Measuring the Degree of Street Vitality in Excavated Towns

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How can Macro and Micro Spatial Analyses Tools Contribute to Understandings on the Spatial Organization of Urban Life in Pompeii?

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Abstract
The aim of this contribution is to show how it is possible to indicate degrees of street life and economical attractiveness in excavated towns through micro and macro spatial configurative analyses. When applying these tools on excavated sites, socio-economic empirical knowledge from a present urban context are required. Combining these with the archaeological data makes it possible to calculate degrees of street life, poverty and various degrees of social control for these settlements.

Pompeii is one of the best preserved towns from the Roman period and it is used as an example in order to illustrate the potential of using spatial analyses in the analyses of excavated settlements. The spatial analyses of the street net give indications on possible functions of adjacent buildings where identifiable artifacts are lacking on archaeological sites. Moreover, the statistical data from the micro and macro scale spatial analyses and the agent based modelling can give indications on the degree of vitality in shopping streets and where the largest flow of human movement took place in excavated towns.

As the Pompeii case study shows, the way a society organizes its functions spatially and the way its spatial structure affects human behaviour in terms of the location pattern of its activities has not changed significantly in 2000 years. Shops and bakeries locate themselves in the most integrated streets with high number of connections to other streets in a short metrical distance. Moreover, the entrances along these streets are directly connected to the street, have a high density and high degree of inter-visibility. Religious buildings (such as temples) and political institutions locate themselves one topological step (or one direction change) away from the most integrated streets. Brothels locate themselves in constituted side streets metrically close to the integrated main streets. However, the workshops and taverns are located along the main streets and in side streets topological close to the main streets. Conversely, the public baths, theatres, inns or hotels, sport and leisure facilities are spread around through the town's street net.

As it turns out from this inquiry, the same tendencies on space and location pattern of various urban functions in old Roman towns can be seen in present urban centres.

1 - The private – public space relationship

Human beings are social beings. Event though they have their private spaces inside buildings, they also seek spaces to interact socially or economically with others. Activities in society take place in physical space. How a society organises its activities, privately as well as officially, gives impact of its built environment's spatial set-up. Conversely, a built environment's spatial structure affects how individuals behave in urban space in terms of possibilities for social control, opportunities for economical activities and social interaction.

The recent versions of the Depthmap software are able to calculate topological distance (how integrated a street is in relationship to all others in terms of the number of direction change),

geometrical distance (how integrated a street is in relationship to all others in terms of the angular relationship between them), and metrical distance. Moreover, the software is able to both describe and visualise a built environment's spatial inequalities, and to simulate and trace movement routes of computer-generated agents. The way these agents move is based on research in a present urban context (Turner 2004). Researcher all over the world has applied the space syntax method on their various local contexts. Hence, a substantial database exists in order to draw some general conclusions on the relationship between space and society for a present urban context useful for interpretations of the spatial analyses of excavated towns.

As research has shown on a macro level, there are correlations between a built environment's spatial layout of its street and road net and the location of economic activities, crime dispersal, land use along streets and property values (Hillier et.al. 1998). At present, on an urban micro level, few research projects have taken into account the spatial relationship between buildings and streets. Seemingly, these micro spatial conditions affect the degree of street life and safety in urban areas (López and van Nes 2007).

When revealing the remaining urban artefacts and the spatial layout of the 2000 years old town Pompeii, its inhabitants had their houses connected to public streets. Since the town was suddenly buried through an unexpected eruption of the volcano mountain Vesuvius on 24th August 79 AD, its spatial layout is preserved as it was for 2000 years ago. The town was buried under a 6 meters layer of volcano ash, in which preserved forever evidence on urban life at that moment for two millenniums ago. This makes it interesting for interpretation the results from the spatial analyses on its social and economic related street life. Since many items found in buildings are well preserved, it is possible to identify from an archaeological point of view what kind of function the various buildings had in the past. This contribution will focus on how the dispersal of urban functions relate to the spatial configurative analyses of Pompeii's street net. The visualized results from the spatial analyses are correlated with the location of various functions inside buildings – identified by the archaeologists.

2 - Pompeii's macro scale analyses

When applying space syntax on excavated sites, it is important to decide from which time period one wants to make the spatial analyses. Often, changes on the street net and buildings through history are layered upon each other. Some layers might be lost while others are highly visible. There exist several maps of Pompeii's street net. Even though 2/3rd of the town' surface is excavated, it is possible to reconstruct its entire street net. Hans Eschebach (1970) and Liselotte Eschebach (1993) registered every excavated building and draw their walls and openings carefully on maps. Through the items found in buildings, their various functions could be identified (Eschebach 1993). It is easy to recognise bakeries, public baths, temples, taverns, wool workshops, smiths, inns, drinking places and the brothels. Shops, however, are difficult to identify since items found inside buildings could be used for private use as well for exchange. Ray Laurence used the length of the streets in meters and divided it with the number of doorways (Laurence 1996, 89). According to him, it indicates a high number of comings and goings on these streets through these doors in which is a condition for micro scale economic activities.

Table 1 gives an overview over the relevant micro and macro spatial variables used in the Pompeii analyses. The various spatial variables' relation to socio-economic variables is indicated in the right column. These indications are based from research results in a present context.

The spatial integration analyses on Pompeii's street net indicate the location of the most vital treets. Figure 1 shows a global integration analyses with the location pattern of shops. It shows how accessible each street is in relation to all others. The black colour shows the highest integrated streets, while the light grey the most segregated ones. As research has shown in present day cities, the highest integrated streets have the highest flows of pedestrians and shops locate themselves in the most integrated streets (Hillier et.al, 1998; van Nes 2005). In Pompeii, the two main cross streets Via Stabiana and via di Nola have the highest integration values, followed by the street Via dell Abbondanze. These streets are known to be the typical main streets in Roman town planning named

decumanus and cardus. When revealing the results from the various local integration analyses, the same integration structure can be seen as in the global integration analyses.

Spatial variables micro scale analyses	What it implies	Relation to socio-economical variables
Visibility	Measures how many entrances are visible to one another in a street	Indicates degree of social control from buildings to the street and between buildings
Topological depth between private and public space	Measures how many semi public or semi private spaces there is between a house and a street	Indicates the streets' degree of privatedness and degree of social control from street to buildings
Constitutedness	Measures how many entrances are directly connected to a street	Indicates the degree of safety and street life
Density of entrances	Measures the degree of density of entrances	Indicate the degree of street life
Spatial parameters macro scale analyses		
Global integration (r=n) Topological distance	Calculates how integrated and connected a street is in relation to all others in a city in terms of the total number of direction change	Indicates the most centrally located street and the most central economical core in cities
Local integration (r=3) and 2 steps analyses Topological distance	Calculates how integrated and connected a street is in relation to its other streets in its vicinity in terms of 2 times of direction change from each street	Indicates the location of successful shopping streets in local urban areas
Local angular analysis (r=3) Geometrical distance combined with metrical distance	Calculates how integrated a street is in relation to its vicinity in terms of the degree of angular changes	Indicates the most frequented streets in local areas and the main routes through and between urban areas
Isovist analyses and all lines analyses 2 dimension space	Calculates degree of inter-visibility of urban spaces	Indicates the most frequented and visible urban spaces or degree of vitality of urban squares
Agent based modelling	Show the traces of a various numbers of computer generated agents walking randomly through a city's public spaces in a given time.	Indicate the dispersal of people or how they do they way finding in urban public spaces

Table 1
Overview over relevant micro and macro spatial parameters

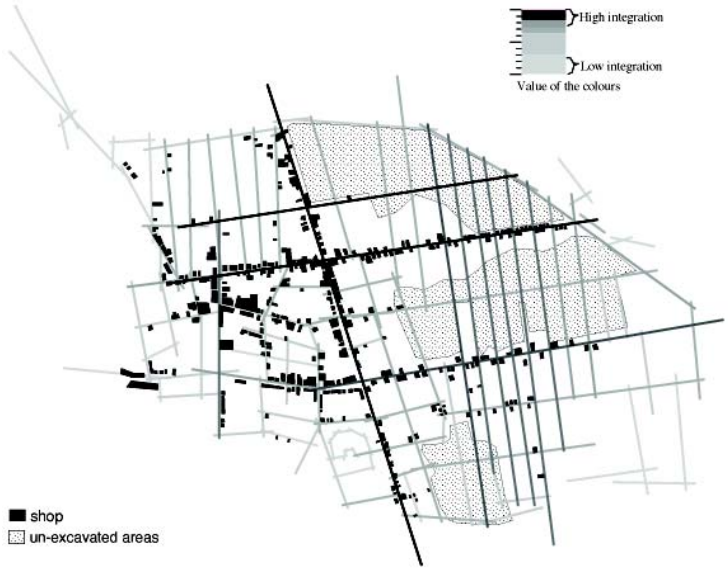

Figure 1:
Global integration analyses of Pompeii with location pattern of shops

The two highly spatial integrated main cross streets are planned according to the ideal roman city planning, the decumanus and cardus. Pompeii's oldest urban areas have an organic street net. At the moment of the eruption, it is slightly adjusted to the ideal roman town plan with its strict orthogonal street pattern.

The Forum is considered to be the most important meeting place in Roman towns. At the forum most important urban public buildings with their containing functions were located, such as temples, justicial centre, theatre, basillicum, and a marcellum (Laurence 1996, 20). These urban functions function as an attractor for human movement, in which also attracted economic activities. However, the forum has not the highest spatial integration values in Pompeii. It is located one topological step from the highly integrated decumanus. When analysing only Pompeii's oldest part (Reg. VII and VIII), the forum had the highest spatial integration values. Originally, it was thus the economical, political and religious centre of pompeii. At the time of the eruption, the economic activities had spread out to the highest integrated main streets as an effect of urban expansion.

A 2 steps analysis shows how much an area can be reached when changing directions two times from a particular street. When applying it on the most integrated streets or the main streets, it covers most of Pompeii's streets when changing direction two times from the decumanus and cardus. Moreover, the density of side streets is very high along these integrated main streets. As concluded, shops locate themselves in the most topological and metrical centrally located streets in Pompeii, like they do nowadays in most cities (van Nes 2005). The black pattern of shops (as indicated by the Eschebachs) corresponds with the global as well as local integration values from the macro scale analyses.

Figure 2
Above: Angular analyses of Pompeii with location pattern of shops; Below: Topological distance with a radius of 80 metres with the location pattern of water fountains

In the angular analyses, the decumanus and cardus are highlighted more than in the global integration analyses. The correlation between the location pattern of shops and the occurrence of graffiti on the walls (or messages) (Laurence 1996, 98) tend to be in streets with a high local angular integration value. One can presume that these streets were the most frequented ones than the others in Pompeii.

In his book, Roman Pompeii Space and society, Laurence identified the location of the various local neighbourhoods' centres on basis on the location of public water fountains and provision of high-quality drinking water (water towers). As he argues, these fountains would have been used by people living in close proximity to them and they probably functioned as a natural contact point between neighbours (Laurence 1996, 43). These water fountains were nearly always located at a street junction. If the water quality is equally distributed around the town, one can presume that the locals choose the closest located water fountain. When carrying out topological analyses with short metrical radiuses, the same neighbourhoods' centres identified by Laurence is highlighted to have high local integration values in short metrical distances. Figure 2 (below) shows the location of the various local centres for the various neighbourhoods (or vicus) from the spatial topological analyses with a metrical radius of 80 metres. Presumably, there might exist two or three more local centres under the unexcavated areas. In these areas the streets have both high integration values and a high density of streets within a short metric distance.

When carrying out various point depth and all lines analyses of Pompeii's public spaces, the same results from the axial and segment analyses can be seen. Interesting enough, there must be a hidden strong local centre under the unexcavated areas in the eastern part of the town. One has to wait for the results from future excavations in order to confirm the results from the spatial macro scale analyses.

3 - Pompeii's micro scale analyses

Spatially, the focus in the macro scale analyses is on how one street relate to all others in a city, while the focus in the micro scale ones is on the spatial relationship between spaces inside buildings and the streets. More precisely, it aims at defining the inter-relationship of buildings or private spaces and adjacent street segments. The focus is on how dwellings relate to the street network, the way buildings' entrances constitute streets, the degree of topological depth from private space to public space, and inter-visibility of doors and houses across streets. As Jane Jacobs (2000) and Jan Gehl (1996) argue, many entrances and windows facing a street is one formula to ensure urban liveliness. The challenge is to quantify these kinds of spatial relationships. It is about measuring various degrees of urban active frontages on the relationship between buildings and streets. Only then it will be possible to gain a genuine understanding on the spatial conditions for vital street life and urban safety.

In a research project on space and crime in Alkmaar and Gouda, an opportunity was provided to register various spatial relationships between private and public spaces and compare the results with numerical social and economic data in a present context (López and van Nes 2007). In total 1.168 street segments were observed and 25 different spatial features registered for each segment. The results of the micro spatial registrations were put in a SPSS database, together with various macro scale variables derived from the space syntax analyses of the street and road net, and the number and characteristics of residential burglaries and thefts from cars for each street segment.

As the results from the spatial analyses in Gouda and Alkmaar show, both micro and macro spatial variables are highly inter-dependent for describing areas' degree of liveliness (López and Van Nes 2007). Especially the topological depth of a street segment in relationship to its nearest main route gives a detailed description of the spatial set up of the area. Most micro spatial variables turn out to be related to the macro scale variable local angular analyses. This variable identifies the main routes through cities and shows strong correlations with the micro-scale variables.

Through the Eschebachs' detailed registration of buildings it is possible to carry out the micro scale spatial analyses in Pompeii in only the excavated areas. All entrances in the excavated areas are directly connected to the streets. Pompeii has in comparison with other European cities a spatial well-connected and well-integrated street net. This might explain as to why there are almost no entrances hidden away from the public streets. When changing directions two times from Pompeii's main streets, one is likely to end up in streets with no or few entrances. However, they are still directly connected to the streets.

A street's degree of constitutedness depends on various degrees of adjacency and permeability from buildings to public space. When a building is directly accessible to a street, then it constitutes the street. Conversely, when all buildings are adjacent to a street, but the entrances are not directly accessible, then the street is un-constituted (Hillier and Hanson 1984, 94).

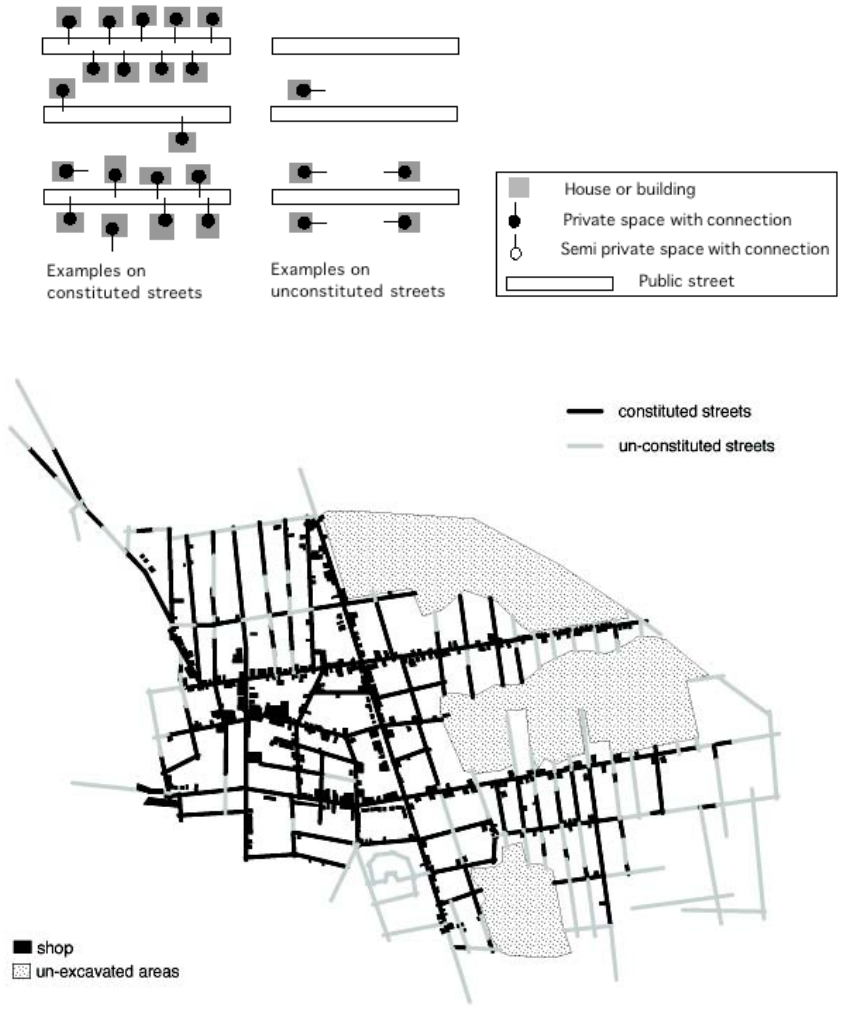

Figure 3
Above: How the degree of constitutedness is measured. Below: visualisation of the constituted and un-constituted streets in Pompeii with the location pattern of shops

The diagram in figure 3 (above) illustrates the differences between constituted and un-constituted streets. The number and density of entrances are not at issue. The degree of constitutedness is about the number of entrances connected to a street divided by the number of buildings located along that street.

Figure 3 visualises the difference between constituted and un-constituted streets in Pompeii. Un-constituted street segments are marked with a grey colour, while the constituted ones are in black. All the shops are located along the constituted streets. The more entrances connected to a street, the higher the probability that someone comes out from a private space into public space.

However, high density of entrances connected to a street does not always imply high inter-visibility. There is a distinction in the way entrances constitute streets and in the way they are inter-visible to each other. The way entrances and windows are positioned to each other influences the probabilities for social control and street life.

Figure 4 (above) shows some diagrammatic principles on the relationship inter-visibility and density of entrances. In Pompeii the percentages were grouped in 100%, 50% and 0% inter-visibility for each street segment. The density of entrances and degree of inter-visibility was registered separately. Thus, two buildings with two entrances facing towards each other indicate 100% inter-visibility of doors. Conversely, a street segment with high density of entrances on only one side of the street segment is defined to be 0% inter-visible.

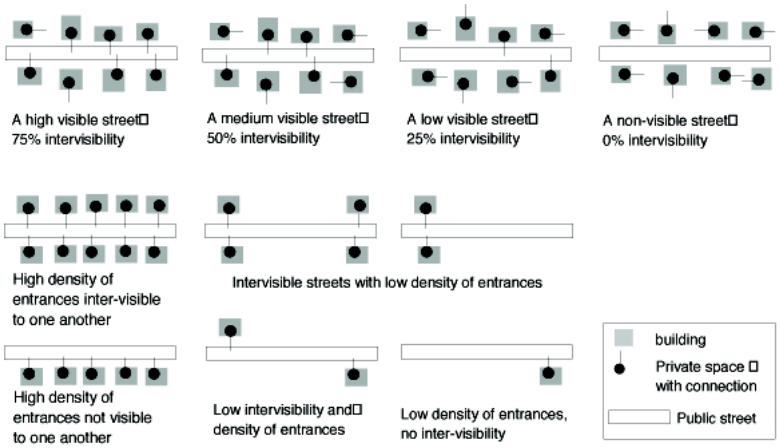

Figure 4
Diagrammatic principles on the relationship inter-visibility and density of entrances.

Figure 4 (below) shows an example on a street with low inter-visibility and low entrance density (left) and an example of a main street with high inter-visibility and high density of entrances (right). The left example is a typical back street with only dwelling entrances, while the right example is a typical main shopping street in Pompeii.

Figure 5 shows the density (above) and degree of inter-visibility (below) of entrances. The most integrated streets have the highest inter-visibility and density of entrances. When revealing the degree of constitutedness, it shows that Pompeii also had silent side and back streets with no entrances connected to it.

Figure 5
Example on a side street with low inter-visibility and density of entrance (left) and a main street with high inter-visibility and density of entrances (right) in Pompeii

A combination of various micro and macro spatial measurements makes it possible to gain spatial data for testing on socio-economic data and provide understanding on the spatial conditions for safe and vital urban areas. Through the use of Depthmap software, various macro scale spatial variables can be calculated and visualized. For example, a street with few connections to its vicinity (macro scale analyses) can still be full of social activities if a high density of entrances constitutes the street and when there is high visibility between public and private spaces (micro scale analyses). The reverse can be seen in un-constituted streets with a low number of entrances and low inter-visibility, but where the connections to other streets are high. Independent of cultures and architectural styles, micro spatial measurements make it possible to describe the spatial set up of built environments on a local scale level.

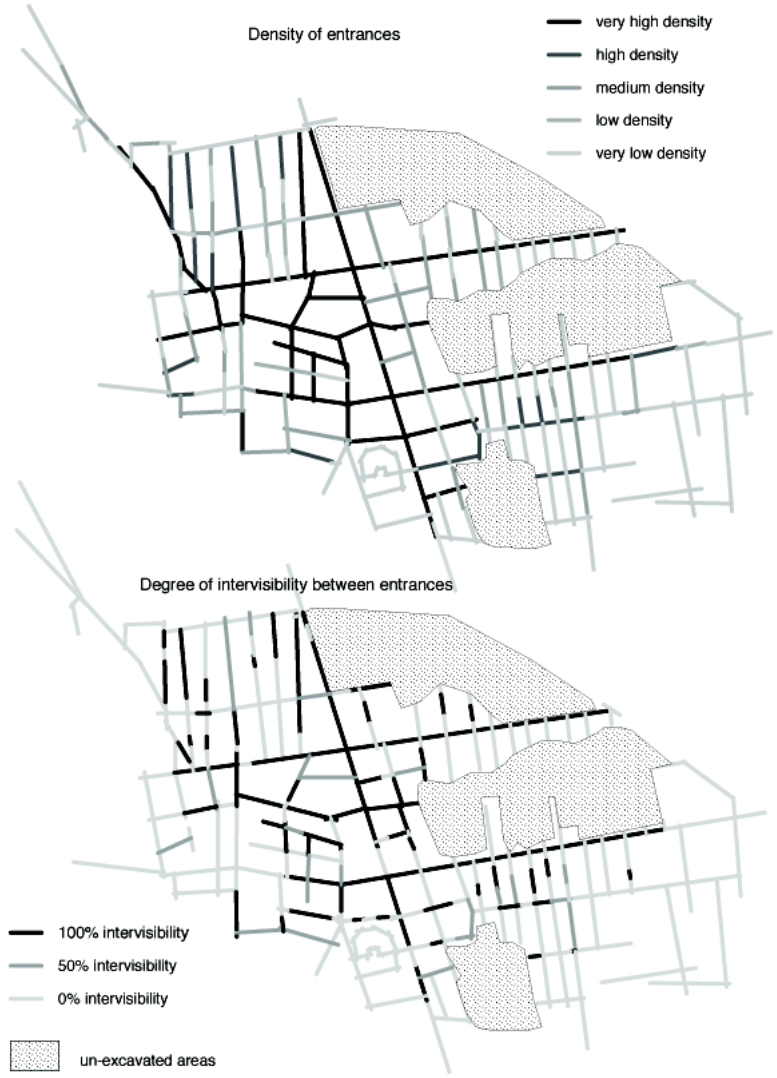

Figure 6
Entrance density (above) and degree of inter-visibility between entrances (below).

The following results were obtained for a present urban context: The further away a street segment is from the main routes net, the greater the topological depth between private and public space. Along the main routes through urban areas, most entrances are directly connected to the street. When changing direction two times from the main routes, the average topological depth for entrances is 2 while it is 3 in all street segments that are located more than six topological steps from the main routes. Pompeii's orthogonal street grid is topological shallow. By changing direction on time from the main routes, which is cardus and decumanus, most of the town's streets are covered. Hence, all entrances in Pompeii are directly connected to the streets.

As research has shown in a present urban context, the more segregated a street segment is, the more mono-functional the adjacent buildings tend to be. Topological deeply located street segment usually only have a residential function, since offices, shops and public buildings tend to locate themselves along the main routes. The semi-private segments are among the topological deepest and segregated streets (López and Van Nes 2007). In Pompeii dwellings entrances tend to dominate the side streets, whereas there is a large mix of urban functions along the cardus and decumanus.

The further a street segment is away from the main routes, the lower the values of spatial integration and constitutedness. The un-constituted back alleys tend to be the most segregated street segments.

As the study of street segments in a present urban context clearly shows, the micro spatial conditions of the street segment are inter-related to the macro spatial conditions of the cities' street network (López and Van Nes 2007). The definition and operationalisation of the micro scale conditions is, however, still in a preliminary phase and an area that can be improved upon in the near future. At least, some concepts useful are introduced in order to describe and analyse the relationship between space and society on urban micro scale level for excavated towns.

4 - What space syntax adds to archaeology

How do the spatial analyses of Pompeii contribute to an understanding of the social and economic life in past built environments? Through putting all archaeological data from the Eschenbachs and the results from the various spatial analyses in different layers in auto-cad or GIS, it is possible to visualize the correlations between various data. Moreover, by using SPSS, multi-variable analyses between macro and micro spatial parameters and socio-economic data from the past can be carried out. Given the archaeologists' detailed registrations of the various functions inside buildings, the following can be said:

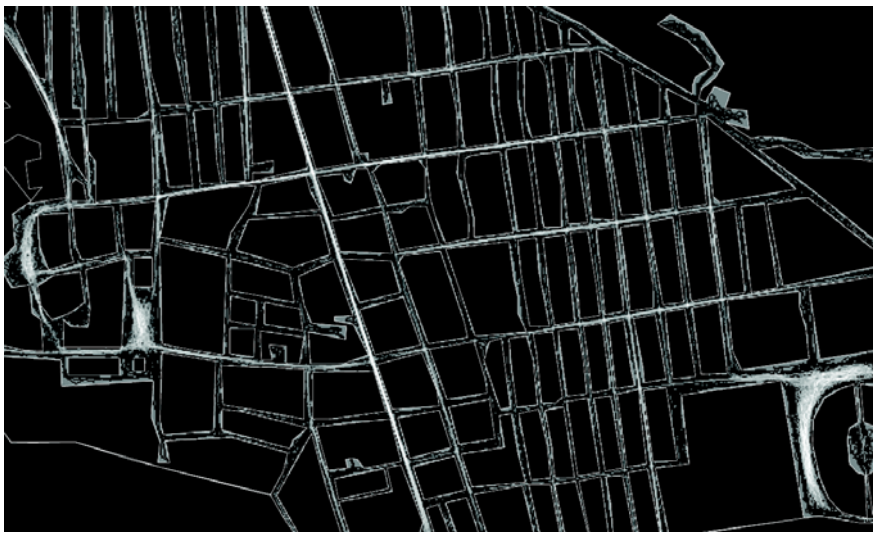

Figure 7
Agent based modelling of Pompeii's public spaces

Shops and bakeries locate themselves in the most integrated streets with high number of connections to other streets in a short metrical distance. Moreover, the entrances along these streets are directly connected to the street, have a high density and high degree of inter-visibility. Religious buildings (such as temples) and political institutions locate themselves one topological step (or one direction change) away from the most integrated streets. They are never located along or at the end of the integrated main streets. The entrances around these buildings have low density, but they still constitute the streets. Brothels locate themselves in constituted side streets

metrically close to the integrated main streets. However, the workshops, taverns and drinking places are located along the main streets and in side streets topological close to the main streets. Conversely, the public baths, theatres, inns or hotels, sport and leisure facilities are spread around through the town's street net.

Presumably, the largest flow of pedestrians and horse with carry traffic occurred along the highest integrated streets. Figure 7 shows the traces of 1500 people moving inside Pompeii's public spaces from the agent based modelling in Depthmap. The way computer generated agents choose their routes is dependent on the angular deviation of their moving directions. It has been tested out in a present context in galleries. When comparing figure 7 with the spatial analyses, the highest locally and globally integrated streets (from the macro scale analyses) combined with the highest density of entrances (from the micro scale analyses are the most frequented urban spaces.

In general, it can be said that the way a society organise its functions spatially and the way its spatial structure affects human behaviour in terms of the location pattern of its activities has not changed much in 2000 years. The same tendencies on space and human behaviour can be seen in urban centres in present cities.

Micro and macro spatial relationships play a crucial role in the socio-economic life of human beings in built environments. All these activities depend on how the spatial configuration is on the plinth or built up street sides. It is at the street plinth where the micro scale and macro scale analyses are inter-connected, in which determinate the degree of liveliness in streets. The micro spatial structure of urban street plinth affects the direct interface of public and private life of a built environment's inhabitants and visitors in an informal way. It has always been like this in built environments. Even through Pompeii's street net was planned according to the roman ideal city ideas with its strict orthogonal street grid with two main cross streets intersection in the middle, the location process of buildings along streets occurred naturally. The most integrated and crowded streets had the highest attraction for the location of an adjacent building's entrance. Hence, a street net's macro spatial structure affects the degree of attractions of economic and social activities. In Pompeii most entrances are packed together at the shortest sides of their blocks (or insulas) due to high spatial integration values on the streets on that side. These micro and macro spatial conditions made it optimal for exchange of goods, shopping activities, social interaction and vital street life in Pompeii's main streets.

Since Pompeii offer a comprehensive set of data of archaeological artefacts which make a precise registration of the various buildings' content possible, what are then the challenges for future application of spatial configurative methods on other excavated sites? In the first instance, a reconstruction of a town's street pattern must be available. It is the necessary base for the macro scale spatial analyses. This makes it possible to indicate the spatial potential for the degree of street vitality and street life. Secondly, precise registrations of walls and entrances provide the base for the micro scale spatial analyses. In cases where it is impossible to get an idea over a site's whole street net, a micro scale analyses can to some extent give the spatial indications on how lively or quit a street probably was in the past. Herculaneum represents a town of this kind, where larger parts are still un-excavated. Its present 12 excavated street segments show a large variation in inter-visibility, permeability and adjacency between private and public space on the street plinth level. It is at least a beginning for indicating various degrees of street life in past built environments.

What does the application of space syntax and the micro scale tools add to archaeology? It contributes to understandings on how cities function on the relationship between spatial layout and socio-economic activities. The spatial analyses of the street net give indications on possible functions in adjacent buildings where identifiable artefacts are lacking on archaeological sites. Finally the statistical data from the micro and macro scale spatial analyses and the agent based modelling can give indications on the degree of vitality in shopping streets and where the largest flow of human movement took place in the past.

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