1, whilst the deepest spaces within the network are 8 and 13.

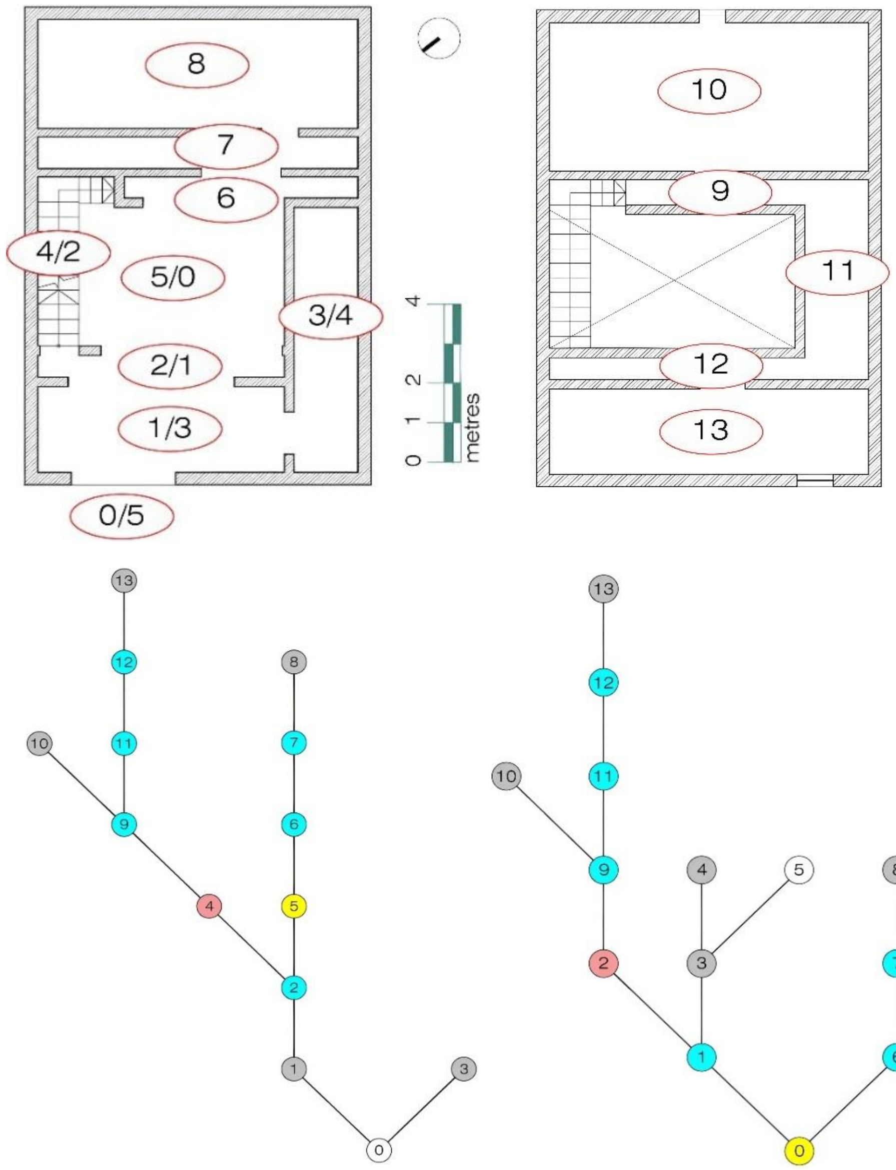

Figure 2. House H4: (top) – (left) ground floor plan, [x/y] refer to movement along the entrance root [x] and the courtyard [y] root, and (right) first floor plan; (bottom) – justified accessibility graph for (left) entrance root and (right) courtyard root

4.1.2. House H8

The justified accessibility graphs are given in Fig. 3. H8 – a convoluted residence in terms of room number and arrangement – depicts a shallow graph where most rooms are accessed individually and centred around a singular space, the courtyard (1). The shallowness of the graph is also seen through its highest level of depth from the main entrance, being rooms 14 and 16, located 3 steps away. The courtyard is the first space located beyond the main entrance, making it a public space in which to greet visitors. This is reflected in the resulting high CV and i values the space scored. It also reflects its low TD(n) and MD(n) values, meaning that it is centrally located within the domestic network. The number of spaces comprising the upper floor level is significantly lower than the ground floor, indicating that it includes the private spaces within the residence. The courtyard root exhibits a shallow map structure with most rooms centred around the courtyard (0); both the CV and i are high. To access all rooms, users need to pass through the courtyard, making it a central space within the domestic network. This parameter is reinforced by the low TD(n) and MD(n) values, showing that the courtyard is in close proximity to most spaces within the system.

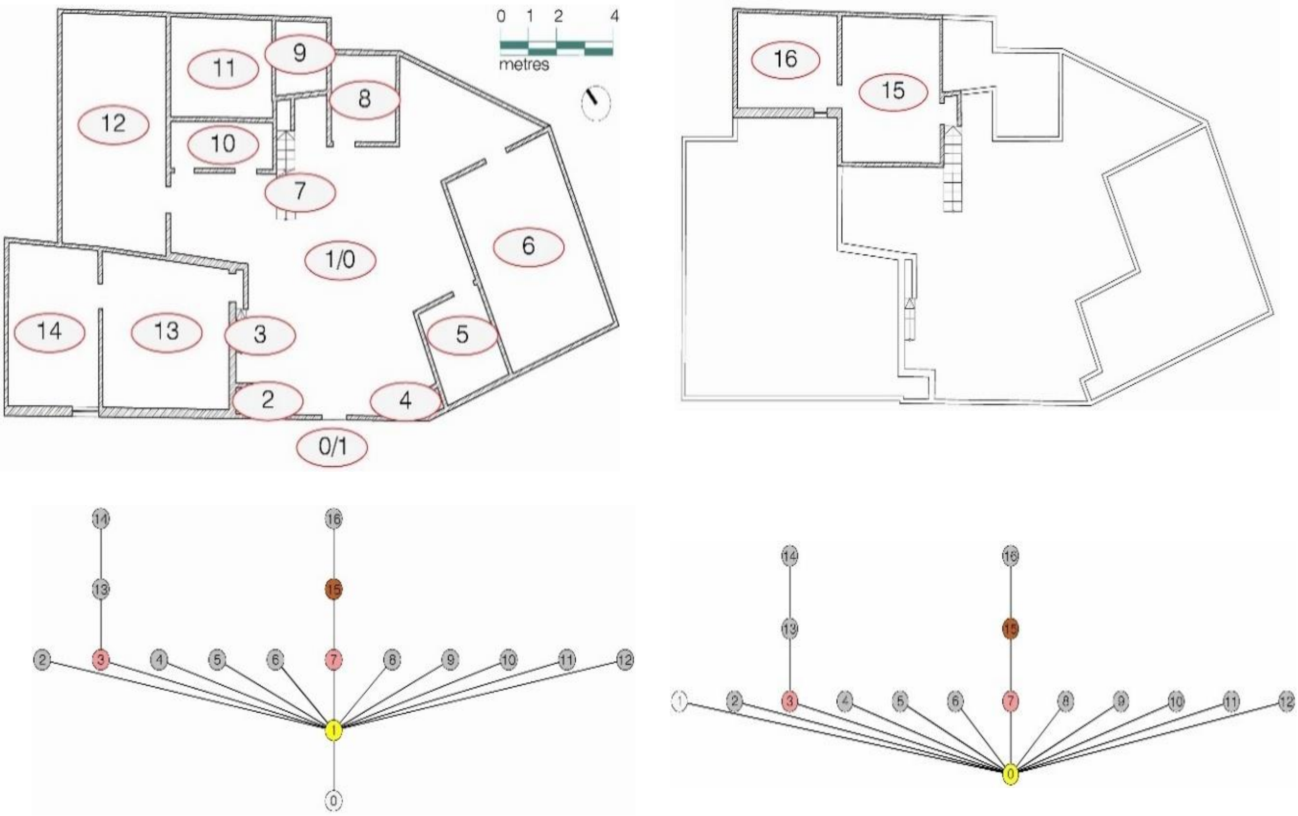

Figure 3. House H8: (top) – (left) ground floor plan, [x/y] refer to movement along the entrance root [x] and the courtyard [y] root, and (right) first floor plan; (bottom) – justified accessibility graph for (left) entrance root and (right) courtyard root

4.1.3. House H10

The justified accessibility graphs are given in Fig. 4. House 10 results in a shallow map structure where most spaces are accessed through a courtyard (1) which is located just behind the main entrance (0), thus making it the shallowest, most public space within the dwelling. The courtyard provides access to the upper level through an open staircase (2). The upper level consists of one space (6), located 3 steps away from the root position, the most private room in the house. The courtyard has the highest CV and i values; it is the space exhibiting the lowest TD(n) and MD(n) values, making it a central space within the residence. With the courtyard (0) at its root position, the map's structure is shallow with most spaces centered around it, resulting in the ability to carry out undisturbed activities at the same time within said spaces. The most remote spaces from the courtyard are the upper floor room (6), the deepest space TD(n), accessed via the staircase (2) and transition space (5). Similar to the entrance root map, the courtyard remains the most integrated and controlling space of the residence.

4.1.4. House H11

The justified accessibility graphs are given in Fig. 5. House 11 presents a shallow map structure where most rooms are accessed separately, through the courtyard (2). As opposed to H4 and H8, H11 is simple in terms of arrangement and number of rooms. The courtyard is sequentially located 2 steps away from the main entrance. From it, all other rooms can be accessed, making it a highly integral space within the domestic network. This is reinforced through the courtyard's high CV and i values, which is also the case for the courtyard root map. Room 1 and the courtyard present the lowest TD(n) and MD(n) values, suggesting that both are central in the network. Having the courtyard as the root space, the dwelling retains a shallow map structure where spaces are accessed mainly through the courtyard (0) except for the main entrance (2), which is accessed sequentially through room 1. The courtyard is the centre of the dwelling – all rooms centre around it whilst most are accessed through it; it has the lowest TD(n) value.

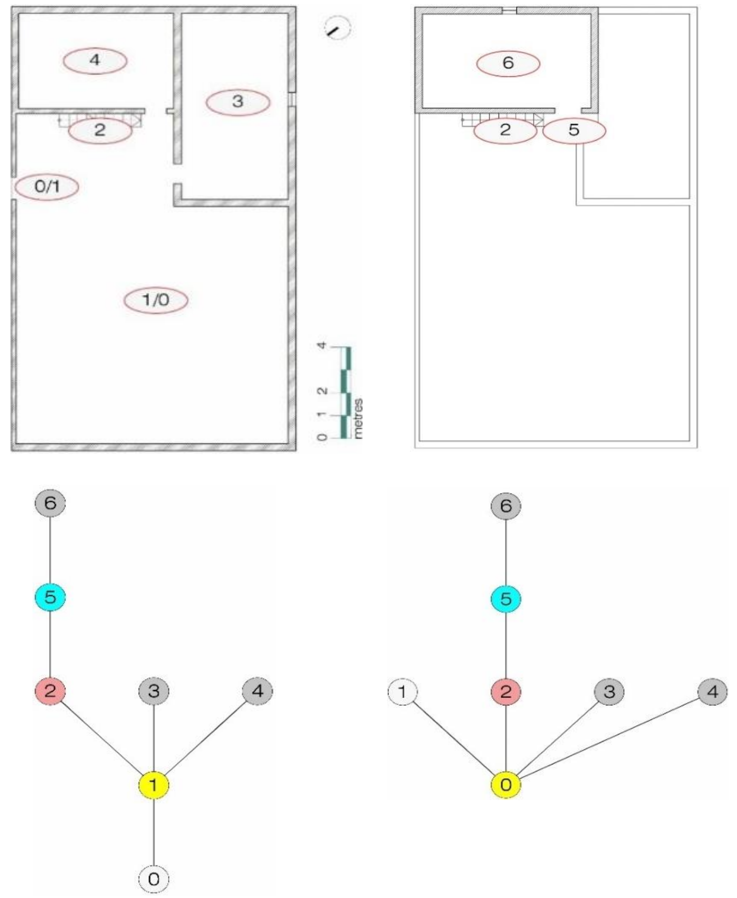

Figure 4. House H10: (top) – (left) ground floor plan, [x/y] refer to movement along the entrance root [x] and the courtyard [y] root, and (right) first floor plan; (bottom) – justified accessibility graph for (left) entrance root and (right) courtyard root

4.2. Visibility graph analysis

Where applicable, data secured through VGA for each floor of each case study were tabulated, to three significant figures, for the following six parameters: (a) connectivity (connect), (b) point first moment (Point 1), (c) point second moment (Point 2), (d) visual integration (HH), (e) metric mean shortest-path distance (MMSPD), and (f) through vision (TV) (Table 3). Each can produce either 'local' or 'global' values. The local values are based on point locations' immediately surrounding cells; the global ones are affected by the selected grid area. The graphs for connectivity are reproduced in Fig. 6. This parameter in VGA represents the direct visual connections of a cell with the others and is indicative of the level of exposure [14]. The graphs with respect to the other parameters are reproduced in Borg [12: 122-124, 136-138, 141-143, 145-146].

Table 3. Visibility graph analysis

		H4			H8			H10			H11		
		mean	min	max	mean	min	max	mean	min	max	mean	min	max
Ground floor	Connect	320	0.00	632	875	0.00	1880	1150	0.00	1630	1470	181	2630
	Point 1	1160	0.00	2980	3440	0.00	8960	6990	0.00	13800	10300	483	21300
	Point 2	5670	0.00	23400	18400	0.00	67900	54400	0.00	156000	93800	1380	260000
	HH	10.3	1.75	18.8	11.0	4.69	115	19.2	6.51	33.4	15.4	6.20	33.1
	MMSPD	6.28	0.00	11.3	6.94	0.00	13.3	8.52	0.00	13.6	11.1	7.68	17.5
	TV	3290	0.00	11500	14900	0.00	75400	20200	0.00	60800	30300	0.00	116000
First floor	Connect	230	41.0	329	420	122	652	707	32.0	744	*	*	*
	Point 1	677	83.4	1410	1020	268	1810	2080	27.9	3080	*	*	*
	Point 2	2630	181	7450	3330	724	8280	7710	29.8	15300	*	*	*

	HH	4.06	2.86	6.34	20.9	8.11	178	240	6.29	749	*	*	*
	MMSPD	7.59	5.64	11.0	3.30	2.35	5.04	3.03	2.22	4.78	*	*	*
	TV	1940	0.00	6620	4300	0.00	16400	8960	0.00	21000	*	*	*

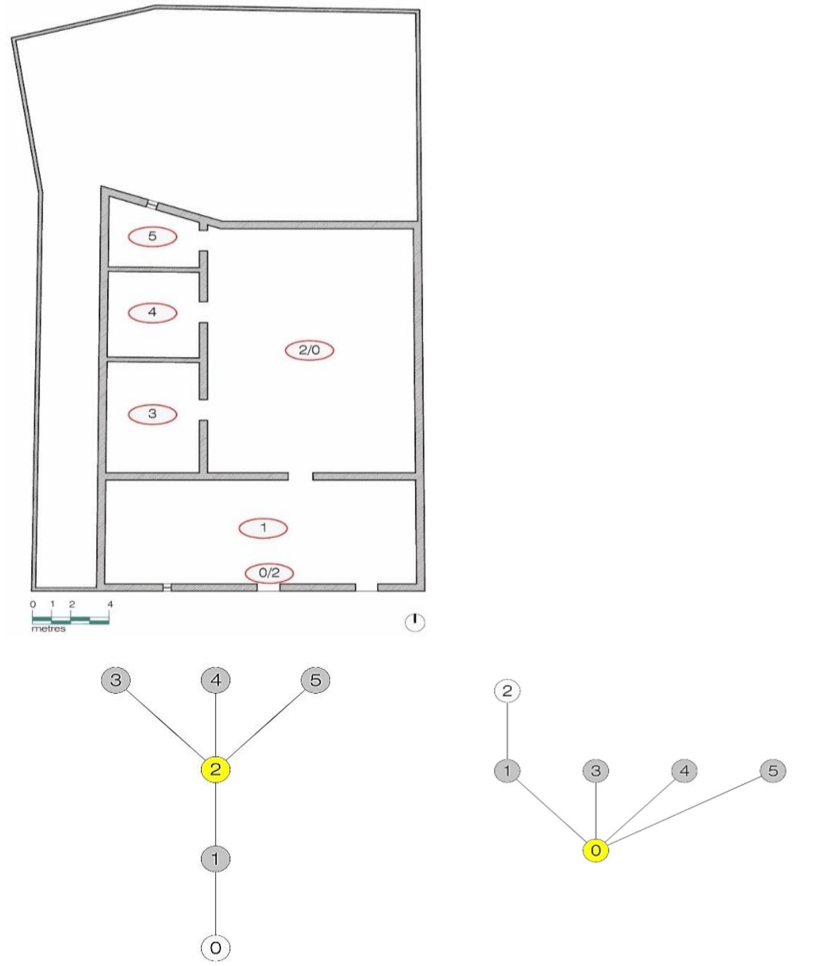

Figure 5. House H11: (top) – (left) ground floor plan, [x/y] refer to movement along the entrance root [x] and the courtyard [y] root, and (right) first floor plan; (bottom) – justified accessibility graph for (left) entrance root and (right) courtyard root

4.2.1. House H4

High visible connectivity values occur at the transition points between the rooms at the ground floor level, including transitions in and out of the courtyard and within a space on the upper floor level. Point 1 and Point 2, indicative of high visual control areas, are at the deepest parts of the ground floor level and the farthest corners of the deepest space on the upper floor level. The most integrated areas are around the entrance to and exit from the courtyard, whilst at the upper-level high integration levels occur at the upper-level corridor and the back room. Analyzing the MMSPD reveals that the courtyard provides the highest ease of access (marked in light blue) due to its centrality with the system. At the upper level, the corridor spaces exhibit the lowest distances (light and dark blue) making them central and easily accessible. The center of the dwelling, including the courtyard, at the ground floor also exhibits high through-vision values. High through-vision levels are present at the back room of the upper floor.

4.2.2. House H8

Within House 8, the highest visually connected area across the dwelling lies in the center, the courtyard. At first floor level, it is located at the junction between the two rooms. High Point 1 and Point 2 values occur at the courtyard's edges implying high levels of visual control. Similarly, from the first floor such distances can be viewed from the junction between the two rooms and a corner that allows a glimpse across both rooms. The courtyard is the heart of the dwelling, both in location and in influence; the further one moves from it, the more segregated and visually and physically closed off the spaces are. Visual integration values throughout the dwelling appear uniform. This is present also at first floor level. The courtyard displays low metric distance values; the lowest occur within separate spaces as they are analyzed in isolation. With respect to the courtyard, values increase as one moves away from the center. This suggests that the center of the courtyard is very engaging within the system due to the ease of access the user experiences when traversing the dwelling. High through-vision values are noted at the courtyard's center and at the rooms' junction at first floor level.

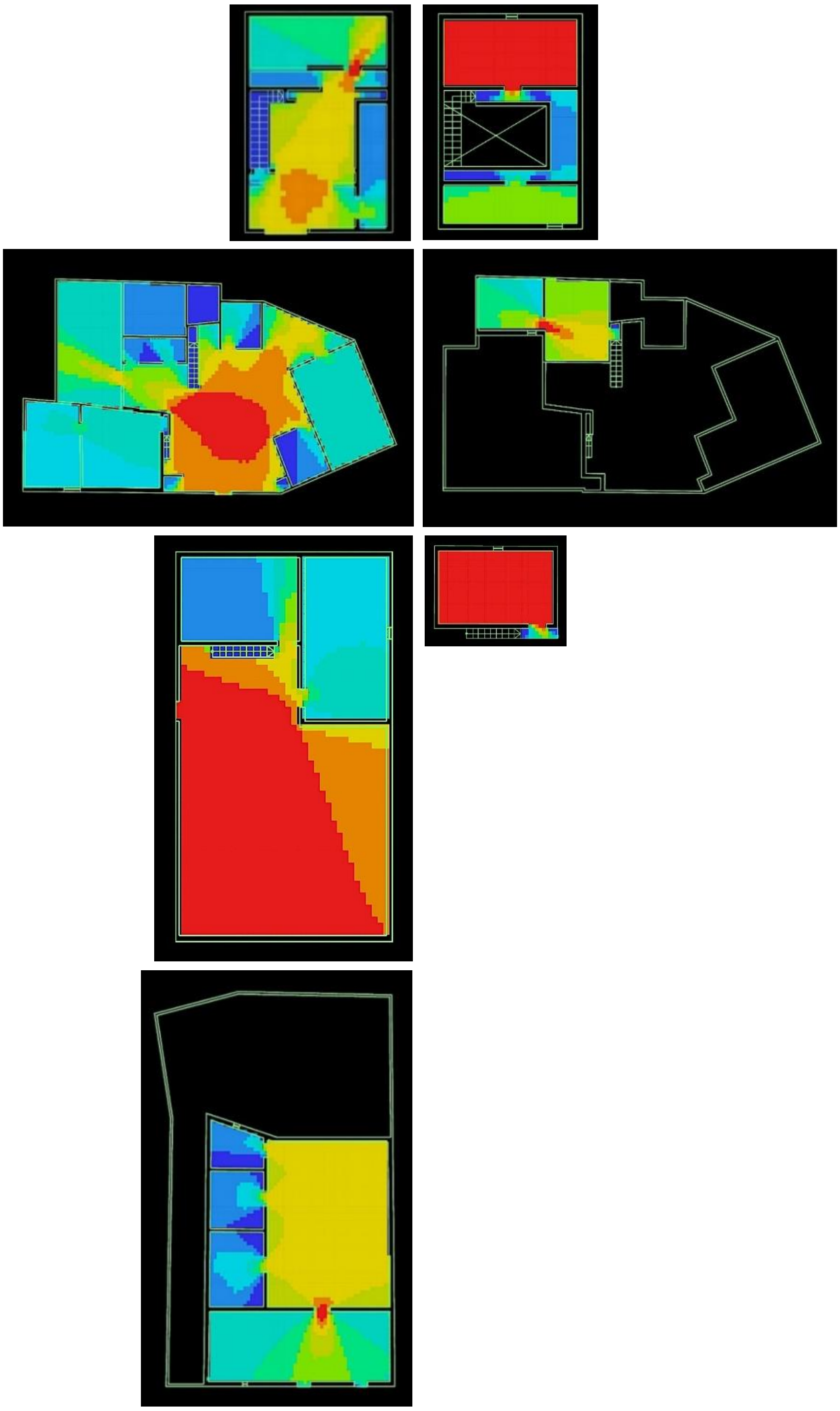

Figure 6. Visibility Graph (Connectivity): (a) House H4, (b) House H8, (c) House H10, (d) House H11; (left) ground floor and (right) first floor)

4.2.3. House H10

H10 is similar to H8: the courtyard presents the highest visual connectivity at ground floor level; the room at first floor level is isolated. The highest Point 1 and Point 2 values occur at the courtyard's edges, similar to the room at first floor level, implying that this space has high visual control and information within the network. The spectrum of visual integration values ranges from high to low in the courtyard and the dwelling edges, respectively. On the first floor, the opening of the room contains the highest visual integration, thus, one can take in a view of the entire room from that point. The courtyard displays low metric distance values, indicating that it provides ease of access to other spaces when the user traverses the dwelling. At first floor level, the center of the room provides the same effect. The central courtyard also has the highest through-vision value, as does the center of the upper-level room. Both results indicate that such areas are actively used within the network.

4.2.4. House H11

High visual connectivity values occur at the opening/junction between the courtyard and an adjacent room. The junction, along with the courtyard edges, represents the location where optimal visual information is read by the user through accessing long-distance views across the dwelling, namely, Point 1 and Point 2. The highest level of visual integration occurs at the junction between the courtyard and an adjacent room. The MMSPD graph indicates that the lowest distance values are at the center of the courtyard. Similar to H10, given that the courtyard is significantly traversed, this area is easily accessible within the network. The highest through-vision scores are at the junction, thus implying this location opening is a highly used point within the dwelling.

4.3. Axial line analysis

Results of the ALA for each floor of each case study were tabulated to three significant figures for the following parameters: connectivity (connect), choice, entropy, HH (visual integration), and MD (mean depth) (Table 4). The respective graphs for connectivity are reproduced in Fig.7. The plots for the other parameters are included in Borg [12: 174-176, 187-189, 192-194, 197-198].

Table 4. Axial line analysis

		H4			H8			H10			H11		
		mean	min	max	mean	min	max	mean	min	max	mean	min	max
Ground floor	Connect	101	25.0	173	111	5.00	188	40.6	12.0	55.0	36.3	4.00	73.0
	Choice	112	0.00	720	179	0.00	1190	30.1	0.00	148	148	0.00	555
	Entropy	1.03	0.65	1.43	1.13	0.946	1.63	0.992	0.738	1.43	1.59	1.41	1.82
	HH	11.3	4.53	31.4	9.77	2.73	17.4	10.3	3.71	18.0	4.67	1.39	7.48
	MD	1.54	1.16	2.14	1.66	1.32	3.03	1.44	1.20	1.99	2.13	1.61	4.25
	Control	1.00	0.30	1.82	1.00	0.182	1.75	1.00	0.288	1.39	1.00	0.228	1.61
First floor	Connect	11.5	6.00	14.0	21.4	13.0	27.0	12.1	3.00	17.0	*	*	*
	Choice	34.4	0.00	216	7.60	0.00	48.0	6.63	0.00	28.0	*	*	*
	Entropy	1.84	1.29	2.32	0.795	0.397	1.01	0.946	0.367	1.48	*	*	*
	HH	2.22	1.12	3.67	13.1	4.59	36.7	8.48	1.61	35.3	*	*	*
	MD	2.23	1.68	3.21	1.26	1.07	1.55	1.37	1.06	2.22	*	*	*
	Control	1.00	0.55	1.19	1.00	0.583	1.32	1.00	0.341	1.43	*	*	*

4.3.1. House H4

H4 displays high connectivity axial lines cutting across the dwelling through sequential openings that lead diagonally from one dwelling edge to the other. The courtyard lies within the routes of the highly connected axial lines, indicating that this space is one that is frequently crossed. On the first-floor high connectivity values are more dispersed, with the most highly connected routes at the back of the dwelling, connecting the transitory corridor to the back room. At ground floor level, high choice values occur at locations of high connectivity values, whilst at first floor level, a high-value axial line cuts across the transitory corridor. The lowest entropy values – on the ground- and first-floor levels – cut diagonally across the dwelling and center around the corridor, respectively. High integration values run across similar paths as the high connectivity and choice axial lines. This suggests that the courtyard is located on highly integrated movement pathways, the case for the transitory corridor at first floor level. Such paths result in the lowest mean depth values and the highest control values, recalling that the former suggest that the pathways/axial lines require the least effort to get from one space to another whilst the latter suggests that along the high value paths, the user is provided with multiple choices to access different areas of the dwelling.

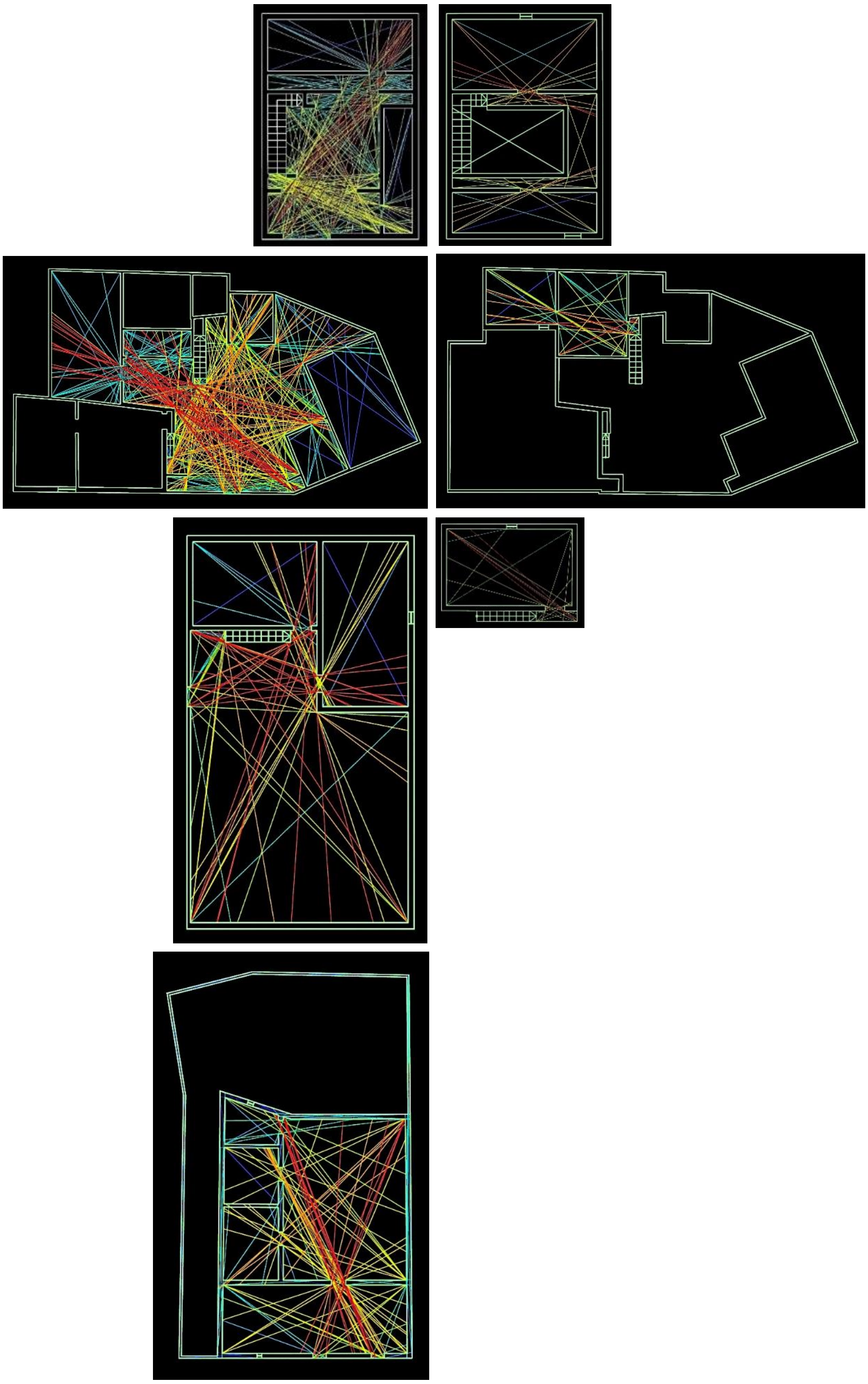

Figure 7. Axial Line Graph (Connectivity): (a) House H20, (b) House H21, (c) House H23, (d) House H24; (left) ground floor and (right) first floor)

4.3.2. House H8

At ground floor level, high connectivity axial lines run across the dwelling, some leading from the courtyard to adjacent spaces. High-value choice axial lines cut through the courtyard and lead to an adjacent space with similar high connectivity values. Both parameters indicate that the courtyard lies along the most connected paths within the dwelling which connects one space with another. Low entropy values are concentrated around the courtyard, with some axial lines extending to adjacent spaces. This implies that it is the most central space within the dwelling, with the other spaces equally distributed around it. High integration axial lines run across the courtyard with highly integrated paths reaching adjacent rooms, whilst within the same areas low mean depth values can be noted. Similarly, high control axial lines are located within the courtyard, some accessing an adjacent space. This suggests that users moving along these pathways are given access to multiple other spaces within the dwelling at either level. At the upper level, most ranging characteristic axial lines cross between one space and another.

4.3.3. House H10

At ground floor level, connectivity values cross all the spaces within the courtyard, whilst high choice axial lines run across it into an adjacent space. The distribution of high connectivity axial lines indicates that spaces at this level are equally interconnected. High choice axial line paths from the courtyard to the adjacent space offer the user choices to traverse different areas within the dwelling. Similarly, low entropy axial lines appear to cross all spaces through the dwelling. Such values indicate that the effort required to traverse all spaces on this level is minimal. This is also the case with high integration values, where high-value axial lines cross the house, intersecting within the courtyard space and reach all ends of the dwelling. This distribution indicates that all spaces are integral to the dwelling network, including the courtyard, as the common integrated space across each path. Furthermore, both low mean depth values and high control values exhibit similar cross-dwelling distribution, with the courtyard as a common intersecting space. These values suggest that the user requires minimal effort to access all spaces at this level and that the spaces are dependent on the courtyard for access. Within the room at the upper level, high to low values pertaining to each characteristic cross the space.

4.3.4. House H11

Erected on a single storey, H11 includes high connectivity values that reach across the courtyard and the transition to an adjacent room at the front of the dwelling. This suggests that the courtyard lies on a highly connected path within the dwelling. A high-value choice axial line crosses through the courtyard into another adjacent space, suggesting that it lies on the path that offers the user the choice to access different parts of the dwelling, whilst the lowest entropy values diagonally across the courtyard space. Similar to high connectivity values, high integration, and low mean depth values occur across the courtyard and an adjacent room. These scores indicate that the courtyard lies on users' most frequent movement paths. Low mean depth values are distributed across the dwelling. With regard to control values, high-value axial lines cross through the courtyard and reach adjacent spaces, thus suggesting the courtyard is a highly controlling space.

5. Conclusions

The main conclusions of the SSA can be categorised in terms of the types of analysis, namely, (a) access analysis, (b) VGA, and (c) ALA:

1. In terms of the access analysis, given that the courtyard is often located close to the entrance of a farmhouse, it exhibits the lowest depth values as it is nearest to all other spaces within the network. In terms of control and integration, it is influential, possibly due to:
    a. its location – as the first or one of the earliest spaces that the user/visitor experiences on entering the dwelling; and
    b. the limited number of other spaces within the dwelling.

Thus, the courtyard is the focus of control of other spaces within the dwelling; navigating choice and movement through the unit is dispersed from the yard. The uncovered staircase to the upper level strengthens the significance of the courtyard as a mode of control.

2. The highest visual connectivity values of the dwelling often occur at the courtyard's centre or edges or at connections with adjacent rooms. Point first moment and point second moment values are particularly frequent along its internal perimeter. This demonstrates that the courtyard is a location of visual control whereby a significant visual distance can be captured. This suggests that, as a space, the courtyard allows the user to choose the route within the dwelling and interact with other users more effectively. Visual integration graphs indicate equal values across the ground floor, but these tend to vary on the first floor. Rarely, higher values are attained at the centre or in proximity to the courtyard.

    With respect to metric distances, the shortest are noted within isolated rooms; segregated room distances are calculated as spaces within themselves, disconnected from the rest of the dwelling. Reinforcing the traditional observations, VGA indicates that the centre of the courtyard is a highly used space – connected by the shortest distance to all other spaces within the network – as it scored the second-lowest value. The courtyard is one of the most visible spaces within the farmhouse, as indicated by the high through-vision ratings.

Given the courtyard's characteristics and position, VGA shows that it serves as a gathering place as well as a transitional area, a place for residents and, occasionally, a threshold for visitors. As a result, it is an extremely important area in the farmhouse since it promotes interactions and communication among users.

3. Values are distributed along axial lines representing user movement paths analysed in terms of connectivity and choice. The spaces determine the frequency of the program-generated axial lines. The more axial lines, the more potential routes one can take within a given dwelling. The dispersal of characteristic values increases as the complexity of the domestic network increases. The simpler the network, the more mobility channels overlap thus leading to increased interdependency and interaction between spaces – and hence, living spaces which are better integrated into the system.

   The courtyard is the area where high movement paths intersect due to its location and accessibility. Instead of being a segregated space, the courtyard is often central with respect to the planning layout of the farmhouse. Due to its accessibility and location, it is on frequently traversed pathways which integrate and connect the various spaces within the residential network. Paths with low entropy and mean depth values are more prevalent in the farmhouse typology, accentuating the significance of the courtyard. Such parameters illustrate how easily accessible some spaces are compared to others. ALA demonstrates that the courtyard is located on recurrent traversed movement paths and is thus frequently an essential space for users to navigate to other spaces within the dwelling.

   SAA is useful to assist the evaluation and analysis of visual and physical connectivity of courtyards within farmhouses. It offers insights into how this space mediates social activity and informs both dwelling perception and movement, thus reflecting the broader relationship between space and community life. Furthermore, it reveals broader insights into how spatial arrangements and social dynamics influence and mirror one another. SSA is a technique which supplements traditional observation. Unlike those which are single-layered, SSA – notably *Depthmap* software analysis – is a multi-layered analytical technique which increases the accuracy of the data gathered within given spatial networks.

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Data availability

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