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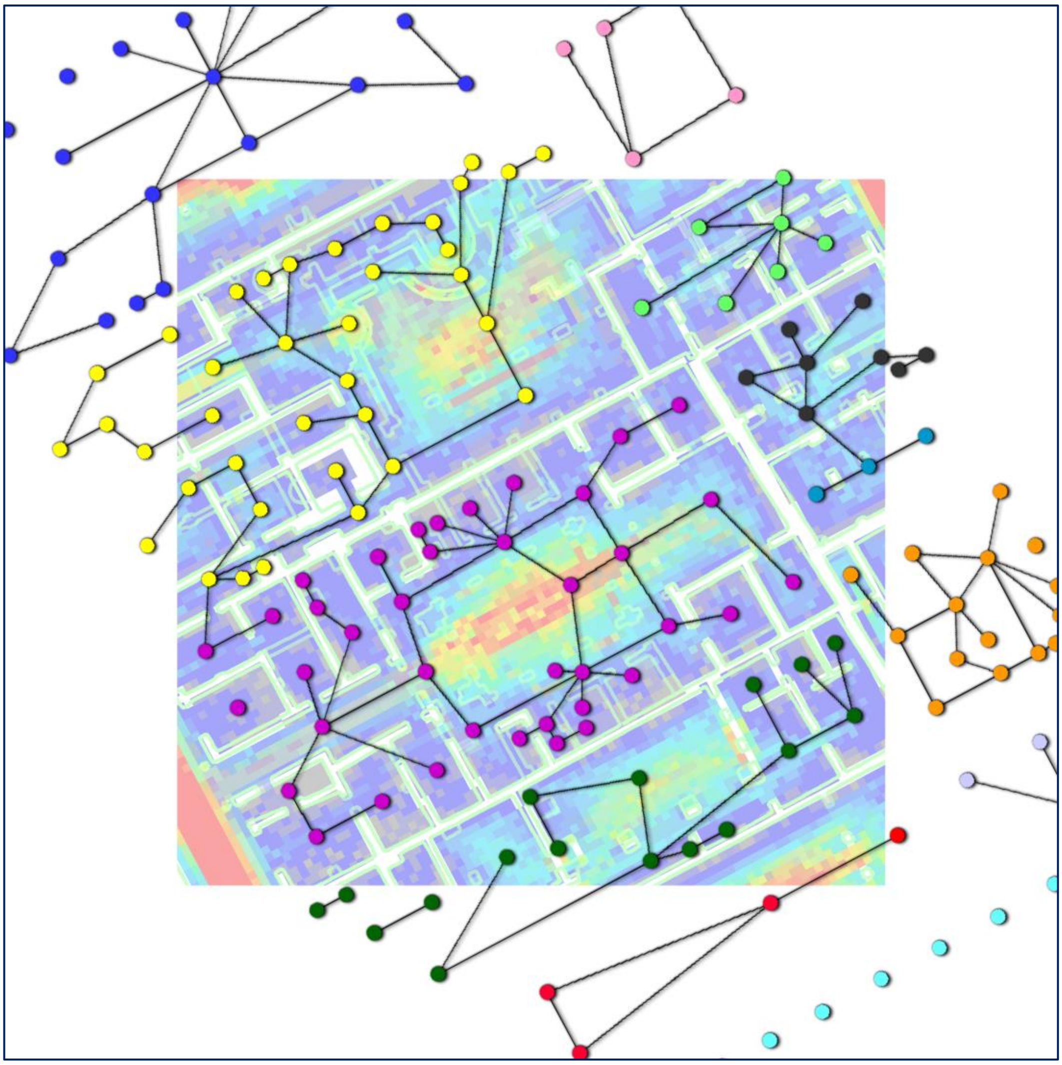
Applying space syntax methods to insula V ii in Ostia

To gain new insights into the effects of changes in the spatial organisation of urban buildings during the Late Roman Empire

Alexander C.Q. Jansen



2 July 2018

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Cover image: Section of the topological graph (excluding the root node) of the final phase of insula V ii, shown on top of two agent analysis graphs (ABM) of the Severan and final phase merged together (by author).

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Master's thesis

Dr Lambers

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In memory of dr. Hanna Stöger (1957-2018),
an amazing and caring supervisor.

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I would also like to thank Mark Locicero for his advice and interest in my research.

1. Introduction

This thesis presents a spatial study of city block V ii located in Ostia, the principal port city of Imperial Rome. In order to gain a better understanding of how people lived here or how they could have experienced this city block, space syntax methods are applied to perform a spatial analysis of the architectural remains of the buildings. In this study, an innovative approach is taken. The analysis focusses on changes in the same buildings, instead of on a comparison between different structures or on testing the effects of hypothetical scenario's. Two different temporal phases of the city block are compared with each other to examine how the city block changed over time, and how these changes affected the inhabitants. The space syntax methods are combined with basic statistical analysis in order to assist with the interpretation of the computed data. As space syntax was not originally developed for use within the field of archaeology, multiple ways to present the data are used in this study. These are then discussed to identify the approaches that allow for interpretations that are relevant to archaeologists. Based on the results of the case study, recommendations are given for when and how to apply space syntax methods on archaeological datasets.

The results of the analysis are compared and contrasted with previous archaeological interpretations of city block V ii, as published in *Amoenissima civitas: Block V.ii at Ostia: description and analysis of its visible remains* (Boersma 1985). This publication presents a description of the visible remains, a structural analysis of the walls, a descriptive analysis of the buildings, and a reconstruction of the history and chronology of the buildings. Boersma's descriptive analysis addresses the possible function(s) of spaces, dates of construction or remodelling, possibilities for (now mostly missing) ceilings, upper floors and windows, the brightness of rooms, the use of plaster on walls, and drainage methods. Additionally, suggestions for reconstructions are discussed and presented as isometric drawings. Boersma's isometric reconstruction of the final phase of the city block (c. 400-500 AD) has been included in appendix F2.

The spatial analysis is performed using space syntax methods. Space syntax consists of a set of theories and techniques for the analysis of the layout of space. It is mainly used in the fields of architectural and urban research and design (Al-Sayed *et al.* 2014, 7) to aid in our understanding of the social aspects of urban space, and to predict how it will influence human movement. Moreover, it allows us to explore space systematically and in a quantitative manner (Weilguni 2011, 11). According to space syntax theory, knowledge of social relations is embodied in the spatial structure of the built environment. The concept of space represents more than a physical location, as space "encodes, communicates and reproduces social meaning" (Stöger 2014, 298).

The space syntax methods are applied on a Roman city block in Ostia Antica, the port-city of Imperial Rome. The Ostian city block which is now known as insula V ii has been selected as a case study for this research. An *insula* is a building or conglomeration of buildings which is separated from the surrounding structures by streets on all its sides, or clearly divided from other city blocks in another manner. Insula V ii is a city block located in the south-eastern part of the city (fig. 1 and 2, appendix A1 and A2). It is referred to by the Roman numerals V and ii: "V" refers to its location in the fifth region of Ostia (fig. 1), and "ii" identifies it as the second insula within this region. This modern numbering system was first presented in *Scavi di Ostia I: Topografia generale* (Calza and Becatti 1953). The city block is bordered by four streets: the Semita dei Cippi to the west, the Via della Fortuna Annonaria to the north, the Via della Casa del Pozzo to the east, and an unnamed street to the south. It should be noted that the names of the streets in Ostia are of modern origin (Newsome 2011, 12), with one exception, which is discussed in section 2.2.2.

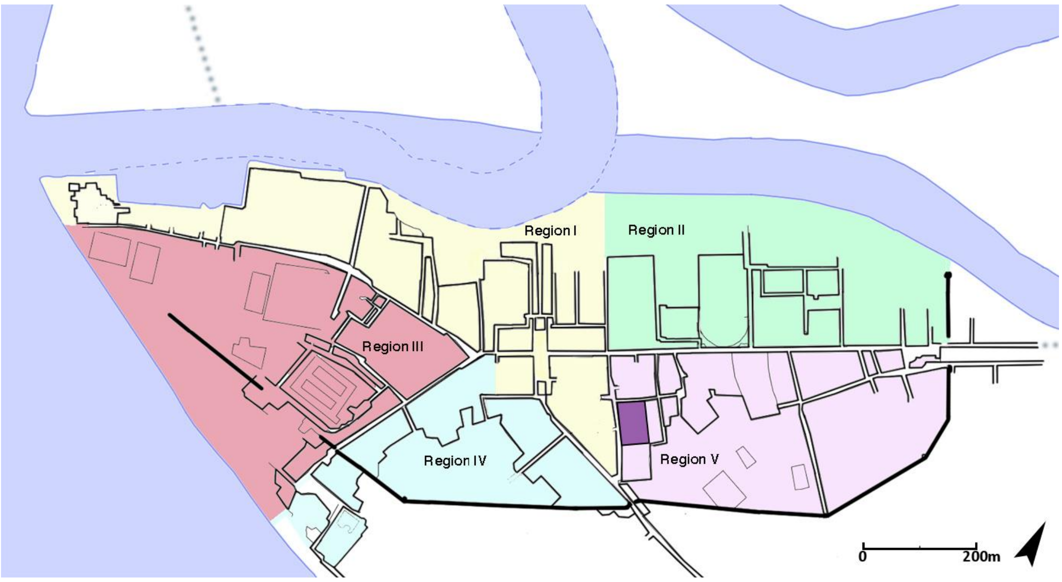


Figure 1: Overview of the five modern regions of Ostia Antica. These regions were established by the excavators and are delimited by Ostia's major streets. Insula V ii, coloured purple, is located at the western border of Region V. The present-day course of the Tiber is marked with dotted lines (commons.wikimedia.org).

Figure 2: Satellite photograph of Ostia, with insula V ii marked red (after anonymous author via mapknitter.org, based on satellite photographs from Google Earth, 2007).

Using insula V ii as a case study allows for the juxtaposition of the two different approaches: a traditional archaeological interpretation directly based on archaeological remains, and a spatial analysis (in which only the layout of the buildings is analysed) based on space syntax theory. This is further explained in section 1.2. Insula V ii is particularly suitable for this purpose due to the relatively accurate and detailed, but also underused, data which has been made available by Boersma's publication. In this thesis, space syntax methods are used to compute and interpret the relative accessibility of the spatial units in the buildings. This can be used to estimate the degree of privacy of the spaces. By combining several methods, it becomes possible to learn more about past life in an urban environment, about the insula itself, and about possible motivations for architectural changes in this city block.

In order to learn more about the city block, this thesis studies the development of insula V ii by focussing on two major phases. The architectural remains of the insula date show a long history of occupation, lasting for at least seven centuries, from the first century BC (or possibly earlier) up to at least the sixth century AD (Boersma 1985, 7-8). The chronology of the insula is further discussed in chapter 2.

This thesis presents guidelines for applying space syntax methods that can be understood by archaeologists without a background in architecture. The dataset used for the space syntax analysis does not include the archaeological finds. It focusses only on the spatial organisation of the spaces. On the other hand, in Boersma's publication, conclusions on the history of the buildings and their functions were drawn from both the architectural remains and archaeological finds. Based on a comparison between the results of this study with those from Boersma's publication, recommendations are given on how to handle datasets that only consist of plans of structures. This could be helpful for researchers who are trying to find an approach for getting the most out of incomplete datasets (e.g. archaeological sites where most archaeological finds have been lost or destroyed, and only the architectural remains can still be studied). Such an approach may also prove useful for the analysis of plans which have been derived from geophysical data. Datasets produced by methods such as ground penetrating radar and electrical resistivity, may become more common in the future due to the increasing preference towards non-invasive research. It is difficult to use the data that is obtained by such research to reconstruct the changes in the spatial organisation of individual structures, as such data does not show their time depth, construction history and history of use. Nonetheless, such data could still be used to reconstruct a general image of the street networks of unexcavated cities, which could then be spatially analysed. In this thesis, the space syntax methods are used in a way primarily aimed towards the detailed analysis of structures, which is most suitable for increasing our understanding of buildings that have already been excavated.

As several Latin terms are used, a glossary is included at the end of this thesis with brief definitions. The first time such a term is used, it is shown in cursive and explained.

1.1 Status Quaestionis

Considering the large size of the excavated part of Ostia, the amount of research that occurred and the number of publications about the site were relatively low prior to the 1990s (Stöger 2011, 1). What follows is a short overview of several notable publications about Ostia. The first volume of the *Scavi di Ostia* (Calza and Becatti 1953), a series on the excavations in Ostia, was published in 1953. This publication is a topographic index of all buildings within the excavated area, and it provides dating indications for structures based on brickstamps. It also presented the modern numbering system of the insulae and structures, as well as information on the history of research. Since then, additional volumes were written, with volume 15 *Insula delle Ierodule* (Falzone and Pellegrino 2014) being published in 2014. In 1960, Russel Meiggs published his historical study of the city, titled *Roman Ostia*. A second edition, including new archaeological and historical data, was published in 1973 (Meiggs 1973).[1] Carlo Pavolini published a detailed archaeological guide in 1983, titled *Ostia* (Pavolini 1983), and in 1986 the book *La vita quotidiana a Ostia* (Pavolini 1986). Since the 1990s, the situation has improved. The number of individual researchers and Italian and international research teams has increased. For example, the geophysical research and targeted excavations of the DAI Forschungsprojekt Ostia from 1996–2001 (Bauer *et al.* 2000, 375-415), allowed the estimated extent of the city to be extended greatly. It is now thought that the excavated area is just roughly a third of the entire city, and that only the central areas of the city have been excavated (Stöger 2011, 68).

Insula V ii was first excavated in 1940, during Benito Mussolini's rule. The documentation from this period is severely lacking, as this was done mainly through hand-written notes (Boersma 1985, 1). However, the city block was extensively documented in the seventies by a team from the University of Amsterdam, led by Johannes Boersma. The fieldwork occurred between 1973-1976. Their documentation, as published in *Amoenissima civitas*, represents the state of the architectural remains in those years. To date, no research focussing on an analysis of the spatial organisation of insula V ii has been conducted. This is possibly due to the complex nature of Boersma's publication, which is further discussed in chapter 2.3. References to insula V ii in scientific literature are generally limited to relatively small sections of the city block, e.g. focussing only on a single building or feature. For example, in the eleventh volume of the *Scavi di Ostia*, on the subject of bathhouses in Ostia, only building V ii 6-7 is mentioned, as a large part of this structure consists of a bath complex known as the Terme del Filosofo (Cicerchia and Marinucci 1992). Several buildings are also mentioned by Ricciardi and Scrinari, who studied the water infrastructure of Ostia (Ricciardi and Scrinari 1996a and Ricciardi and Scrinari 1996b). The lack of

[1] Only the second edition from 1973 will be referred to in this thesis.

further research provides an excellent opportunity to analyse insula V ii with space syntax methods in order to learn more about the structures as well as about the methods themselves. This city block offers a great opportunity to apply the non-destructive methods that have been selected for this study.

Space syntax was pioneered by Bill Hillier and Julienne Hanson in the late 1970's (Stöger 2011, 43). Their publication *The Social Logic of Space* (Hillier and Hanson 1984) first presented the conceptual framework of space syntax. The research area of space syntax was developed in the context of "architectural design and movement in small-scale regions of the built environment, but has been extended to apply to much larger urban areas" (de Smith *et al.* 2007, 343-4). Since 1984, Hillier and his colleagues at University College London (UCL) conducted research on how space features in the form and functioning of buildings and cities (Hillier 2007, i).

1.2 Research question

This thesis seeks to contribute to the use of space syntax method in the field of archaeology. The analysis and interpretation of the archaeological remains presented by Boersma (1985, 11-189) focussed on the individual buildings. The focus of Boersma's analysis lies on understanding and documenting the different construction styles and materials, and on proposing a chronology of the buildings. Based on the data from this tentative reconstruction of the building phases, he created a general account of the development of the block as a whole (Boersma 1985, 201). This also resulted in several reconstructed plans of different phases of the insula (appendix A). These plans are used as the basis for the space syntax in this study. The dataset that is used to answer the research questions consists mainly of the plans of the Severan and final phase of the insula.

This study includes a comparison of Boersma's descriptive analysis with the results of a new spatial analysis. This comparison is used to investigate what new insights can be gained into buildings and their use by applying space syntax methods on an archaeological dataset. The comparison also allows for an evaluation of the selected methods. Additionally, it can be ascertained if, and discussed why, conclusions based on these two different approaches are contradictory.

This is done by attempting to answer the following question: Which of the four selected space syntax methods are of the most explanatory value for the analysis of changes in of the interior spaces of buildings, taking the required time and effort into consideration? The following two sub-questions are interdependent and collectively seek to answer the principal research question:

1. What changes occurred in the spatial organisation of insula V ii (Ostia, Italy) between the Severan phase (c. 200 AD) and the final occupation of the insula (c. 400-500 AD)?
2. What new insights are gained through this space syntax approach, compared to Boersma's interpretations?

1.3 Structure of the thesis

This thesis consists of six chapters. **Chapter one** serves as an introduction and presents the research questions of this thesis. In the Status Quaestionis, the current state of the research on the topics of space syntax and Ostia is discussed. In **chapter two**, the dataset is presented. In order to understand the changes which occurred in insula V ii, it is important to be conscious of the context in which they occurred. Thus, this chapter also contains background information on the city of Ostia, and the history of insula V ii. Additionally, the location of the insula within the city is briefly discussed.

Chapter three introduces the reader to the main concepts of space syntax, discusses how space syntax is being applied in archaeology, and explains the methodology used for answering the research question of this thesis. The techniques are explained in the order in which any prerequisite knowledge is already explained in the previous section. The workflow that was developed during this study is also explained and presented, so that it can be used as a guideline for future applications of space syntax in archaeology. As both the theory and the workflow are explained, it is hoped that this will make these methods more accessible to archaeologists without a background in architecture, as the handbooks for these approaches have been developed for architects and are thus not aimed towards archaeologists.

The subsequent chapters 4 and 5 form the core argument of this thesis. In **chapter four**, the analyses and the results from applying these methods on insula V ii are presented. First, the results of the access analysis are presented and interpreted. This is followed by the isovist analysis and visibility graph analysis. Lastly, the results of the agent-based model are interpreted. The chapter closes off with an overview of the results of the analysis, which are used to reconstruct the functions of the individual spaces. These are presented separately for both the Severan and final phase and compared with the functions in the final phase suggested by Boersma. In **chapter five**, an overview of the outcome of the spatial analysis is presented and compared with Boersma's statements and conclusions about insula V ii. Additionally, an assessment of the advantages and disadvantages of each method is presented. In the **concluding chapter**, the answer to the research questions are presented and discussed. This chapter also discusses future directions for research on space syntax.

2. The Roman city of Ostia

This chapter offers historical background information on the ancient city of Ostia. The city has a long and diverse history, which should be taken into consideration when analysing architectural changes during a period of over two centuries. The same can be said about the historical context. The Roman Empire was certainly not stagnant between the late second and early fifth century AD. Next, insula V ii is discussed in more detail. Lastly, this chapter also presents the dataset used for the analyses in chapters 4 and 5. Unless specified, years mentioned in this thesis refer to dates in AD, not BC.

2.1 Ostia Antica

2.1.1 Ostia in Antiquity

Ostia has a long and rich history, ranging from the Bronze Age and the earliest beginnings of Rome up to the early medieval period. During its lifetime, the nature of the settlement changed multiple times. These major transformations shaped the history of the city.

The earliest evidence of human activity in the region surrounding the archaeological site of Ostia is associated with salt processing during the Bronze Age (Stöger 2011, ii). Pottery finds from the fifth century BC suggest that settlers already lived in this area at that time (Meiggs 1973, 579). There may have been a small settlement located close to the salt flats (Becker 2007, 46-7), fig. 3, which could be regarded as a precursor to Roman Ostia. Alternatively, Bispham (2000, 158) suggests that the Archaic pre-Roman settlement was located at or near the site of Ostia.

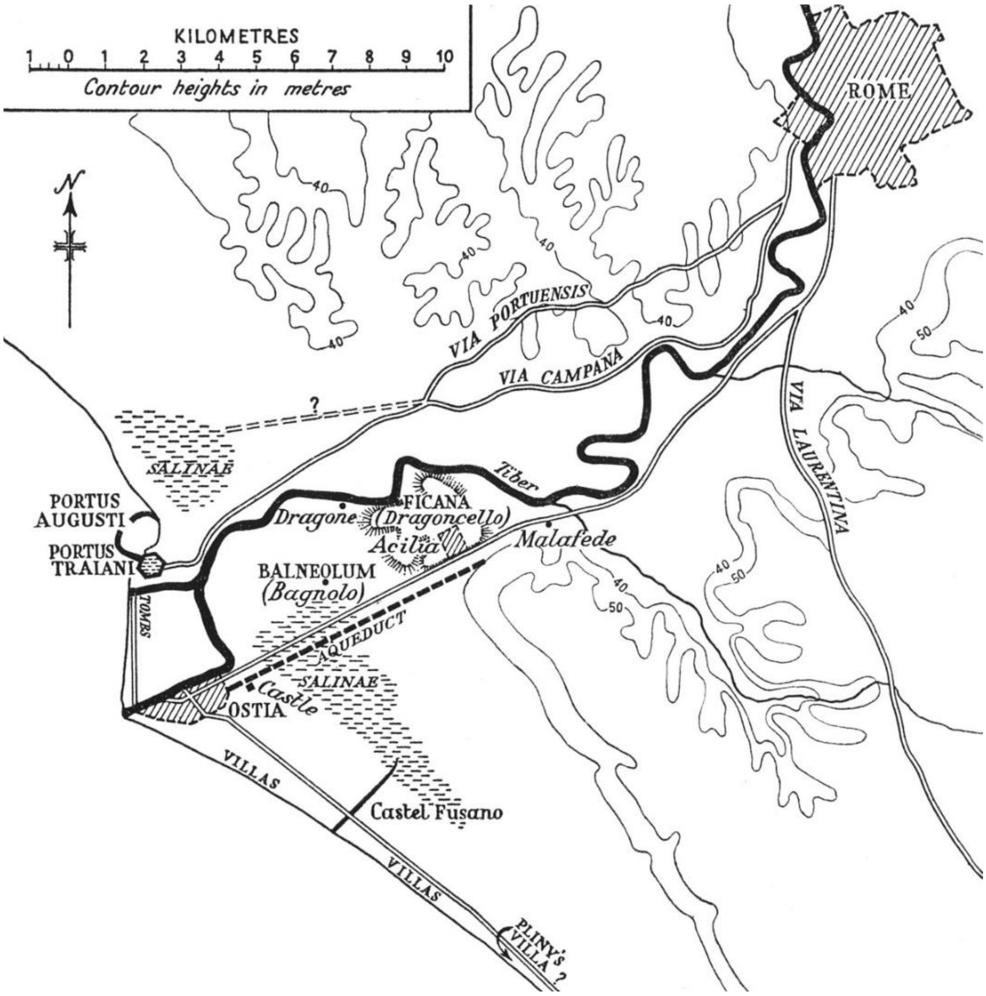


Figure 3: Map of the area around Rome and Ostia, showing the geography, roads, and other key features such as the 'salinae', or salt flats (Meiggs 1973, 112, fig. 1).

The founding date of Ostia is difficult to establish. The *castrum*, a military structure, is the earliest known evidence of Roman presence at Ostia (Stöger 2011, iii). Some modern authors consider this as the start of Ostian history (Hermansen 1981, 3). According to myth, the fourth king of Rome, Ancus Marcius, founded Ostia during the seventh century BC. However, this myth originated sometime during or before the end of the third century BC (Meiggs 1973, 16), so it should not be used as a reliable source of information. This date cannot be confirmed based on archaeological evidence (Becker 2007, 46-7).

The castrum was built c. 300-275 BC, and its military nature suggests that it may have functioned as one of the *coloniae maritimae* along the Tyrrhenian coast, intended to secure the coastal lands. It functioned primarily as a naval base (Stöger 2011, iii). Ostia grew, and by the end of the third century BC, the settlement already exceeded the boundaries of the castrum (Bispham 2000, 158 and 171). It gradually developed into a commercially focussed harbour city which supplied both Rome and its own growing population (Stöger 2011, iii-iv). Ostia supplied Rome with foodstuffs as part of the *annona*, the grain supply, with grain from Egyptian and African sources likely being the principal imported commodity (Keay 2012, 2-3). After the Punic Wars the number of soldiers and navy ships in Ostia was probably reduced, although its naval importance did not immediately decline (Bispham 2000, 172). However, during the Republican period the military function of the settlement slowly diminished (Stöger 2011, iii-iv).

Ostia underwent another transformation during the late first and early second century AD. Rapid urban expansion occurred, commonly associated with the increase in trading volume caused by the construction and extension of the port facilities at Portus (Stöger 2011, iv). Supplying Rome was a logistical challenge, and additional capacity was needed. Portus was an artificially constructed port, located 3 km to the north of Ostia, which dwarfed the river harbour of Ostia (Keay 2012, 2 and 34-41). Nonetheless, the city limits of Ostia continued to expand in all directions (Stöger 2011, iv). This development could be explained by a relative lack of control exerted by public institutions (Stöger 2011, 12). Ostia could even be described as a 'boomtown', a settlement with a combination of weak public institutions and a highly competitive private economy focussed on production (Stöger 2011, 7). During the reign of Claudius, the first large horrea were constructed, and under Trajan construction activities intensified (Calza and Becatti 2008, 11). Horrea are warehouses or storage buildings (Stöger 2011, 300). The intense building activities continued during the Antonine and Severan periods (Calza and Becatti 2008, 11).

During the third century, there was a noticeable decrease in building activity (Calza and Becatti 2008, 12). The growth of the city slowed down, but it continued to be prosperous (Stöger 2011, iv). Ostia remained a centre of population, commercial transactions and administrative activities until at least the fourth century AD (Keay 2012, 2). However, Ostia lost its political autonomy around the middle of the third century (Meiggs 1973, 84). Additionally, the establishment of Constantinople as the 'New Rome' in 330 AD, meant that Rome no longer had direct access to the supply of grain from Egypt. This also included the marble quarries and gold mines of the Eastern Desert, as well as papyrus, textiles and wine imported through ports from Egypt, mainly the great port of Alexandria (Keay 2012, 15). Nonetheless, during the fourth century, Ostia continued to have an active civic and religious life, reflected by the presence of multiple large, wealthy *domus* throughout the city, the restoration of baths, and the embellishment of several public buildings (Calza and Becatti 2008, 12). A domus is a term used for a Roman town house, a domestic building (Stöger 2011, 299).

While the number of Late Roman domus that appeared during the fourth and fifth century attest that a relatively high number of wealthy Romans lived in the city, other parts of the city were falling into decay (Stöger 2011, iv). As Ostia declined, marble decorations were stripped from buildings, civic authority was absent or indolent, and the remaining population lived between partially demolished buildings (Calza and Becatti 2008, 12). The site continued to be inhabited after the fall of the Western Roman Empire. When Rome was sacked in 410, Portus was captured as well. At this point in time, Ostia was a decaying city with an impoverished society (Meiggs 1973, 97-8). Pope Gregory IV (827–844) founded the settlement of Gregoriopolis nearby Ostia in order to remake the ancient city into a military outpost (Calza and Becatti 2008, 13-15). Gregoriopolis was little more than a stronghold of defence. Ostia itself was abandoned as a living-centre, and by the twelfth century only a handful of people still lived there (Meiggs 1973, 101-3). Under Pope Boniface IX (1389-1404), Ostia was incorporated into the Papal States (Calza and Becatti 2008, 13-15).

2.1.2 Excavating Roman Ostia

After the abandonment of Ostia during the ninth century, the site was exploited for several centuries before the excavations began. As the ancient city was not yet completely covered by earth, collecting marble would have been relatively easy. In 1191, a Papal Bull refers to a location close to Ostia as *calcaria*, or 'lime kiln', where marble was converted into lime. Evidence of medieval lime kilns can also be seen among the ruins of Ostia (Meiggs 1973, 102). Additionally, building materials were collected to be reused in new construction projects. For example, in the cathedral of Pisa, constructed during the eleventh century, an inscription refers to building materials taken from Ostia (Meiggs 1973, 102-3). From the fifteenth century onwards, the ancient city was systematically exploited for materials for buildings in Rome. During the Renaissance, people began collecting inscriptions, statues and other objects from Ostia. However, the random raids for movable 'treasures' further damaged the site. They broke through walls and left no record of the buildings that were unearthed. Many objects ended up in the private collections of European nobility, but most were eventually passed to national museums (Meiggs 1973, 103-5).

The plan in fig. 4 shows which parts of Ostia had already been unearthed by 1805. During the nineteenth century, private exploitation had been forbidden and official excavations began under the authority of the pope. The intention of these excavations was to uncover the ancient city as much as possible, to publish plans and accounts of the buildings, and, of course, to enrich the Papal Collections. The excavations took place at several locations scattered throughout Ostia between 1802 and 1804 (Meiggs 1973, 105). The Papal excavations ended in 1870, when Ostia came under the control of the newly established Italian government. From 1907 onwards, the excavations became continuous and were conducted systematically (Meiggs 1973, 108-9).

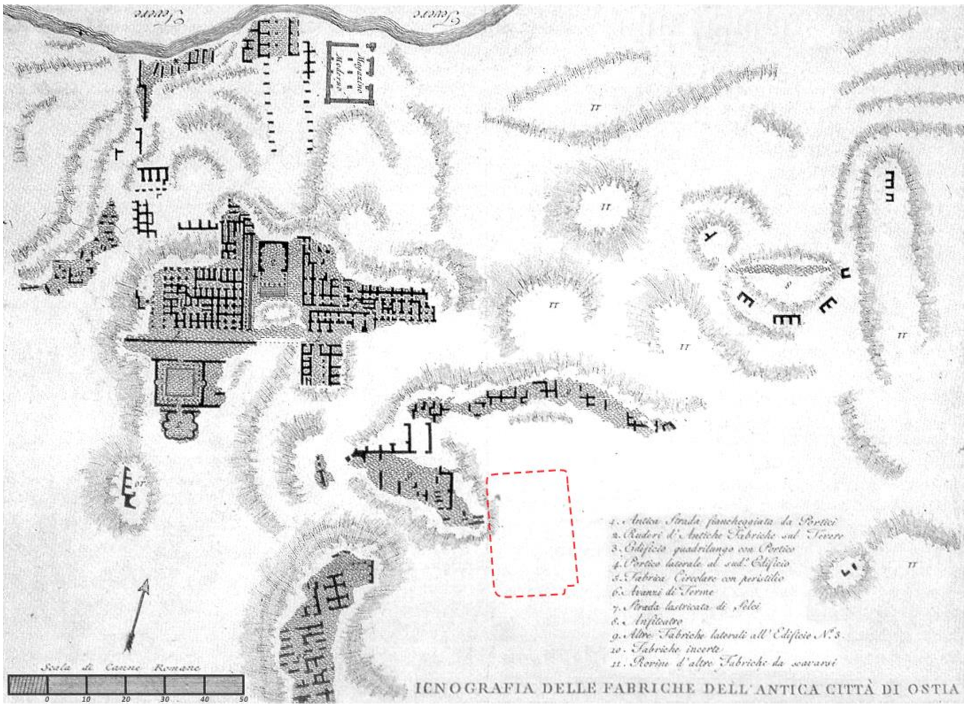


Figure 4: Plan by Zappati/Holl of 1805 of the excavated areas of Ostia, showing the estimated location of insula V ii in red dashed lines (after www.ostia-antica.org).

Between 1938 and 1943, under Mussolini's government, extensive excavations took place in anticipation of the (cancelled) Italian world exhibition of 1942. It is likely that during these years, valuable archaeological evidence has been lost (Meiggs 1973, 5). The hurried excavations resulted in relatively little documentation taking place (Boersma 1985, 1). Since the Second World War, the focus has shifted towards research on and conservation of the excavated areas, and towards non-destructive fieldwork, with only few new excavation projects taking place, such as the Porta Marina excavation by the University of Bologna (Orofino and Turci 2011, 393-402.).

2.2 Insula V ii

2.2.1 Development of the city block

In Boersma's publication from 1985, the multiple periods of building activity (table 1) are divided into major and minor building phases, although it is not possible to draw a sharp line between these two categories. Some small alterations to individual buildings also occurred between the phases, but these had little effect on the plans of the buildings. Boersma presented reconstructed plans of the whole insula for four phases: the Claudian phase (fig. 5), the Trajanic phase (fig. 6), the Severan phase (fig. 7), and the final phase (fig. 8). Only two phases, apart from the initial layout of the city block, were classified as major phases: the Trajanic and Severan phase. During these two periods, substantial changes occurred in a relatively short time (Boersma 1985, 209). Not much is known about the internal spatial organisation of multiple buildings during (fig. 6) and before (fig. 5) the Trajanic phase. The high degree of demolishment and rebuilding that took place during and after the Trajanic period contributed to the lack of information. This problem also applies to previous phases (Boersma 1985, 211-220).

Boersma used two ways to describe the time periods in his publication: exact dates in years, and construction phases. Most phases are named after an emperor or ruling dynasty. In order to clarify the history of the city block, an overview made by the author of this thesis is shown in table 1. Some difficulties were present during the interpretation of Boersma's building history. The oldest construction phase in the table, the pre-Sullan phase (before c. 80 BC), could not be dated with a high degree of certainty. Instead, the pre- or early-Augustan phase (before c. 30 BC, or c. 30–10 BC) could be the earliest phase that can be attested to (Boersma 1985, 209). Boersma did not specify the extend of the so-called "early-Augustan phase", so the year 10 BC (roughly halfway during the reign of Augustus) has been arbitrarily chosen as the end of this phase. Additionally, in several cases it was not specified whether the name of the phase refers to the reign of a single emperor or to an entire dynasty. Based on the dates used by Boersma, it is assumed that the Late-Flavian phase refers to the reign of emperor Domitian and that the Late Severan phase refers to the Severan

Table 1: Overview of the known building phases of insula V ii described by Boersma. Phases not named after emperors are only referred to by date. The unnamed phase of 500-600 AD refers to the construction of a bench in building V ii 8 (by author, based on Boersma 1985, 7-8 and 209-20).

Name of phase	Emperor	Reign	Building phase
Pre-Sullan	-	-	before c. 80 BC
Pre- or early-Augustan	- Augustus	- 27 BC – 14 AD	before c. 30 BC or c. 30 – 10 BC
Claudian	Claudius	41 – 54 AD	c. 50 AD
Late-Flavian	Domitian	81 – 96 AD	c. 80 – 100 AD
Trajanic	Trajan	98 – 117 AD	100 – 125 AD
Antonine	Antoninus Pius Marcus Aurelius Lucius Verus	138 – 161 AD 161 – 180 AD 161 – 169 AD	150 – 175 AD
Severan and Late Severan	Severus Severan dynasty	193 – 211 AD 211 – 235 AD	190 – 200 AD 200 – 235 AD
Post-Severan and later third century	-	-	c. 250 – 300 AD
Constantinian	Constantine	306 – 312 AD	c. 300 – 325 AD
Final	-	-	350 – 400 AD
Unnamed	-	-	an unknown year between 500 – 600 AD

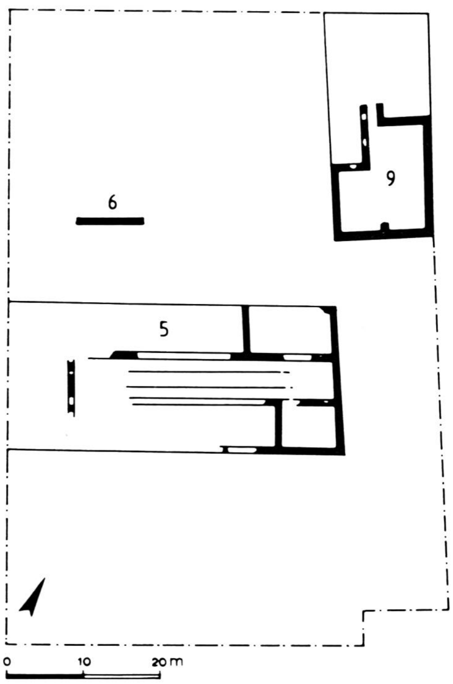


Figure 5: Plan of the registered remains of insula V ii dating to the Claudian phase (Boersma 1985, 210, fig. 200).

Figure 6: Reconstructed plan of the Trajanic phase of insula V ii (Boersma 1985, 212, fig. 201).

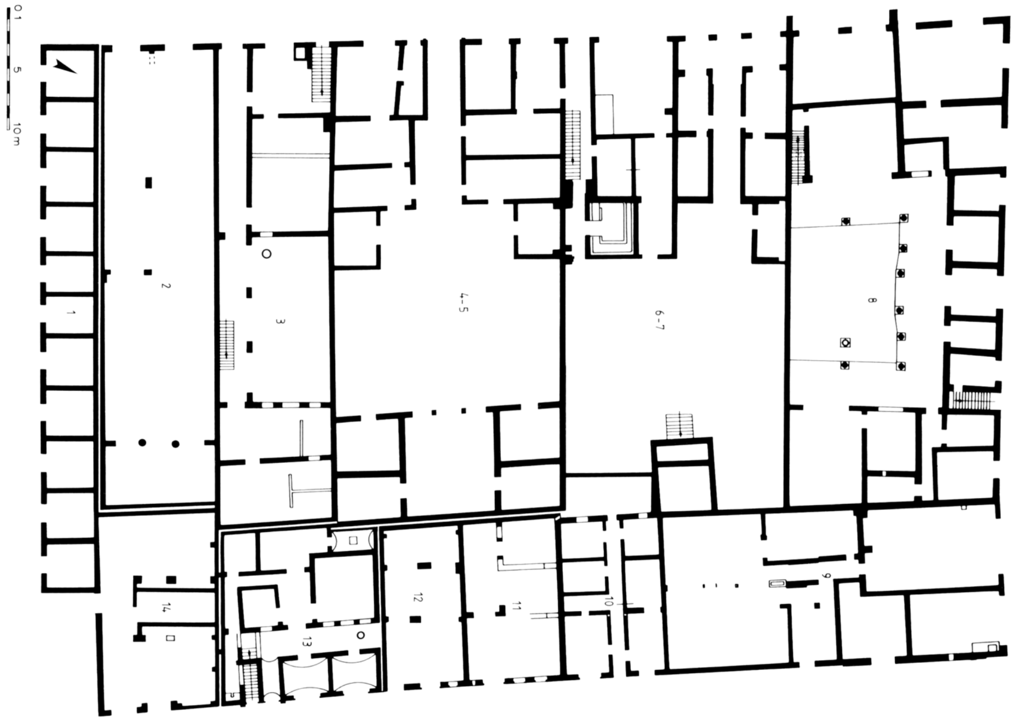


Figure 7: Reconstructed plan of the Severan phase of insula V ii (Boersma 1985, 218, fig. 202).

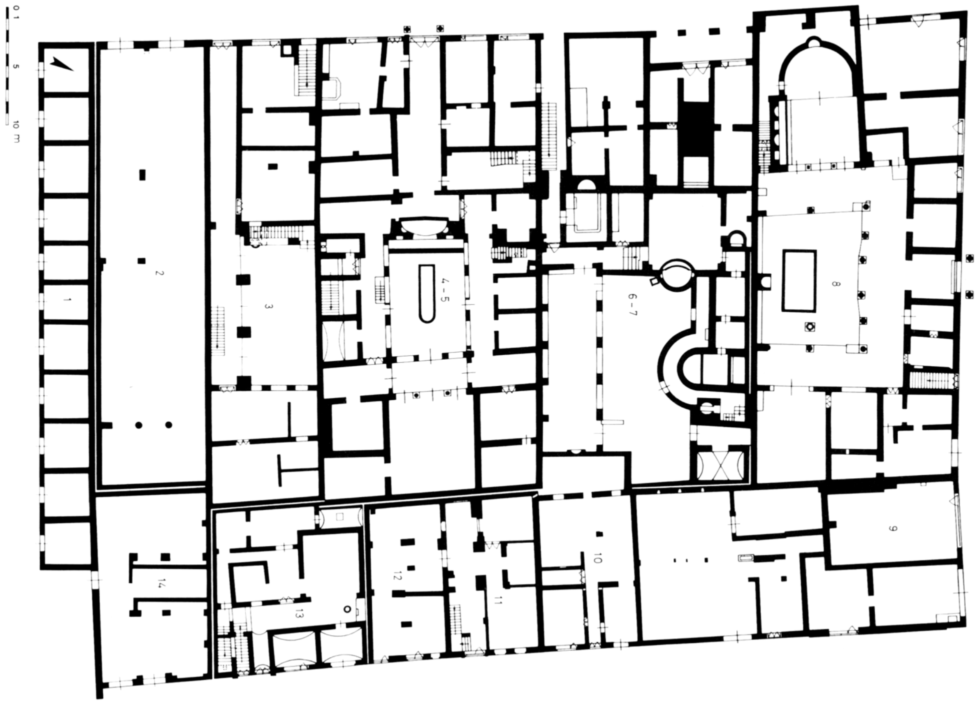


Figure 8: Reconstructed plan of the final phase of insula V ii (Boersma 1985, 214, fig. 204).

dynasty after the death of Septimius Severus. Thus, table 1 shows how the author of this thesis interpreted Boersma's chronology, based on dates assigned to the imperial periods. Recent excavations in building V ii 2 uncovered a more complex layout for this building (Petriaggi 1987, 193-200), as shown in appendix A10, than suggested by Boersma. However, these excavated remains pre-date the Severan phase and are thus excluded from the analyses in this thesis.

The construction phase of 350–400 AD is referred to as the 'final phase', as later changes are virtually non-existent (Boersma 1985, 209-20). Because of this, relatively much is known about the final phase. This is also the reason why this phase has been selected for this research, together with the preceding Severan phase of roughly 190–235 AD. This is discussed further in section 2.3. To study how the changes between these two phases affected visitors and the inhabitants of the insula, the spatial organisation of these two phases of the insula are analysed and compared with each other. However, it should be noted that the analyses performed in this thesis use the plans that include all architectural changes of their respective construction phase. Hence, the terms 'Severan phase' and 'final phase' refer to the period directly after the dates given by Boersma, with the end of these periods occurring at the beginning of the next construction phase. Using this definition, the Severan phase studied in this thesis refers to 235–250 AD, and the final phase to the period between 400 AD and the (gradual) abandonment of the city block at an unknown date. After 400 AD, very few architectural changes took place. It is not known exactly when insula V ii was abandoned, but some degree of continued habitation is suggested by archaeological finds. The only known architectural change after 400 AD is the addition of a bench in building V ii 8 during the sixth century (Boersma 1985, 7-8 and 219), which is referred to as the unnamed phase in table 1.

2.2.2 The streets of Ostia

The layout of the streets of Ostia suggests that the city grew more organically than later colonies, such as Cosa. The streets of Cosa, founded in 273 BC, were laid out in a straight, grid-like, pattern (Salmon 1969, 36-9). This layout could suggest that it was planned top-down to a high degree (Bispham 2000, 157). The irregular (not grid-like) alignments of the streets in Ostia (fig. 1) could thus suggest a lower degree of top-down planning. The layout of the main streets can be traced back to the original orientations of the roads which pre-date the city (fig. 9 and appendix A2). These roads were influenced by an archaic road system, which was used for the transport of salt (Stöger 2011, iii). After the construction of the castrum, the roads were redirected to its four gates. During the Republican and Imperial periods, these roads were further incorporated within the layout of the city as it grew.

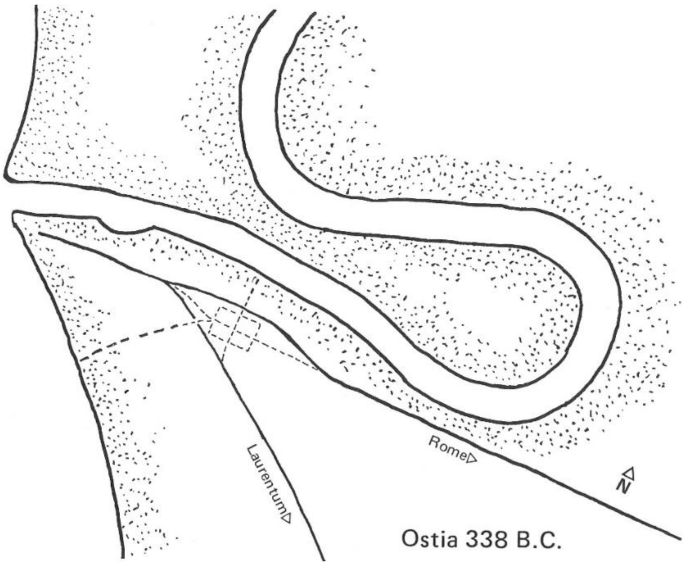


Figure 9: Schematic plan of the region surrounding Ostia in 338 BC. The old roads from Rome and Laurentum had been re-routed, shown in dotted lines, to serve the newly built castrum (Hermansen 1981, 3, fig. 1).

Insula V ii is located at a prominent position within the spatial organisation of the city. It was located along the Semita dei Cippi, an important street that is part of Ostia's north-south axis, also known as the *cardo maximus* (Stöger 2011, 217). This would have meant that a relatively high number of people would have passed by, and thus seen, this insula. Although, an axial line analysis of the street networks of Ostia performed by Stöger could suggest that the importance of this street within the network may have been somewhat overrated in Ostian research (Stöger 2011, 227). Nonetheless, the results from her analysis suggests that both the Semita dei Cippi and the via Fortuna della Annonaria were among the most prominent streets of the (excavated parts of the) city (Stöger 2011, 231).

The Semita dei Cippi that borders the west side of insula V ii, actually is the only street in Ostia of which the ancient Roman name might be known. The name of this street is based on what has been interpreted as a possible street sign. Two *cippi*, small inscribed stone pillars, were found directly west of insula V i (Newsome 2011, 12), the block to the south of insula V ii. Both cippi are inscribed with the following inscription: "*HAEC | SEMITA HOR | P R I | EST*". The meaning of the abbreviation '*P R I*' remains somewhat unclear, but, according to Bakker, '*HOR*' is an abbreviation of *horrea* (Bakker 1994, 197-8). Then, the inscription translates to 'this is the path of the warehouses'. Whilst this may have been the antique name of the street, its present name is not actually based on the inscription. The Latin words 'Semita dei Cippi' roughly mean 'Street [or path] of the Cippi' (translated by the author of this thesis). Hence, this name should only be seen as a modern interpretation. Nonetheless, it is the only street in Ostia where an inscription has been found that gives a clue towards what its ancient Roman street name could have been.

The city block is located close to the *Forum* at the centre of the city, to the west of insula V ii. It is also nearby one of the main city gates, to the southeast, as can be seen in appendix A1. Except for the narrow insula V iii, directly east of insula V ii, not much is known about the area to the southeast and east of the city block, as it has not yet been excavated. The streets that would have been located in that section of the city can thus not be described nor analysed.

2.3 The dataset

Crucial for answering the research questions of this thesis are the published site-plans of the Severan phase and the final phase of block V ii, produced by Boersma and his team in the 1970s (fig. 7 and 8, appendix A7 and A8). Due to the lack of information on the major Trajanic phase and earlier minor phases, as discussed in section 2.2.1, they are not suitable for a spatial analysis. Analysing the Trajanic or earlier phases without an established internal layout would not allow for valuable interpretations. The plans are too incomplete for an extended analysis or comparison.

Boersma's plans are complemented by a plan of the streets in Ostia from the *Scavi di Ostia I* (Calza and Becatti 1953), shown in appendix A1. Additionally, the author of this thesis carried out an on-site study in Ostia and created three-dimensional models of the insula, shown in appendix F. These models aided with interpreting the spatial layout of the buildings, and also include the outer face of reconstructed roofs and upper floors. Photographs made in 2017 by the author of this thesis are included in appendix H to show the current state of the visible remains of insula V ii, and have been used to assist with the interpretation of the plans of the buildings.

Insula V ii was excavated in the year 1940 (Boersma 1985, 1). As can be seen in fig. 4, the city block had not yet been unearthed in 1805. The excavators documented little during the hurried excavations in 1940 (Boersma 1985, 1), so the dataset used in this study is largely based on the publication from 1985 by Boersma. During the fieldwork campaigns conducted by Boersma and his team in the 1970s, several trenches were dug in the westernmost parts of building V ii 4-5 to gain a better understanding of its building history (Boersma 1985, 1). As stated in section 1.1, Boersma's documentation reflects the state of the architectural remains during their campaigns. Since 1976, after Boersma's fieldwork campaigns, additional restorations have been performed. In some of the restored sections one can find bricks with stamps of the restoration dates, ranging from the 1940s up to the 1990s.

Boersma's publication presents an elaborate documentation of the remains of all fourteen buildings in the insula. *Amoenissima civitas* contains a wide array of data, including (but not limited to): basic measurements, photographs of objects and the architectural remains, drawings of walls, mosaics and frescos, plans of the insula as well as the individual buildings, isometrically drawn reconstructions, and detailed textual descriptions. In several cases, Boersma used photogrammetry to produce even more accurate drawings.

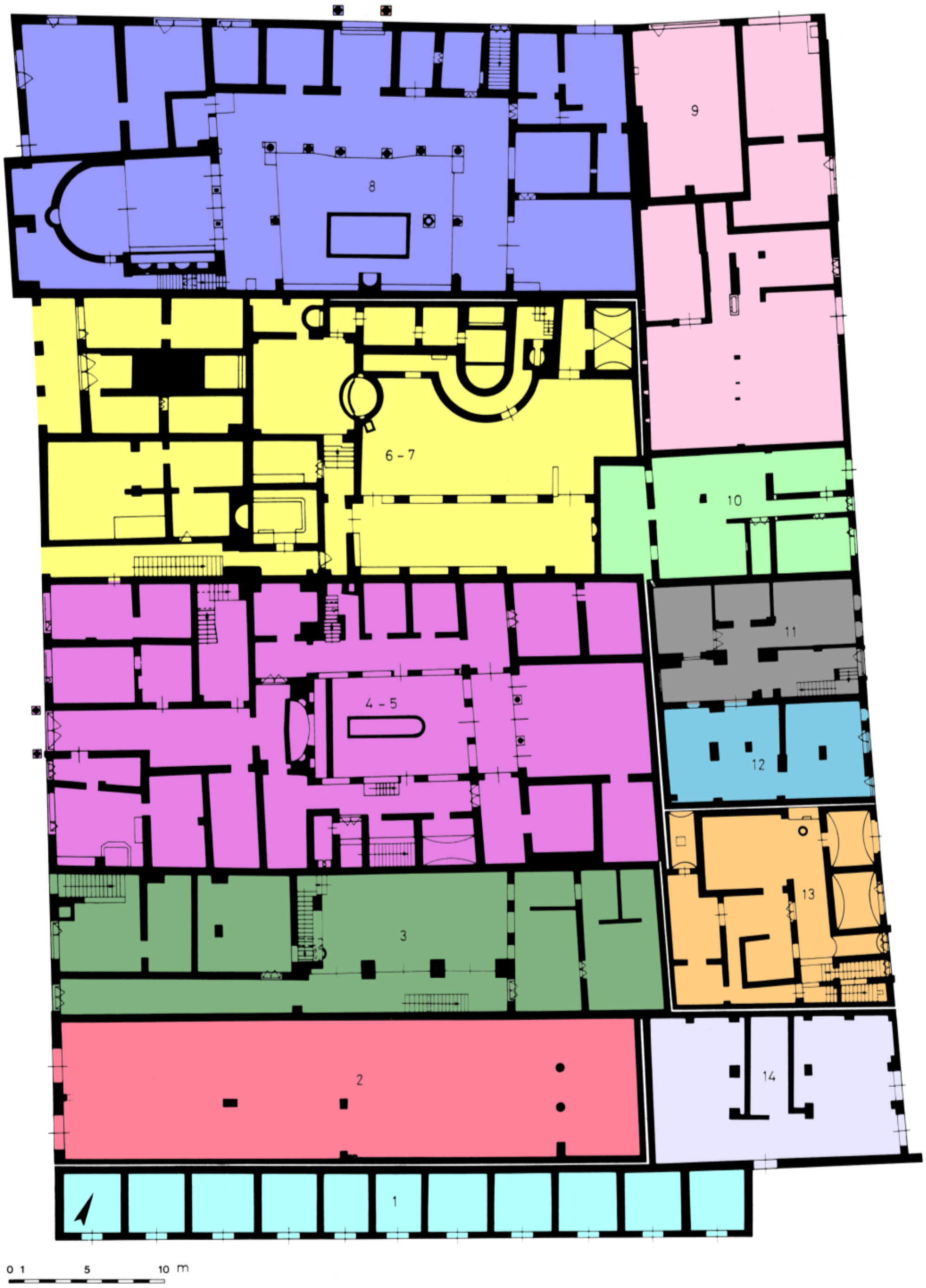
Boersma made the plan of building V ii 4-5 independently of the older plans from *Scavi di Ostia I* (Boersma 1985, 2). For the other buildings, the *Scavi di Ostia I* plans were enlarged from a 1:500 scale to 1:100. Due to the increased scale, inaccuracies became apparent in the older plans. Boersma updated these plans by correcting minor details, but the general measurements could not be changed as this would have required him to draw new plans. Thus, whilst these building plans are currently the most reliable ones available, they are less accurate than the plans of building V ii 4-5 (Boersma 1985, 2). However, for this study this slightly lower level of accuracy is not a problem, as the Visibility Graph Analysis and agent-based models required the plans of the insula to be converted to a grid. This is further explained in section 3.3.3.

The original aim of the publication by Boersma was to "register the remains of the buildings as they appeared during the years between 1973 and 1976 […] with the purpose of preserving them for future generations, at least on paper" (Boersma 1985, 1). The publication serves this purpose well and is accurate and detailed, but it can be difficult to use. Its complexity made the publication rather inaccessible for many researchers. This could explain why, until now, this publication has remained underused (limited usage includes Pavolini 2002 and Locicero forthcoming). Hopefully, this thesis could make the data more accessible for others. Additional aims of Boersma's study were "to analyse the plan and structure of the individual buildings, to reconstruct their history as far as the available evidence permitted, and in general to present an account of the history of the block as a whole, as far as can be composed from the visible remains" (Boersma 1985, 6). Boersma presented the interpretation of the architectural remains and archaeological finds as a separate chapter (Boersma 1985, 72-191). The structuring of his publication allows for a clear comparison with the results of this study.

During the Severan and final phase, insula V ii consisted of fourteen buildings (V ii 1 up to V ii 14), shown in fig. 10. Buildings V ii 4 and 5 were described and analysed together as building V ii 4-5 by Boersma, because they had an interwoven history at this time. The rooms on the western side made up the ground floor of building 4, a multi-storey apartment building, whilst the remaining rooms form building 5, the domus. This is also the case with building V ii 6-7. Building 6 was the multi-storey apartment next to the street and, during the final phase, building 7 was the bath complex in the eastern part of the structure. The buildings of insula V ii have been given multiple names since they have been excavated. These names are based on how the buildings were interpreted by previous researchers. According to Boersma, the original Italian names do not do much to define the building's actual purpose (Boersma 1985, 166). He suggested alternative names for the buildings based on their main function, as shown in table 2. Because of this, not all of his English names are translations of the original Italian names.

Table 2: Overview of the three different names of every building in insula V ii (by author, based on Calza and Becatti 1953 and Boersma 1985, IX).

Designation	Italian names (*Scavi di Ostia I*)	Names from Boersma
V ii 1	Caseggiato	Row of shops
V ii 2	Caseggiato	Storage buildings
V ii 3	Caseggiato	Apartment house
V ii 4-5	Domus del Protiro	House of the Porch
V ii 6-7	Terme del Filosofo	Baths of the Philosopher
V ii 8	Domus della Fortuna Annonaria	House of Fortuna Annonaria
V ii 9	Caseggiato	Shop-and-factory building
V ii 10	Caseggiato	House
V ii 11	Caseggiato	House
V ii 12	Caseggiato	Building
V ii 13	Caseggiato del Pozzo	House of the well
V ii 14	Caseggiato	Building



- **V ii 1**: Row of shops
- **V ii 2**: Storage building
- **V ii 3**: Apartment house
- **V ii 4-5**: House of the Porch
- **V ii 6-7**: Baths of the Philosopher
- **V ii 8**: House of Fortuna Annonaria
- **V ii 9**: Shop-and-factory building
- **V ii 10**: House
- **V ii 11**: House
- **V ii 12**: Building
- **V ii 13**: House of the well
- **V ii 14**: Building

Figure 10: Plan of the final phase of insula V ii, with the different buildings coloured (after Boersma 1985, 214, fig. 202).

It should be noted that Boersma's publication is somewhat focussed on one specific building within the city block. When Boersma and his colleagues began examining the insula in 1973, it was only intended to document the House of the porch (V ii 4-5). They selected this building because relatively little attention had been given to this structure in archaeological literature, and because they thought of it as "undoubtedly one of the most splendid examples of the late-Ostian domus" (Boersma 1985, 1). Their first three fieldwork campaigns were used to document this building. It was extensively drawn, described and photographed. The other buildings were documented only during a single campaign in 1976. This speed was possible thanks to the experience that the team had gained by working on V ii 4-5, but also because the other buildings were documented less meticulously. Of the other buildings, only a few drawings of profiles or details which were regarded to be "interesting" were included in the publication. Nonetheless, the textual description of the other buildings is just as extensive as that of the House of the Porch (Boersma 1985, 1-2).

However, building V ii 11 lacks a clear internal layout, especially during the Severan phase, which made it difficult to interpret for Boersma (Boersma 1985, 172-7). As this thesis studies the insula as a whole, the building has still been included in the analysis. It is assumed that Boersma's suggestions, as described and as shown in his plans, represent the complete and correct spatial organisation of the building. However, any conclusions about this building may be somewhat speculative. This building will thus not be discussed in detail.

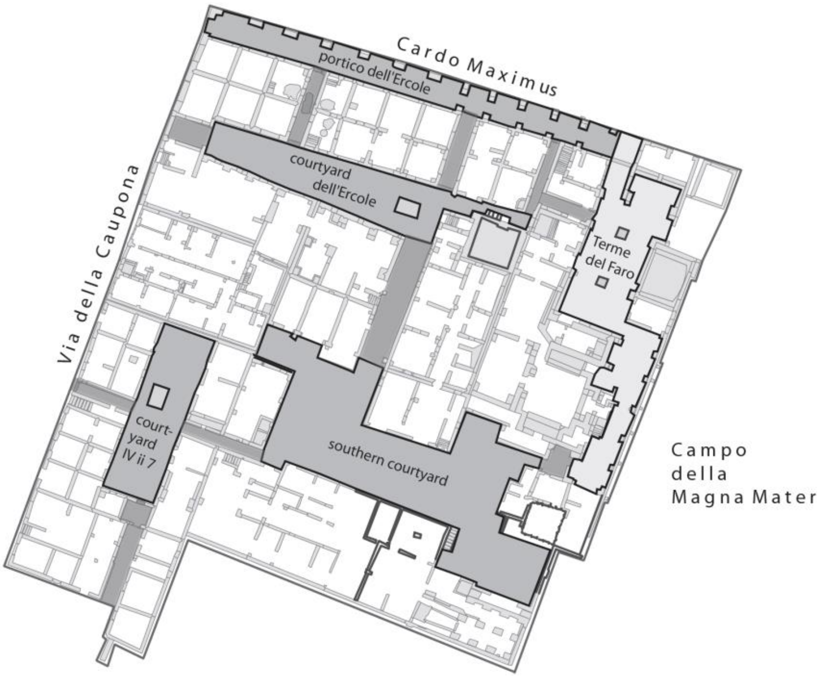


Figure 11: Example of internal public spaces in insula IV ii in Ostia, showing the courtyards which could be used to access the buildings. These courtyards are connected to the streets through multiple passages, coloured grey (Stöger 2011, 189, fig. 6.19).

Insula V ii does not have any public spaces within its spatial organisation that link the buildings to each other. For example, an internal courtyard, as can be found in insula IV ii in Ostia (Stöger 2011, 92): a space that can be used to access multiple buildings whilst not necessarily being located directly adjacent to the streets (fig. 11). Such a space would be indirectly linked to the streets through one or multiple entrances. However, in insula V ii, the only way to access most buildings from another is by leaving the insula and walking through the streets. To study the effects of the streets on insula V ii, it was decided to include the streets in the Visibility Graph Analysis analyses and agent-based models. As this study focusses on the interior of the city block, only a small section of the street network of Ostia was included. Moreover, the importance of the streets lies in their effect on the insula, therefore the streets themselves are not investigated in-depth during the analysis. Based on a personal assessment on-site by the author, the streets were added up to an arbitrary boundary after which insula V ii is no longer visible or visually recognisable. For example, the Via della Fortuna

Annonaria has been included up to where the street bends towards the Via degli Augustali by 90 degrees (appendix A1). The parts of the streets which were excluded have no direct influence on the interior spaces of insula V ii in the visibility analysis. The vector plan of the streets used for the analysis (Appendix A12 and A13) was drawn by hand by the author of this thesis and is based on the plan of the entire city from *Scavi di Ostia I* (Calza and Becatti 1953). The section that was used from this plan can be found in Appendix A1.

3. Theory and methodology

This chapter first presents a general introduction to the theories and methodologies of space syntax. Next, it discusses how space syntax is applied within archaeological research. Lastly, the individual methods, and the software, which were selected by the author are described in more detail. This chapter also provides guide lines for how these methods should be applied on archaeological datasets by describing the workflow of each method in detail. The decisions which had to be made by the author in the process of creating an analysable dataset are elaborated as well.

3.1 Space syntax theory

The term 'space syntax' refers to a set of theories and techniques for the analysis of spatial configurations. The approach of space syntax as a whole "combines theory and methods directly concerned with the relationship between society and its architectural and urban forms" (Stöger 2011, 42). Such relationships are interactive, as people both create the built environment and are influenced by it. The built environment constitutes, in its broadest sense, any physical alterations of the natural environments, through construction by humans. However, the exact nature of the relationship between human behaviour and the built environment remains a subject of debate[2]. Different formulations have been used in order to conceptualise this relationship, with each one representing a different theoretical perspective: accommodation, adaptation, expression, representation, production and reproduction (Lawrence and Low 1990, 454). Each formulation has a different (although sometimes overlapping) set of questions and data, corresponding to specific aspects of the built environment and human behaviour. Despite the differences between these theories about the relationship of human beings to their constructed environment, most

[2] See Lawrence and Low (1990) for a more detailed discussion on the different research areas, theoretical approaches and literature contributing to the debate on society and the built environment.

researchers agree that the way people construct, organize and furnish their physical living spaces can be used to learn more about individuals or groups (Cutting 2003, 3). Inferences can be made "regarding the social, cultural, political or symbolic structures which had been informing the spatial responses or choices" (Stöger 2011, 41).

The theoretical basis of space syntax is partly rooted within structuralism, a theoretical approach within the field of social sciences (Stöger 2011, 41-2). According to this theory, unconscious mental structures are able to generate patterned cultural behaviour (Lawrence and Low 1990, 467-8), and the capacity to form patterns is imparted to space. Space syntax includes the pattern of spatial inclusion and exclusion into its theoretical framework (Stöger 2011, 42). Hillier and Hanson agree with the principal ordering aspects of structuralist theories (Hillier and Hanson 1984, 5). However, they recognise other problems within these approaches to space. First, structuralist anthropologists are mostly concerned with a limited number of cases where order in space can be identified as the imprint of the social structure within the spatial configuration. Second, Hillier and Hanson disapprove of the notion that space is a by-product of something else, whose existence is anterior to that of space and determinative of it. This denies space its own descriptive autonomy (Hillier and Hanson 1984, 4-5).

In order to establish a theory of space that does not include these problems, Hillier and Hanson specify several requirements. First, the theory has to establish a descriptive autonomy for space: spatial patterns have to be described and analysed in their own terms, prior to any assumption of a determinative subservience to other variables. Space should not be reduced to being only a by-product of external causes. Second, the theory must be able to account for wide and fundamental variations in morphological type (space can be organised in closed or open patterns, be hierarchical or non-hierarchical, dispersed or compressed, etcetera). And third, it has to account for basic differences in the ways in which space fits into the rest of the social system. According to Hillier and Hanson, the descriptive basis of the theory has to be able to describe systems with fundamental morphological divergencies, as well as systems which vary from non-order to order and from non-meaning to meaning (Hillier and Hanson 1984, 5). Based on these requirements, Hillier and Hanson constructed a theoretical framework, known as the ‘social logic of space’. They suggest that “real-life spatial arrangements can be understood as the products of generative rules, acting as restrictions on an otherwise random process” and that “these rules themselves [might] be well ordered, in the sense of being themselves the product of an underlying combinatorial system governing the possibilities of forming rules” (Hillier and Hanson 1984, 65). By isolating and representing elementary concepts[3], a syntax could be constructed for the morphic language of space. This offered them a way to formulate a theory of spatial arrangements, which is also an attempt to represent these arrangements as a ‘field of knowables’: a “system of possibilities governed by a simple and abstract underlying system of concepts” (Hillier and Hanson 1984, 66). If humans are able to learn these concepts, then “it is reasonable to expect that more complex cases are understood through the recursive and combinatorial application of these concepts” (Hillier and Hanson 1984, 66).

Space syntax is built on two formal ideas which try to reflect both the objectivity of space and our intuitive engagement with it. First, we should think of space not as the background to human activity, but as an intrinsic aspect of everything human beings do (Hillier and Vaughan 2007, 207), as shown in fig. 12. Within space syntax, space tends to be conceptualized as a form of geometry, and all human activity is anchored in spatial geometry (Stöger 2011, 31 and 43). Movement is essentially linear, and the interaction between people requires a convex space in which all points can see each other, and from any point in space

[3] For a detailed explanation of these concepts, see page 52-81 of *The Social Logic of Space* (Hillier and Hanson 1984).

one can see a visual field known as an isovist. These three geometric concepts each describe some aspect of how people experience space. By being clear about this geometry, we can begin to see why urban space is the way it is. Second, human space is not just about the properties of individual spaces, but about the 'configuration of space'. Configuration refers to the interrelations between the spaces that form the spatial layout of a building or city. The importance of the concept of configuration lies in its ability to "express the property of space that, more than any other, is the main means by which space both acquires social meaning and has social consequences" (Hillier and Vaughan 2007, 207). From different locations within a layout, the spatial configuration looks different. This, and the concept of a root point, will be further discussed in section 3.3.1.

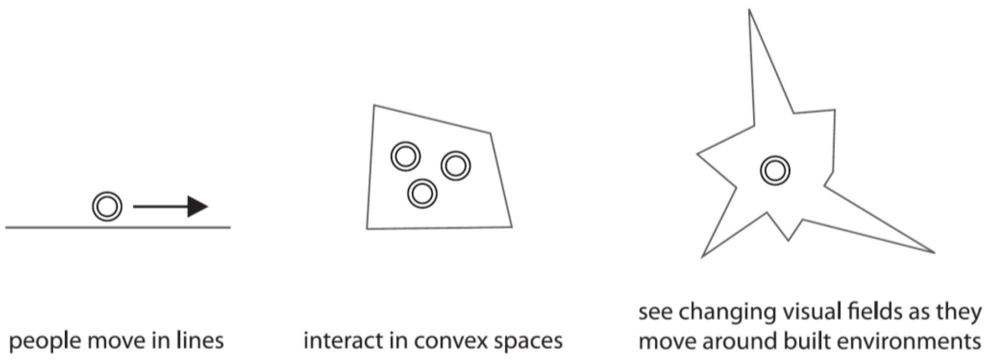


Figure 12: Space is not a background to human activity, but an intrinsic aspect of it: moving through space, interacting with people, or just seeing ambient space (with the visual field being known as an isovist), all have a natural and necessary geometry (Hillier and Vaughan 2007, 207, fig. 1.1).

The three geometric concepts (fig. 12) translate to actual behaviour as follows: people occupy a particular piece of space, and in order to be able to do anything, must move from one point to another. The configuration of space affects how people move through and use spaces. And in turn, such movement and use affect the behaviour of these people (Cutting 2003, 3). Within a configuration, spaces can be integrated or segregated. This reflects the "degree to which one must pass through other spaces to go from a particular space to all others" (Stöger 2011, 42). Integrated sections of a configuration are areas where people tend to experience more unplanned encounters with others (e.g. streets), whilst segregated areas offer more privacy (e.g. bedrooms). Configurations can create and maintain social hierarchy and control by giving spatial privileges to certain individuals, whilst denying them to others. The built environment both passively expresses social processes and actively directs and shapes activities. These activities are "concerned with social interaction and with controlling behaviour in host-guest or insider-outsider relations" (Stöger 2011, 43). Thus, the "configuration of inhabited space has a fundamentally social logic, and at the same time social structure is inherently spatial" (Stöger 2011, 43).

There are three core concepts in space syntax related to describing buildings and cities: spaces, buildings and structural properties. A single space can be defined as an area which is confined by obstructions that limit access, block view, or do both. For example, spaces can be rooms, courtyards, parks, etcetera. For the sake of simplicity, they are referred to as 'spaces' in this study. In space syntax, the buildings themselves are seen as series of spaces, with every space being connected to at least one other space (Al-Sayed *et al.* 2014, 7). The way a building is structured can relate strongly to its function. For example, prisons and museums use their spatial organisation in different ways for different means. A museum often consists of continuous rooms that follow each other. This forces the visitor to walk through them in a certain order, which can be used to create a narrative in exhibitions. Prisons, on the other hand, are generally build in a way to reinforce power and control. To this end, the architect can use visibility relationships and accessibility. The prison cells have low accessibility and (inter-)visibility. Many types of buildings have spatial characteristics which are recognisable based on their function. In order to uncover these characteristics, the buildings are converted into graphs and their structural properties are measured (Al-Sayed *et al.* 2014, 7-8).

3.2 The application of space syntax in archaeology

Space syntax is commonly used in the fields of architectural and urban research and design (Al-Sayed *et al.* 2014, 7), transportation, planning, and interior design (Stöger 2011, 43). At first, these theories and techniques were developed to help architects predict what social effects their designs could have, as explained in section 3.1. As Hillier and his co-authors beautifully formulated, space syntax "does not tell designers what to do. It helps them to understand what they are doing" (Hillier *et al.* 1993, 60). The process of understanding space is that what makes space syntax valuable for archaeologists.

Over the past decades, space syntax has also begun to be applied on other fields of research, including urban and human geography, information technology, anthropology and archaeology (Stöger 2011, 43). Space syntax is being used more and more in the field of archaeology for studying architectural remains, by analysing their spatial characteristics. One can attempt to identify the functions of buildings and spaces, or to reconstruct how the social organisation could have functioned (Al-Sayed *et al.* 2014, 7-8). It can be used to reconstruct the effects of an urban environment on multiple aspects of human behaviour in the past (Stöger 2011, 45-9), such as movement. Space syntax methods can be universally applied on ancient cities all over the world. Even though these cities may be very different from a cultural or geographic viewpoint, most of them share the same phenomena (Stöger 2011, 45-6). Stöger argues that the advantages of applying a thorough, analysis-driven approach on the past built space, outweigh difficulties that may be encountered due to the origin of this methodology in empirical research on present-day urban environments. The approach "can lead to new insights into the past urban space which would not have been available by archaeological investigation only" (Stöger 2011, 40). Even if the spatial patterns that result from the spatial analysis appear obvious and almost self-evident, they may not have been detected without the use of this sophisticated approach (Stöger 2011, 31).

The spatial organisation can influence how people use spaces, but the way in which people use spaces can also lead to them changing the space to suit their needs. The relationship between configuration and of how space is used form a two-way exchange. Through the use of space syntax methods, one can attempt to explain both how the spaces could have been used, and why these changes could have taken place.

3.3 Space syntax methods

Space syntax has a core set of tools. The three geometric concepts discussed in section 3.1 are reflected by the space syntax methods: Linear movement is represented by axial line analysis. Interaction in convex spaces is studied through convex spatial analysis, also known as access analysis. And the visual field from a location in space can be ascertained using isovist analysis (Stöger 2011, 43). These methods are used as "tools for thinking the relationship between space and society" (Al-Sayed *et al.* 2014, 7) and allow researchers to identify, compare, and interpret patterns of spatial configuration, with the goal of exposing the underlying social structure (Stöger 2011, 43-5). Visibility Graph Analysis (VGA) is a relatively recent addition to this 'tool kit', thanks to the development of Depthmap software (Stöger 2011, 61). The following methods have been selected for this study: access analysis, isovist analysis, visibility graph analysis, and agent analysis (Agent-Based Modelling, or ABM). The access analysis is performed in JASS software, whilst the other three types of analyses are performed using a program known as depthmapX. Despite not strictly being part of space syntax theory, an agent analysis is also performed to complement this approach. This is further discussed in section 3.3.4. It was deliberately decided to not include axial line analysis in this study, but this is further explained in section 3.3.5.

For the isovist analysis, visibility graph analysis, and agent-based models, it was necessary to assume that all doors of the insula were open simultaneously.

This assumption has to be made in order to be able to analyse the insula as a whole. As the fourteen structures were not internally connected to each other (with one exception in each phase), an analysis with closed doors would only allow for a study of the buildings on an individual level. It is assumed that all doors were open, because they can be opened to allow for the passage of people. They are thus potentially or latently open. Additionally, the presence of doors during the Severan phase could not be reconstructed by Boersma (appendix A7). Only the presence of several doors in the final phase could be confirmed, most of which are located at the entrances of the buildings, as shown in appendix A8. As the presence of doors could not be confirmed for the Severan phase of the insula, only including them in the final phase would produce distorted results. In order to treat both phases in the same way, all doors were excluded from the analyses.

3.3.1 Access analysis

The first space syntax method chosen for this study is access analysis, also referred to as gamma-analysis by Hiller and Hanson. The access graph is a simplified, schematic depiction of a spatial layout. It allows for a syntactic analysis of the internal structure of buildings, and for the development of hypotheses about the "relation between the principle syntactic parameters and social variables" (Hillier and Hanson 1984, 143). 'Syntactic parameters' refer to the spatial values of the structures. 'Social variables' is a relatively broad term, but e.g. includes the functions of spaces and spatial separation based on social status (Hillier and Hanson 1984, 143-97). Access analysis is the most commonly used type of space syntax analysis and is most suitable for the analysis of buildings (Stöger 2011, 61). It allows one to identify the arrangement of spaces, and the relations between them. Then, inferences can be made about the potential of the building's spatial organisation to "mediate the relationship between its occupants and visitors, but also the movements of permanent occupants" (Stöger 2011, 61).

In this study, the definition of spatial configurations proposed by Hillier is used: a configuration is a "set of interdependent relations in which each is determined by its relation to all the others" (Hillier 2007, 23-4). In other words, both the connections between spaces, as well as the (direct and indirect) relations between the connections are taken into account. A 'configuration' addresses the whole of a complex instead of only its parts. Spatial relations exist when there is any type of link, which can be in the form of adjacency or permeability. Adjacency refers to spaces being in the relation of neighbour to each other. If space "a" is the neighbour of space "b", then b must also be a's neighbour, as shown in fig. 13. This is an objective property of the relation of a and b, and does not depend on how we choose to see the relation. A relation of permeability between spaces can be created by having a doorway or other form of connection between them (Hillier 2007, 23-4).

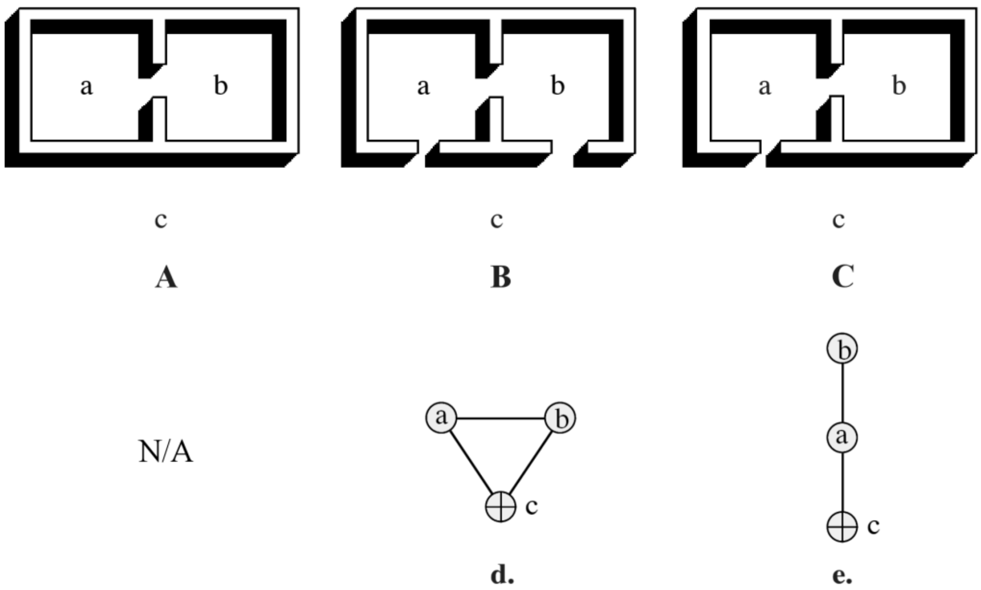


Figure 13: Three examples (A, B *and* C) *of different configurations for two directly connected spaces* (a *and* b)*, with below them their justified graphs* (d. *and* e.)*. The justified graph of* A *cannot be created as the two spaces do not have a connection to the outside space (c) which functions as the root point (after Hillier 2007, 24, fig. 1.3).*

Access analysis consists of two main parts. First, a topological graph is created by the user. This is a translation of the building floor plan into a graph, consisting of nodes and connections (fig. 14). The nodes represent spaces, and the lines drawn between them represent how these spaces are connected to each other. One connection represents the movement from one space to another (Hillier and Hanson 1984, 149). Second, the topological graph is used to generate a justified access graph (or j-graph), and to compute the spatial variables of every node (Stöger 2011, 61).

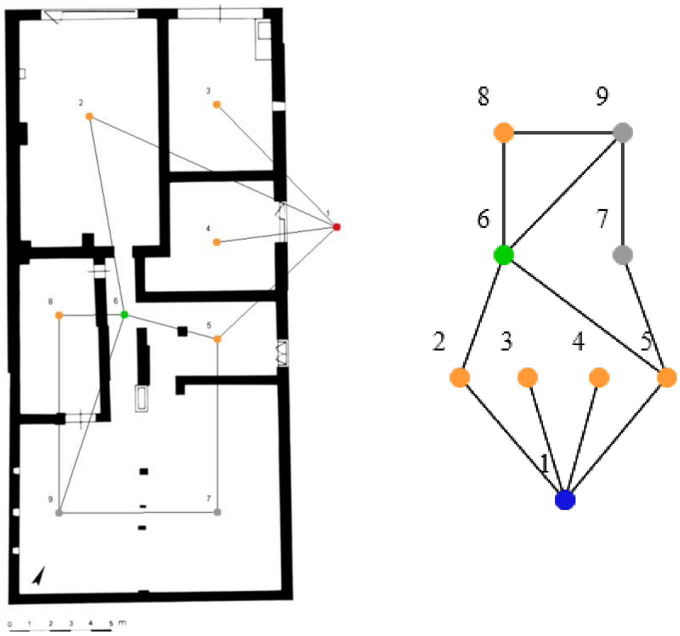


Figure 14: Example of a topological graph (left) and justified access graph (right) of the Severan phase of building V ii 9 (Jansen 2016, 36 and 37, fig. 18 and 19).

The access graphs shown in this thesis are justified. The graphs are structured with a specific space placed at the bottom, known as the root space or root point. The graph originates from this space, meaning that it is created from its perspective. Any node from the topological graph can be selected to be the root point in order to show its perspective. In this study, the four streets (the public domain) surrounding the insula all function as the root point together, as it is not possible to have multiple root points. Connections shown in access graphs are known as syntactic steps. The lowest number of syntactic steps required between two spaces is known as the depth between them. Spaces that are just a single syntactic step away from the root point, are placed on the first horizontal level of the access graph above the root point. Spaces that are two syntactic steps away from the root point, are placed on the second level. This continues for every increased number of syntactic steps required to reach the spaces (Klarqvist 1993, 11). In this study, when referring to the depth value of a space, the minimum number of syntactic steps between this space and the root point of the graph is meant (Hillier and Hanson 1984, 149). The spaces at the top of the access graphs are located the furthest away (in number of connections, not physical distance) from the streets (Hillier and Hanson 1984, 106). The justified graph presents a visualisation of the overall depth of a lay-out as seen from the selected root point (Klarqvist 1993, 11). As the streets were chosen as the root point, it results in a graph that describes a city block from the perspective of a person entering it from the outside.

Access analysis is also known as convex analysis, as the spaces in the graph are defined as convex spaces. A convex space is defined as "a space where no line between any two of its points crosses the perimeter" (Klarqvist 1993, 11), as shown in fig. 15. The results of the analysis are influenced by how the user interprets the spatial organisation. In this study, the spaces have been defined as convex spaces as much as possible. However, it can be difficult to directly apply the definition of convex spaces on archaeological case studies. Due to the irregular shapes of the spaces, many do not classify as convex spaces if the definition is applied too strictly. In insula V ii, many spaces have very slight curves in seemingly straight walls, and there are small architectural elements that block vision between relatively small areas within a single space. Hypothetically, rooms with round, inward-curved walls would require the space to be divided in an infinite number of increasingly smaller convex spaces. This is not practical, and pointless to analyse as it should be regarded as a single space. Thus, exceptions had to be made where non-convex spaces were still defined as a single space.

Additionally, several spaces where a single pillar is located roughly at the centre of a room were still regarded as single spaces, because the effect of one pillar is not significant enough to divide the room into two spaces. When deciding this, the size of the pillar as well as the width of the connections should be taken into consideration. For example, when there exists a row of pillars or columns instead of a single supporting pillar, they should be considered as a division between two convex spaces.

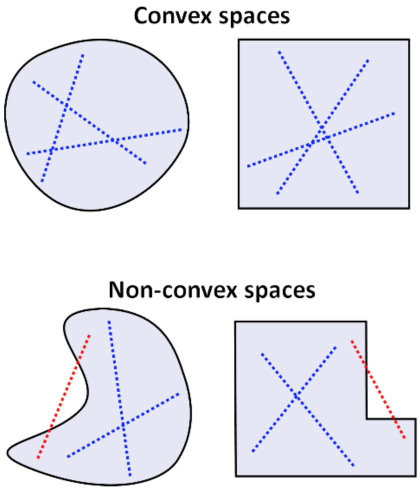


Figure 15: Example of convex spaces and non-convex spaces. Convex spaces are open areas without anything blocking the line of sight. The blue lines represent visibility between two random locations. The red dotted lines represent blocked visibility, indicating that those spaces are not convex spaces (by author).

In this study, a new numbering system of the spaces has been created specifically for the access analysis. Boersma's divisions and numbering system of the spaces is not used or referred to, as it is unsuitable for this analysis. It includes non-accessible spaces, uses the same numbers for spaces in different buildings, and does not use the definition of convex spaces. In the system created for this thesis, each node has been given a short numeric code, consisting of two parts: the first two numbers represent the building number, and the next two numbers indicate which space it is within the building. For example, "0203" refers to space 3 of building V ii 2. Although the numbers given to the spaces are arbitrary and do not carry any meaning, they were created systematically, beginning at the left-most (from the perspective of the street) entrance of every building.

Justified access graphs have different aspects that can be interpreted. To begin with, the shape of the graph can be used as an indication of the degree of privacy. A justified graph in the shape of a tree (house delta in fig. 16 and 17) suggests an increased presence of relatively private spaces. A tree-shaped graph is relatively narrow and has most nodes located further away from the root point, where the graph can become wider. Such a system has a relatively high mean depth, and is described as deep (Klarqvist 1993, 11). In a bush-shaped graph (house gamma in fig. 16 and 17), on the other hand, most spaces are located close to the bottom of the graph. Such a system tends to be relatively wide, has a relatively low mean depth, and is described as shallow (Klarqvist 1993, 11). This means that in a bush-shaped graph, on average, the spaces can be accessed from the root point through a relatively low number of syntactic steps. These spaces are thus more accessible and less private than those in a tree-shaped graph.

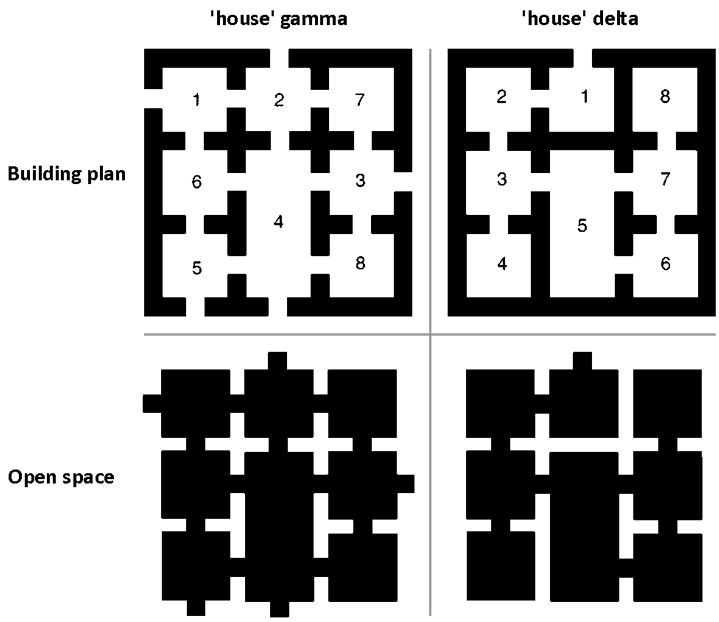


Figure 16: The building plan and open space of two different fictional houses, gamma and delta, that have the same rooms, but with a different configuration (after Hanson 1998, 25, fig. 1.8).

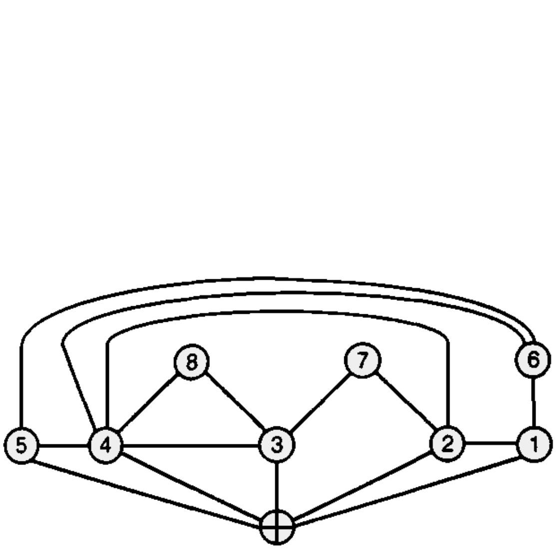


Figure 17: Justified access graphs of the fictional houses 'gamma' and 'delta'. The graph of house gamma is bush-shaped, whilst the graph of house delta is tree-shaped (Hanson 1998, 26, fig. 1.9).

Aside from the graph itself, the creation of an access graph also results in a high amount of data. Multiple values are calculated for every node. Three important and useful variables are the integration value (RRA or Real Relative Asymmetry), the control value and the connectivity value.

Integration is a static global measure, as it describes how the mean depth of a space relates to all other spaces in the graph (Klarqvist 1993, 11). This means that it shows how relatively deep or shallow the location of a space is within the graph. Using this value, the nodes can be hierarchically ordered from most integrated to most segregated. Segregated spaces are more private than well integrated spaces. Integration can be used as an indicator of the likely rate of interaction between people, in a specific space. According to Hillier, this value could represent rates of social encounter and retail activities (Hillier 1996, 41-60). The integration value of every node, also known as real relative asymmetry (RRA), requires several formulas to be calculated. First, the relative asymmetry (RA) has to be calculated, using: $RA = \frac{2(\mathrm{MD}-1)}{k-2}$. In this formula, MD refers to the mean depth of the graph and k to the total number of spaces in the system. RA compares the depth of the system from the perspective of the node it is calculated from, with how deep or shallow it theoretically could be. The lowest possible depth occurs when all spaces are directly connected to the root point. When the spaces are connected as a sequence of rooms, it will result in the highest possible depth. Calculating the RA always results in a value between 0 and 1. Values close to 0 represent spaces that are shallow, meaning that it is well integrated into the system as a whole. Spaces with a value close to 1 are described as deep, and are segregated from the system. MD is calculated as follows: $MD = \frac{sum\ of\ depth}{k-1}$. The total depth of all nodes added together is divided by the number of spaces, excluding the root point (Hillier and Hanson 1984, 108-9).

However, the RA value does not allow for comparisons between graphs consisting of a different number of spaces. In this study, the number of spaces in the graph of insula V ii increased between the Severan and final phase. As this causes the syntactic size of the graph to change, the RRA value has to be calculated to compensate for this. The formula is $RRA = \frac{RA}{Dk}$. The RRA is an empirical way of normalising total depth. This formula compares the RA value of a node with the RA value of the root of a perfect diamond-shaped pattern. The D value is the RA value for perfectly diamond-shaped complexes that have k number of spaces. It does not have to be calculated, but is selected from the table shown in Appendix G1. In a 'diamond-shaped' justified graph (fig. 18), k number of spaces are located at the average depth level. In the example shown in fig. 17, k is 16, as sixteen nodes are located on the fourth depth level. This continues with $\frac{k}{2}$ spaces at one level above and below the average, $\frac{k}{4}$ spaces at two levels above and below, etcetera. This pattern repeats until the level is reached in which only one space remains. This is at both the top and bottom of the graph; at the root and at the deepest point.

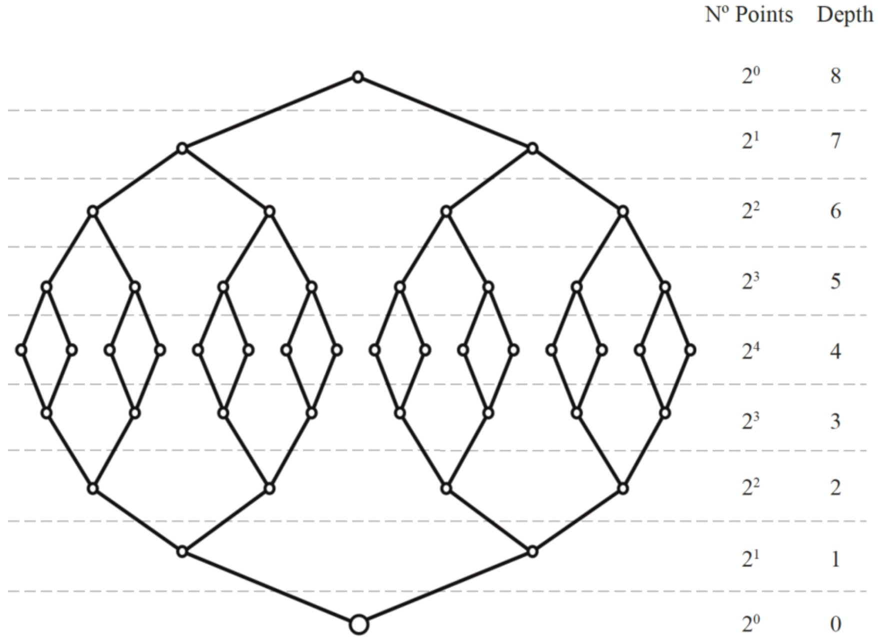


Figure 18: Example of a perfectly diamond-shaped graph with 46 nodes and a maximum depth of 8 (after Kruger and Vieira 2012, 198 , fig. 3).

The RRA can have a value above or below 1. Rooms which are strongly integrated will have lower values (for example, c. 0,4-0,6), whilst values around and above 1 will be more segregated (Hillier and Hanson 1984, 109-13). The core of a system consists of the most integrated spaces. The 10% most integrated spaces are generally referred to as the integration core of a system. This core can consist of fully connected spaces, but can also be split or spread over different parts of the graph. Regardless of its shape and location, the core is an important property of all layouts (Klarqvist 1993, 12).

The second studied access analysis variable is control. Control is a dynamic local measure in access analysis that serves as a measurement of how much a space controls the access to its immediate neighbours (Hillier and Hanson 1984, 108-9). It also takes into account the number of alternative connections that every neighbour has (Klarqvist 1993, 11). Control can be calculated as follows. Every space has an *n* number of neighbouring spaces and gives every neighbour, which are then "summed for each receiving space to give the control value of that space" (Hillier and Hanson 1984, 109). A control value greater than 1 means that a space has strong control; spaces with a value below 1 are weak control spaces. The combination of a high control value with a low RRA suggests that the space was a central unit in the layout (Hillier and Hanson 1984, 109-13).

Lastly, connectivity is a static local measure which calculates the number of nodes directly connected to a space (Klarqvist 1993, 11). This value equals the number of nodes that fall within the range (the number of syntactic steps) chosen by the user. The node from where it is calculated is not included in this value. In this study, connectivity is calculated for a range of three levels, meaning that nodes up to a distance of three connections are included in the calculation. For example, a range of one will only include the nodes which are directly connected to the node, whilst a very high range (e.g. hundred) would include every node in the entire graph. An example is shown in fig. 19. In the left graph, all nodes have the same value. This is because every single node falls within the range of every other node; every space can be reached within a maximum of five syntactic steps. Hence, a lower range has to be used. A relatively low range better visualises the perspective of the individual nodes. With a range of three, the graph on the right presents a clear representation of the number of spaces that can be accessed from every node within three connections. Insula V ii has several buildings with a similar number of spaces as the graphs shown in fig. 9, so a range of three was found to be suitable for this study.

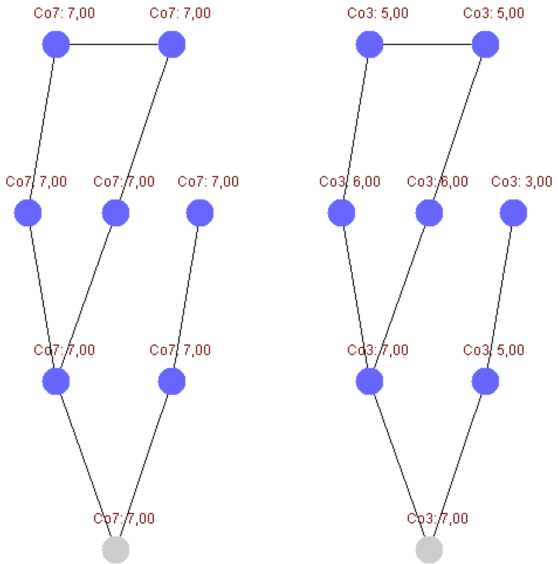


Figure 19: Two examples of the connectivity values of nodes in a justified access graph, calculated using seven levels (left) and three levels (right) (by author).

Multiple buildings of insula V ii used to have one or perhaps even more upper floors. As very little archaeological evidence remains of the upper floors, their spatial organisation could not be reconstructed. In reality, there may have been connections between the upper floors via the staircases. In this study, the presence of an upper floor is referred to as an additional node at every staircase that leads upstairs. In the graphs, these nodes are only connected to their corresponding staircase. However, there were two exceptions. One staircase in building V ii 6-7 was not given an additional node. These stairs, located in the north-eastern part of the bathhouse, probably lead to the top of the boiler instead of to another floor or accessible space (Boersma 1985, 45). As there was no upper floor here, no additional node was created for this staircase. The second exception is the staircase in building V ii 4-5 which leads downstairs. This staircase was not given one additional node, but multiple, as the underground area has been preserved and its layout is known. In the topological graphs, the small plan of the underground area is shown below the plan of the whole insula. The nodes placed in the underground area connect to the staircase in building V ii 4- and are treated the same as all other nodes.

The access analysis has been performed in JASS (version 1.0), an acronym of 'Justified Analysis of Spatial Systems'. It is a simple program for convex space analysis, which is achieved by creating and analysing justified access graphs. JASS allows one to import raster images, on which a node network graph can be created. The software uses this node network to automatically generate a justified access graph (www.arch.kth.se). JASS was selected because of successful personal previous experiences with this software, and because it is simple to use and freely available. The software was developed in 2003 as a research tool by the SAD research group (Spatial Analysis and Design) of the Royal Institute of Technology in Stockholm (KTH), Sweden. It should be considered to be a working prototype and a driving part of the research (www.arch.kth.se). JASS has three main functions: creating topological graphs, generating justified access graphs, and computing the spatial variables of nodes in the access graph. The spatial variables can be exported as a table containing the data of the entire access graph. The following section of this paragraph is a description of the workflow for JASS that was used and developed during this study. It is intended as a general guideline for using JASS to analyse archaeological plans of buildings.

First, the user needs a raster image (".jpg", ".jpeg", ".gif", ".png") of the building plan that is to be analysed. In JASS, the quality of the image does not influence the results, as long as the different spaces in the plan can be clearly identified by the user. In this study, a scanned image from a printed book is used, as Boersma's publication is not digitally available. This raster image should then be imported to JASS. It will be displayed in the background on a separate, uneditable, layer. Next, the user has to manually create the topological graph. The plan is interpreted by the user through the process of creating nodes, representing the individual spaces. The user then has to connect the nodes to each other, reflecting doorways or other forms of permeability between the spaces. The result is known as a topological graph. An example of this can be seen in the left side of fig. 14. Categories can be manually created, named, coloured, and given to the nodes. This has no effect on the calculations by the program, but can help to quickly visually identify spaces in a graph. In this study, the nodes were coloured based on the building they belong to, using the colours shown in fig. 10.

This topological graph is then used to generate a justified access graph. This is an automated process that does not take overlapping connections into consideration when determining the location of the node in the graph. Hence, all horizontal connections between nodes that have the same depth should be manually checked by the user. Nodes that have no connection to others on the same level are sometimes placed between two other connected nodes. This makes them appear as if all three (or more) of them were connected. After the justified graph has been checked, it can be exported as an image. The different variables of the nodes can be toggled on or off, which allows the user to export multiple graphs showing different variables. In this study it was not possible to include multiple variables in a single graph, as the large size of the graph would cause the text to overlap making it unreadable. Instead, separate images were made for the different variables. The access graph is accompanied by a table containing all variables that have been calculated for every node. In this study, the data was exported to Microsoft Excel in order to create the tables and bar charts shown in chapter 4. SPSS was used for the boxplots and scatter graphs. JASS exports the tables as '.txt' files, but uses an unusual layout. The data first has to be reorganised in Excel in order to be able to use it. The tables in appendix B12 and B13 use an improved layout in which the nodes are spread out vertically, and their respective spatial values horizontally. Once these steps have been completed, the topological graphs, justified access graphs, tables, and bar charts can be interpreted by the user.

The naming system for the nodes requires some further elaboration. As explained earlier, the names consist of four numbers which are used to identify in which building it is located, and which space within that building it refers to. It is important to note that the sequence in which the nodes are automatically sorted in the justified access graph, is based on several factors: the order in which they were created, the first half of their name, the second half of their name, and how the nodes are connected to each other. In JASS, the two halves of the names of the nodes (e.g. "0203") are entered as two separate entities ("02", and "03"). The software seems to treat these two parts differently when sorting the nodes. Although nodes in the justified graph can be manually dragged on a horizontal axis, the automatically generated sequence can only be changed by deleting every single node and recreating the entire graph. Fortunately, this problem only influences the visual representation of the graph. It does not have any effect on the data whatsoever. Nonetheless, the nodes in this study were numbered to reduce the chance of erroneous interpretations of the graphs. The numbers given to the spaces begin at '01' for every building. In order to assist the graph generating algorithm, some adjustments were made. JASS seems to prioritize sorting the nodes based on their name. Nodes with lower numbers in their name tend to be placed on the left side of the graph, whilst nodes with higher numbers are placed on the right. The nodes were numbered in such a way that they would be placed at locations where there are no overlapping connections or connections between unconnected nodes on the same level. Checking this manually becomes difficult when facing large and complex graphs, so it is preferable to avoid it altogether.

In this study, the graph of the final phase has been created first, as it has the highest number of spaces. For the Severan phase, all spaces that did not yet exist were simply deleted from the existing graph. Spaces that existed in the Severan phase but not in the final phase are numbered 90 or higher to prevent different nodes from being assigned the same name in the two different phases, and so that they can be quickly identified.

3.3.2 Isovist analysis

The second space syntax method used in this study is isovist analysis. An isovist is the area in a spatial environment directly visible from a specific point within the space. They are always single polygons without holes, as shown in fig. 20. Isovists provide a "description of the space `from inside', from the point of view of individuals, as they perceive it, interact with it, and move through it" (Turner *et al.* 2001, 103). The analysis can be performed at different scales, from large regions (e.g. the street network of a whole city) to individual buildings (www.ucl.ac.uk). This method can be seen as complementary to Visibility Graph Analysis and agent-based modelling. Compared to visibility graph analysis, isovists provide an alternative visualisation of visibility which is straightforward and easy to understand. The results can be interpreted more directly than the other methods, by using the images that result from this analysis.

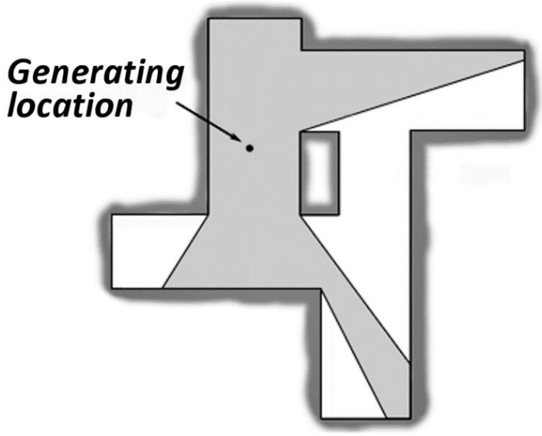


Figure 20: Example of an isovist polygon. The area that can be seen from the selected location is shown as a grey polygon (after Turner et al. 2001, 104, fig. 1).

In this study, depthmapX (version 0.6.0) has been used to generate the isovists. DepthmapX is a multi-platformed open source tool which is based on University College London's (UCL) DepthMap, and was selected because it includes multiple methods that are part of the core tools of space syntax. In this study, it is also used to perform Visibility Graph Analysis, and to run agent-based simulations. UCL DepthMap was originally developed by Alasdair Turner (www.archtech.gr) and written in 1998 for the Silicon Graphics IRIX operating system as a simple isovist processing program (otp.spacesyntax.net). DepthmapX is a continuation of this software developed by Tasos Varoudis, within the UCL Space Group, and includes the same functionalities as UCL DepthMap (www.archtech.gr). As of 2017, Petros Koutsolampros (also from UCL) took over the development.

Alternative software for creating isovists inside 2D vector plans does exist, for example the program known as 'Isovist_2.1'. The numeric export standards of this software were even reworked to align with depthmap. The output of Isovist_2.1 correlates to depthmap, but it can calculate maps at a significantly higher data resolution and in a shorter timespan (isovists.org). However, this also makes it more difficult and time consuming to interpret when applied on archaeological case studies. According to its developers, it is a "high speed, high definition alternative to traditional Visibility Graph Analysis" and it "scans architectural plans using the principles of the isovist to derive a series of local perceptional measures, as well as the global Space syntax measures of Mean Visual Depth and Mean Metric Depth" (isovists.org). However, it was released relatively recently, in late 2017, which was too late for it to be incorporated into this study. Regardless, depthmapX is more suitable for this study because of its multifunctionality, allowing the user to both create isovists, perform visibility graph analysis, and run agent-based simulations. These aspects of the software are further discussed in section 3.3.3 and 3.3.4.

In this study, the isovist analysis is based on the creation of point isovists. These can either be full isovists with a 360 degree view, or partial isovists that face a specific direction and have a limited field of view. The software is vector based, so if the building plans are only available as raster images, they have to be vectorised. In this study, they are used to determine what areas inside building were visible when one faced the entrances of every building from the streets, offering an outside perspective of the buildings. In order to use the isovists for a comparison between the two phases through a relatively objective approach, they were created systematically from the same locations and with the same angles in both phases of insula V ii. The isovists are generated from the centre (in width) of the streets, directly in front of every entrance to the insula. This allows for a comparison of the surface areas of the isovists, to determine an increase or decrease in visibility from an outside perspective. However, the software does not include a function that allows the user to import or create a set of predetermined locations and directions for the isovists. The isovists have to be created individually, by manually selecting a location. In this study, two categories of guide lines were manually drawn to mark the locations of the isovists to alleviate this problem. The first type is drawn through the middle of the streets (blue in fig. 21), whilst the second type leads from every entrance towards the centre of the streets (red in fig. 21).

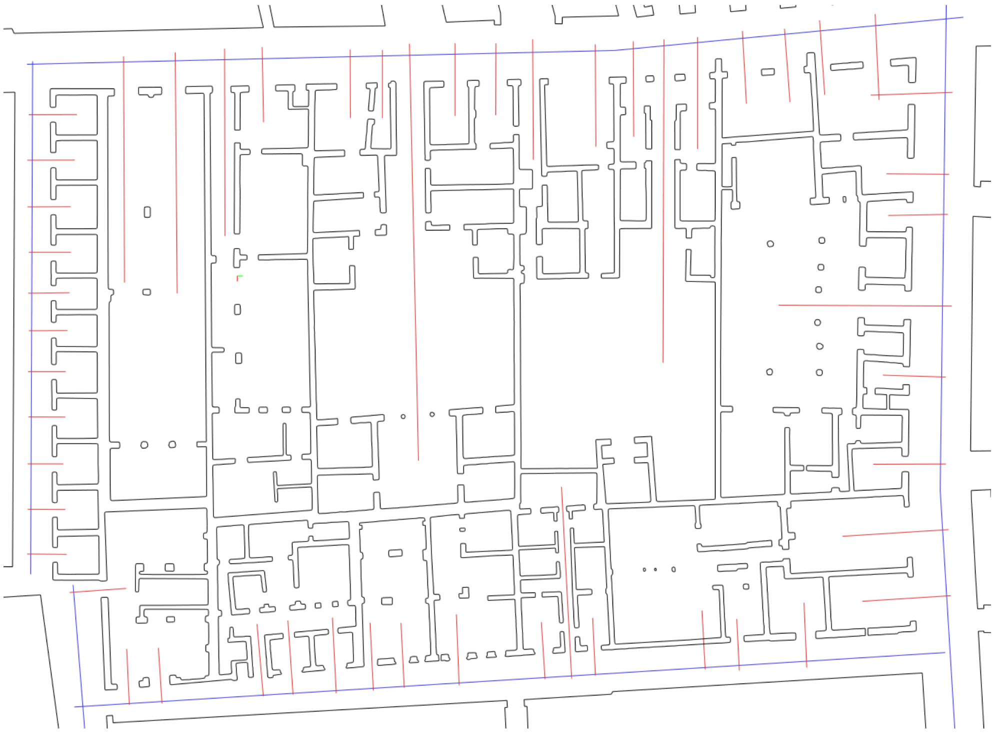


Figure 21: Guide lines that mark the locations from where the isovists were created. The blue lines represent the middle of the streets, whilst the red lines mark the entrances and the direction of the isovists. However, in practice, most isovists had to be created somewhat closer to the entrances or at a slightly different angle in order to avoid overlap with other isovists (by author).

The user then has to click on the locations where the two lines intersect to generate the isovists, whilst zooming in as much as possible to increase the level of accuracy. This approach allows for a much higher degree of accuracy compared to selecting the points based only on only a visual estimation. However, as it still has to be done by hand, it is not possible to achieve perfect accuracy. From these intersections, the isovists were generated with a 90 degree field of view, facing the entrance. This relatively narrow field of view was chosen to minimize overlap between the polygons of different isovists. This way, every isovist focusses only on the entrance it is placed next to. This also minimizes the effect of the slight differences in the selected locations between the two phases, as the surface area of the large open spaces of the streets is no longer included. In order to objectively compare the surface area of the two isovists between the two phases, the isovist is still created for both phases when an entrance did not exist in one of the two phases. This way, when comparing the total values, the irrelevant section of the isovist (the part that is outside of the buildings) can be subtracted from the comparison to prevent getting distorted values. Using this approach, the two phases can be compared regardless of the absence of such a function in the software.

3.3.3 Visibility Graph Analysis

The third method selected for this study is Visibility Graph Analysis (VGA). This method contributes to the results of space syntax analysis through visual analysis (Stöger 2011, 61). Similar to isovists, VGA focuses on the visual properties of the spatial organisation. It could be described as a more complex development of isovists, through the process of integrating a set of isovist polygons into a single visibility graph (Stöger 2011, 64). This approach takes into account "how visual characteristics at locations are related and one that has a potential 'social' interpretation" (Turner *et al.* 2001, 104). Isovists and VGA are "techniques for the representation and analysis of bounded spatial systems [that] add yet another perspective to the available space syntax tool kit by offering a way of addressing the relationship between the viewers and their immediate spatial environment" (Stöger 2011, 64). VGA allows us to "describe a configuration with reference to accessibility and visibility, to compare from location to location within a system, and to compare systems with different geometries" (Turner *et al.* 2001, 103). Visibility graph properties may be closely related to manifestations of spatial perception, such as way-finding, movement, and space use (Turner *et al.* 2001, 103). The VGA consists of a grid of points taken across the spaces. Each cell represents a point location within the open space of the configuration. The cells "are linked according to one of two rules: the first rule creates a link in the graph between two nodes if they are mutually visible. The second rule requires that a link is only created if the Isovist polygons from each node location intersect" (Stöger 2011, 64). After the VGA has been generated, various measures can be taken. VGA concentrates on the integration of a point in the graph. The integration is "a normalised (inverse) measure of the mean shortest path from the point to all other points in the system" (Stöger 2011, 65).

The first application of Visibility Graph Analysis was a study of the Tate Gallery in London, conducted by the UCL Bartlett School of Architecture (Turner and Penn 2002, 103-21). The integration values from the VGA were compared with the first ten-minute movement traces of people walking through the gallery (Turner and Penn 2002, 117-118). The movement traces were recorded by Hillier *et al.* (1996), who tracked people walking through the building. A visual comparison of the VGA results with the movement of these people showed that "the highest integration values corresponded well with where movement occurred" (Stöger 2011, 65-6).

The analysis of insula V ii includes both interior and exterior visibility relationships. The main reason for why the exterior (the streets) are included in this study, is to study its effect on the interior or the buildings. The exterior itself is not studied. In order to analyse the insula as a whole, it is necessary to include the streets in the VGA and agent analysis. As insula V ii does not have public spaces within its spatial organisation to allow for access between the buildings, the streets function as the only (indirect) connection. Excluding the streets results in an analysis of the individual buildings only, and ignores the effect the buildings had on each other.

As discussed in section 3.3.2, depthmap software is also used for the VGA. It can be used to analyse networks in plans of connected open spaces (www.ucl.ac.uk). At the building or small urban scale, in this case a single insula with nearby streets, the visual accessibility of the spaces can be assessed. The aim of this approach is to help understand social processes within a built environment, as variables which are derived from the analyses may have social or experiential significance (www.ucl.ac.uk). The VGA analysis in this study was first performed in UCL DepthMap (version 10.14.00b from 2011), but the data was transferred to version 0.5.0 of depthmapX due to its improved performance. When depthmapX 0.6.0 was released in November 2017, the analyses were performed again to guarantee that the data does not contain any legacy errors from the other two versions. Compared to depthmapX 0.5.0, version 0.6.0 includes several improvements and bug fixes, but most importantly uses OpenGL to render the map window live (github.com). This is a huge improvement for users, as it allows the user to check vector plans and results without having to wait for the map to render when scrolling around.

The input consists of a vector file (in ".dxf" format) of the building or street layout. In this study, the vectors were drawn using Adobe Illustrator. The vector map is used to generate a grid of points or cells on the parts of the plan that are to be analysed. Depthmap calculates the Euclidian inter-visibility between every pair of cells, which produces a visibility graph (de Smith *et al.* 2007, 343-4). Turner *et al.* (2001, 103-4) describe this process as isovists being used to derive a visibility graph of the environment. It should be noted that the software uses the centre of the cells to compute visibility. Even if the majority of a cell is visible, its visibility will not get registered if the point at the centre cannot be seen. This is illustrated by fig. 22. Each node represents the centre of a cell. The T-shaped vector in the centre represents an object or building that obstructs sight, so no nodes are present within this area. The lines that connect the nodes visualise which cells can be seen from each other. In fig. 22, an isovist (the region marked grey) has been generated from a cell on the left side. The boldened lines show which cells are directly visible from this selected cell.

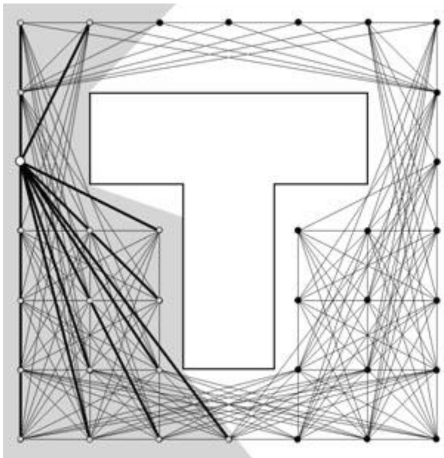


Figure 22: Visualisation of visibility. The region marked grey is an isovist generated from the selected node on the left side of the T-shaped object (Turner et al. 2001, 108, fig. 3).

This approach is somewhat comparable to a cumulative viewshed or cumulative isovist, as the software uses isovists calculated from every cell. The resulting graph shows where, within a confined space, the most highly visible areas are. In order to visualise the results, the cells can be coloured in a raster view of the plan based on the number of other points they are visible from. This can be described as a form of global visibility ranking (de Smith *et al.* 2007, 343-4). In this study, the cells with the highest visibility are marked red, and those with the lowest visibility blue. The values of the cells can be exported as a table or shown by selecting one or multiple cell in the map window of Depthmap. Based on the visibility graph, additional visibility and connectivity measures can be computed (de Smith *et al.* 2007, 343-4). The visibility graph can also be used as the basis for an agent-based model, as is further explained in section 3.3.4. In this study, the analysis focusses on the visibility and integration values. As shown by the Tate Gallery study (Turner and Penn 2002, 103-21), “the highest integration values corresponded well with where movement occurred” (Stöger 2011, 65-6).

The background colour of the images and the colour of the grid and vectors can also be changed. By default, the background is black, and the grid and vectors are green. In order to make the images clearer and easier to understand, in this study the background has been made white, and the grid and vectors black. By making the vectors black, they can be seen more clearly on top of cells which are coloured green.

The following sections discuss several problems which had to be overcome, and what choices had to be made in order to be able to use the dataset (vector plans of insula V ii) in depthmapX. First, the grid requires some additional explanation. In depthmapX, a single grid cell is intended to represent the size of a human body (as seen directly from above). The recommended scale is c. 0,6-0,7m per individual cell, as the software has been programmed with this scale in mind (Al-Sayed *et al.* 2014, 34). In this study, a scale of 0,5 by 0,5 metres has been chosen to allow for a better representation of the buildings. When the cell size is set at a higher value, a high number of architectural elements with smaller dimensions than the cells are not registered by the grid. However, as depthmapX uses the vector plan to calculate the intervisibility of the centre of the cells (fig. 22), even small architectural elements can influence the results by blocking sight (and movement). The main reason why the cells were given this size, was to make sure that the grid properly represents the walkable areas for the agent-based model.

It should also be noted that the spatial layout of these Roman structures cannot be perfectly aligned to any sort of square or rectangular grid. In insula V ii, the walls of different buildings are often placed at different angels. This, combined with the size of the cells (0,5 by 0,5 metres), makes it somewhat challenging to depict the original plans in a grid. This is a disadvantage of this method that is difficult to circumvent. A few minor adjustments were made by manually adding or removing cells, to make sure that the grid-based plan represents Boersma's plans as much as possible. These adjustments are shown as green vectors in appendix A14. The plan in fig. 23 shows the effect of converting the plan of the final phase of insula V ii to a grid.

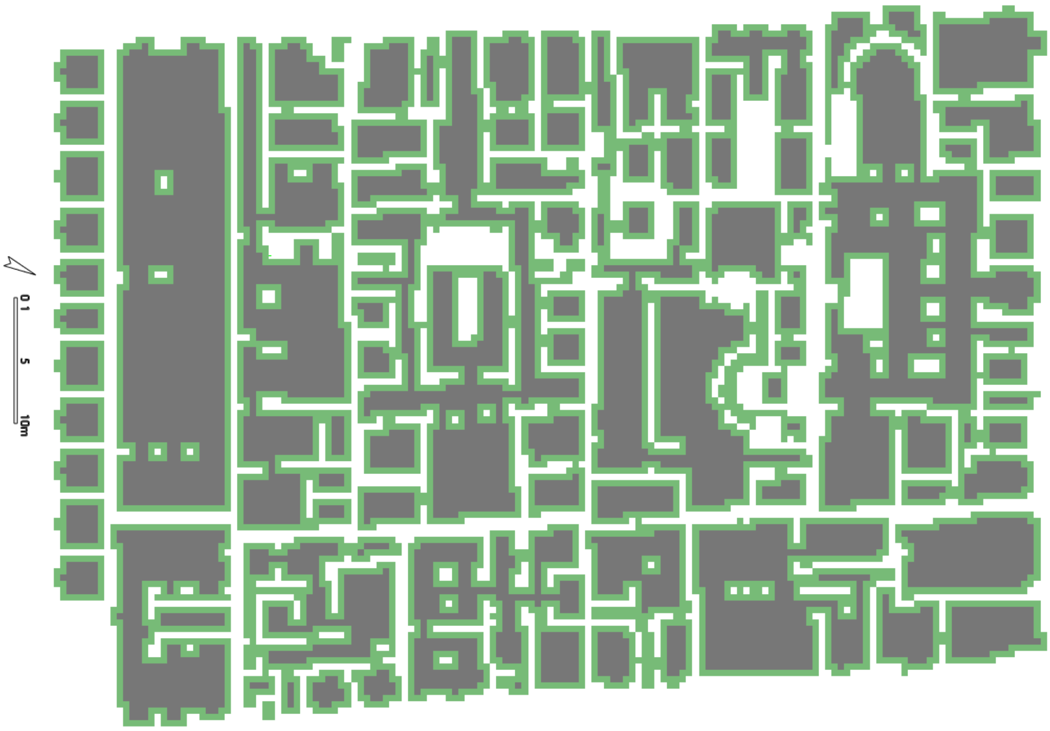


Figure 23: Active cells in the internal space of insula V ii during its final phase. Green cells are located adjecent to a physical border (by author).

Depthmap does not include a function which allows the user to mark a cell in the grid as one that only blocks movement but not visibility. The insula has many of such features, like windows, low walls, fountains, basins, benches, etcetera. Manually deselecting cells in the grid produces the desired results, as deselected cells do not block vision, but do stop agents from stepping on them. In this study, these areas were excluded by drawing the elements on a separate vector layer in Adobe Illustrator. The different vector layers can be manually toggled on and off in depthmap at any point during the analysis. By activating the two layers containing the plan and the obstructions, the depthmap 'filler'-tool can be used to select all walkable cells at the same time, as shown in fig. 24. When performing the analysis, all layers except for the layer containing the plan should be turned off to prevent them from affecting the computed data.

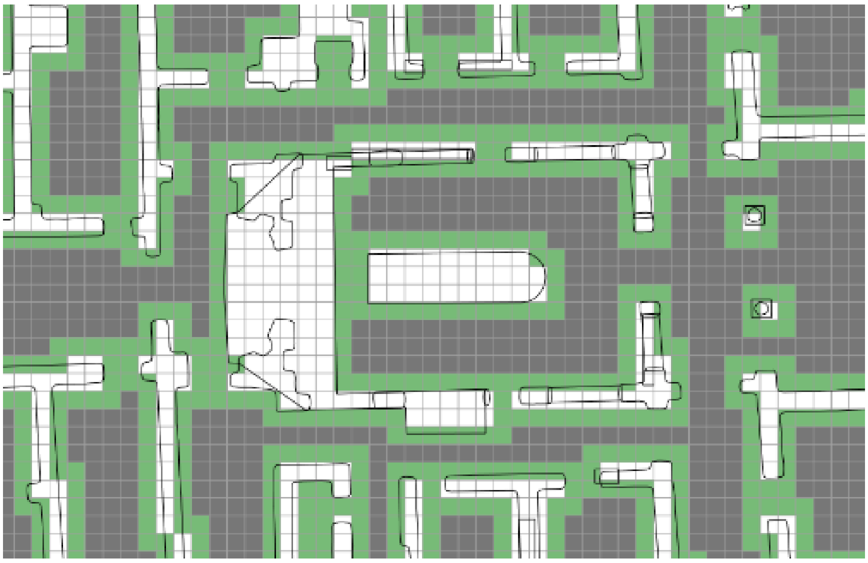


Figure 24: Converting the vector plan to a grid, using multiple vector layers. The plan of the final phase is shown, centered on the courtyard of building V ii 4-5 (by author).

Stairs are also a phenomenon that does not translate well into depthmap, as people can of course go up or down a stair, but it is not possible to move off them to the sides. Additionally, stairs do not completely block vision, as one can look over the lower steps, and in some cases underneath the higher steps. In Depthmap, forcing the agents to move in these two specific directions does not seem possible. Additionally, the differences between every staircase makes it difficult to present a uniform approach on how to treat them. In most cases a barrier was arbitrarily added roughly at the estimated location when the staircase reached a height at which a human being can no longer look over the steps. As most stairs had accessible spaces underneath, these areas were classified as open spaces. Only when there was no way to access the space underneath, or when no such space existed, that part of the staircase was marked as a solid obstruction. The staircase in building V ii 4-5 (visible in fig. 24, in the corridor directly below the courtyard) which leads downstairs to a small underground area was treated differently, as it did not obstruct the visibility on the ground floor. It has been treated as an open space that does not block sight but cannot be entered by agents.

An additional unknown factor is furniture. It is not possible to accurately reconstruct their presence, size, and placement. Furniture is not static and can be moved around at any point in time without leaving behind archaeological evidence. For these two reasons, the movement and visibility-blocking effects of furniture are not considered in the analyses.

3.3.4 Agent analysis

The fourth method used to analyse insula V ii, is agent analysis. In this study, the agent-based model consists of a simulation in which agents, representing human pedestrians, are set free in an urban environment and allowed to walk around. Agent-based analysis can make interesting contributions to archaeology "since it comes very close to actual patterns of observed movement, and therefore allows insights into the relationship between the built environment and spatial behaviour" (Stöger 2011, 65-6). Like isovist analysis and visibility graph analysis, the agent analysis has been performed in depthmapX. Agent-based modelling is included in this study in order to study the possible effects of the architectural changes in insula V ii on pedestrian movement. It is also used as an alternative to studying movement through axial line analysis, which is not used in this thesis as it only analyses linear movement and has several methodological problems when applied on the dataset used in this study (see section 3.3.5). Agent analysis, on the other hand, allows for the free movement of agents through open space in its entirety.

On a theoretical level, the agent model is different from the space syntax analyses in the way it is modelled. The resulting patterns of movement activity are formed through an emergent process. Movement decisions taken by individual agents for the duration of the simulation determine the outcome of the model as a whole. Space syntax, on the other hand, builds on a synchronic reduction of spatial relationships. It focusses on static analyses of the built environment and does not involve emergent processes. As is explained throughout chapter 3, the space syntax analyses consist of directly calculating the spatial variables of nodes, cells or lines, without the use of simulations. The values that are calculated are the direct result of the spatial configuration itself. Nonetheless, space syntax and agent analysis agree on the relationship between space and society, and the agents of depthmapX have proven to be an effective tool to simulate natural movement (github.io).

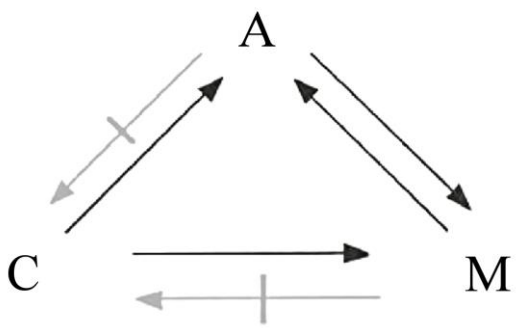


Figure 25: Visualisation of the relationships between attraction (A), configuration (C) and movement (M) (after Hillier et al. 1993, 31, fig. 16).

A study published in 1993 (Hillier *et al.* 1993) first proposed using the term 'natural movement'. The tests from their study were performed with axial line analysis, but natural movement is also simulated by the agents in this study. They presented evidence that suggested that the configuration of space is the main generator of patterns of movement. Central segments are likely to be the most used, and peripheral segments the least. However, this does not mean that the majority of movement is always generated by configuration. The combination of other effects that attract movement can have a higher impact than the configuration. These effects are described as the attraction theory of pedestrian movement: movement is seen being both to and from built forms with differing degrees of attraction (Hillier *et al.* 1993, 29-33). A schematic visualisation of how movement, configuration and attraction effect each other is shown in fig. 25. Attraction and movement can influence each other, but the other two relations are asymmetric. It is possible for the configuration to influence the location of attractors, but the location of attractors cannot influence configuration. Additionally, configuration can have an effect on movement, but movement cannot influence configuration. Hence, if “strong correlations are found between movement and both configuration and attractors, the only logically possible lines of influence are from configuration to both movement and attractors, with the latter two influencing each other” (Hillier et al. 1993, 31).

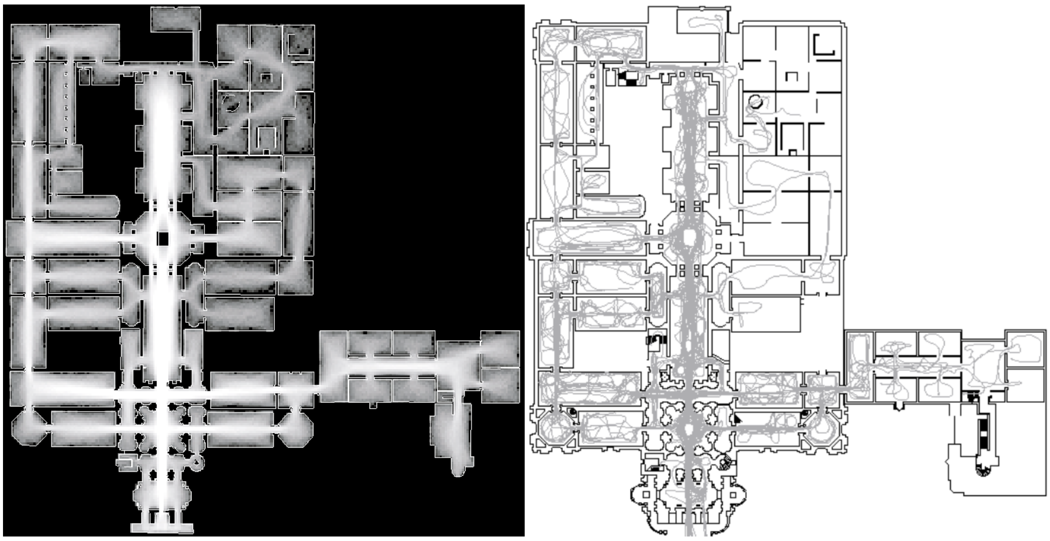


Figure 26: Result of the agent-based model, showing trails left by agents walking through the Tate Gallery in London (left), compared to the actual movement traces of 19 people followed for the first ten minutes of their visit to the gallery (right) (Turner and Penn 2002, 484, fig. 6).

The movement strategy of the agents is partially based on Gibson’s theory of natural vision (Gibson 1979). Space syntax research has shown that “it is possible to emulate human-movement patterns within a building environment by encoding Gibson's principle of affordance in the context of natural movement” (Turner and Penn 2002, 486). Empirical tests, in which real world pedestrian movement was compared with the number of agents passing through cells in the simulations, were performed by the UCL Bartlett School, using the Tate Gallery in London as a case study (Turner and Penn 2002, 473-90). This comparison is shown in fig. 26. When an agent steps on a grid square, it increments the local counter of that cell. In the model shown in fig. 26 (left), areas coloured black or dark grey have relatively low counts, and white areas have relatively high counts. The recommended default settings used in this thesis are based on these tests. The agents were given two basic guidance rules: a destination may only be chosen from a 170° visual field from the current heading, and the destination is reassessed every three steps (Turner and Penn 2002, 486). These settings resulted in the highest correlation between observed movement and the model (Turner and Penn 2002, 486-8). Applying these guidance rules for the agents resulted in an R^2= 0,76 (Stöger 2011, 65-6), which represents a high positive correlation. The effect of these two rules are visualised in fig. 27 and 28.

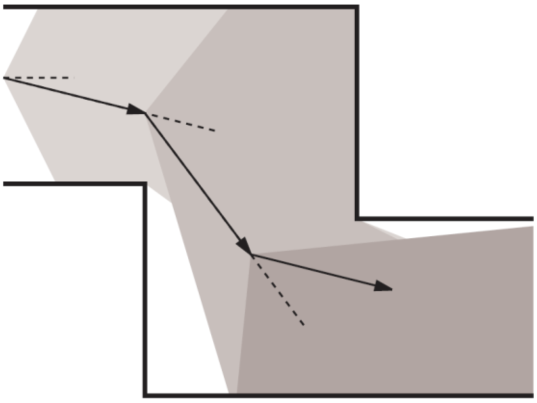


Figure 27: By selecting destinations from the visibility graph through a stochastic process, the agent is drawn through a configuration (Turner and Penn 2002, 481, fig. 3).

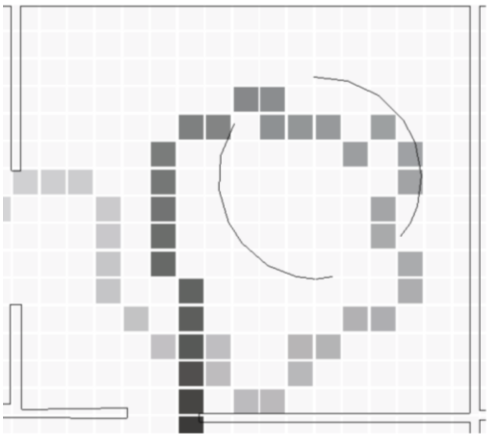


Figure 28: Example of simulated natural movement. An agent is drawn through the configuration of an objet d'art (the two semi-circular walls in the room). The cells, in this case with a size of 0,75 by 0,75 m, are coloured darker the more recently the agent has moved through them (Turner and Penn 2002, 481, fig. 4).

What follows is a description of the agents, their behaviour and their environment. These are written down in the same manner as the characteristics of agent-based models discussed by Downey (2012, 92). During the simulation, autonomous agents walk around in an urban environment. The agents are autonomous, meaning that there is no top down control over their behaviour. They are not heterogeneous, as all agents are identical to each other, nor are they grouped in homogenous pools (Epstein 1999, 41-2). During the simulation, the agents do not change or learn. They do not have any additional attributes, nor do they interact with each other.

The agents move for a specific number of steps, set by the user. One timestep represents the movement of an agent from one cell to an adjacent cell, so it reflects the amount of time it takes for a pedestrian to walk 0,5 metres. The user can set the number of steps before an agent has to make its next turn decision. In this study, the agent re-evaluates in which direction it will move every three steps, or earlier if forced to by an obstacle. This has proven to correlate best with real-life movement patterns (Al-Sayed *et al.* 2014, 104). The simulations presented in chapter 4 have a duration of 20.000 timesteps. In depthmap, the number of agents depends on the duration of the simulation. A new agent is spawned every 10 timesteps. This means that, at the end of the simulations run in this study, 2001 agents existed, whilst only a single agent existed during the first timestep. The 2001st agent had not yet moved when the simulation ended, as it was spawned during the last timestep. The agents are spawned at random locations, in open space within the insula or on the streets. The spawn points of the agents may be different in each simulation. Because depthmap does not include an option for selecting a seed number, the spawn locations are randomized every time a simulation is run. Using the same seed number would allow the user to obtain the exact same 'random' results when using software with a pseudorandom number generator. However, as this option does not exist, the user cannot recreate the same random spawn locations from a previous simulation by using the same seed number. Alternatively, spawning a high number of agents and using a long run time for the simulation can compensate for this by averaging out the results. It is also possible to manually select one or more cells in the grid where all agents will spawn. However, in this study, to prevent areas close to such a spawn location from having abnormally high visitor counts, the spawn locations were set to be random.

In order to simulate realistic human movement, data from the VGA is used by the agents when they have to choose their next destination, as “an understanding of the visual perception of the built environment might help forecasting how accessible spaces afford movement” (Al-Sayed *et al.* 2014, 29). The agents can only obtain data at a local level, from the cells that are in their direct field of view. In this study, the agents have infinite sight. The small size of the research area means that even two locations on the opposite side of the research area would have been visible from each other, assuming that visibility is not blocked by anything. Even factors such as fog generally would have had little effect on this scale. However, the agents cannot look behind them, as their field of view is limited to 170 degrees (85 degrees to the left and 85 degrees to the right), as shown in fig. 29. A field of view of 170 degrees has proven to be the most effective when comparing the results of simulations with real-life movement patterns (Al-Sayed *et al.* 2014, 104).

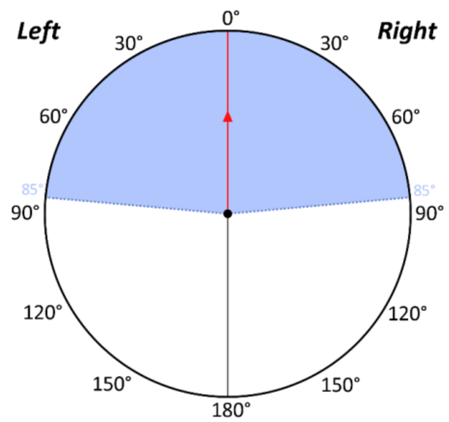


Figure 29: Visualisation of a 170 degrees field of view (shown as the area marked blue) of an agent (represent by the black dot in the centre). The red arrow shows the direction which the agent is facing (by author).

The environment in which the agents move consists of the plan of the Severan or final phase. This environment is static. It does not change during the simulation, as the Severan and final phase are two separate simulations. The same scale and input were used as in the visibility graph analysis. As explained in section 3.3.3, the grid size (cells of 0,5 by 0,5 metres) was chosen with the agent-based models in mind. The spatial organisation is represented by the active grid cells and vector plan. The active cells are located in open space, whilst the boundary of open space is marked by the vector lines. Every active cell records the number of agents that have visited it as the variable 'gate count'. When no agents pass through a cell, it has a value of -1. The first agent that enters the cell sets the gate count to 1. For every agent that is present on a cell after every time step, +1 is added to this variable. After the simulation has finished running, the cells are coloured based on their gate count value. This produces a graph of the research area (fig. 30) that shows which cells were commonly visited and which were mostly or completely avoided.

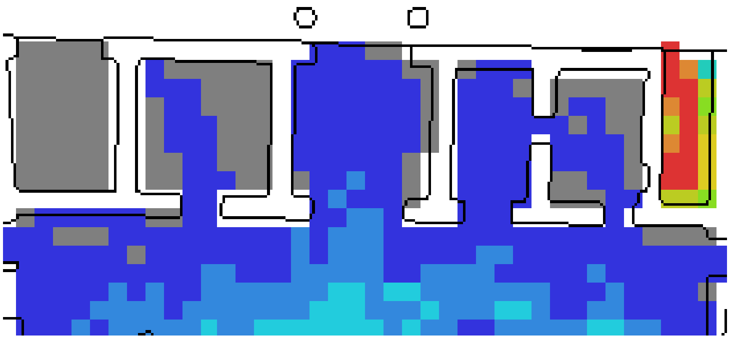


Figure 30: Section of the result of an agent analysis (with a duration of 2000 time steps) of the final phase of building V ii 8 in which the streets were not included. Cells coloured grey were not visited by agents (by author).

The agent-based model contributed to the decision to include the streets nearby insula V ii into the analysis. Excluding the streets distorts the results, as shown in fig. 30. If a relatively high number of agents is randomly spawned in a single building, the cells within this building would have a relatively high visitor count compared to other buildings as the agents cannot leave the area. This problem is even more pronounced in single rooms that are only connected to the streets.

When an agent is spawned there, it is forced to repeatedly walk over the same cells, resulting in a very high number of visits to these cells (such as the small room in the top right of fig. 30). Alternatively, if no agents are spawned in such a space, no data is generated for that location (such as the room in the top left of fig. 30), meaning that no meaningful conclusions can be drawn from these parts of the model. Thus, it was decided to include the streets into the analysis.

3.3.5 Excluding axial line analysis

Axial line analysis has deliberately been excluded from this study, meaning that an analysis of linear movement is not performed. The research area in this study has a relatively small scale: a single city block with its surrounding streets, as opposed to the street network of a whole city. At the high level of detail used in this study, even the generally linear movement on the streets can no longer be considered linear. At this scale, the smaller variations on different sections of the width of these streets become apparent. The level of detail also caused several methodological problems. Axial lines are defined as "the longest visibility lines (or 'lines of direct movement') in the 2D public urban space" (de Smith *et al.* 2007, 343-4). This concept does not function well when applied on the complex interior spaces of insula V ii, which includes detailed and irregularly shaped objects and features. Even the walls themselves are not perfectly straight. A high number of axial lines are automatically generated from every corner of their complex geometry. The computation of axial lines and maps is slow, complex and not an exact process (de Smith *et al.* 2007, 343-4). Moreover, the results would not be of much added value, as ABM is already used to study movement at a higher level of detail.

In the example of the Tate Gallery shown in fig. 31, the axial line analysis works relatively well as it does not feature many of the smaller and more detailed elements found in the plans of insula V ii, e.g. windows, low walls, niches, columns, wells and fountains. This is one of the disadvantages of using software that is not specifically designed for archaeological applications.

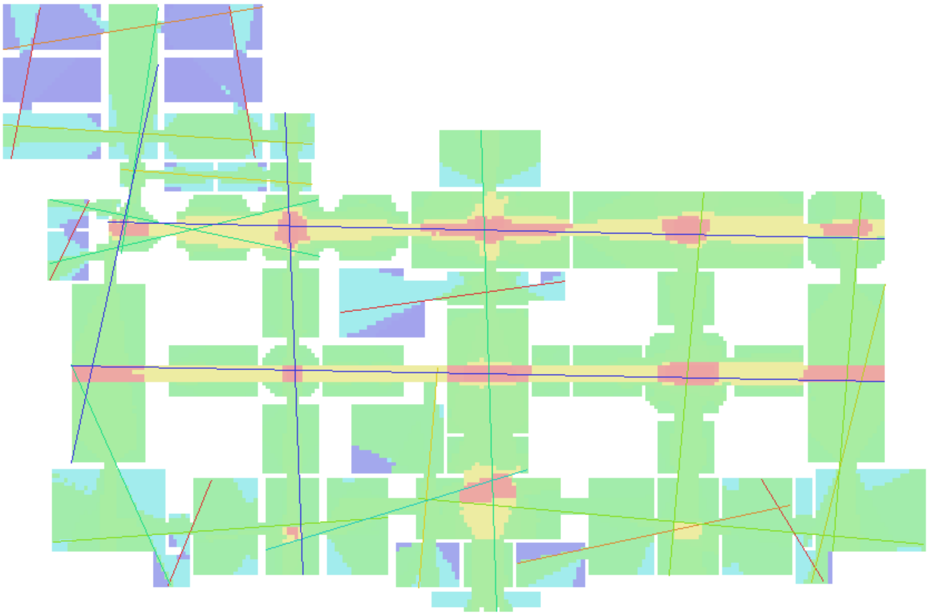


Figure 31: Depthmap visibility map of the internal space of the Tate Gallery. Locations with the highest levels of overall visibility are coloured red, and the lowest blue. A fewest line map of the automatically generated axial lines is shown on top of the visibility map (de Smith et al. 2007, 344, fig. 6-26).

The two plans of insula V ii by Boersma are not optimal for performing an axial analysis. Generating axial maps is an automated process, so it can be difficult to create an axial map that is representative of the spatial organisation. Whilst it may be effective when applied on large street networks, the complex and detailed nature of the plans of the insula do not allow for the proper generation of two axial maps that can be directly compared with each other. Because of the high number of (both large and small) differences between the two phases, the software generates two highly different axial maps. As a high number of axial lines present in one phase do not exist in the other phase (and vice versa), their data cannot be directly compared with each other. Additionally, the corners of the spaces are slightly curved, because the vectors are based on raster images. Attempting to generate axial lines for the interior of the buildings produces unexpected results. The software generates an additional axial line for every part of the curve of every corner. The fact that most walls of the buildings are not perfectly straight in the vector plans adds to this problem. When reducing the axial graph to a fewest line map, such as shown in fig. 30, only the axial lines of the streets around insula V ii appear to be generated properly. This may be explained by the fact that streets were drawn by hand as straight lines with straight corners. Lastly, axial line analysis presents a less detailed overview of the spatial organisation, as all the spaces are reduced to lines. VGA and ABM offers a more detailed approach by generating data for every ½m^2 cell in a grid. This is more suitable for analysing complex internal spaces such as those of insula V ii. Thus, it was decided to not include an axial line analysis in this study.

3.4 Applying space syntax methods on insula V ii

Thus, the four methods that are applied on insula V ii are access analysis, isovist analysis, visibility graph analysis, and lastly agent analysis. Access graphs focus on studying the configuration of convex spaces and are applied first. Isovist analysis and VGA both study visibility. As isovist analysis is essentially a simplified form of VGA, the former will be applied before the latter. However, VGA studies more than visibility alone, as it also includes visual integration. Because the agent analysis requires data from the VGA, it has to be performed last. The two agent-based simulations of the Severan phase and final phase are both run with the exact same settings, with the only difference being the plan of the insula.

These methods will now be applied to the plans of insula V ii. Each method is applied separately to the Severan and final phase of the city block. The results of each phase are then compared with each other to study the effects of the architectural changes.

4. Spatial Analysis

This chapter presents the results of the spatial comparisons of the Severan and final phase of insula V ii, performed with access analysis, isovist analysis, visibility graph analysis, and agent analysis. This chapter intends to demonstrate the possibilities of each space syntax method. The results of these analyses are used in section 4.5 to reconstruct the functions of spaces during the Severan phase, and to suggest several minor changes to Boersma's view on the functions during the final phase. This chapter aims to analyse and explain the changes that took place, to allow for a comparison with Boersma's interpretation of the archaeological remains. Changes in the spatial organisation of insula V ii may reflect change in the ownership, inhabitants, or tenants of spaces. To avoid relying only on a visual comparison of the changes in the images, this chapter also uses statistics to interpret the generated data. Please note that, when suggestions are made about ownership or the inhabitants of buildings during the Severan and final phase, roughly two centuries had passed between these two phases. Thus, when terms such as 'owner' or 'tenant' are used, they do not refer to the same person in both phases.

In this chapter, spaces are referred to by numeric names, given by the author of this thesis and shown in fig. 33, 34 and 35, as well as in appendix B2, B4, B6 and B8. Tables with the generated data from the space syntax analyses and enlarged versions of the images shown in this chapter can be found in appendices B, C, D and E. To avoid confusing the access analysis 'connectivity' variable with the variable of the same name from the VGA, the latter is referred to as 'visibility'. Please note that the values in the tables use a dot instead of a comma as their decimal separator.

4.1 Access analysis

The first analysis which is applied on insula V ii, is access analysis. The internal layout of the buildings can be quickly understood by showing the topological graph without the root point and its connections to all entrances, resulting in fig. 32. One of the main spatial characteristics of both phases of the city block that immediately becomes visible, is the lack of public spaces within the insula that connect the individual buildings. Most buildings are separate entities in the graph. During the Severan phase, a single connection existed between different buildings (V ii 4-5 and 6-7), and two existed during the final phase (between V ii 4-5 and 6-7, and V ii 11 and 12). The other buildings could only be accessed from one another by leaving the insula and walking through the streets.

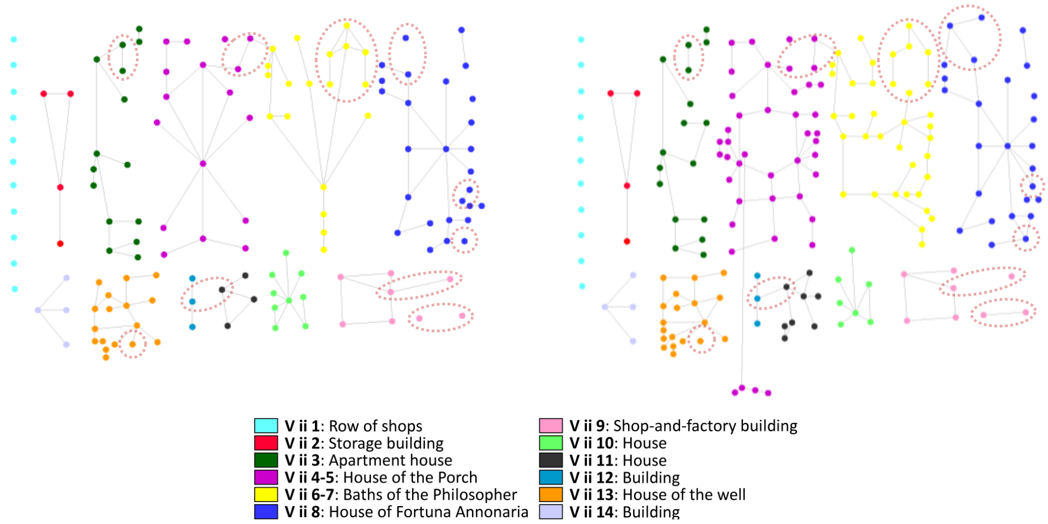


Figure 32: Topological graph of the Severan phase, left, and final phase, right. The colour of the nodes shows what building they belong to. Changes discussed in section 4.1 are encircled in both graphs (by author).

In both phases, the doorway connecting buildings V ii 4-5 and V ii 6-7 is located at the lowest possible depth (at a depth of 1, between spaces 0405 and 0601), meaning that it had little effect on most of the spaces within these two buildings: they were still very separated from each other. Additionally, during the final phase, rooms 0407 and 0408 were not even connected to the rest of the building, further diminishing the effect of the connection. Space 0407 was split into two rooms, 0407 and 0408, which were not connected to each other, which caused spaces 0405 and 0407 to be only connected to the street, and to building V ii 6-7. This could suggest a change in ownership, function, or both, of these two rooms in building V ii 4-5. Spaces 0405 and 0407 could have been owned by the inhabitants of the domus during the Severan phase, with the ownership having been transferred to the owner of building V ii 6-7 by the time of the final phase. Considering its connection to the central hallway (0403) of the building, Space 0407 may originally have had a domestic function during the Severan phase. When it was split into two, the southern half (0407) remained connected to the domus and retained its domestic function (unless it already had a commercial function). The northern half (0408) may have gained a commercial function, as it was solely connected to the shop at the front of the building. The connection to building V ii 6-7 may also have been intended to attract visitors of the temple (Severan phase) or bathhouse (final phase) to this shop, who walked through hallway 0601. The back half of building V ii 4-5 changed drastically. Compared to the Severan phase, a high number of spaces was added, which highly increased the complexity of this part of the building.

The two connected rooms at the front of building V ii 3, space 0303 and 0305, used to be connected to the rest of the building through hallway 0304 during the Severan phase, but were separated in the final phase. Perhaps the tenants or owners lived in the domestic part of this building during the Severan phase and used this door to access their shop without having to walk through the streets. During the final phase, the owner or tenant may have lived in a different building or insula, making this doorway redundant.

Rooms 0604 and 0610 of building V ii 6-7 seem to have formed a single shop, with another shop next to it consisting of rooms 0611 and 0615. In both phases, a commercial function seems like the only plausible explanation. The shops were located next to the prominent Semita dei Cippi, and the four spaces were too small to be domestic or industrial, and had a very simple configuration, consisting of only two connected rooms. Space 0605 of building V ii 6-7 was located between these two commercial units and provided access to the courtyard with the temple at the back of the building during the Severan phase.

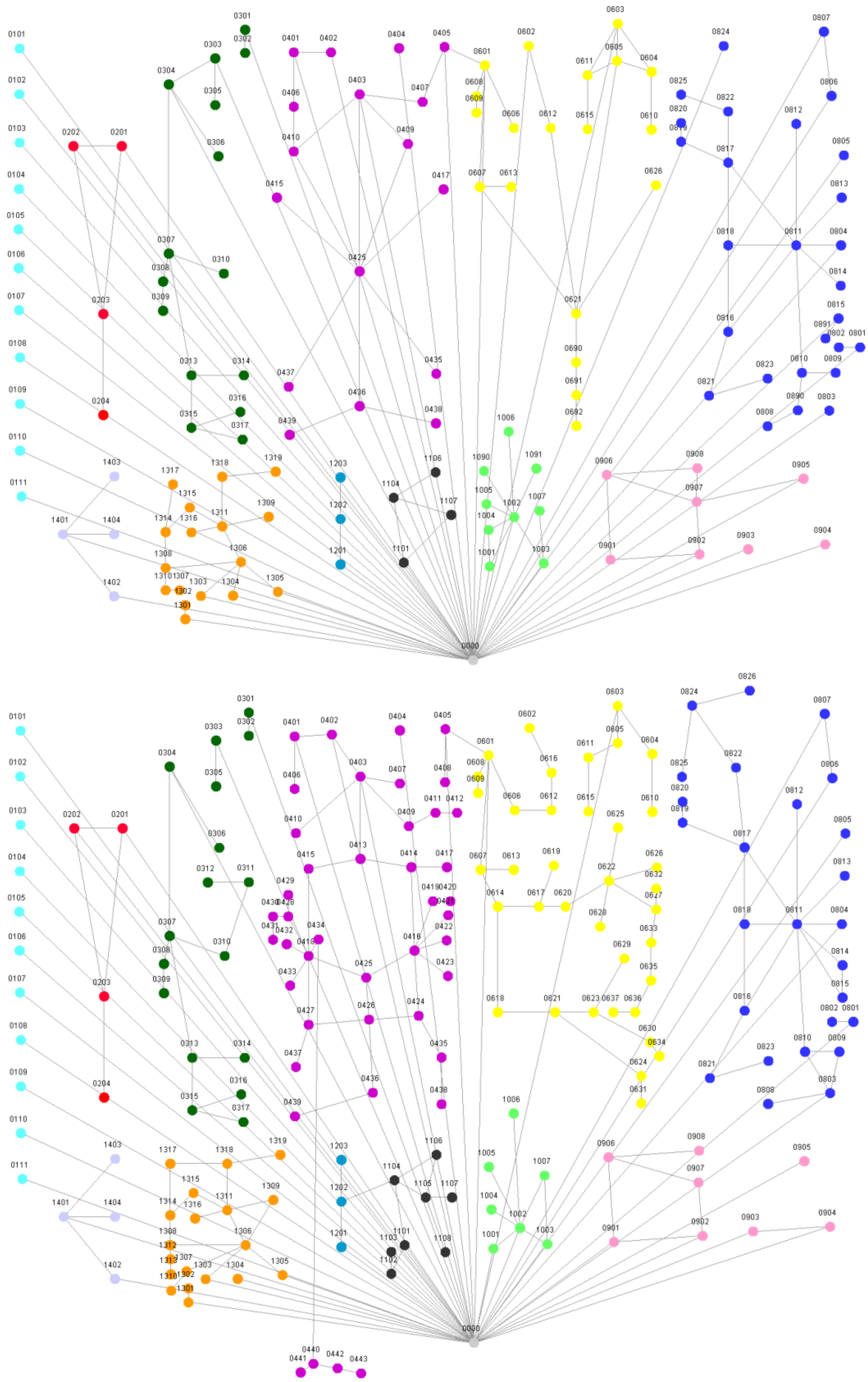


Figure 33: Topological graph of the Severan phase, top, and final phase, bottom, with the name of every node shown above them (by author).

However, due to the construction of the bath complex, this hallway had been completely blocked off in the final phase and was drastically reduced in length. One part of the hallway was re-purposed and became one of the baths (space 0625) of the bathhouse. The remaining part of hallway 0605 became an additional room for the shop, as well as its only entrance as the door to space 0611 was removed. Similar to building V ii 4-5, the back part of building V ii 6-7 underwent a large transformation. The nature of this half of the building changed completely. The temple had been removed, and a high number of spaces was added for the bath complex.

In building V ii 8, space 0824 used to be completely separated from the domus during the Severan phase. Due to its location close to a corner of the city block and next to the Semita dei Cippi, it seems to have been a shop. It is likely that the owners of the domus either gained ownership of this space, or revoked the tenancy if they already owned it, in order to facilitate the extension and renovation of space 0822. The *exedra*, the large semi-circular wall, enlarged space 0822 at the expense of space 0824. The renovation also added a new *nymphaeum*, an elaborate decorative fountain structure, to space 0822. A nymphaeum was also built in building V ii 4-5, located between room 0413 and courtyard 0425. It has a much more central (fig. 33, 34 and 35) and visible (as shown in section 4.2 and 4.3) position within the spatial organisation of its parent building than the nymphaeum in building V ii 8. Nymphaea tend to be placed outdoors (or partially, such as in building V ii 4-5) and in more publicly oriented space (Stöger 2011, 300). What remained of space 0824 behind this exedra, was split into two rooms, space 0824 and 0826. A similar change occurred to space 0815 and 0891. These used to be commercial spaces, with space 0891 (located underneath a staircase) probably being used for storage. During the Severan phase, these two spaces were separated from the domus but could be accessed from the street, just like the other shops in this building (rooms 0805, 0806 and 0807). During the final phase, two new doorways were created. This connected room 0815 to space 0811, the *peristyle* (a colonnaded hall surrounding an unroofed courtyard) of the domus, and to its neighbouring room 0814. This clearly suggests that it was incorporated into the spatial organisation of the domus, and thus became domestic space. However, space 0891 was no longer accessible during the final phase, as its only entrance was blocked off. Room 0803 underwent a transformation similar to spaces 0815 and 0824, from a commercial space only connected to the street to a domestic space connected to rooms 0808, 0809 and 0810. It even became one of the most integrated spaces of the insula, as can be seen in fig. 43. Unlike the other spaces that were incorporated into the domus, room 0803 retained its door to the street. This created a short route from the street to the heating oven located in room 0808, which could suggest that this door was primarily used by slaves.

During the Severan phase, room 0905 of building V ii 9 formed a single entity together with spaces 0901, 0902, 0906, 0907 and 0908: two rooms with a hallway in between and two courtyards. These five spaces clearly had an industrial function: as a whole they were relatively difficult to access from the streets, so a commercial function can be ruled out. At the same time, their configuration would be unsuitable for a domestic function: the only rooms that are roofed are spaces 0902 and 0908 (as well as space 0907, but this is a hallway), but these were separated from each other by the hallway. Additionally, there was no upper floor that could have added potential living space. Having a house consisting of two indirectly connected rooms, combined with two courtyards that are much larger than these two spaces, does not seem feasible. Furthermore, the small basin for water in the courtyard could have been used for an industrial function (Boersma 1985, 166). Thus, because these spaces formed an entity together with room 0905, it could suggest that room 0905 used to have an industrial function during the Severan phase. Although the width of the door between room 0905 and the street is not known for the Severan phase, the doorway as a whole may have been large enough to allow a cart to enter the building. However, as the top of the doorway is missing, it cannot be established if it would have been tall enough for a cart. Nonetheless, Boersma's isometric reconstruction of the façades (shown in appendix F1) suggests that this building would have been the tallest single floor structure of the insula, which would make this theory plausible. During the final phase, the door would have been much too small for carts to enter, as its width was roughly one fifth of the whole doorway, as can be seen on Boersma's plan of the final phase (appendix A8) and on the reconstruction of the façades in appendix F1. The doorway to courtyard 0901 may have been added to compensate for the loss of access to the entrance through room 0905. Whilst it probably would not have allowed carts to enter the courtyard, the carts could have simply been unloaded from the street to deposit resources or goods into this part of the building. Blocking traffic in this street would have been less of a problem than on the Via della Fortuna Annonaria due to the relatively low amount of traffic in this street, which is further discussed in section 4.4. Room 0905 was an independent unit during the final phase, suggesting that it had a different tenant than the spaces in the southern half of the building which it used to be connected to. Additionally, it may have become a commercial instead of industrial space. Its separation from the industrial section of the building, and its location close to the corner of the insula and next to the street (fig. 33), would have made this space more suitable for commercial than industrial purposes during the final phase. This resulted in an interesting situation for space 0907, as the function of this hallway seems to have been to provide access between these two areas, by connecting room 0905 to the southern half of the building. Without the connection to room 0905, space 0907 would have lost this function. Perhaps it simply ended up as a small storage space. Two other rooms in this building, 0903 and 0904 underwent a different change. Whilst they were separate, individual entities during the Severan phase, a doorway was created between them in the final phase, suggesting that both of them were used by the same tenant. It also suggests that they had the same owner, as he would have had to give permission for this, or even initiated this change.

The connection between buildings V ii 11 and V ii 12, during the final phase, had a much larger effect. This doorway is placed at a central position within the spatial organisation of these two buildings, transforming them from two separated buildings into a single entity. This suggests that, during the final phase, both V ii 11 and 12 had the same owner, and that they were both used or inhabited by the same people. During the Severan phase, they were probably inhabited separately.

Lastly, room 1304 in building V ii 13 underwent a change similar to space 0303. It used to be connected to domestic space, in this case a courtyard (1306) instead of a hallway, during the Severan phase. In the final phase this doorway had been walled up, showing that easy access to the domestic space behind this room was no longer considered important. This could suggest that the shop was no longer run by an inhabitant of the house behind the shop, or of the apartment on the upper floor that could be accessed from the staircase next to the internal courtyard.

The justified access graphs also allow for an analysis of the insula as a whole. The access graph of the Severan phase (fig. 34) has a typical bush-shape: shallow and wide, decreasing in width as the depth increases. The graph has a syntactic depth (the maximum depth excluding the root point) of 6. Generally, this means that most spaces could be accessed from a street relatively easily, and that the insula was not very private: it was more outward focussed than during its final phase.

The justified access graph of the final phase (fig. 35) is also somewhat bush-shaped, but much deeper and wide, with a syntactic depth of 11. This means that, on average, the spaces had a lower degree of accessibility but were more private. During this phase, the city block was focussed inwards to a higher degree.

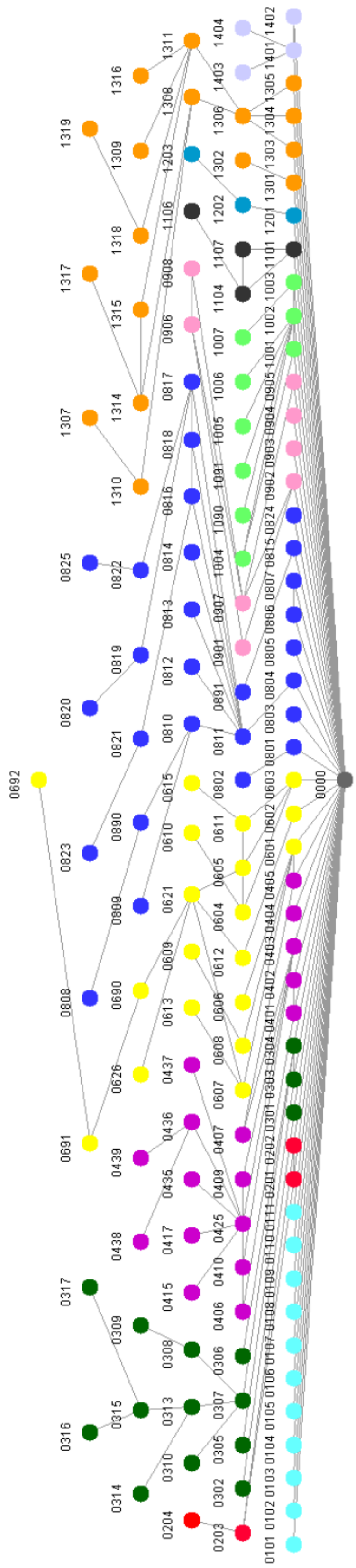


Figure 34: Justified access graph of the Severan phase of insula V ii (by author).

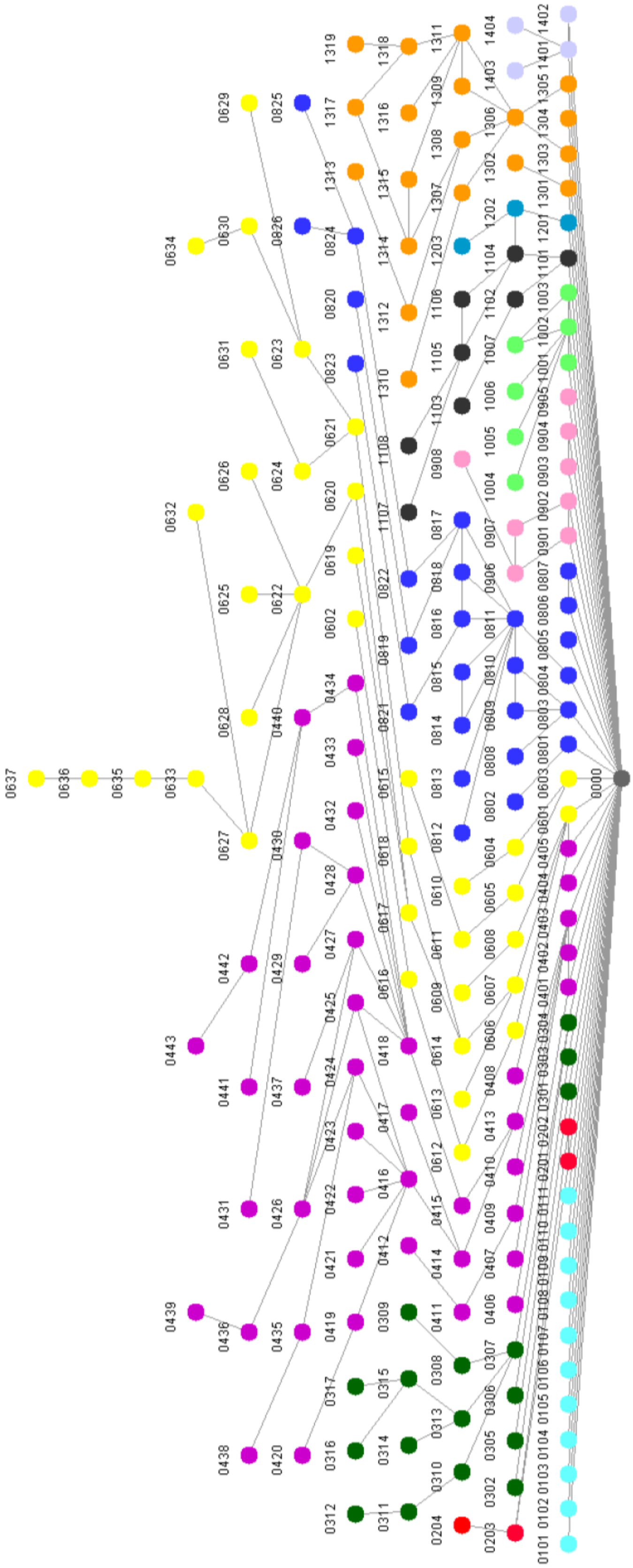


Figure 35: Justified access graph of the final phase of insula V ii (by author).

In the j-graph of the Severan phase (fig. 34), space 0808 is located relatively deep within the spatial organisation of building V ii 8 (at the fifth level of depth). However, during the final phase of this building, space 0808 is located much lower in the graph (fig. 35), on the second level of depth. During the Severan phase, slaves would have had to bring fuel through the main entrance of the building and walk through multiple spaces in order to reach room 0808. Perhaps the owner of the domus did not like this and created the new entrance to stop the slaves from having to go through the main living area of the building.

In the graph of the final phase, the deeper levels are more emphasized. The total number of convex spaces (including the root node that represents the four streets) increased from 139 to 188. The number of nodes on the first level is slightly lower, whilst the number of levels and number of nodes at the deeper levels increased drastically. This is visualised by the two bar graphs in fig. 36. The relatively higher number of spaces located at deeper levels within the graph, suggest that the insula became more private; more intimate. More spaces required the visitor to pass through a higher number of other spaces before they could be reached from the streets. The main contributors to this change are buildings V ii 4-5 and V ii 6-7, as shown in figure 37. They both roughly doubled in size and maximum depth. One interesting addition is the underground complex in building V ii 4-5. The underground spaces, 0440, 0441, 0442 and 0443, each have high RRA values (between 1,42 and 1,81), reflecting a high degree of segregation. These spaces also had low connectivity values (between 4 and 11) and a high depth, ranging from 6 to 8. Hence, the underground complex would have been very private. Whilst significant changes occurred to the spatial organisation of most other buildings (except for buildings V ii 1, 2 and 14), these had little relatively effect on the overall depth of the spaces.

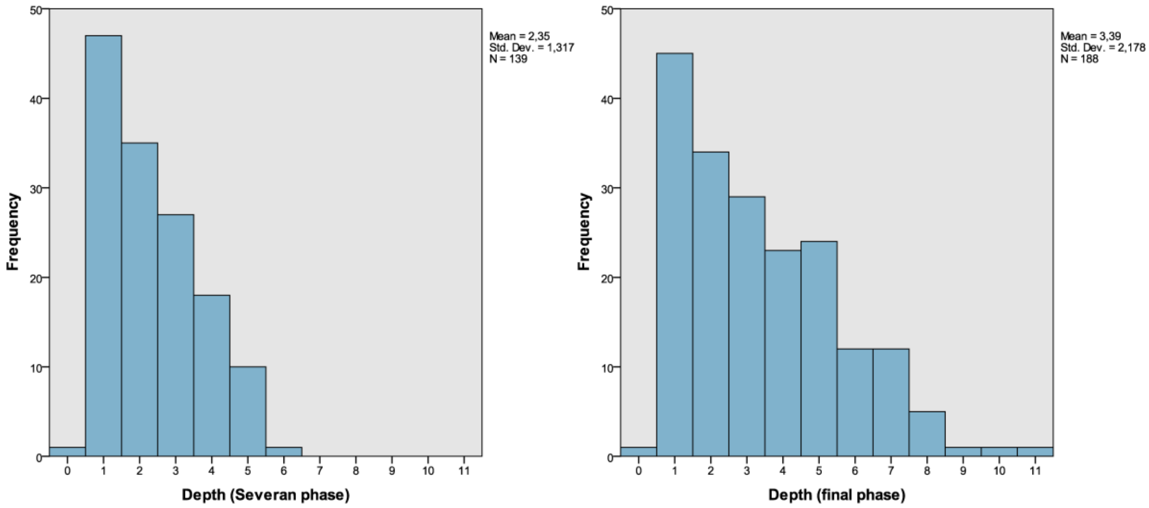


Figure 36: Bar graphs of the frequency of depth values in the Severan phase access graph, left, and the final phase access graph, right (by author).

The depth values (fig. 36) and control values (appendix B5 and B10) of the nodes show that, during the final phase, relatively fewer spaces controlled access to a higher number of spaces. There are several specific spaces in the lower levels of the graph one has to pass through in order to reach the deeper spaces. For example, the hallway of the apartments and domus, or the multiple hallways leading up to the bath complex in the back half of building V ii 6-7. In fact, building V ii 6-7 has the highest number of spaces one first has to pass through (spaces 0601, 0607 and 0614) in order to reach the main part of the building, the bath complex. This means that the bath complex had low accessibility and a high degree of privacy. Another notable aspect of the bathhouse in building V ii 6-7, is that slaves would have had to use the same entrance as the visitors, as everyone had to pass through spaces 0601, 0607 and 0614 in order to reach the bath complex in the back of the building. Then, the slaves still had to pass through the portico (0618) and courtyard (0621) in order to reach the *praefurnium*, the furnace or stoke hole of a Roman bath from where the water was heated (Stöger 2011, 301). In building V ii 6-7, the praefurnium consisted of spaces 0623, 0630, 0634 and 0629. This relatively low degree of social segregation may be explained by the small size of the bathhouse. There may not have been sufficient space available to create an alternative path that the slaves could take.

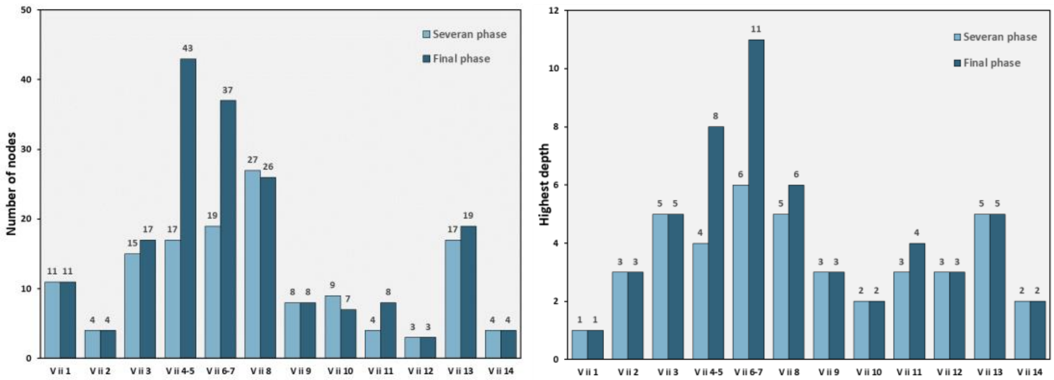


Figure 37: Bar graph of the number of convex spaces in each building, left, and the highest level of depth in each building, right. The values of the Severan and final phase are shown separately (by author).

Whilst the mean RRA of each building changed, the ratio of the values between the different buildings in the same phase remained similar for both phases (fig. 38 and 39). In a boxplot, circles represent values that are outliers. Outliers have a value that is more than 1,5 times the interquartile range (the spread of the middle 50% of values, which can also be described as the difference between the value at the bottom end and the top end of the blue box) higher than the value of the third quartile (the top end of the blue box).

Whilst the boxplot of the final phase (fig. 38) is placed higher than that of the Severan phase, the spread of both the box and the whiskers (the black lines which indicate the lowest or highest value), remained similar. Hence, whilst the values generally increased, their distribution was similar. For most buildings, the mean RRA increased by a value of around 0,15. The increased mean RRA of the buildings reflect an increase in the overall segregation of spaces within every building. This suggests that there would have been a lower rate of interaction between people. The decreased mean RRA also reflects a possible decrease in social encounter and retail activities throughout the buildings. Thus, overall, the buildings became more private, and it can be expected that the number of commercial spaces would have decreased.

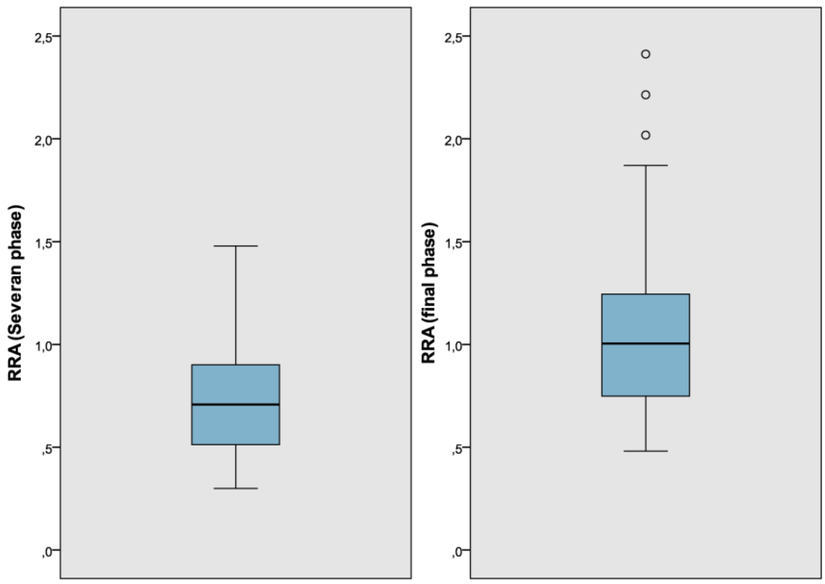


Figure 38: Boxplots of the real relative asymmetry values of all spaces in the Severan phase access graph, left, and the final phase access graph, right (by author).

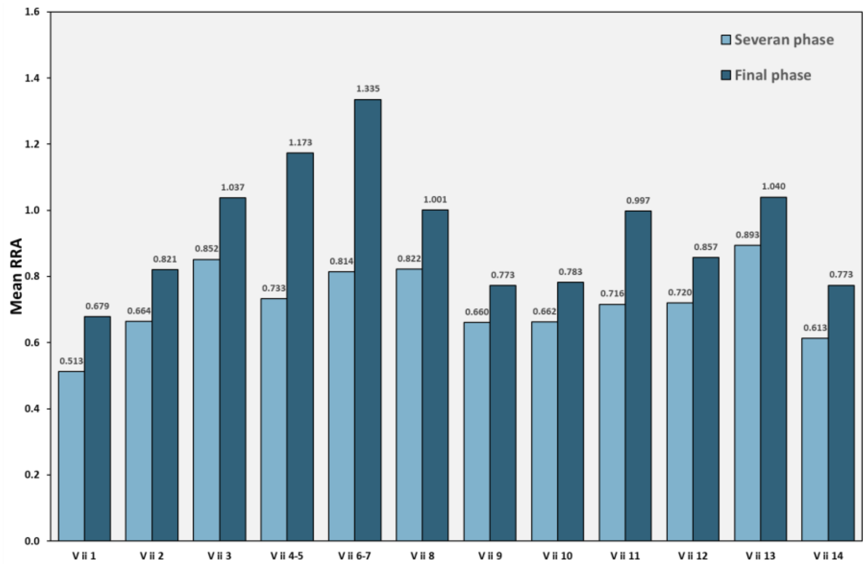


Figure 39: Bar graph of the mean real relative asymmetry of the nodes of the individual buildings, for the Severan and final phase (by author).

The mean RRA values of buildings V ii 4-5, 6-7 and 11 increased more drastically than those of the other buildings. Although building V ii 11 will not be discussed because of its lack of a clear internal layout, the changes in buildings V ii 4-5 and 6-7 suggest a decrease in social encounters and hence a drastic increase in privacy.

The mean RRA of building V ii 4-5 increased from 0,733 to 1,173. During the Severan phase, the spaces within this building were relatively strongly integrated. During the final phase, the mean RRA value is above 1, which shows that the spaces became more segregated. The significant increase in segregation suggests that the building became much more private. The likely rate of interaction and random social encounters between people would have decreased.

The value of building V ii 6-7 increased from 0,814 to 1,335. This is the highest increase of all buildings. For most types of buildings, this would suggest a large decrease in random social encounters. This is further supported by the three outliers in the boxplot in fig. 38, which represent room 0635, room 0636 and bath 0637. When entering the building from the street, one would have had to pass through eleven other spaces in order to reach space 0637 (fig. 35). These spaces, which all belong to the bath complex, were the most segregated spaces in the entire insula during the final phase. However, because a large part of this building consisted of a bath complex during the final phase, it has to be interpreted somewhat differently. Whilst the increased mean RRA does reflect an increase in privacy of the bath complex, social encounters may have been more common than what one would expect from such a high RRA because of the public nature of Roman bathhouses. Alternatively, the high mean RRA could support the interpretation that this bath complex was privately owned, instead of being a public bathhouse.

Table 3: Differences in the average and total values of spatial variables of all nodes from the access graph, between the Severan and final phase. The change in percentage reflects the change compared to the value of the Severan phase (by author).

Variable	Severan phase	Final phase	Difference	Change (%)
Number of nodes	139	188	49	35.25%
Mean RRA	0.76	1.06	0.31	40.42%
Maximum Depth	6	11	5	83.33%
Mean Connectivity (3)	46.55	34.94	-11.61	-24.94%
Mean Depth	2.35	3.39	1.05	44.70%
Mean Control	1.00	1.00	0.00	0.00%

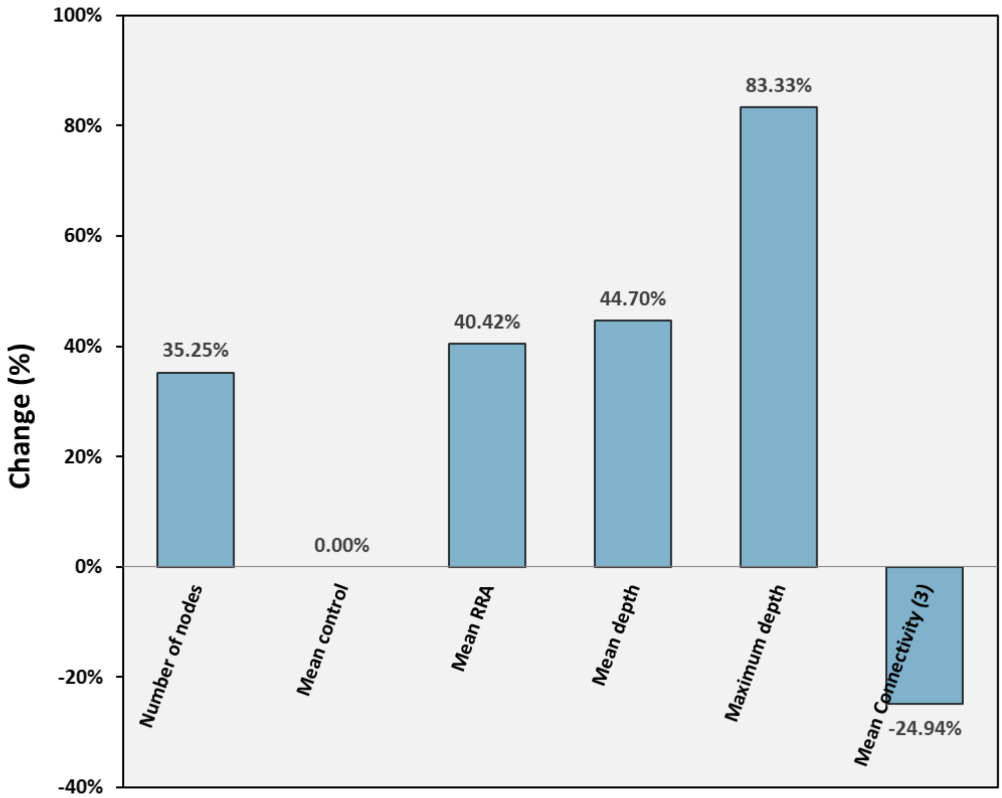


Figure 40: Bar graph of the difference, in percentages, between access graph values of the Severan and final phase (by author, based on table 3).

Table 3 shows the changes in the values of the variables between the Severan and final phase. The bar graph in fig. 40, which is based on table 3, gives a clear impression of the major changes between the two access graphs. Except for connectivity (for a range of 3), all these variables have a higher total or average value in the graph of the final phase. The increased mean depth and maximum depth shows that the emphasis of the graph moved more towards the deeper depth levels, reflecting an overall increase in privacy throughout the city block. The boxplot in fig. 41 visualises the increased average and maximum depth of the graph. Both the average and total depth increased drastically. During the final phase, there are also two outliers: nodes 0636 and 0637. Once again, this reflects the high degree of privacy within the bathhouse.

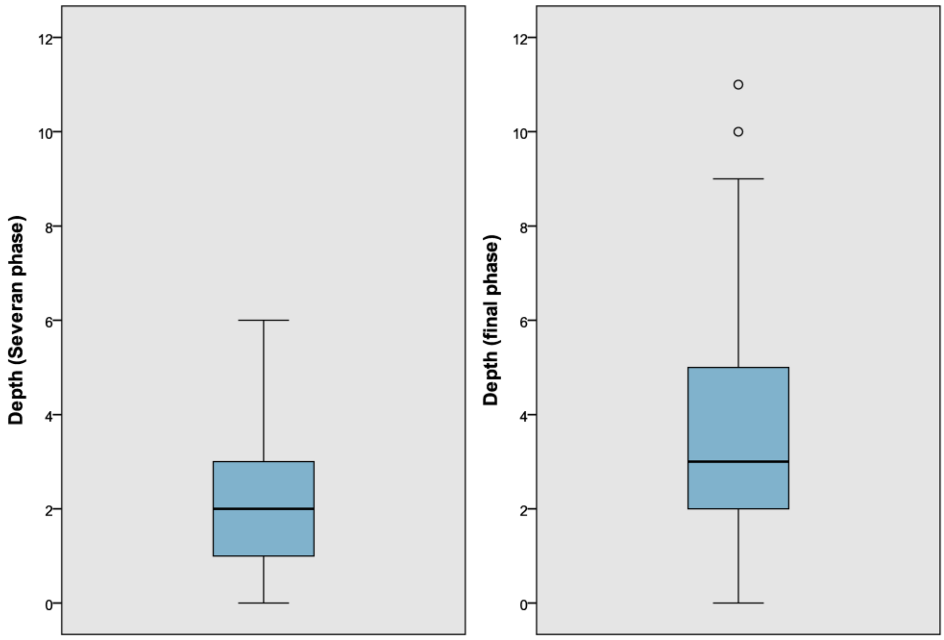


Figure 41: Boxplots of the depth values in the Severan phase access graph, left, and the final phase access graph, right (by author).

The mean control value has been included in fig. 40 to show that the calculations do not contain errors. As control is a relative measurement, the average value of all nodes in the graph is exactly 1. Hence, this value should not change. However, this also means that the mean control value of a graph cannot be used to interpret the effect of any changes in the city block.

The decrease in connectivity reflects an overall decrease in accessibility, which in turn could suggest an increase in the degree of privacy as well. Whilst the mean connectivity decreased by roughly 25% (table 3), fig. 42 shows that the lowest and highest values remained stable. Whilst the maximum and minimum values remained roughly the same, the spread of the values changed drastically. A major change can be seen in the lowest 50% of the values. Especially the length of the second quartile (the lower half of the blue box, representing 25% of the values) decreased drastically, meaning that the same number of nodes have a connectivity value that falls within a highly compressed range. This further supports the interpretation of a decrease in accessibility between the Severan and final phase of the insula.

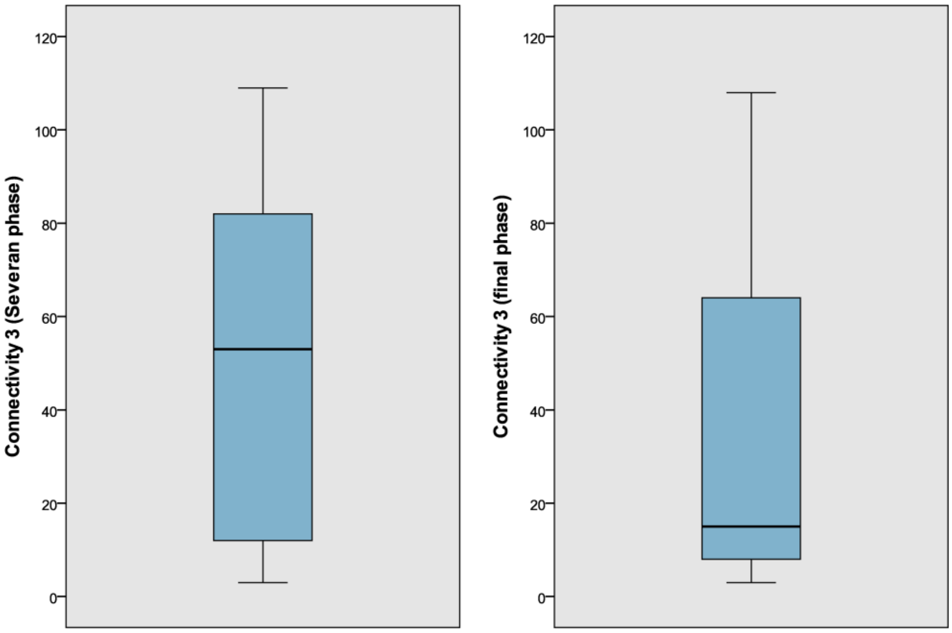


Figure 42: Boxplots of the connectivity (3) values in the Severan phase access graph, left, and the final phase access graph, right (by author).

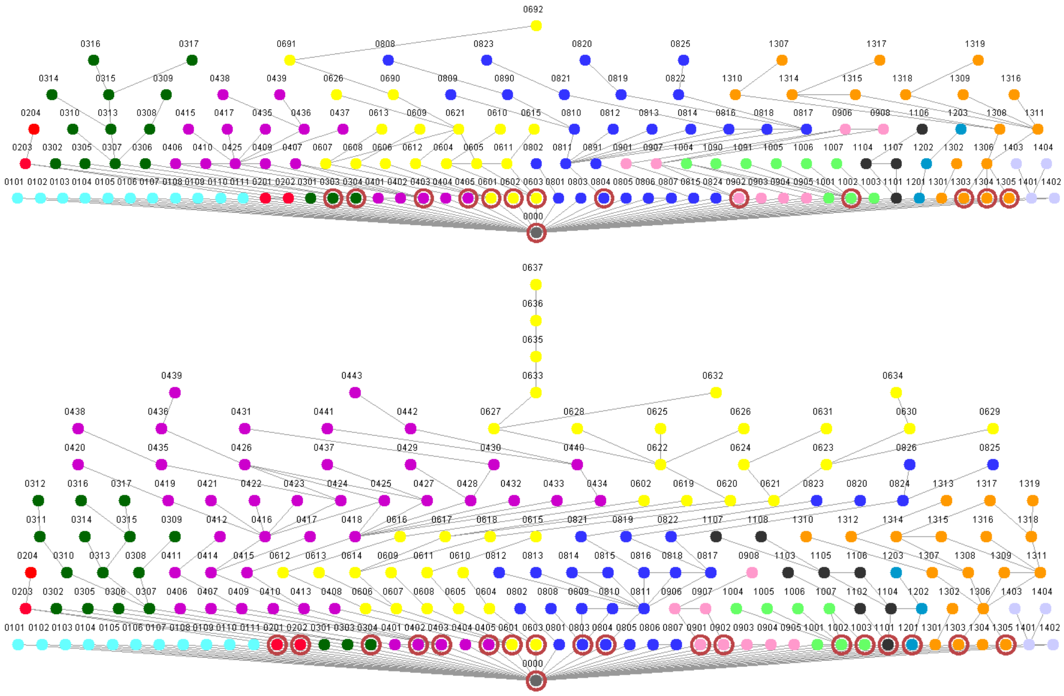


Figure 43: Location of the integration core (10% lowest RRA values) in the justified access graph of the Severan phase, top, and final phase, bottom (by author).

The spaces belonging to the integration core of the two phases of insula V ii are encircled in the j-graphs in fig. 43. These were the least segregated, and thus the least private, spaces of the entire insula in their respective phase. In both phases, the nodes with the 10% lowest RRA values are all located on the first depth level (excluding root node 0000). The integration core of the insula is spread across the buildings in both phases, meaning that the insula did not have a focal area within its spatial organisation. This reflects the lack of a public courtyard or similar space within the insula that connects the buildings. Please note that the graph of the final phase has a higher number of spaces in its integration core because the graph has a higher total number of nodes. This is why two nodes of building 2 belong to the integration core of the final phase, even whilst the configuration of this building did not change.

4.2 Isovist analysis

This section presents the results of the isovist analysis, the second analysis used in this study. In order to visualise the major changes in the surface area of the 52 isovists from all entrances of insula V ii are coloured in fig. 44 based on the size of their surface area. No isovists were made of the three doorways that only lead to a staircase. Isovists with a relatively small surface area are coloured blue, whilst the largest isovists are coloured red. The surface area of each isovist (in m^2) can be found in the bar graph in fig. 45.

Most buildings have a high metric depth (reflected by one or multiple isovists reaching the opposite end of the building). The only two buildings where this is not the case, are V ii 6-7 and 13 during their final phase. This would suggest that, during the final phase, the rooms located far away from the streets in these two buildings are relatively private compared to those in the other buildings.

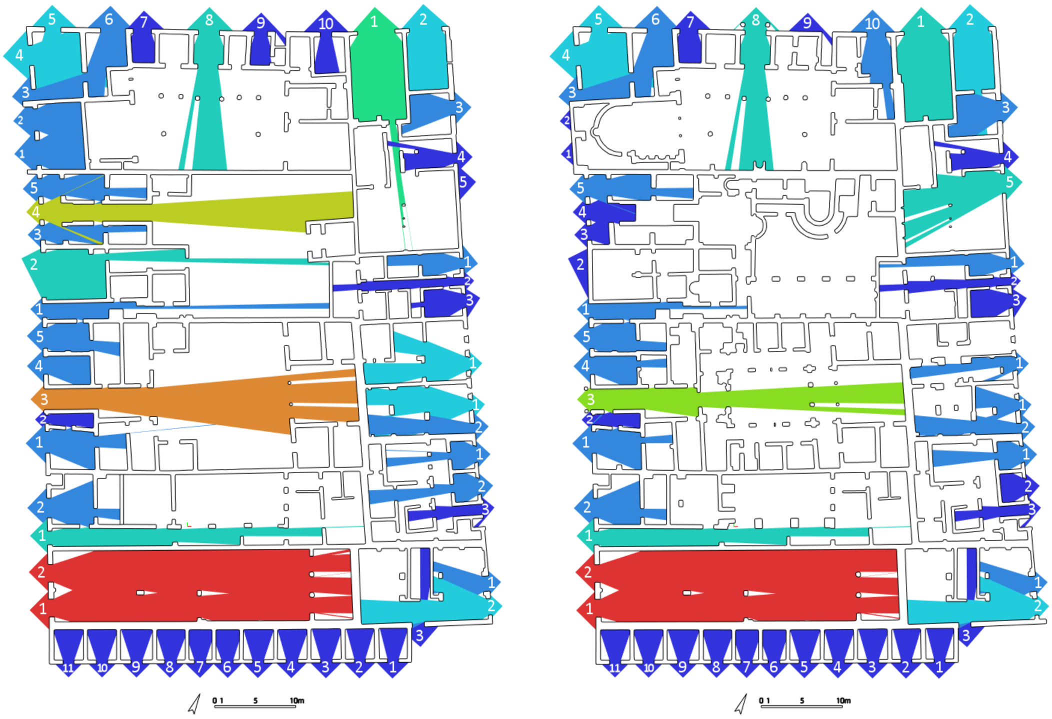


Figure 44: Isovists created in the plan of the Severan phase (left) and final phase (right), coloured based on their relative surface area. The colour distribution begins with blue at a value of 0 and ends with red for values above 200. The isovists are numbered clockwise and begin counting at 1 for every building (by author).

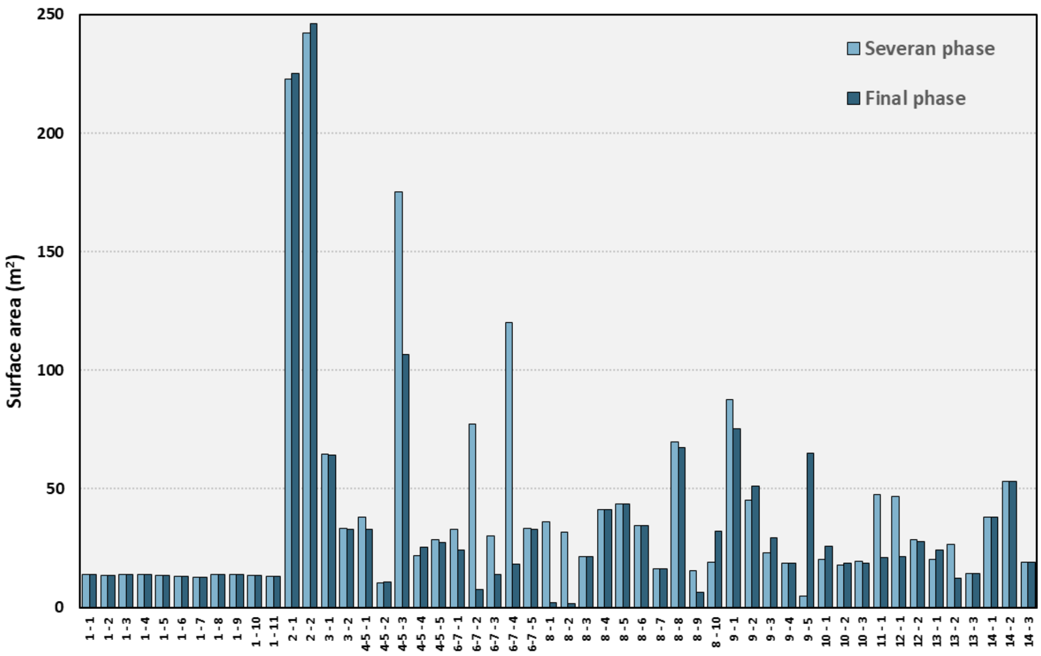


Figure 45: Bar graph of the surface area of the individual isovists during the Severan and final phase. Because of how the isovists are numbered, their location in the graph reflects their adjacency in the real world, looping back from '14 - 3' to '1 - 1' (by author).

In the two domus (V ii 4-5 and 8), it is possible to see relatively far into the structure from their main entrance. This could have increased the curiosity of visitors, in order to 'lure them in', so to speak. Whilst this was also possible in building V ii 6-7 during the Severan phase, this cannot be said about its final phase. Four out of five isovists of this building reduced in size over time. The entrance at isovist 2 was completely blocked off. Only isovist 5 of this building remained unchanged. This decrease in visibility could reflect an increase in privacy. This supports the function of this structure as a bathhouse.

The nymphaeum in building V ii 4-5 (appendix H5) was placed in an eye-catching location between room 0413 and courtyard 0425, directly visible from the main entrance (isovist 3 of V ii 4-5). However, the nymphaeum of building V ii 8 (in room 0822) would not have been visible from the street (isovist 8 of V ii 8), not even from the *fauces* (the main entrance hall or corridor, in this case space 0804). Nonetheless, this nymphaeum would have been visible from most areas within and surrounding the courtyard of the building. Perhaps it was considered more important that the nymphaeum would function as decoration within this specific room. Alternatively, maybe it was placed here because it was the only location where it would fit, without having to partially demolish the courtyard.

The large size of the isovists in building V ii 2 may be explained by the need for accessibility, combined with the shape of the building plot. The façade is relatively small compared to the total surface area of the building. In this case, accessibility was clearly considered more important than privacy. The internal space of the building is very open in both phases. During the final phase, visibility would have been slightly higher due to the removal of a short wall in the back part of the building.

Generally, the visual fields of the isovists at buildings V ii 1, 2, 9, 10 and 14 suggest that people walking through the streets would have been able to see a substantial part of the interior of these buildings (fig. 44). This is not the case for the larger buildings (V ii 3, 4-5, 6-7 and 8). The interior of these four buildings would have remained mostly hidden from people on the streets, especially during their final phase. This reflects a relatively high degree of privacy compared to the other buildings of insula V ii.

The visibility of buildings V ii 11 and 12 lies somewhat in between that of the aforementioned categories. Their rooms that lie adjacent to the streets were highly visible during both phases, with limited view of spaces deeper in the buildings (and even less during the final phase). While a relatively large part of the interior of these buildings could be seen during the Severan phase, this decreased significantly in the final phase.

In building V ii 13, the rooms at the front of the building were highly visible. The rest of the interior, however, had a lower degree of visibility and thus would have been more private. Isovist 1 increased in size, but only slightly, due to the removal of a pillar. Isovist 2 roughly halved in size between the Severan and final phase. During the final phase, its view was limited to the front room as a door was blocked off. This suggests that the back half of the building became even more private.

Compared to the Severan phase, most isovists decreased in size or remained unchanged (fig. 44 and 45). Only ten isovists increased in size in the final phase: isovists 1 and 2 of building V ii 2, isovist 4 of building 4-5, isovist 10 of building V ii 8, isovists 2, 3 and 5 of building V ii 9, isovists 1 and 2 of building V ii 10, and isovist 1 of building 13. However, the increase of most of these isovists is relatively small. Hence, the overall size of the areas that are visible from the streets clearly decreased in the final phase. The total area decreased by roughly 322m^2 (table 4). This corresponds to a decrease of 15,03 percent. This decrease in the visual fields of the isovists suggest an overall increase in the levels of privacy within insula V ii.

Table 4: Isovist analysis data (by author).

Phase	Total surface area of isovists (m^2)	Number of isovists
Severan	2140.27	52
Final	1818.62	52
Difference	-321.64	0
% change	-15.03%	0%

According to Boersma, the total practicable area (consisting of open space, excluding walls and staircases) of the ground floor of the insula would have been 3515m^2 during its final phase (Boersma 1985, 294). However, due to overlap between isovists and the including of small sections of the streets, the total surface area of the isovists would be too high when compared to the total surface area of the insula. For example, the size of the two isovists of building V ii 2 added together is 471,30m^2, whilst the surface area of this building is only 335m^2 (Boersma 1985, 294). Nonetheless, a very rough comparison can be made with Boersma's measurements. On average roughly 5m^2 is deducted for each isovist in order to remove the street section. This brings down the surface area of the final phase to 1557m^2. To compensate for the overlap between the isovists, an estimated 265m^2 is deducted.[4] This brings the surface area down to a more realistic 1292m^2 for the final phase. This would mean that roughly a third of the interior space of the city block could have been visible from the streets during the final phase. Sadly, this cannot be compared with the Severan phase as no measurements of the practicable area during that period are available. However, the decrease in size of the isovists between the Severan and final phase suggest an overall increase in the privacy levels throughout insula V ii.

[4] This was calculated by adding up the estimated overlap within each building: 160m^2 for V ii 2, 20m^2 for V ii 6-7, 50m^2 for V ii 8, 5m^2 for V ii 9, and 30m^2 for V ii 14.

Figure 46: Two isovists, created from the southern end of the Semita dei Cippi (orange), and the eastern end of the Via Della Fortuna Annonaria (red), showing the plan of the final phase of insula V ii (by author).

Two additional isovists shown in fig. 46 reveal the high degree of visibility of the entire northern and western façade of the insula. As there were no changes to the shape of the exterior boundaries of insula V ii between the two phases, this applies to both phases. Due to the slight curve in the Semita dei Cippi to the south of the city block, it was possible to see the block's entire western façade from a considerable distance during both the Severan and final phase. The same applies to the Via della Fortuna Annonaria, which is also slightly curved. Interestingly, the main entrance of building 4-5 and 8 have a similar, central, position on their respective sides of the insula. They are well visible and during the final phase their location is further emphasized by the columns with pediment. Even from a distance, before it would have been possible to look inside the buildings or clearly distinguish their façade, the porches of building V ii

4-5 and V ii 8 would have focussed the sight of passers-by on these areas. The fact that it is placed in front of the building causes it to block sight of a relatively large area behind it, meaning that it is clearly visible.

4.3 Visibility Graph Analysis

This section presents the results of the third method applied on the city block. The enlarged visibility graphs, which also include the streets, can be found in Appendix D. For transparency, appendix D includes both the graphs with the default colour distribution, and those with an adjusted colour distribution. As the default colour range depends on the minimum and maximum value in the graph, using the default distribution does not allow for a direct comparison between the two phases. It results in different colour ranges for the graphs of the two phases. In order to be able to identify the differences between the graphs, the figures that are used for the comparison in this section have the same colour range. The different variables are shown with different ranges, but they are the same for both phases.

Due to the high number of cells in the graphs of the Severan (32 499 cells) and final phase (31 602 cells), this section relies mostly on a visual comparison of the graphs. There are simply too many cells in the graph to be able to present the differences in the spatial variables of every individual cell. Additionally, presenting a selection of the data exported from Depthmap based on their highest values would not give us much useful information about the insula itself, because many of these cells are located on the streets. Thus, for the purpose of comparing the two phases, the images of the graphs are the most useful.

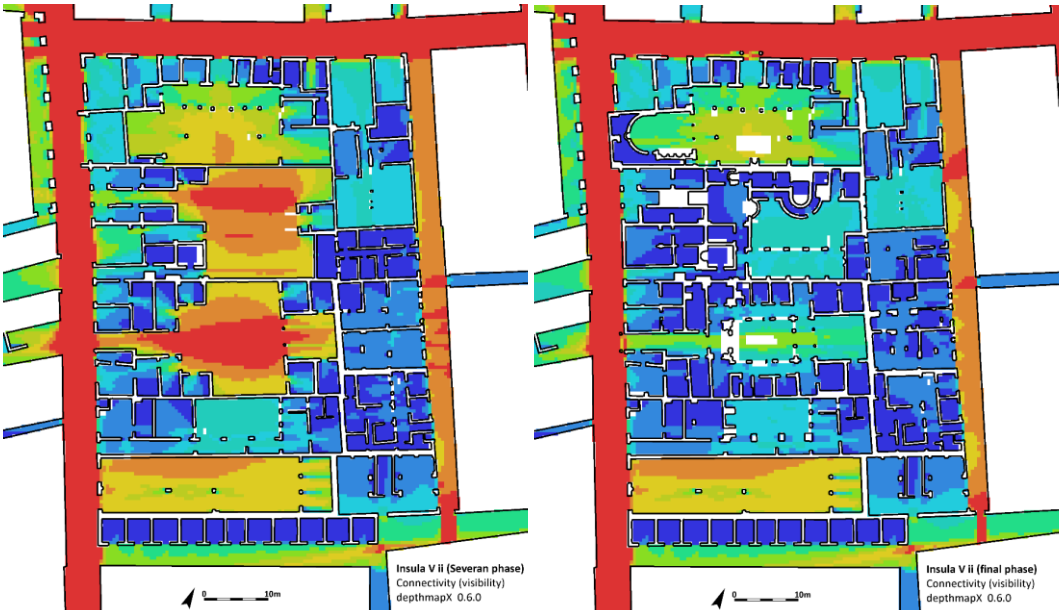


Figure 47: Graph of the connectivity values (visibility) of insula V ii during the Severan phase (left) and final phase (right), with a colour distribution of 7 (blue) – 1600 (red) (by author).

Including the streets in the visibility graph analysis has had a pronounced effect on the results of most of the corner buildings of the insula (fig. 47). Buildings with wide or large doorways also have a relatively high degree of visibility in both phases. A simple example of change can be seen in building V ii 8, where the width of the doorway of room 0813 was reduced, resulting in a substantial decrease in visibility. This would have made the interior of this specific room less visible, which could also indicate a need for more privacy, and may have led to a decreased number of people visiting to the room.

Many changes in visibility directly reflect the changes in the configuration of the spaces that are already discussed and interpreted in section 4.1. For example, the creation of a doorway in building V ii 9 between spaces 0904 and 0903 increased the visibility between these two spaces. This supports the interpretation given in section 4.1 that these two spaces may have been used by the same tenant during the final phase. As these interpretations are essentially the same as the ones discussed in section 4.1, they will not be repeated.

The graph of the final phase shows that the nymphaeum in building V ii 4-5 was placed in a location within this building where visibility converged during both phases. Whilst the courtyard had a higher degree of visibility, the location of the nymphaeum was among the most visible ones of the building. This supports that the owner or architect may have deliberately placed it there based on the visibility of the location. The nymphaeum would have turned this already highly visible location into one of the visual focal points of the ground floor of the building.

The large open areas of the insula, located in buildings V ii 2, 4-5, 6-7 and 8, all had a high degree of visibility during the Severan phase. In the final phase, these areas either disappeared or drastically decreased in size. Only the visibility within building V ii 2 remained relatively unchanged.

The large decrease in visibility within building V ii 4-5 is caused by the construction of a high number of architectural elements and rooms. These additions cause building V ii 4-5 to appear less open (and thus more private), but it also forces visitors to focus their view on the area which was still open when entering the building and walking through the main hall. Visibility within the central area of this building (hallway 0403, courtyard 0425 hallway 0426 and room 0436) remained relatively high compared to the rest of the insula. Through the window of the courtyard (this window was part of the nymphaeum), visitors would have been able to see all the way from the entrance to the back wall of the building. Within building V ii 4-5, these rooms would have been the least private. Hence, room 0436 can be identified as a *tablinum*, a reception room where guests would have been received. One could expect the wall at the back of the building to have been lavishly decorated, or that statues would have been placed in this area. Due to being a focal point of visibility, the courtyard may have been attractive to enter.

The disappearance of the highly visible area in building V ii 6-7 was caused by to the construction of the bath complex. This suggests an increase in the degree of privacy of this area, which clearly reflects the function of the bathhouse. The only area which remained relatively visible are the courtyard (space 0621) and portico (space 0618). Based on their high visibility and location, it seems likely that spaces 0621 and 0618 functioned as the *palaestra* of the bathhouse during the final phase. A palaestra is the exercise court of a bath complex, an open space (0621) for people practicing sports. It often has a colonnaded enclosure (Stöger 2011, 301), in this case represented by space 0618.

As far as its internal visibility is concerned, building V ii 8 remained relatively unaffected by its high number of architectural changes. The intervisibility of the large open courtyard decreased only slightly. The decrease in visibility within the rooms that used to be connected to the streets during the Severan phase (spaces 0803, 0815, 0824 and 0826), shows that they were incorporated into the domus, as discussed in section 4.1. Similar to building V ii 4-5, the courtyard of building V ii 8 would have been a focal point of visibility. Even though building V ii 8 had a lower metric depth than building V ii 4-5, caused by its different orientation (horizontally alongside the streets, as opposed to the vertical orientation of building V ii 4-5), visitors would have been able to see the back wall of the building, with the basin in the courtyard directly in front of it. Guests were likely received in room 0822, as it had both a relatively high degree of intervisibility, as well as a nymphaeum.

However, it should be noted that the visibility within the two domus (V ii 4-5 and V ii 8) may be somewhat underrepresented during their final phase. The cells that signify the addition of several new features, like the two basins, have been taken out of the equation. Thus, the visibility values of the surrounding areas are lower than they could be. The removal of these cells was necessary to document their inaccessibility, but it should be kept in mind when looking at these features, especially when comparing them with each other. An interesting observation is that the two basins (in courtyard 0425 and 0818) that contribute the most to this problem, are both located at the centre of a highly visible area. They were clearly intended to be seen.

The visibility within buildings V ii 10 and 12 increased due to the removal of walls. During the Severan phase, building V ii 10 used to have a much lower degree of internal visibility, the lowest of all buildings of the city block. This, combined with its complex layout, may suggest that it used to have a different function during the Severan phase. The same applies to building V ii 12, which used to be an almost open area during the Severan phase. The three rooms were only somewhat separated by two pillars. The addition of a wall decreased visibility between the front (room 1201) and back half (rooms 1202 and 1203) of the building, although within room 1202 this decrease was compensated by a slight increase in visibility caused by the addition of a doorway to buildings V ii 10. This could suggest that spaces 1202 and 1203 obtained the same domestic function as building V ii 10, which is further discussed in section 4.5.

Whilst the intervisibility of the cells of the graph decreased in most areas (fig. 48), it did increase in several locations. The biggest increase occurred in the courtyard of building V ii 9 due to the addition of a doorway which provided direct access to the street, even though the line of sight between the courtyard (spaces 0901 and 0906) and room 0905 was cut of due to the removal of a doorway. The latter had relatively little effect on the courtyard. The change in visibility reflects a decrease in privacy of the courtyard. Visibility within room 1309 of building V ii 13 increased as well due to the removal of several columns, but at the same time visibility within tooms 1311 and 1318 decreased. Hence, room 1309 became slightly less private whilst rooms 1311 and 1318 became slightly more private.

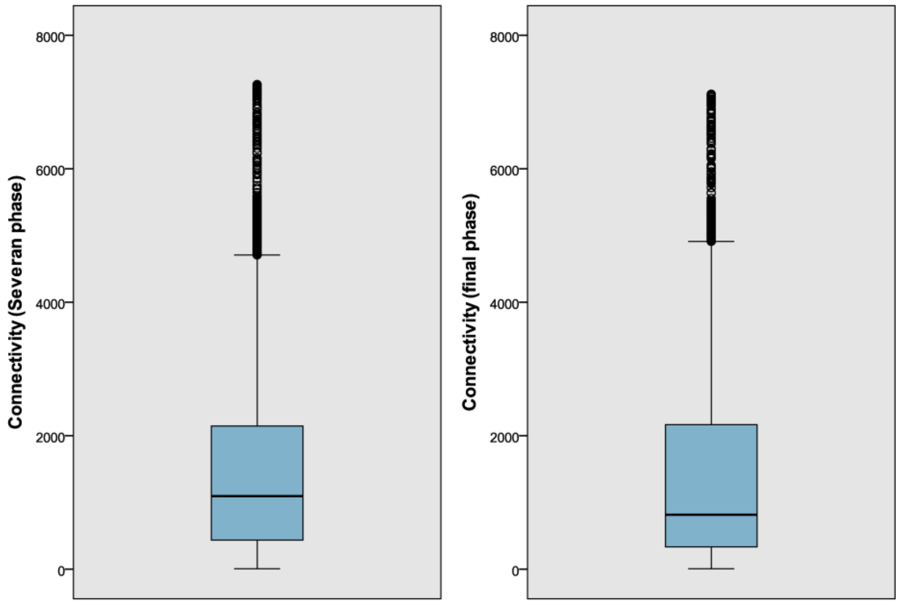


Figure 48: Boxplots of the connectivity values (visibility) of the entire insula during the Severan phase, left, and the final phase, right. The clustered circles at the top reflect the high number of outliers, caused by the high total number of cells in the VGA (by author).

As can be seen in the graphs in fig. 47 and the boxplots in fig. 48, the average visibility of the cells decreased. The overall visibility of the interior of the insula was lower during the final phase due to the construction of new walls, spaces, and other objects. As can be seen from the boxplot, the visibility values of a higher number of cells is concentrated around the lower values during the final phase. The 50% of the cells with the lowest connectivity (represented by the bottom whisker and the bottom half of the box) values moved downwards in the boxplot. The disappearance of the two large clusters of cells with high visibility in building V ii 4-5 and V ii 6-7 are major contributors to the overall changes in visibility. Please note that the data shown in the boxplot also includes the cells that are located on the streets. Hence, this figure reflects the changes within the insula to a lesser degree than one may expect from fig. 47.

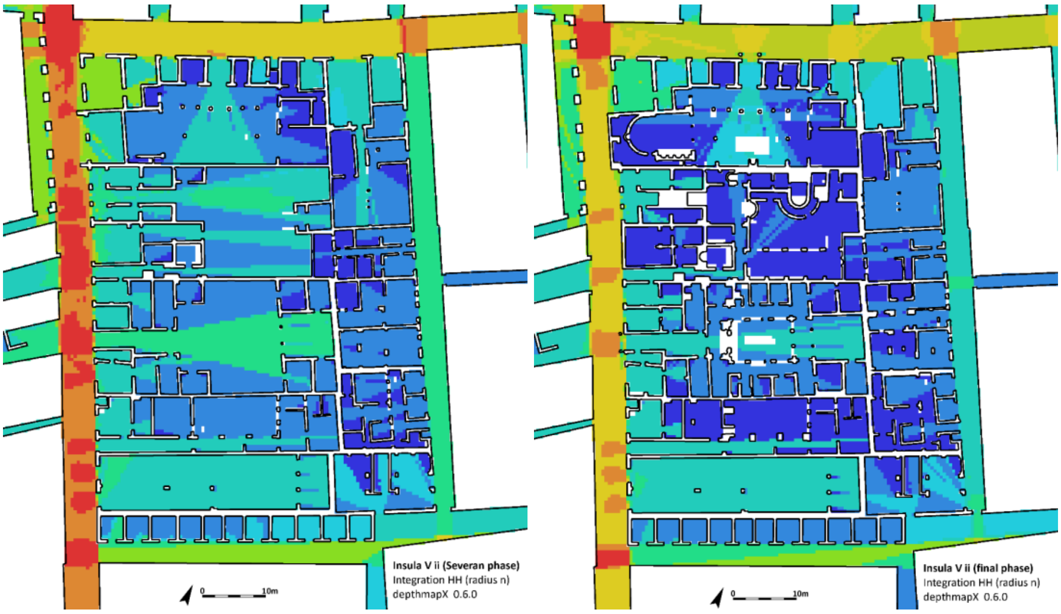


Figure 49: Graph of the integration values (with radius n, or infinite) of insula V ii and nearby streets during the Severan phase (left), and final phase (right) with a colour distribution of 3 (blue) – 9 (red) (by author).

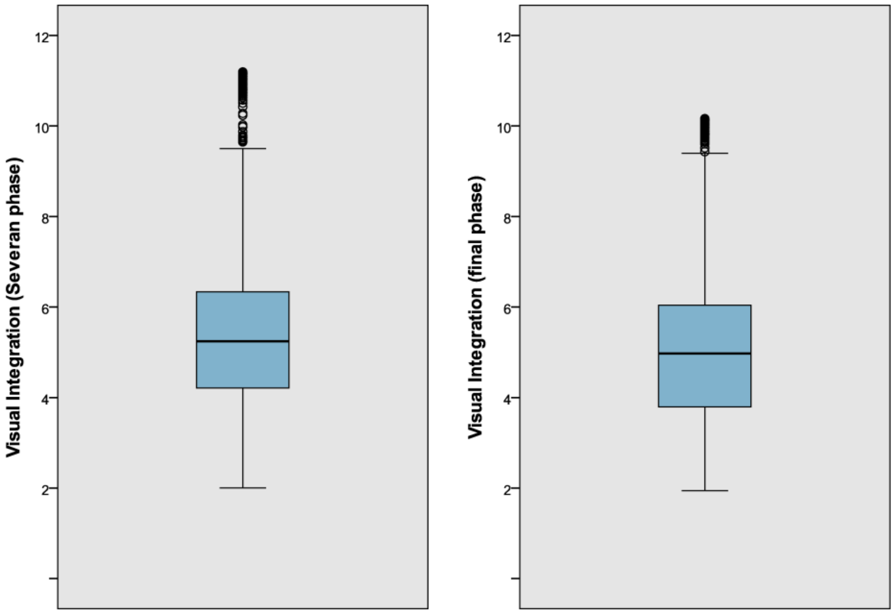


Figure 50: Boxplots of the visual integration values of the entire insula during the Severan phase, left, and the final phase, right. The clustered circles at the top reflect the high number of outliers, caused by the high total number of cells in the VGA (by author).

The visual integration values show patterns (fig. 49) that are similar to the isovist analysis in section 4.3. Hence, these interpretations will not be repeated. However, the integration graph does present new data on the internal spaces of the insula. However, an analysis of the smaller differences is made difficult by the nature of the integration variable. As the integration values of cells are influenced by all other cells in the graph, the values of cells in a building can change even when the building itself did not undergo any changes. For example, this can be seen in the shops in building V ii 1. Nonetheless, there are several major changes that can be interpreted. The boxplots in fig. 50 show a general decrease in the visual integration values, suggesting that the insula would have attracted less movement during the final phase.

The basins of the two domus are both located in areas with the highest integration values of their respective building (in courtyard 0425 and 0818), meaning that these areas would have attracted movement. A relatively high number of people would have passed through these areas. Room 0436 in building V ii 4-5 is one of the most integrated areas within the building. Movement would have been attracted to this area, which supports the interpretation that visitors may have been received here. During the final phase, the high number of rooms surrounding the central area of building V ii 4-5 all had a much lower degree of both visibility and integration (spaces 0417, 0421, 0422, 0423, 0428, 0429, 0432, 0433, 0435, 0438, 0437 and 0439). This suggests that guests would not have been inclined to enter these rooms, and that they were relatively private areas of the ground floor of the domus. However, they may have been able to look inside them whilst walking through the corridors surrounding the courtyard.

4.4 Agent analysis

The fourth analytical method used by this thesis is agent analysis. The results of the agent-based models that include the streets can be found in appendix E. As both models have the same number of agents and duration of 20.000 timesteps, the total and average agent count of all cells combined did not change, so a change in this cannot be discussed. Instead, this section relies on a visual comparison of the graphs of the two phases, shown in fig. 51. Due to the high number and complexity of the changes, this section focusses on building V ii 6-7 as a case study, although several notable changes in other buildings are discussed as well.

Several of the areas where the agents often tend to go to, are centred around locations which are not accessible. Most notably, the fountains or basins of the two domus, V ii 4-5 and 8. This could be explained as a deliberate choice by the architect or owner of the building. Perhaps it was decided to place such features in these locations because the movement of people was already concentrated here before these elements were added, as can be seen in the graph of the Severan phase (fig. 51). One would prefer to add decorative features in locations where they would be seen by a relatively high number of people.

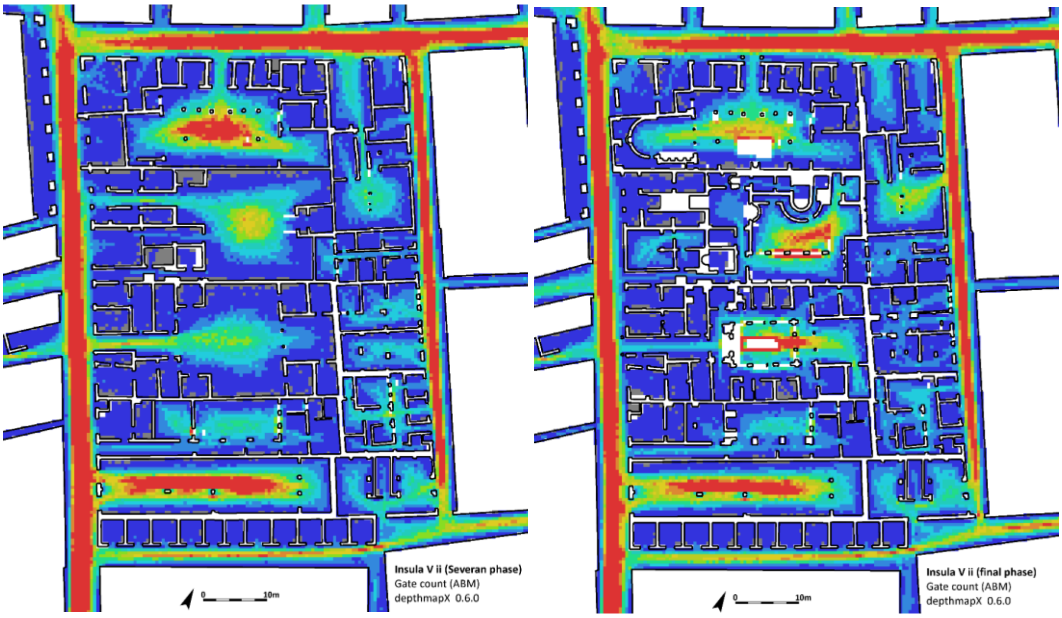


Figure 51: Graph of the gate counts (number of visits) of insula V ii during the Severan phase (left), and final phase (right), with a colour distribution of 1 (blue) – 200 (red). These simulations were run for a duration of 20.000 timesteps (by author).

Although this thesis does not intent to study the streets themselves, they do allow for several interesting observations about the placement of the buildings. The two domus (Vii 4-5 and V ii 8) are located adjacent to the two most-visited streets, whilst the apartments, or at least the ones that have domestic space on the ground floor, are all located on the eastern side, next to a less prominent street.

Whilst no architectural changes occurred within building V ii 1, an interesting observation is that these shops are located next to the least visited street surrounding the insula, in both phases. Perhaps the demand for commercial space was so high when they were built, that it did not matter that they were located in a somewhat less favourable location. Even so, they could have attracted customers from the crossroad with the Semita dei Cippi. Alternatively, maybe the shops themselves already attracted a sufficient number of people based on the demand for the goods they sold or the service they provided. People would come regardless of their location. Additionally, the unknown streets of the unexcavated region to the southeast and east of the city block may have increased the number of visitors through this area.

The results of the agent-based model also highlight differences between the individual entrances of the buildings. In several buildings, the movement of the agents shows a clear preference for specific entrances. These could be interpreted as the main entrance of its respective building. For example, in both phases of building V ii 4-5, agents preferred the central entrance through space 0403, despite the availability of other routes they could have taken to reach the back half of the building.

In the final phase of building V ii 6-7, the agents took a very different path compared to the Severan phase. During the Severan phase, the main entrance seems to have been located in hallway 0605. Two other routes would have been possible, through hallway 0601 or room 0602, but these were used to a much lesser degree. During the final phase, hallway 0601 became the main, and only, entrance of the bathhouse. However, this entrance was used less commonly than the Severan phase main entrance. This may be explained by how thin it is, and the placement of several obstructions in the hallway, including staircase

0608. These two factors would not have attracted movement. The low degree of use of this hallway once again reflects the low degree of accessibility of the bath complex, and its high degree of privacy.

The courtyard of building V ii 6-7, adjacent to the bathing area, also produced some interesting results. The agents have a relatively strong presence in this space. Between the Severan and final phase, two porticoes were constructed in this area. The southern portico received some minor modifications and continued to be used within the bath complex, but the northern one was replaced by the new bathhouse. The high agent counts in the courtyard (space 0621) and portico (space 0618) of building V ii 6-7 seem to support the interpretation that this area functioned as the palaestra of the bathhouse. One of the main changes to the southern portico was the addition of stone benches. This could have allowed visitors of the bathhouse to have discussions with each other whilst sitting in the shade of the roof of the portico. The absence of porticoes on the other three sides of the courtyard can be explained by a lack of available space.

The spatial changes in building V ii 8 may also represent some degree of social segregation. The secondary entrance (which was added between the Severan and final phase) of the building to room 0803 may have been used mostly by the slaves of the household. This entrance primarily allowed access to several rooms that are located outside of the areas with high agent counts, including space 0808 with the oven for heating purposes.

The eastern half of building V ii 4-5 yielded very different results during the two different phases. During the final phase, the movement of the agents is centred around the basin. This supports the interpretation that this basin was places here because a relatively high number of people would have seen it. Additionally, the agent count values within space 0439 are higher than what one would expect from its visibility and integration values. This space may have been more closely related to space 0426 than the other space syntax methods suggested.

4.5 Space syntax interpretation of insula V ii

This section presents a reconstruction, which did not yet exist, of the functions of the convex spaces during the Severan phase, made by the author of this thesis. Boersma only created a reconstruction of the functions during the final phase of the insula, shown in fig. 52. The functions of the spaces during the Severan phase of the insula (fig. 53 and 54) are based on the spatial analysis performed in this study. To allow for a comparison with Boersma's view on the functions during the final phase, the categories used in his publication are applied on the convex spaces. As Boersma uses his own classification system for the functions, it is first necessary to determine the spatial properties of each function in order to reconstruct the functions of the Severan phase. Based on these spatial properties, several minor changes to Boersma's interpretations of the final phase are suggested as well.

It should be noted that Boersma used a qualitative approach for the reconstruction of functions during the final phase. He based his interpretation of the functions of buildings on a myriad of factors, ranging from the appearance of their façades, the presence and number of decorative elements and features such as basins, the width and number of doorways, and the ground plan of the buildings. He gave interpretations that were not based on numerical data, but on estimations. For example, Boersma stated that the east façade of building V ii 9 must have made a rather "dull" impression, and that such simplicity can be expected from a building with an industrial function (Boersma 1985, 160). He supported this interpretation by referring to the relatively wide and high number of doorways, the large size of the rooms, the lack of a roof over and the low-lying floors of the south part, the irregular plan of the building, and the presence of basins (Boersma 1985, 166).

Figure 52: Reconstructed plan of the final phase of insula V ii showing the functions of the spaces according to Boersma (1985, 223, fig. 206).

On the other hand, the reconstruction of the functions during the Severan phase proposed in this study is based on a quantitative approach using space syntax methods. Whilst the interpretation of the results from these methods could be considered as somewhat more qualitative, it is based on data that was generated in a quantitative way. The interpretation of the functions during the Severan phase are primarily based on the access analysis, but the other methods were used to assist with their creation. It should be noted that, in the graph of the final phase, the underground complex in building V ii 4-5 has been given a domestic function because of its location deep within a domus even though this was not explicitly stated by Boersma.

What follows next, is an analysis of the spatial properties of the five categories used by Boersma to express the functions of spaces: domestic, commercial, industrial, social and utilitarian.

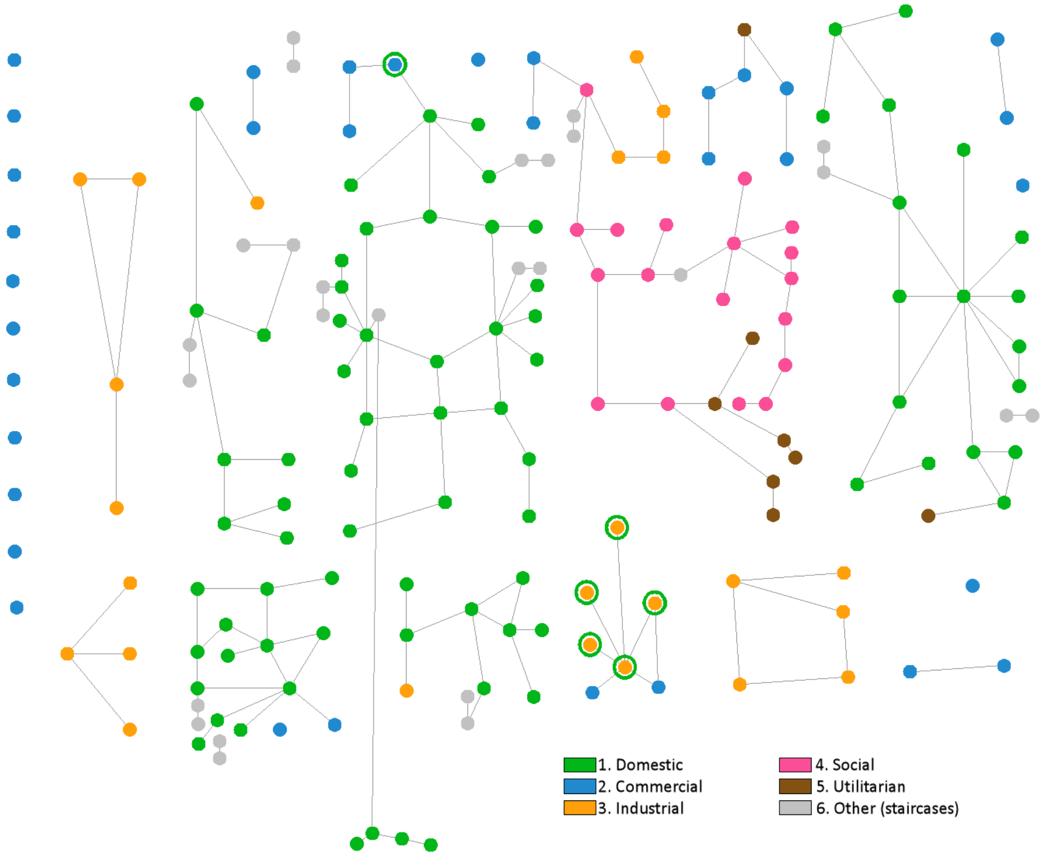


Figure 53: Topological graph of the final phase (without root node), with the nodes coloured based on Boersma's interpretation of the functions. Several nodes are encircled with an alternative function suggested by the author of this thesis (by author, based on Boersma 1985, 223, fig. 206).

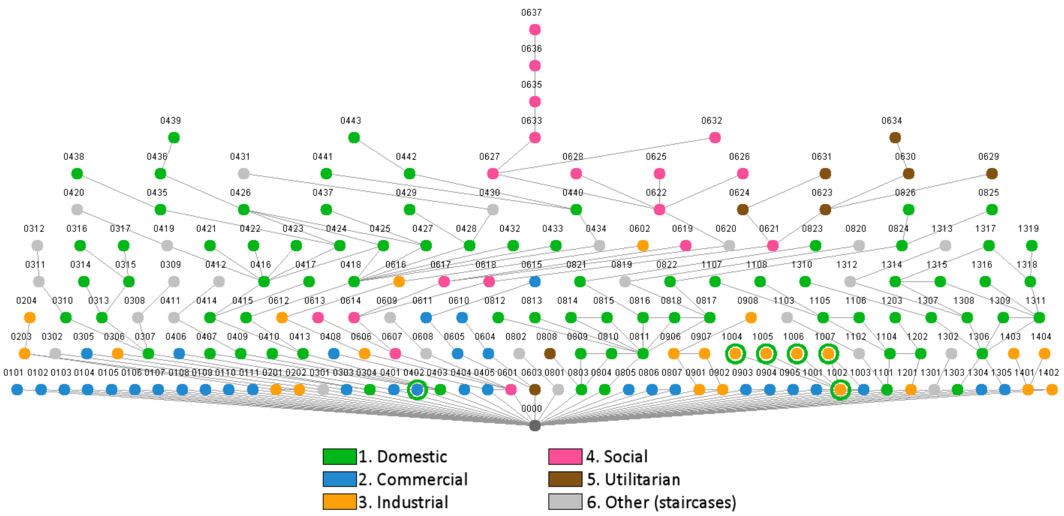


Figure 54: Justified access graph of the final phase, with the nodes coloured based on Boersma's interpretation of the functions. Several nodes are encircled with an alternative function suggested by the author of this thesis (by author, based on Boersma 1985, 223, fig. 206).

Buildings with a primarily domestic function consist of a relatively high number of spaces, with most of this space located relatively deep within the j-graph. Excluding the hallways that connect these buildings to the streets, all domestic space is located on the second level of depth of deeper. Domestic space itself can be divided into two categories: domus and apartments. Compared to the apartments, the domus have a higher of number of spaces. These spaces are also located deeper in the graph, reflecting a higher degree of privacy. The higher number of spaces also mean that the configuration of the two domus are more complex. The two domus (V ii 4-5 and 8) each have a very different configuration, but they are among the most complex and private buildings of the insula. Whilst the apartments have fewer spaces than the domus, they are still relatively complex and private when compared to areas with other functions.

Most commercial spaces consist of relatively small or medium sized spaces that are placed on the first or second level of depth of the j-graph. The majority consists of a single room directly connected to the streets, occasionally with a single room behind them that is not connected to a street. These spaces have a very simple configuration, as most of them do not consist of more than two connected rooms. These spaces tend to have a high degree of visibility.

Industrial space tends to consist of relatively large convex spaces. These areas tend to consist of a maximum of five connected spaces, so they have relatively simple configurations. Additionally, these spaces tend to be located in the lowest three depth levels of the j-graph and tend to have multiple entrances more often than the other categories. This, combined with their low depth, means that they had with good accessibility from the streets. The degree of visibility within these spaces varies highly, and seems to depend mostly on local circumstances such as shape of the building plot. It should be noted that Boersma seems to classify storage space as an industrial function. For example, he suggests that building V ii 14 may have been used for the storage of products that were sold in the adjoining shops (in building V ii 1), although the building may have been converted into a workshop at some point (Boersma 1985, 191). In Boersma's reconstructed plan, in fig. 52, he seems to consider spaces that are directly connected to a commercial space but may have been used for storage, as commercial space as well. To facilitate the comparison between the phases, the storage spaces in this study were categorised in the same way as Boersma did.

All spaces that are classified as social in the final phase, are part of the bathhouse complex (V ii 6-7). The majority of spaces being located relatively deep within the spatial organisation of the building. The top levels of the j-graph are dominated by the spaces of the bathhouse, reflecting the low accessibility and high degree of privacy within the bathhouse. The bathhouse would have been the most private building of the insula during the final phase. The temple that existed in this location during the Severan phase also had a (religious) social function, but with a much simpler configuration. The temple itself probably consisted of two spaces, a main room and a small portico in front of it (Boersma 1985, 131). This reflects the relatively low degree of privacy one would expect from a structure with a less privately oriented social function.

The utilitarian spaces do not seem to have very uniform spatial properties. They are located at varying levels of depth within the configuration of their respective buildings. Most of the spaces that were classified as such by Boersma, had heating functions (in building V ii 6-7 for the baths, and in V ii 8 for an adjacent room). It seems likely that these rooms would have been used primarily by slaves. The only other utilitarian space is located adjacent to a street, and does not seem to have a specific function other than providing roofing in front of several commercial spaces (with the pillars supporting the weight of one or multiple upper floors).

The sixth category is not mentioned by Boersma, but was added represent the staircases and to visualise their locations throughout the insula. As the main function of staircases is to provide access to another floor, none of the five other functions were attributed to them.

Based on these criteria, and on the spatial analyses, several changes to Boersma's interpretations of the final phase are suggested. These changes, to building V ii 4-5 and 10, are shown in fig. 53 and 54 as coloured circles around their respective nodes. It seems likely that space 0402 did not have a commercial function during the final phase. The space seems to be too narrow and small to be effective for commercial purposes, other than perhaps for use as limited storage space. It seems more plausible that this space simply functioned as a side entrance to both the domus and the commercial spaces. It also provided the only available indoor path between these two areas. As for building V ii 10, its non-commercial spaces may have had a domestic instead of industrial function. Both the building as a whole and the individual spaces are relatively small and offer little room for industrial activities. However, the openness of the back half of the building, caused by the removal of multiple walls after the Severan phase, does seem to support Boersma's interpretation (fig. 52). If interpreted as domestic, then this would have been the smallest building in insula V ii with a primarily domestic function. Although, whilst its presence could not be confirmed, an upper floor may have existed (Boersma 1985, 216), and could have added to the available domestic space. Alternatively, the odd combination of features found within building V ii 10 may be interpreted as the result of the conversion of a house into an industrial building. This could also explain the presence of wall decorations (frescoes) in this building, as leftovers from a previous building phase. Hence, this building may have had a domestic function during the Severan phase.

As most buildings were (re-)constructed during (or prior to) the Severan phase (Boersma 1985, 192-220), it can be safely assumed that, unless architectural changes occurred, they had more or less retained the same functions by the time of the final phase. By reversing this concept, the functions of the spaces during the Severan phase can be reconstructed. The functions of spaces that changed are based on the results of the spatial analysis performed in this thesis.

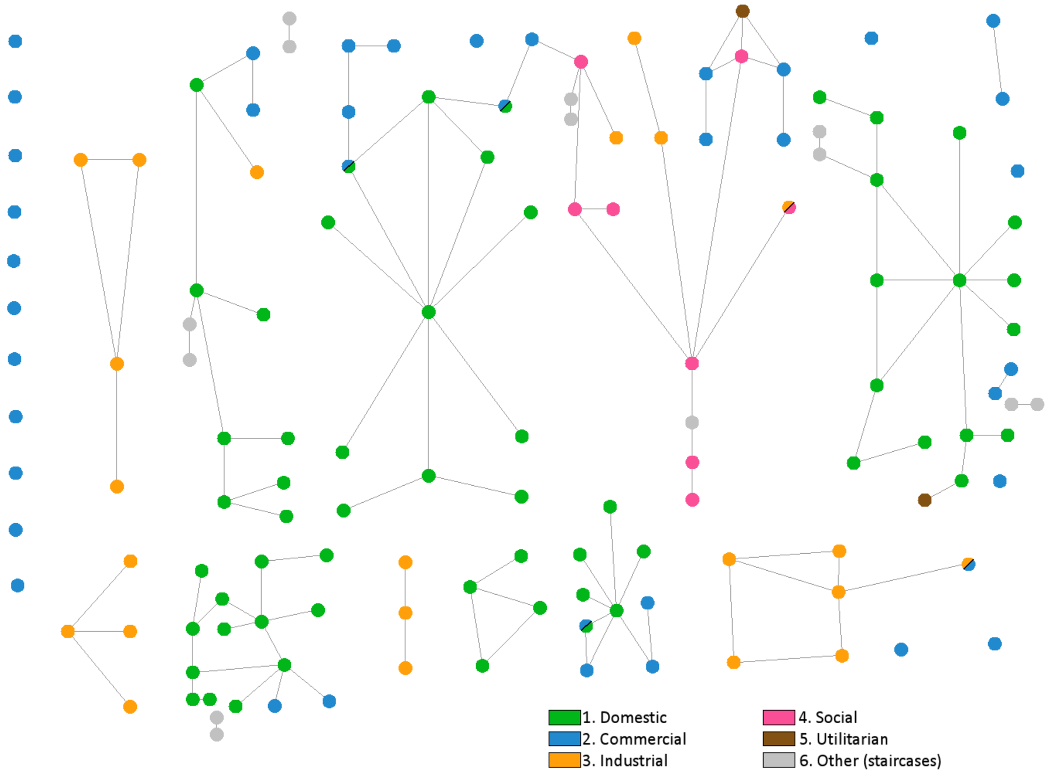


Figure 55: Topological graph of the Severan phase (without root node), with the nodes coloured based on their functions. Several nodes are shown with two colours to represent alternative interpretations (by author).

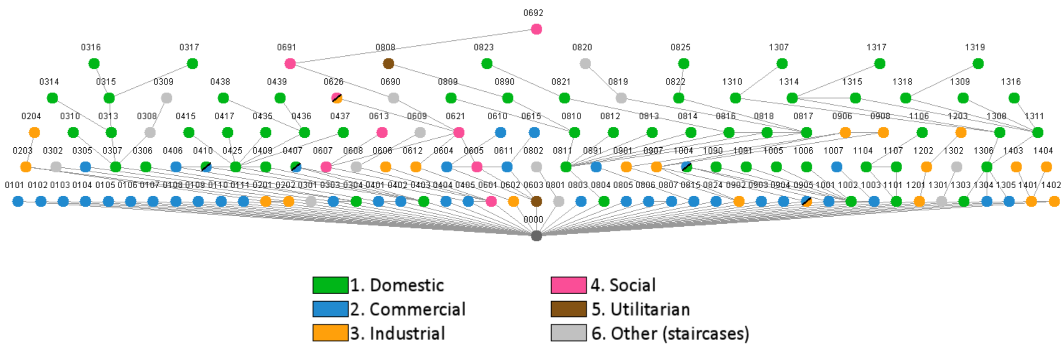


Figure 56: Justified access graph of the Severan phase (without root node), with the nodes coloured based on their functions. Several nodes are shown with two colours to represent alternative interpretations (by author).

One of the most notable changes in function occurred in building V ii 12. The ground floor of this building used to be a nearly complete open space during the Severan phase. The low degree of privacy this would have resulted in, combined with the small size of the building as a whole, would have made this building unsuitable for the (partial) domestic function that it had during the final phase. At the same time, the spaces are too large and open for a commercial function. Hence, the only logical alternative is that the entire building used to have an industrial function during the Severan phase.

The temple in building V ii 6-7, as well as the spaces that provide access to this temple and the toilets in room 0613, are classified as social spaces. However, the temple has a different type of 'social' function than the bathhouse. During the Severan phase, this part of the building had both a social and religious function, whilst the bath complex had a social and sanitarian function during the final phase.

Based on its proximity to four commercial spaces during the Severan phase, room 0626 of building V ii 6-7 could be interpreted as a storage space for them (and is thus classified as industrial) during this period. Alternatively, it could be considered a social space based on the overall social function of the back half of the building. However, this seems less likely as this room is somewhat isolated from the other social spaces within this building. It also should not be considered a commercial space because of its distance to the streets.

During the Severan phase, the internal space of building V ii 10 was more complex than during the final phase. The large open spaces at the back used to be closed off by walls. However, it should be noted that the access graph does not reflect this properly because the rooms were still connected despite the presence of these walls. Because of these walls, the building used to be much more private during the final phase. This makes it possible to interpret the spaces as domestic instead of industrial. Additionally, space 1007 in this building has been interpreted as commercial space, because it used to be connected only to the commercial space in front of it. These two spaces seem to have formed a single entity, so it can be argued that they both had a commercial function.

In building V ii 8, all spaces that used to be separated from the domestic part of the building (but had been integrated into it during the final phase), have been interpreted as social spaces during the Severan phase. This seems most fitting based on their relatively small size and their locations along the Semita dei Cippi or the Via della Fortuna Annonaria, the two prominent streets.

In building V ii 4-5, the connection that used to exist between space 0406 and 0410 could suggest that space 0410 formed a commercial entity together with spaces 0401, 0402, and 0406. Additionally, this connection could also suggest that the inhabitants of the building were not just the owners but also the users of these commercial spaces. The same applies to space 0407, which was later split into a domestic space (0407) and a commercial space (0408). During the Severan phase, it could have had either of these functions.

Table 5: The functions of the convex spaces for the Severan and final phase. The functions suggested by Boersma are shown in a separate column (by author, based on fig. 54 and 56).

Function	Severan	Severan uncertain	Final	Final uncertain	Final (Boersma)
1. Domestic	56	3	77	6	77
2. Commercial	36	4	33	1	34
3. Industrial	19	2	19	5	24
4. Social	7	1	18	0	18
5. Utilitarian	2	0	8	0	8
6. Other (staircases)	13	0	26	0	26
Total	133	10	181	12	187
+ (uncertain/2)	138	-	187	-	187
+ root node	139	-	188	-	188

The following section presents a brief interpretation of the function and location of several nodes in the j-graph. As can be seen from the graphs, there are several significant changes in the functions of the spaces between the Severan and final phase. The number of convex spaces for every function are shown in table 5. The number of domestic spaces increased by roughly twenty, mainly thanks to the changes in building V ii 4-5. The number of commercial spaces decreased slightly, with several shops being transformed into domestic spaces. The number of industrial spaces could have somewhat increased, but this is difficult to establish because of the uncertainties present in the interpretation of several of these spaces. Because of the construction of a bath complex within building V ii 6-7, the number of social spaces roughly doubled. The baths also contributed to the change in the number of utilitarian spaces, thanks to the construction of several spaces from where the water of the baths was heated. Between the Severan and final phase, the number of staircases doubled, which either improved the accessibility of the upper floor(s) where these already existed, or reflects the addition of one or multiple upper floors. However, even when no evidence of staircases was found in a building during the Severan phase, it may already have had an upper floor. Hence, no conclusions should be drawn from this.

The presence of staircases that are directly accessible from the streets could suggest that the upper floor(s) of these buildings, or its respective part of the upper floor, were inhabited separately from the ground floor. In these cases, the upper floor would have formed a separate entity, as it was not connected to the other spaces on the ground floor. This may also apply to staircases located on the second or even third level, when placed in relatively accessible locations, such as staircases 0307 and 0311 in building V ii 3. On the other hand, the presence of a staircase deeper inside the building suggests that the upper floor(s) would have been inhabited or used by the same inhabitants as the ground floor. For example, this seems likely for staircases 0430 and 0419 in building V ii 4-5.

Lastly, during both phases, three corners of the insula were occupied by commercial spaces. These three corners are located on at least one (or both) of the two prominent streets in this part of the city, the Semita dei Cippi and the

Via della Fortuna Annonaria. The only corner space without a commercial function is in building V ii 14, which has an industrial function and is next to the crossroad between the two less prominent streets surrounding insula V ii. This could be explained by a lower amount of pedestrian traffic at this corner of the insula (as shown in section 4.4), meaning that this location may have been less attractive for shops, and by the need for storage space of the nearby shops.

Most changes discussed in this chapter seem to reflect an overall decrease in accessibility and an increase in the degree of privacy in the final phase of the city block, compared to its Severan phase. Now, the results of the spatial analyses will be further compared with Boersma's interpretations and discussed. Based on the case study of insula V ii, an assessment can be presented of the individual space syntax methods.

5. Comparison

This chapter presents a comparison between the results of the space syntax analysis and the interpretations from Boersma's publication. The advantages and disadvantages of the individual spaces syntax methods are discussed to give an assessment of these approaches.

5.1 Comparison with Boersma's interpretations

This section presents a comparison between the results from chapter 4 and the interpretations from Boersma's publication. To allow for the reconstruction of the functions during the Severan phase of insula V ii, some comparisons have already been made in section 4.5. These will not be discussed further. Most interpretations which were based on the spaces syntax analysis do not seem to directly reflect Boersma interpretations. This does not mean that the interpretations conflicted, but that they explained different aspects of the insula.

Many interpretations based on the space syntax analyses reflect changes in accessibility and privacy. Compared to the Severan phase, a decrease in accessibility and an increase in privacy occurred within the insula. Whilst Boersma did not comment on changes in privacy, he did discuss the accessibility of some buildings. However, this is mostly limited to notions about the number of entrances in a building, or their width.

Notably, the space syntax analyses allowed for a complete reconstruction of the functions during the Severan phase, which Boersma did not do. The different functions discussed by Boersma correlated to specific spatial properties. The space syntax analyses also resulted in suggestions for changes in the interpretation of the functions of several spaces, mainly in building V ii 10. Whilst Boersma interpreted this as a building with industrial and commercial functions, it could also be interpreted as a domestic building with two shops. Additionally, in chapter 4 it is argued that space 0402, located next to the main entrance of the domus in building V ii 4-5, may have been part of the domestic part of the building instead of being commercial space.

The changes between the Severan and final phase throughout the city of Ostia, which were discussed by Boersma, correspond with the results of the spatial analyses. During the later third century, the amount of domestic space increased, and during the fourth century, houses were enlarged, which meant a loss of commercial and industrial space (Boersma 1985, 219). This corresponds with the interpretations in section 4.5 of this thesis.

However, the interpretations on changes in ownership seem to fall short when compared with Boersma's interpretations. Boersma's conclusions were based primarily on inscriptions, shared walls, or multiple buildings having similar (re)-construction dates (Boersma 1985, 72-191). For example, according to Boersma, the near total demolition of the pre-Severan structures on the current location of buildings V ii 9, 10, 11, 12 and 13, followed by the redesigning of the plots, suggest that the initiative was taken by one person or group who gained possession of almost the entire east part of insula V ii. Before the demolition, V ii 9 may have been owned by the owner of the neighbouring domus, V ii 8. Alternatively, he could actually have been the initiator of this entire construction project. Boersma suggested that, within this group of buildings, each was inhabited separately by different tenants (Boersma 1985, 201-220). Boersma's approach seems more suitable for interpreting large scale changes in ownership.

5.2 Assessment of the space syntax methods

This section presents a comparison between the results of the four selected methods. Overall, the spatial analysis with space syntax methods allowed us to gain deeper insights into different aspects of the buildings. The results from chapter 4 show many examples of what each method can contribute to the space syntax approach as a whole. Based on the results of each method, their complexity, and the amount of time required to generate and interpret the results, an assessment of the individual methods is made.

5.2.1 Access analysis

Access analysis is a very effective method for studying changes in the spatial organisations of buildings. In this study, the access analysis allowed for a reconstruction of the functions of the spaces during the Severan phase of insula V ii. The other three methods did contribute to this reconstruction, but it was mainly based on the access analysis.

Whilst the clear definition of a convex space increases the objectivity of the results of this method, the manual creation of nodes by the user can still be somewhat subjective. The results are influenced by preliminary interpretations of the spatial divisions whilst placing nodes. If the definition of convex space is applied strictly, then the graphs should be the same regardless of the opinions of those who created them. However, the problem remains that some degree of interpretation is required. In order to be able to apply the concept of convex spaces on archaeological datasets, one must often slightly deviate from the definition due to the irregular nature of Roman buildings. One may have to re-evaluate specific areas multiple times to decide on how to divide them. This means that different people may interpret the spatial divisions slightly differently. However, an advantage of the access analysis is that graphs with different interpretations can be compared with each other relatively easily. This allows researchers to test and compare alternative interpretations, and to discuss the effects of these different possibilities in a relatively objective manner.

The topological graph can already be visually interpreted before attempting to create an access graph or calculate the spatial values of the nodes. When working with complex layouts or a high number of connected buildings, the creation of a topological graph helps to obtain a better understanding of the layout and how it changed.

One of the advantages of this method is that the spatial values of individual nodes can be easily calculated by hand in order to check them. This improves the transparency and reliability of this method. This was done during this study in order to check if the process of converting the data in the tables caused in any errors. Several random nodes were chosen, and all calculated values matched those in the tables.

Another advantage of Access analysis, is that it can be used to analyse multiple floor levels at the same time. It is the only method that was used in this study in which the staircases throughout the insula and the underground complex in building V ii 4-5 could be included and studied. However, the underground spaces may have been even more private than their spatial variables suggest, as their location underground would have caused them to be almost completely hidden from sight.

The control variable in the access analysis is more suitable for detailed studies of individual spaces within buildings. The mean control value of all nodes is always the same for every access graph, as it is a relative measurement. Hence, these values tell us relatively little about changes in the insula as a whole. However, when one has a relatively small dataset, e.g. a single building, or an abundance of time, the control value of every single node could be studied to identify and interpret small-scale changes in the control values.

5.2.2 Isovist analysis

Isovists analysis can be a surprisingly useful approach. Despite the simplicity of isovists, they provide a clear visualisation of visibility from specific locations. Isovists are easy to interpret and allow researchers to clearly convey their results to readers, even those who are unfamiliar with space syntax. Additionally, this method does not require the reader to familiarise him- or herself with any formulas that are used for the computation of the data. Furthermore, relatively little theoretical knowledge is required to be able to apply and interpret this method. The creation of an isovist is also a very simple process, as one only has to select a location, direction and field of view to allow the isovist to be generated. Overall, it is the least time intensive method.

However, it is also the most subjective approach, as the results directly depend on what locations are chosen by the user. This problem can be somewhat alleviated by systematically choosing locations, as shown in chapter 4.2, but it should be noted that systematically choosing locations in a different way would obviously produce different results.

5.2.3 Visibility graph analysis

Visibility graph analysis proved to be the most time intensive method, whilst its results were somewhat underwhelming. The generated data lead to relatively few additional interpretations compared to access analysis. VGA tells us relatively little about large scale changes in the research area as a whole. The results of this method are mostly limited to very local interpretations of the data.

The computation of visibility is very straightforward, as this value equals the number of cells within its 360 degrees field of view. Compared to integration, the visibility variable was easier to interpret, at least for an archaeologist. However, many changes in the degree of visibility directly reflect the changes in the configuration of the spaces which were already interpreted based on the access analysis with less effort.

Many of the patterns in the graphs of the integration values had already been interpreted based on the isovist analysis. Additionally, they did not allow for in-depth interpretations of large scale changes within the insula as a whole. Whilst the integration values did show new patterns deeper within the spatial organisation of the insula, it seems likely that these could have been detected through isovist analysis if a high number of isovists had been generated from the internal spaces of the city block. Furthermore, using integration to study movement seems unnecessary when an agent analysis is performed as well.

The advantage of the grid-based approach is that the measurements of the grid cells from different graphs can be directly compared with each other. It should be noted that this only works when the two graphs have the same height and width, otherwise the cells will be assigned different reference numbers (names). In this study, the names of the cells remained the same because the maximum extend of the grid was determined by the vectors of the streets, not by the insula itself. Theoretically, this would allow for a direct comparison between every cell. However, the high number of cells in the graph makes it difficult to interpret every single change. VGA is difficult to use for studying general changes throughout a research area. Performing a detailed analysis on a large dataset whilst interpreting the changes in every single cell seems unfeasible. As each room consists of a high number of cells with a high amount of variation in their data, it is very time consuming to compare the values of all spaces with the other phase. A comparison between total values of all cells in the two graphs was also difficult because the total and average values include the values of the streets. There is no way to differentiate the cells within the city block from those on the streets. Hence, the analysis had to focus on a visual comparison of the graphs. This also applies to agent analysis.

Theoretically, it would be possible to calculate the visibility and integration values of the individual cells in the VGA graphs by hand in order to check them. However, the large amount of data and its complexity makes this undoable.

5.2.4 Agent analysis

Agent analysis the same disadvantages as VGA because of its grid-based and highly detailed nature. However, this method is not as time consuming as VGA, and it allows for a detailed study on the movement of people through a dataset. The results highlight the different paths that could be taken through the buildings, and which paths were preferred during each phase. It also allowed for estimations of the amount of pedestrian traffic through the streets surrounding the city block.

To allow for a better understanding of how the data from the VGA affects the results of the agent-based model, four scatter graphs are shown in fig. 57, 58, 59 and 60. In these graphs, the agent count value of each cell has been plotted against its connectivity value (visibility) or its integration value. This was done for both phases of the insula. These graphs visualise the correlation between the movement of the agents and the spatial values of the cells. In each graph, a linear regression line has been drawn through the data points. These regression lines show that the agents, more often than not, move through cells that have a relatively high visibility or integration value. However, the coefficient of determination (R^2) of these regression lines is relatively low in each graph, ranging from 0,196 to 0,292. This reflects the high spread of the datapoints compared to the regression line. This means that, whilst the agents are influenced by the data of the VGA, the agent analysis results in different patterns than those that can be seen in the VGA.

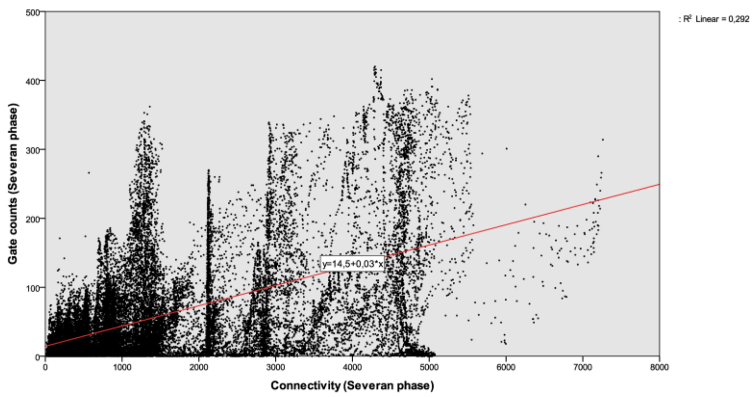


Figure 57: Scatter graph of connectivity (visibility) and gate count (ABM) values of individual cells during the Severan phase. A linear regression line has been drawn through the dots, resulting in a R^2 of 0,292 (by author).

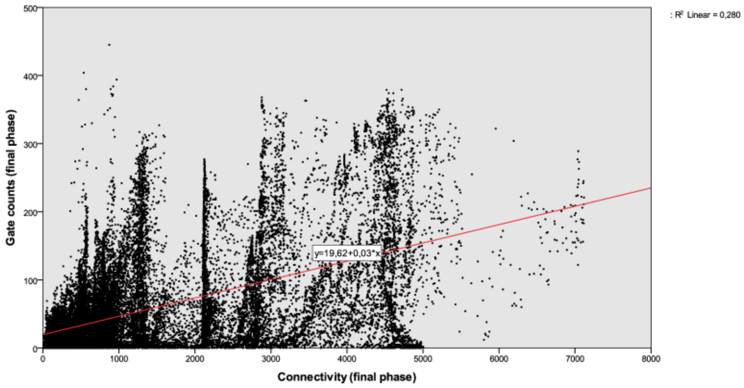


Figure 58: Scatter graph of connectivity (visibility) and gate count (ABM) values of individual cells during the final phase. A linear regression line has been drawn through the dots, resulting in a R^2 of 0,280 (by author).

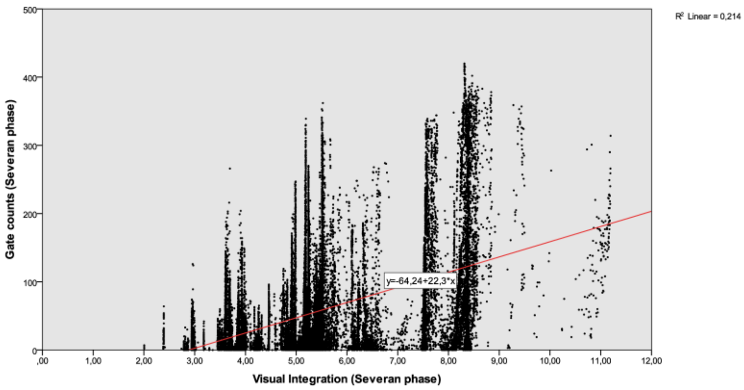


Figure 59: Scatter graph of visual integration and gate count (ABM) values of individual cells during the Severan phase. A linear regression line has been drawn through the dots, resulting in a R^2 of 0,214 (by author).

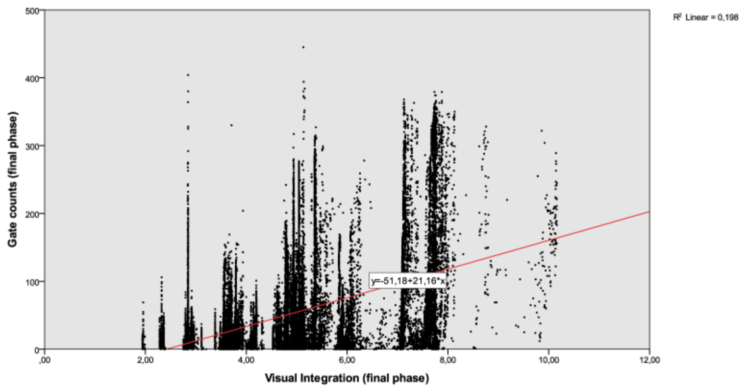


Figure 60: Scatter graph of visual integration and gate count (ABM) values of individual cells during the final phase. A linear regression line has been drawn through the dots, resulting in a R^2 of 0,196 (by author).

6. Conclusion

This thesis sought to study which of the four selected space syntax methods are of the most explanatory value for the analysis of changes in the interior spaces of buildings, taking the required time and effort into consideration.

Including space syntax tools in a study can expand the analytical power of the archaeological dataset. Space syntax offers more than a way to provide mathematical or architectural evidence for the interpretation of structures. It also adds a level of depth to any research projects willing to include this methodology in their approach. Even if much of the archaeological record has been lost, the configuration of the architectural remains can still hold much information, although it should not be seen as an alternative and should preferably be supplemented by other categories of data. The tools themselves allow the user to think about space in a different way and also come up with new theories that are not necessarily related to the computed data. They give inspiration for new ideas, as they force you to think about space (and its multiple features like visibility) in a more intensive and less abstract way. The methods discussed in this thesis work relatively well from an academic perspective: They allow us to gain deeper insights into the architectural remains of buildings, how people used to interact with them, and what could have motivated architectural changes. The results can also be used to support theories for which previously no (relatively) objective data was available that could support them. Space syntax methods can be used to explain spatial patterns, but also to bring to light previously unknown patterns. They can be used to analyse the effect of changes in the configuration of buildings and explain why the owner could have been motivated to initiate these changes. The space syntax methods also allowed for a reconstruction of the functions of spaces during the Severan phase, based on their spatial properties.

However, before deciding to apply such an approach on any dataset, it should be considered if the required time and effort is worth the results that it produces. Some may consider the yield to be relatively little, and applying a complete space syntax approach may not be very cost-effective.

Some aspects of Boersma's conventional approach and the space syntax approach shown in this study, do overlap. So, they should not be seen as two completely different entities. The space syntax analysis would not have been possible without Boersma's plans. Additionally, the interpretation of the convex spaces that was necessary in order to perform the access analysis, has been influenced by Boersma's explanation of the plans.

In this study, access analysis proved to be of the most explanatory value for the analysis of the interior spaces of buildings. It allowed for the broadest range of interpretations and conclusions on the changes in insula V ii. This thesis does not intent to devalue the results of the other methods, but for the purpose of studying change within a dataset, access analysis proved to be the most effective as it allowed for a broad range of interpretations. There is a degree of overlap between the interpretations that can be drawn from each method. However, when using space syntax methods to study changes in a research area, the access analysis already provides access analysis provided the broadest range of results. The access analysis resulted in plenty of insights and data for detailed interpretations. Hence, using all four methods to perform four separate analyses of an entire dataset may be somewhat redundant. Additionally, the isovist analysis, visibility graph analysis, and agent analysis contributed less to the reconstructed functions of the Severan phase of insula V ii than the access analysis. These other three methods do provide other perspectives, but most observations of the data lead to the same or similar interpretations. These methods mostly supported the interpretations that resulted from the access analysis. Individually, they were of relatively little added value compared to the access analysis. On their own, they did not lead to a high number of new, additional interpretations. When sufficient time is available for a study, these methods can be used to strengthen one's interpretations, as they can function as additional arguments for conclusions. In this sense, isovist analysis, visibility graph analysis and agent analysis may be most valuable for their capability of producing results that can be used to support interpretations of the access analysis.

Whilst the other methods allowed for small scale interpretations of specific areas of the insula, they were less useful for studying change on a larger scale, such as entire buildings or the insula as a whole. Nonetheless, isovist analysis is relatively simple to perform, but can still allow for new insights. As this method requires a relatively low investment in time, it can be used as a simplified alternative to visibility graph analysis. If not much time or funds are available for a research project, even only including a visual comparison of the topological graphs and justified access graphs, combined with several isovists, can result in many new insights. Even without calculating variables such as the real relatively asymmetry of every node, the access graph itself can already be used to allow for a clear understanding of the spatial organisation of buildings.

Deciding whether or not to include visibility graph analysis and agent analysis in a study, should be done on a case-by-case basis. Considering the methodological sophistication of VGA, it may generally not be worth the required time investment. The required time and effort do not correlate to the relatively low added value of these methods when used for the interpretation of large scale changes in a city block as a whole. Visibility graph analysis seems more suitable for studies that focus on specific areas within the spatial configuration of a city block or building, in order to study them at a high level of detail.

However, if one decides to apply VGA on a dataset, one should also perform an agent analysis. Since data from the VGA is required in order to be able to perform an agent analysis, it inclusion depends on whether or not VGA is applied.

6.1 Further research

In chapter 4, only a selection of the changes could be discussed. The other changes could still be analysed, and even the changes that were discussed could be studies in more depth. The results obtained from a justified access graph could be very suitable for comparisons with a broader range of archaeological data. For example, it could be compared with the placement of decorative elements such as mosaics and frescos, or with the use of specific building materials such as marble, some of which might give clues towards the functions of rooms. Additional analyses without the streets could be performed for the individual buildings in order to compare the effects of opened doors versus closed doors. Isovist could be created from locations within the insula to show the visibility of specific areas. For example, a 360 degree isovist from both nymphaea (in buildings V ii 4-5 and 8) could be created and analysed to study where they would have been visible from. If an updated plan of the street network were to be published, one that includes a reconstruction of the missing area to the southeast and east of insula V ii, the nearby streets could be included in the dataset of this study to see what their effect could be on pedestrian traffic through the two streets to the east and south of the city block.

This type of research can be developed further in terms of research questions asked and answered. The results of the spatial analyses in this thesis can be compared with other city blocks in Ostia which have already been studied. The result achieved by this thesis are promising and should encourage more research within Ostia following similar combined approached.

Abstract

Over the past decades, space syntax has already proven to be of added value for archaeological research. However, for any researcher unfamiliar with space syntax, a considerable investment in time and effort is required before one can apply these methods on their dataset. One has to understand a complex and broad theoretical framework, and to overcome methodological problems. This can function as a barrier, preventing researchers from using these tools. This study hopes to assist those who are considering these methods, with selecting the space syntax methods that are the most suitable for analysing spatial changes in their dataset. This thesis seeks to answer the following question: Which of the four selected space syntax methods are of the most explanatory value for the analysis of changes in of the interior spaces of buildings, taking the required time and effort into consideration?

The results of four space syntax methods, access analysis, isovist analysis, visibility graph analysis, and agent analysis, are compared with each other. City block V ii in Ostia, Italy, is used as a case study. This thesis presents guidelines for applying space syntax methods that can be understood by archaeologists who not have a background in modern architecture.

This thesis argues that a decrease in the overall accessibility of the spaces within the city block occurred, whilst the overall degree of privacy increased. Based on a comparison of the results of each method, it is argued that access analysis is of the most explanatory value for studying the effects of architectural changes. This study argues that this method is not as time intensive as visibility graph analysis, whilst allowing for a broader range of interpretations than the other three methods. The use of isovist analysis is also recommended. Despite its simplicity, it can allow for new insights on visibility. Isovist analysis could be seen as simpler and less time consuming alternative to visibility graph analysis.

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Glossary

This glossary provides brief definitions of Latin and Italian terms from Roman archaeology used in this thesis. The descriptions are based on (Stöger 2011, iii and 299-301). The definition of 'cippi' is taken from (Newsome 2011, 12) and the definition of 'calcaria' is taken from (Meiggs 1973, 102-5).

Annona	Grain supply to the city of Rome.
Calcaria	Lime kiln, where marble was converted into lime.
Cardo maximus	Central north-south axis in a Roman urban street system.
Caseggiato (-i)	Italian term for a Roman building, divided into separate units, often including commercial space ('tabernae').
Castrum (-a)	Denotes a military camp or fortifications.
Cippi	Small stone pillars that usually carry some information.
Coloniae maritimae	Roman colonies along the Tyrrhenian coast, intended to secure the coastal lands.
Domus	Roman town house, term used for domestic buildings.
Exedra	In architecture, a semi-circular niche forming part of a building, but can also be an outside seating area.
Fauces	Hallway leading from the street into the building.
Forum	Public space in the centre of a Roman town that serves as the political, economic, and social centre.
Horrea	Warehouses and storage buildings.
Insula (-ae)	City block; or a large multi-apartment building.
Nymphaeum (-a)	In general use, an elaborate or monumental fountain structure, often adorning public space. Originally, the term denoted a cave or grotto with a running water source sacred to the nymphs.
Palaestra	Exercise court of the baths, often a colonnaded enclosure.
Porticus	Colonnade or covered walkway.
Praefurnium	Furnace of a Roman bath. The term may denote only the stoke hole of the furnace, or the larger area of the

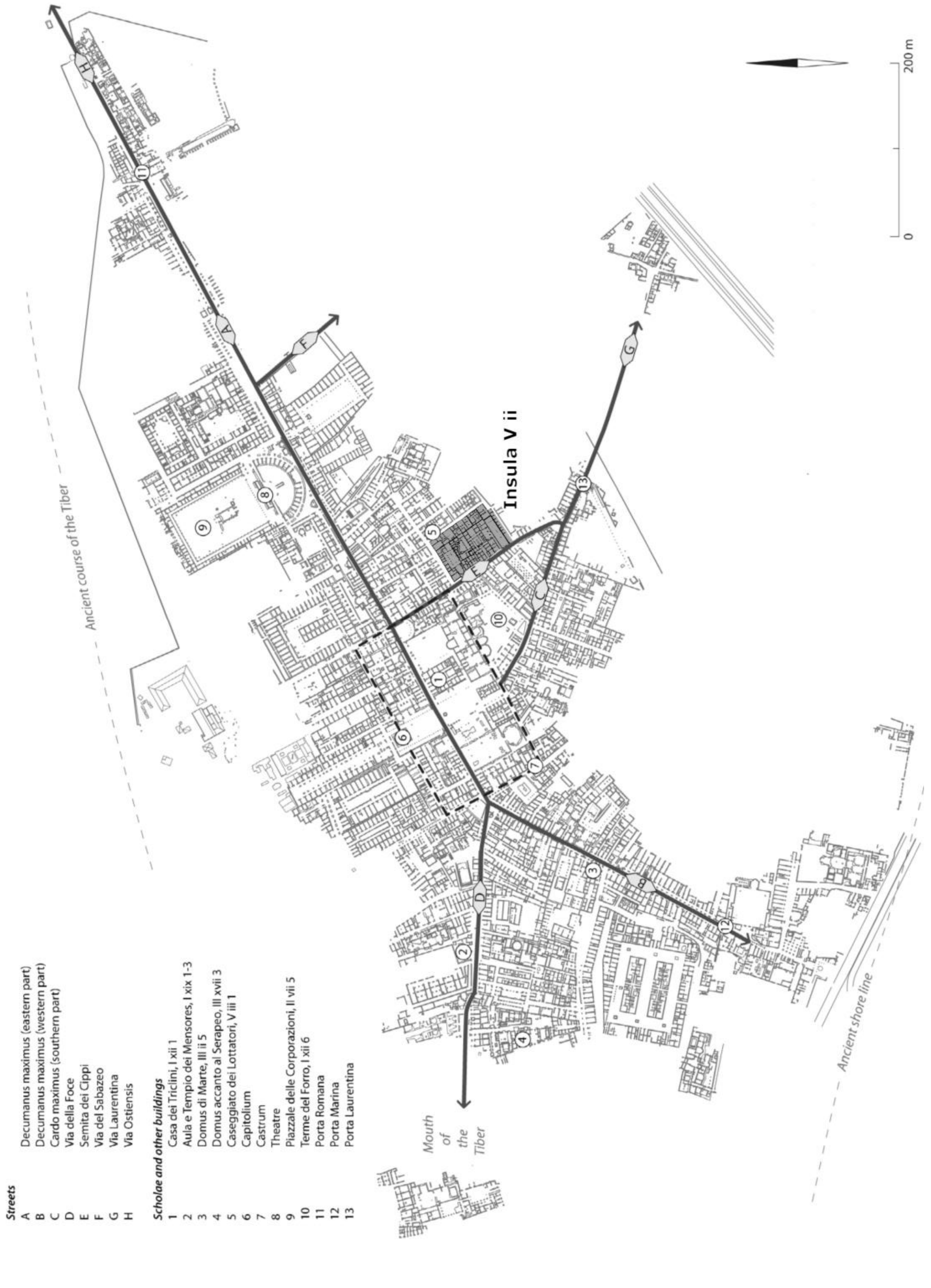
	furnace or furnaces.
Tablinum	Reception room generally situated on one side of the atrium and opposite to the entrance.

Appendices

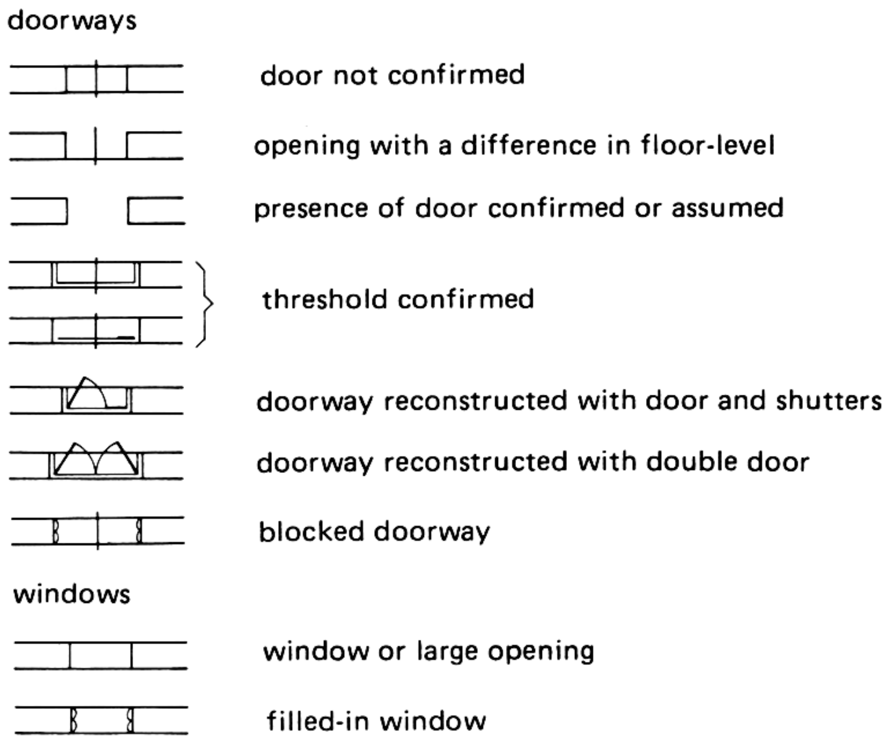
Appendix A: Plans of insula V ii

Appendix A1: Location of insula V ii, marked red, on the plan of the excavated areas of Ostia. The streets shown in the Visibility Graph Analysis and ABM are based on this plan. The southern city wall, with one of the main gates, can be seen at the bottom of the image (after Calza and Becatti 1953, map 8, 9 and 13).

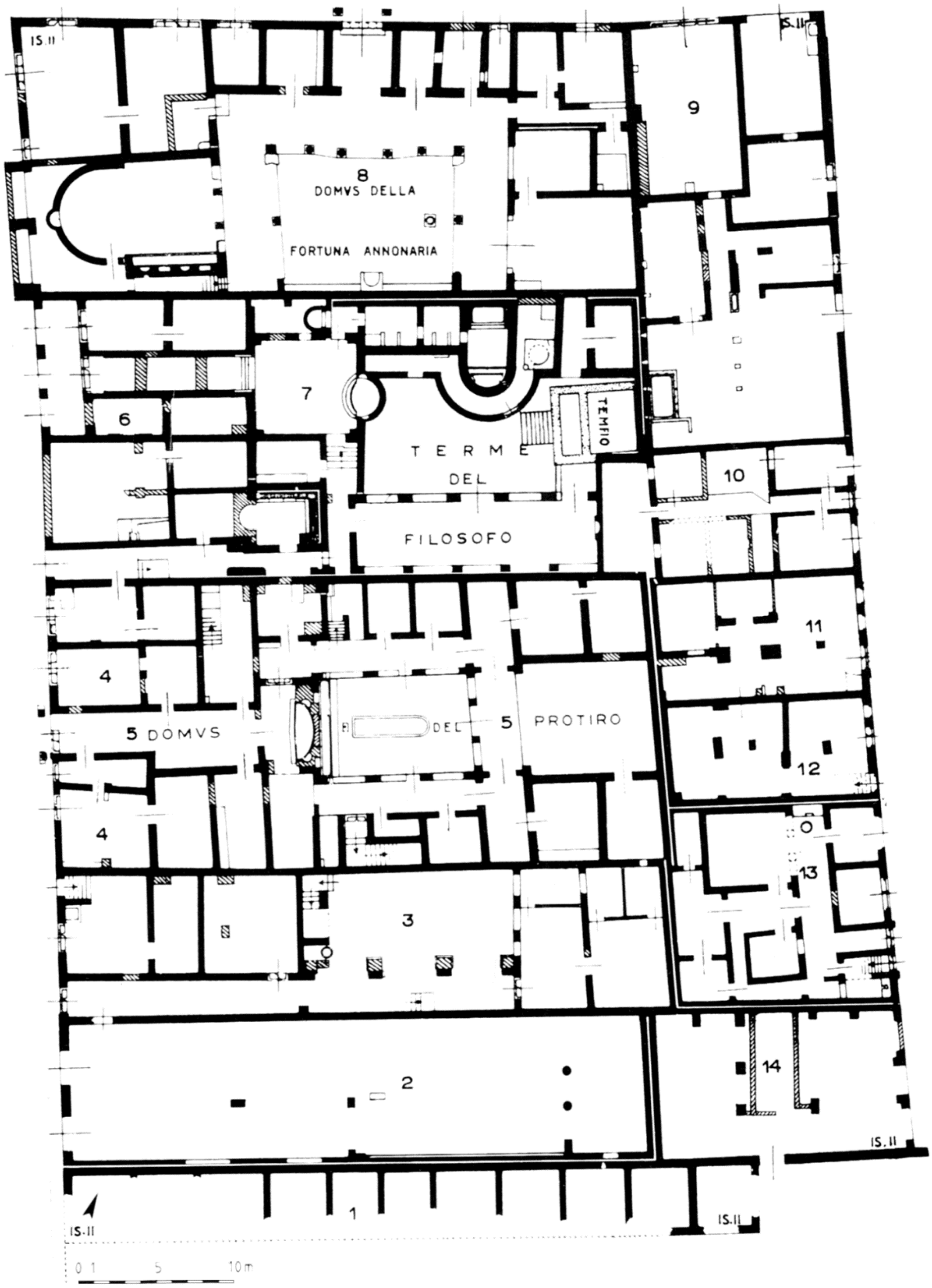
Appendix A2: Plan of the excavated parts of Ostia, showing the location of Insula V ii, the presumed boundaries of the Republican castrum (dotted lines), and the major streets (after Stöger 2011, v, fig. 0.1, with plan of insula V ii after ostia-antica.org 2015).



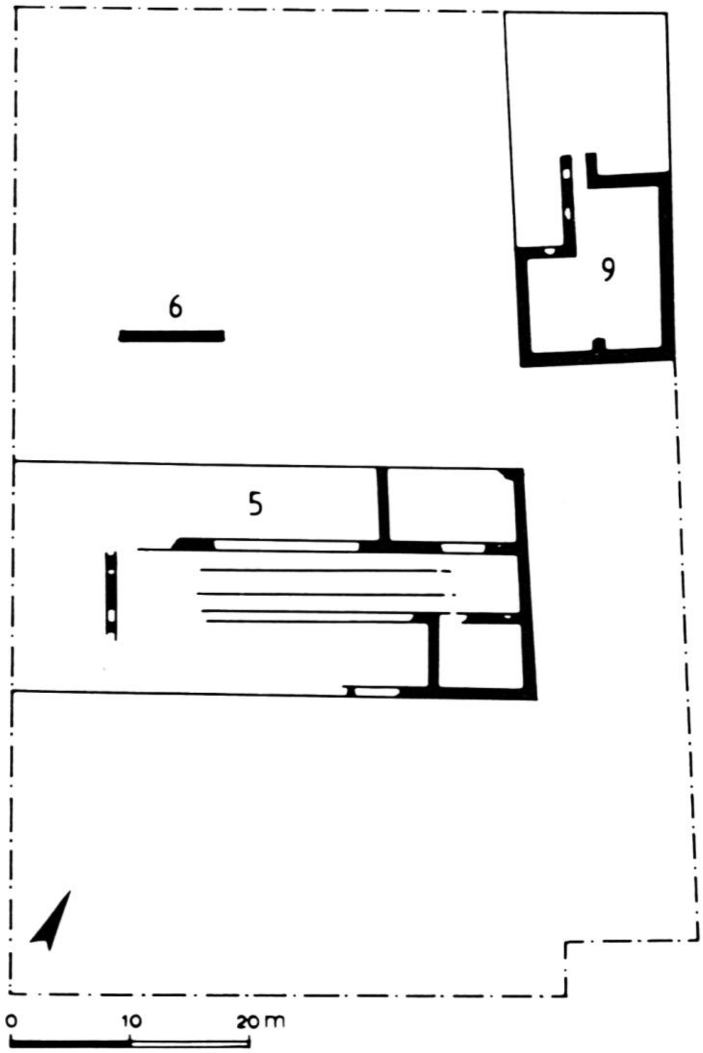
Appendix A3: Legend of Boersma's plans (Boersma 1985, 302-3).



Appendix A4: Earlier plan of the architectural remains of insula V ii, based on the excavations in 1940 (Boersma 1985, 3, fig. 2).

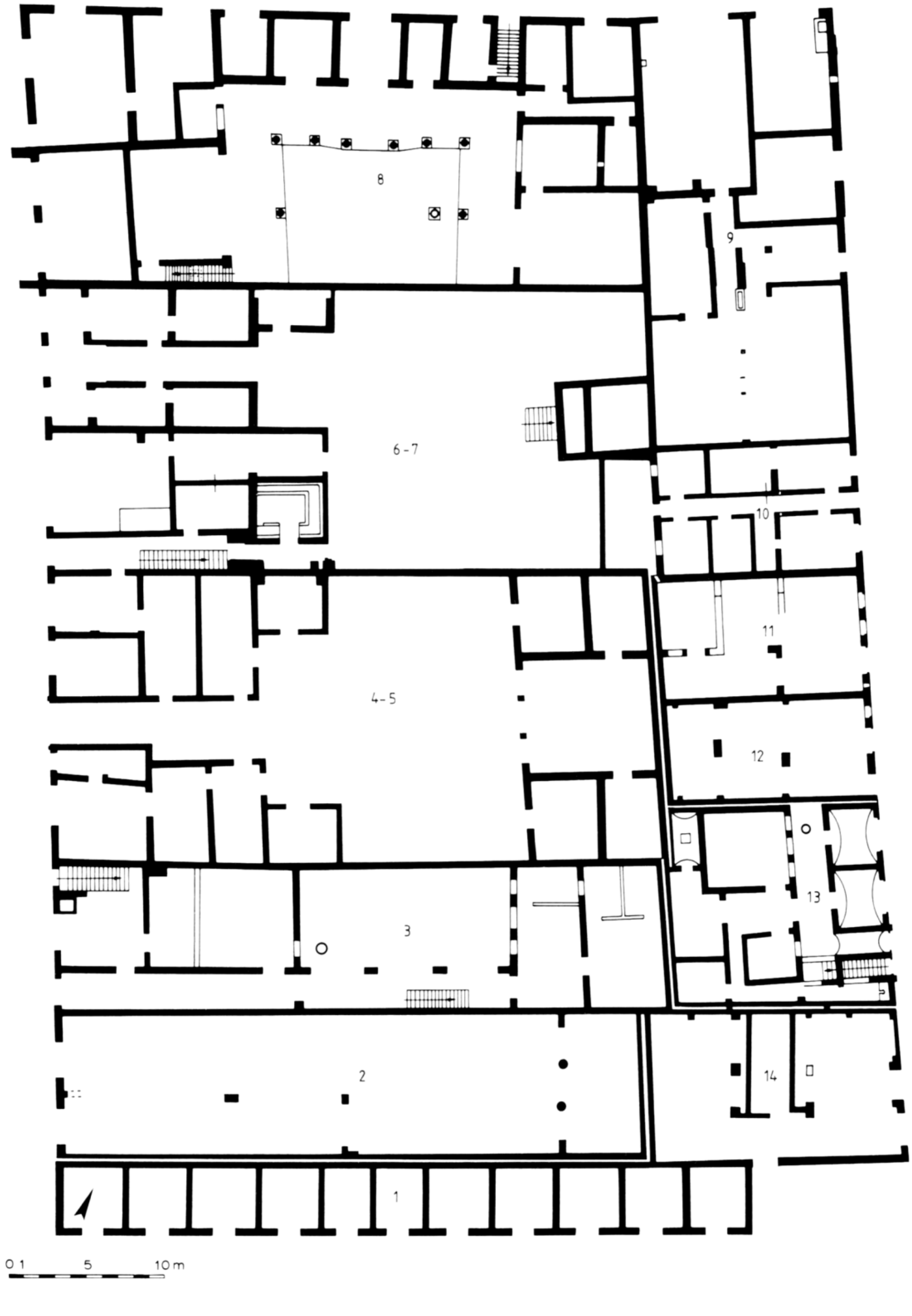


Appendix A5: Plan of the registered remains of insula V ii dating to the Claudian phase (Boersma 1985, 210, fig. 200).

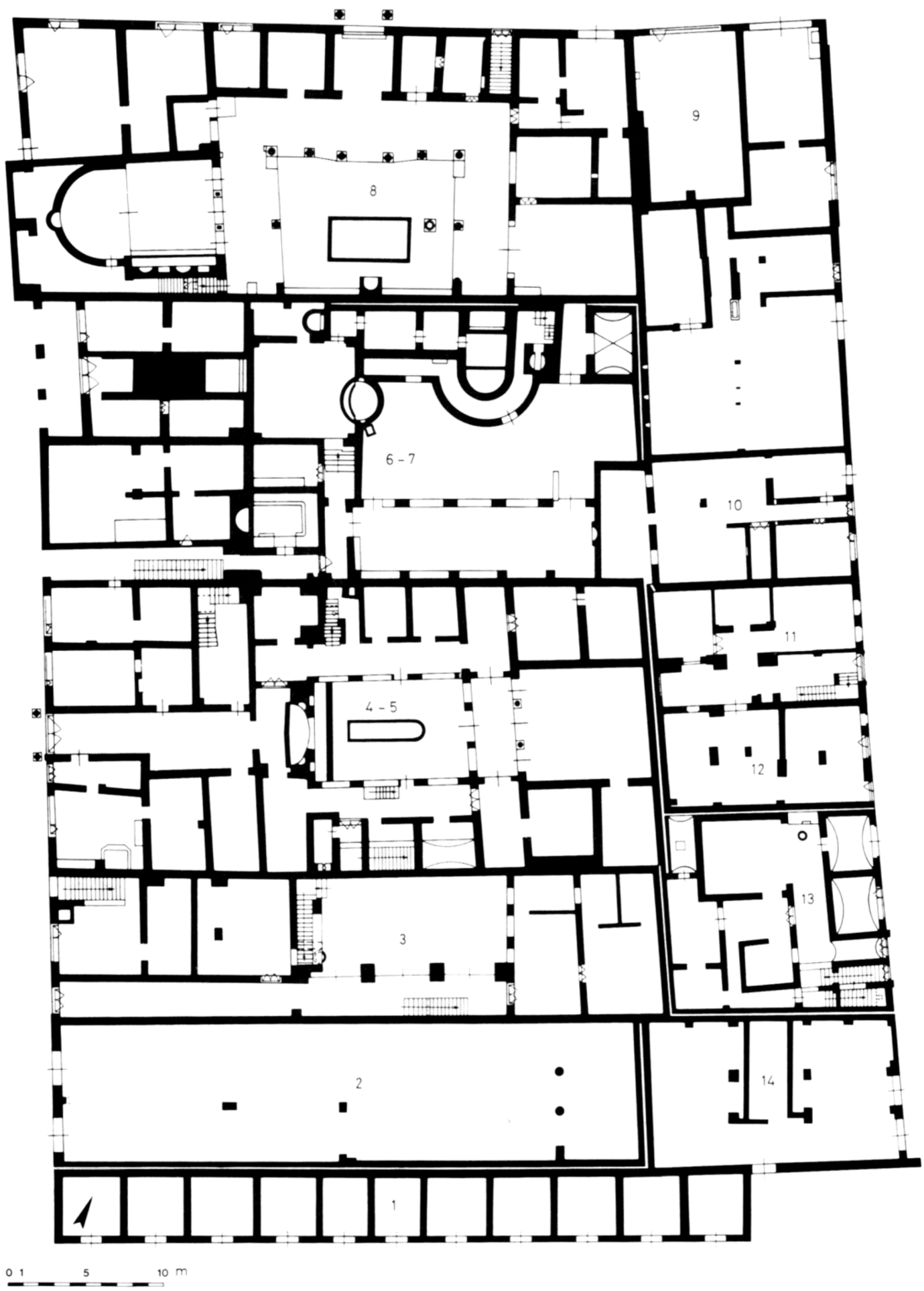


Appendix A6: Reconstructed plan of the Trajanic phase of insula V ii (Boersma 1985, 212, fig. 201).

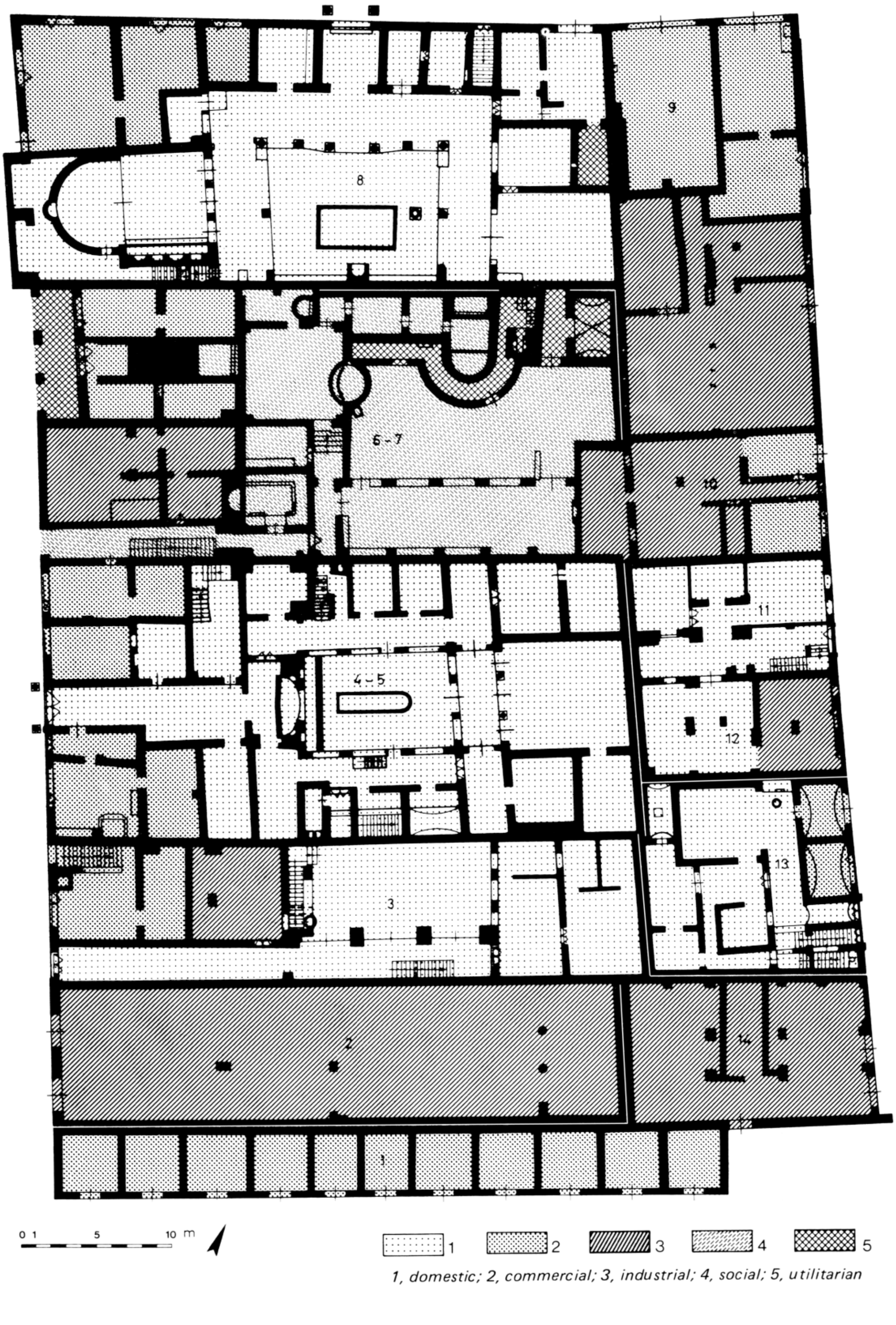
Appendix A7: Reconstructed plan of the Severan phase of insula V ii (Boersma 1985, 218, fig. 202).



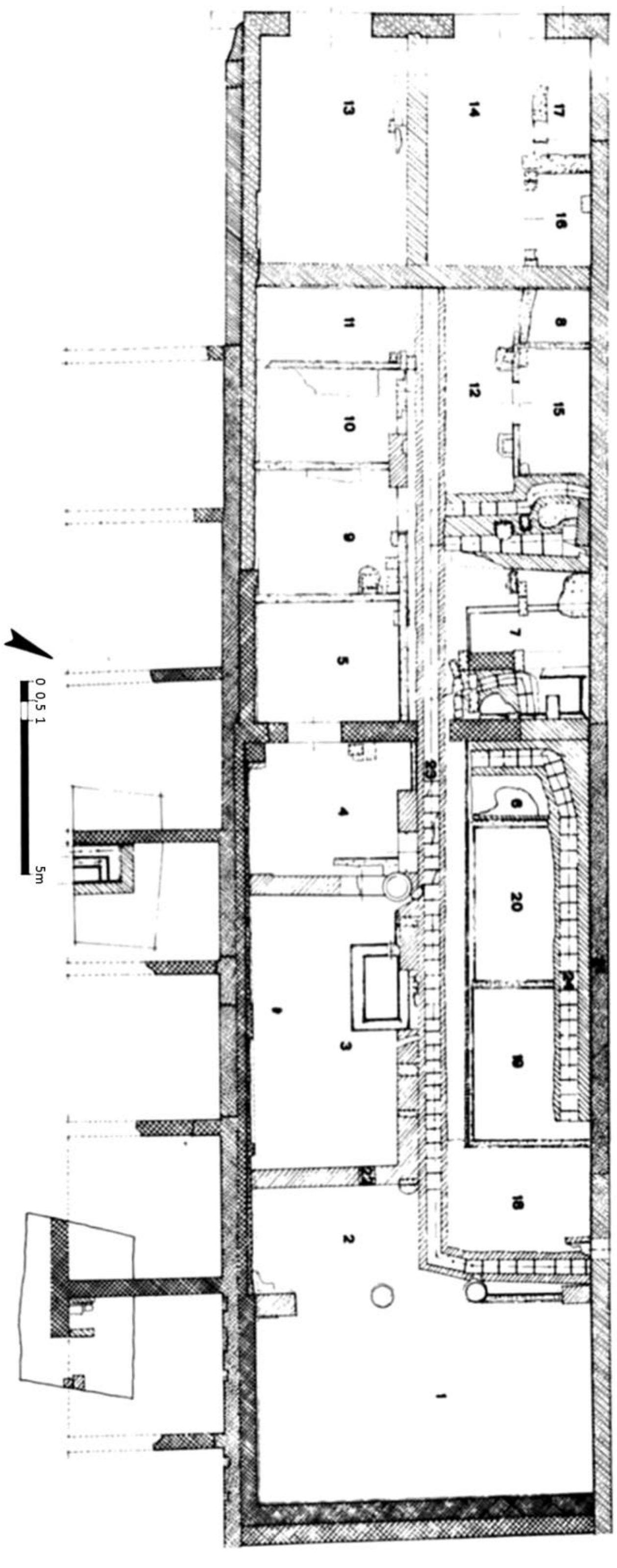
Appendix A8: Reconstructed plan of the final phase of insula V ii (Boersma 1985, 214, fig. 204).



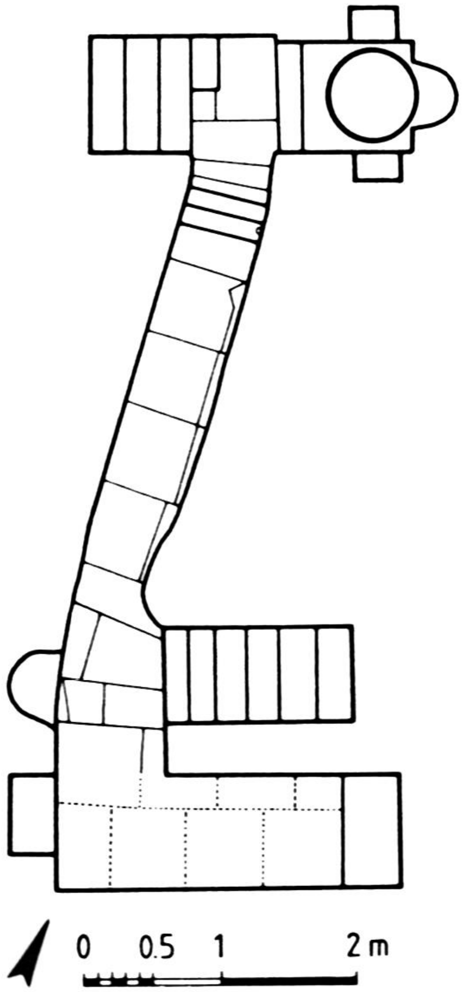
Appendix A9: Reconstructed plan of the final phase of insula V ii showing the functions of the spaces according to Boersma (1985, 223, fig. 206).



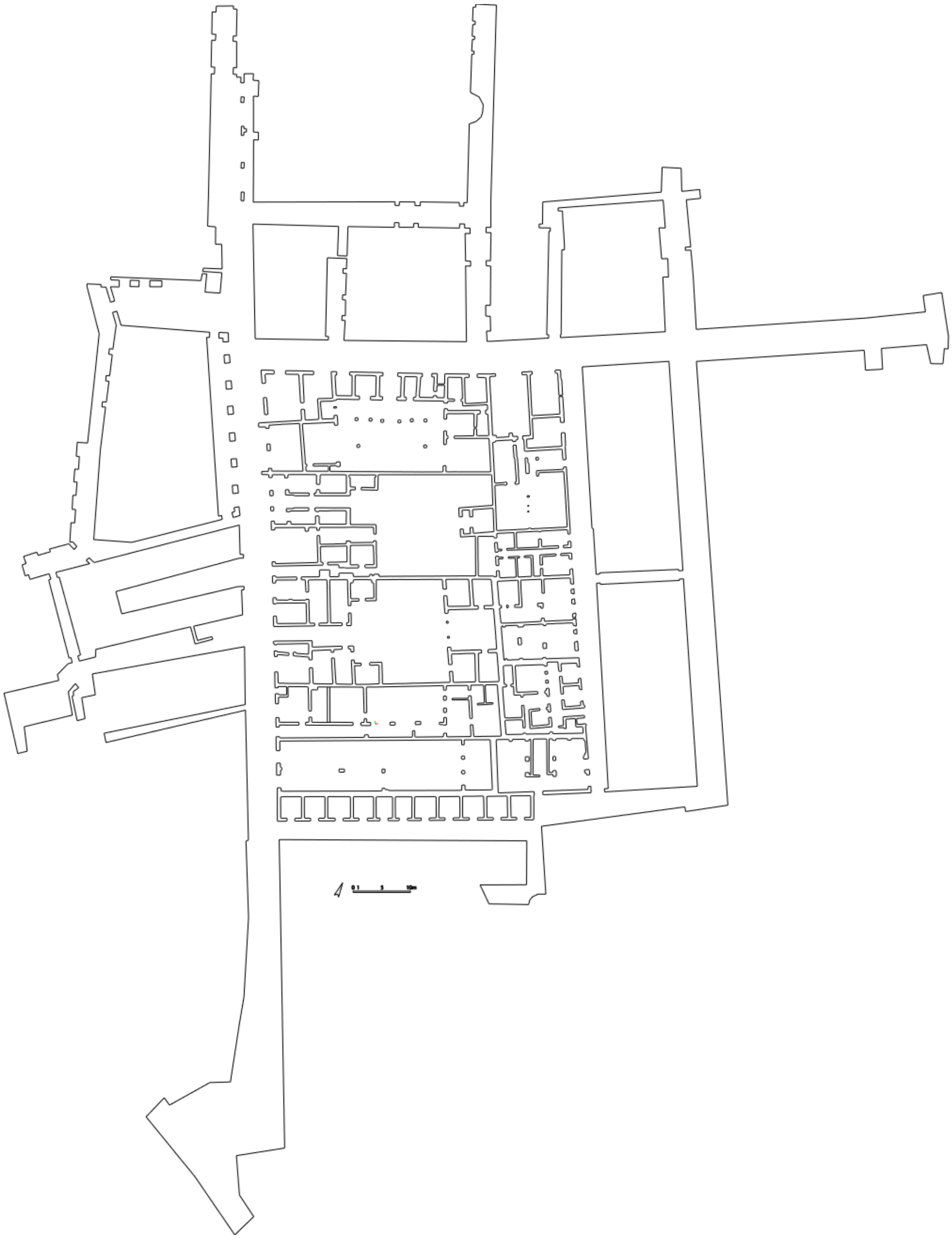
Appendix A10: Petriaggi's plan of building V ii 2 (V ii 1 is also shown), showing architectural remains pre-dating the Severan phase of the building (Petriaggi 1987, 194, fig. 2).



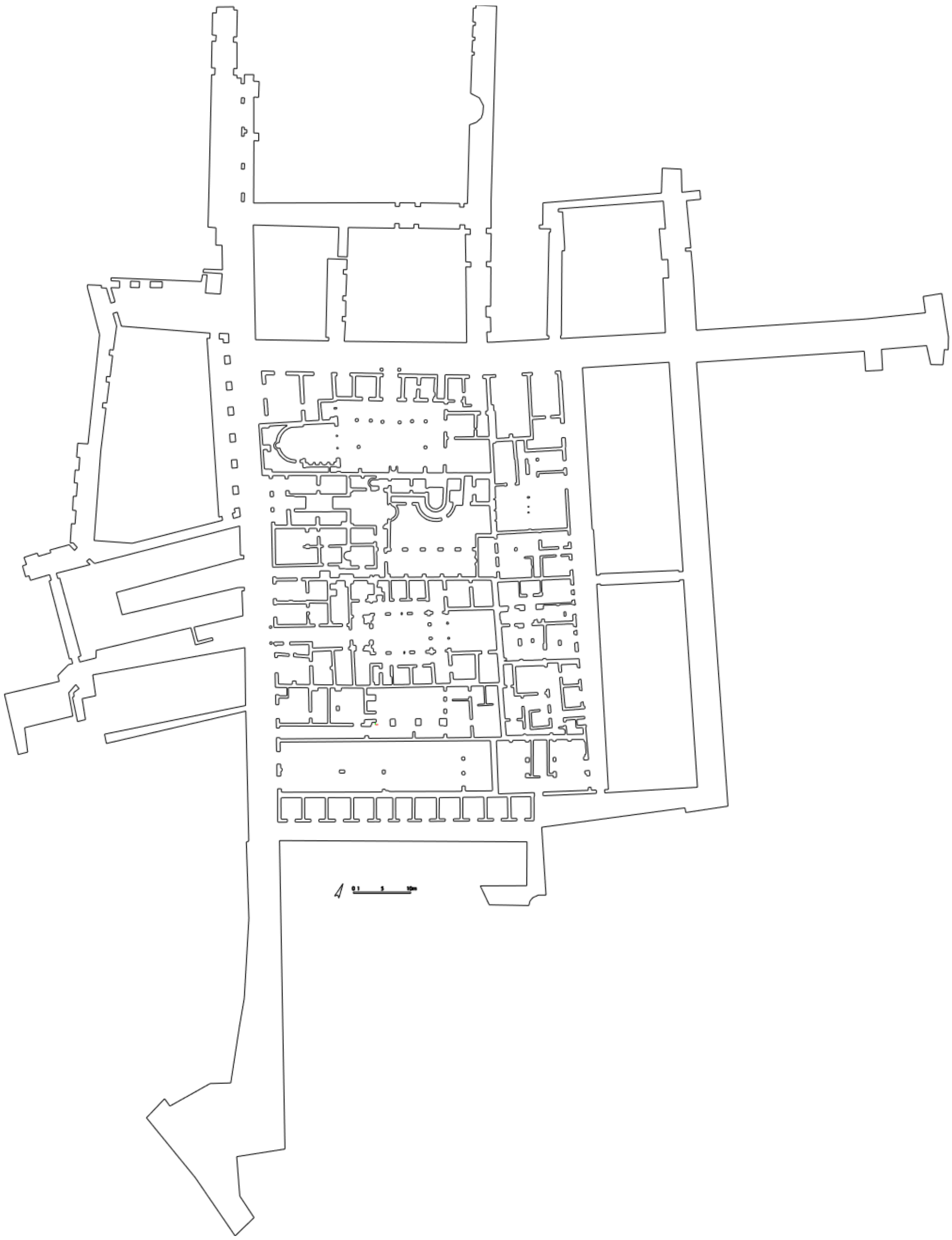
Appendix A11: Plan of the underground complex in building V ii 4-5 (Boersma 1985, 373, fig. 538).



Appendix A12: Vector plan of the Severan phase of insula V ii and nearby streets, used as the input for the visibility graph analyses and agent-based models. Obstructions that do not block view or movement are not shown (by author).

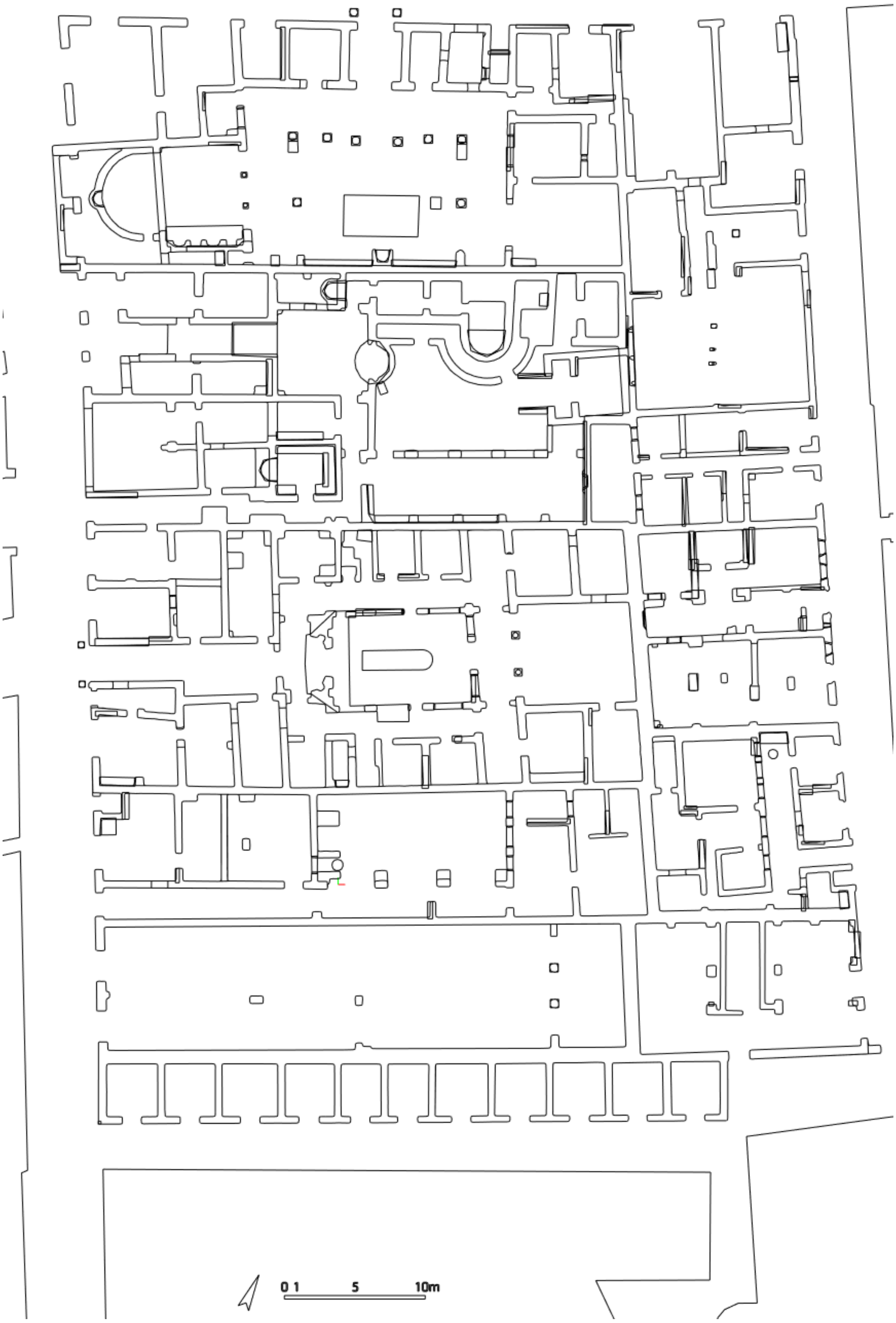


Appendix A13: Vector plan of the final phase of insula V ii and nearby streets, used as the input for the visibility graph analyses and agent-based models. Obstructions that do not block view or movement are not shown (by author).



Appendix A14: Coloured vector plan of insula Vii, showing all vector layers of both the Severan and final phase that were used for the visibility graph analyses and agent-based models. Each layer has been given a different colour: Red=Severan phase plan, dark red=Severan phase obstructions, grey=final phase plan, blue=final phase obstructions, cyan=grid corrections for pillars in both phases, (dark)green=other grid corrections (by author).

Appendix A15: The vector plans of the Severan and final phase, zoomed in on insula V ii, showing every single layer used for the analyses (by author).

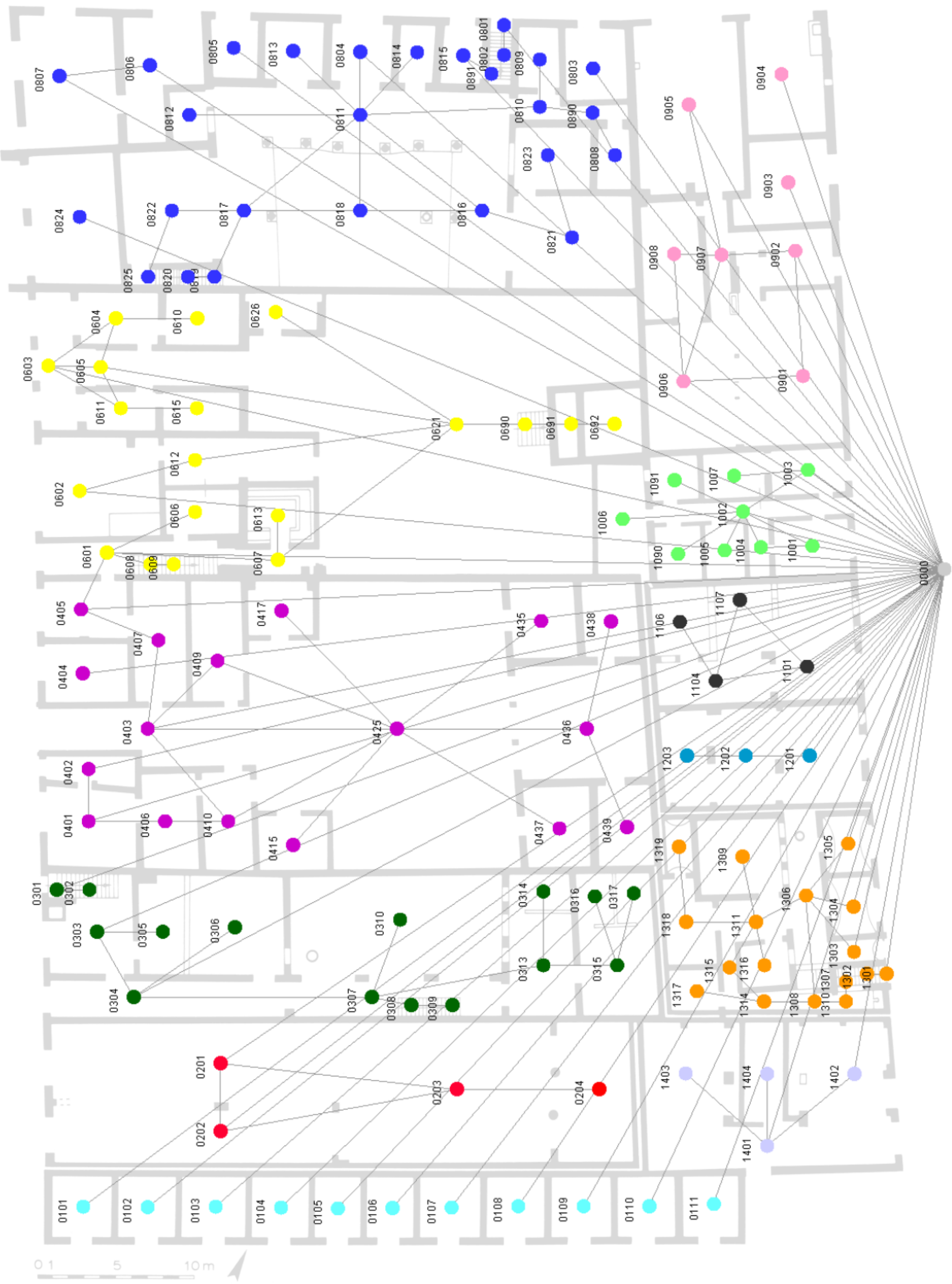


Appendix B: Access analysis

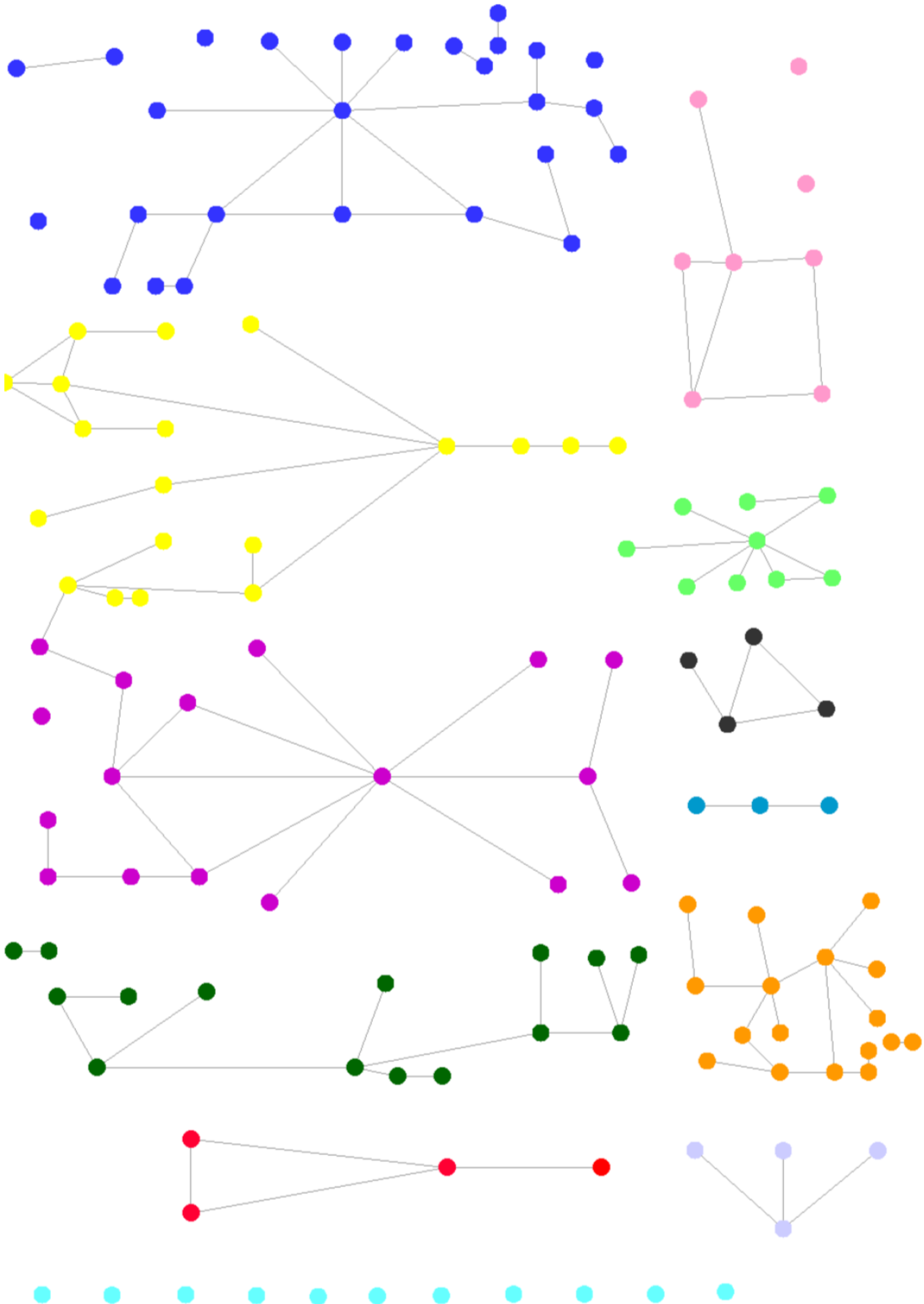
Appendix B1: Legend of the node colours (by author).

- **V ii 1**: Row of shops
- **V ii 2**: Storage building
- **V ii 3**: Apartment house
- **V ii 4-5**: House of the Porch
- **V ii 6-7**: Baths of the Philosopher
- **V ii 8**: House of Fortuna Annonaria
- **V ii 9**: Shop-and-factory building
- **V ii 10**: House
- **V ii 11**: House
- **V ii 12**: Building
- **V ii 13**: House of the well
- **V ii 14**: Building

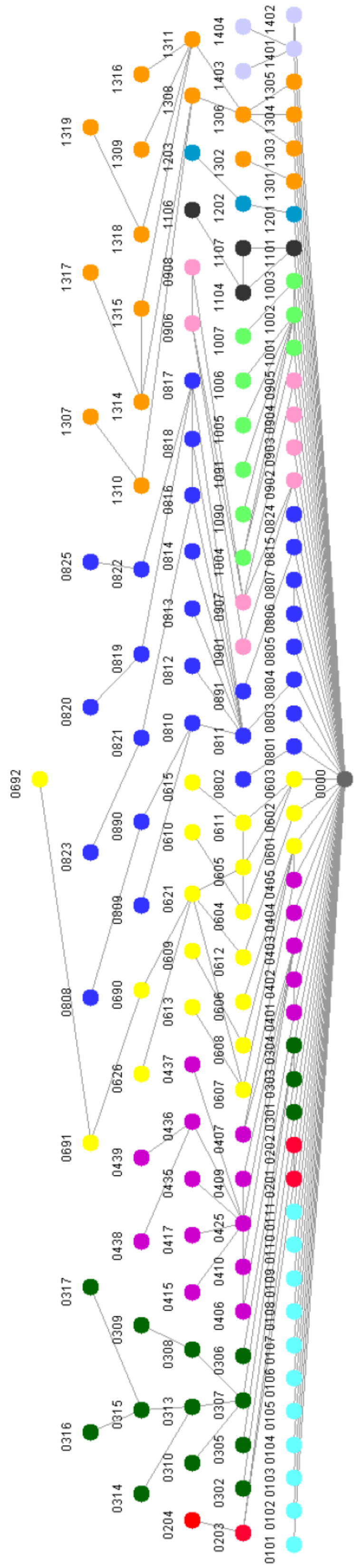
Appendix B2: Topological graph of the Severan phase of insula V ii shown on top of Boersma's plan (background after Boersma 1985, 218, fig. 204).



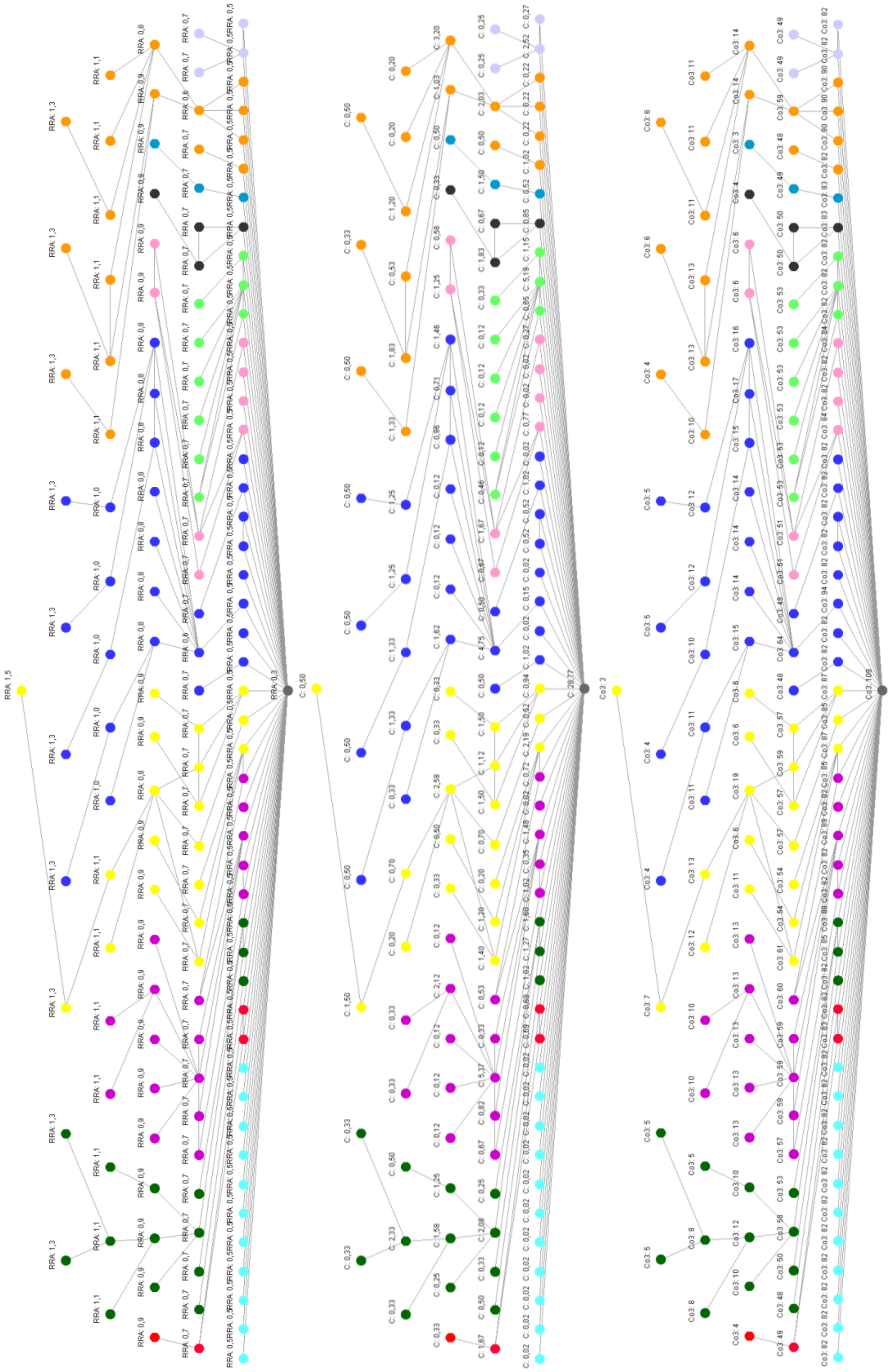
Appendix B3: Topological graph of the Severan phase of insula V ii, without the root point (by author).



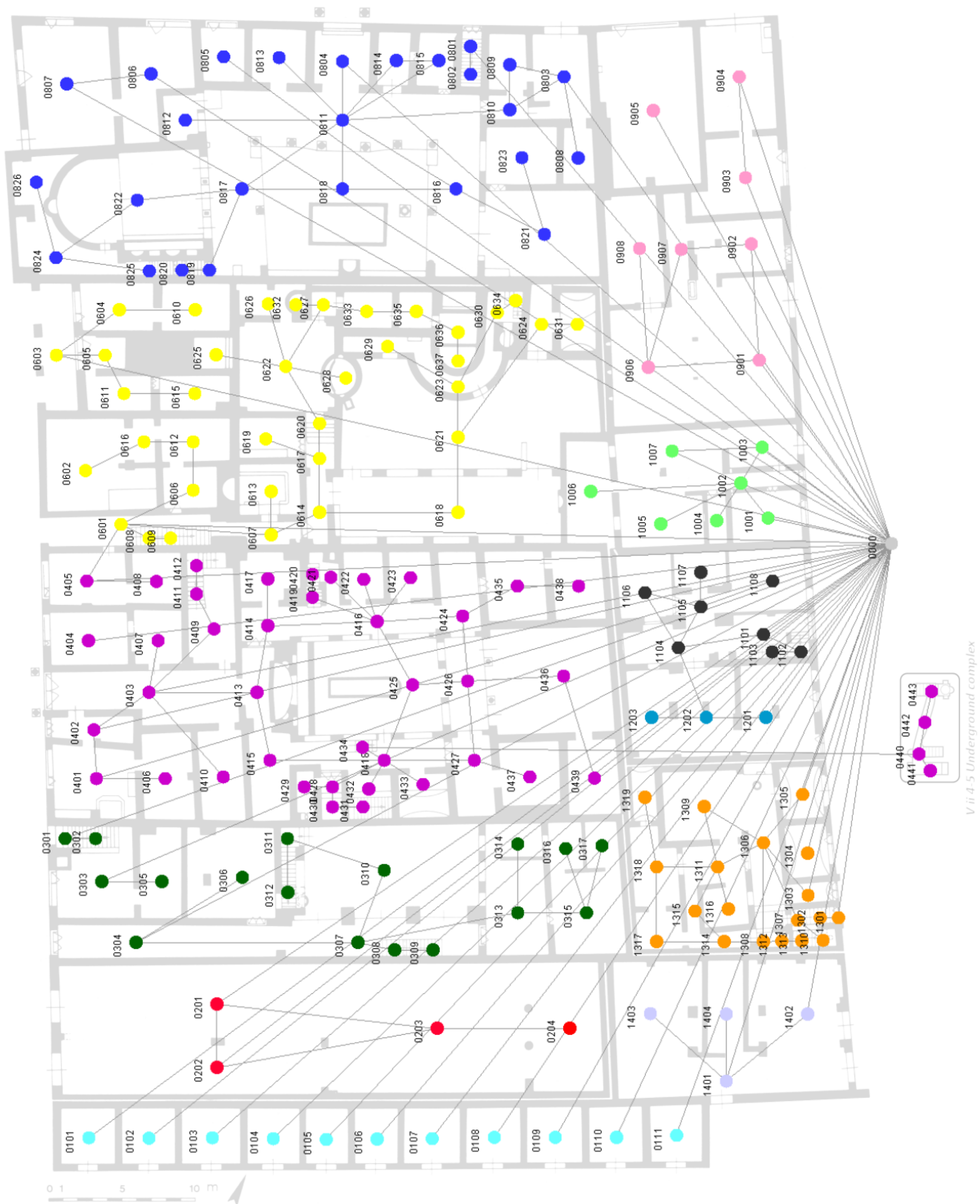
Appendix B4: Justified access graph of the Severan phase of insula V ii (by author).



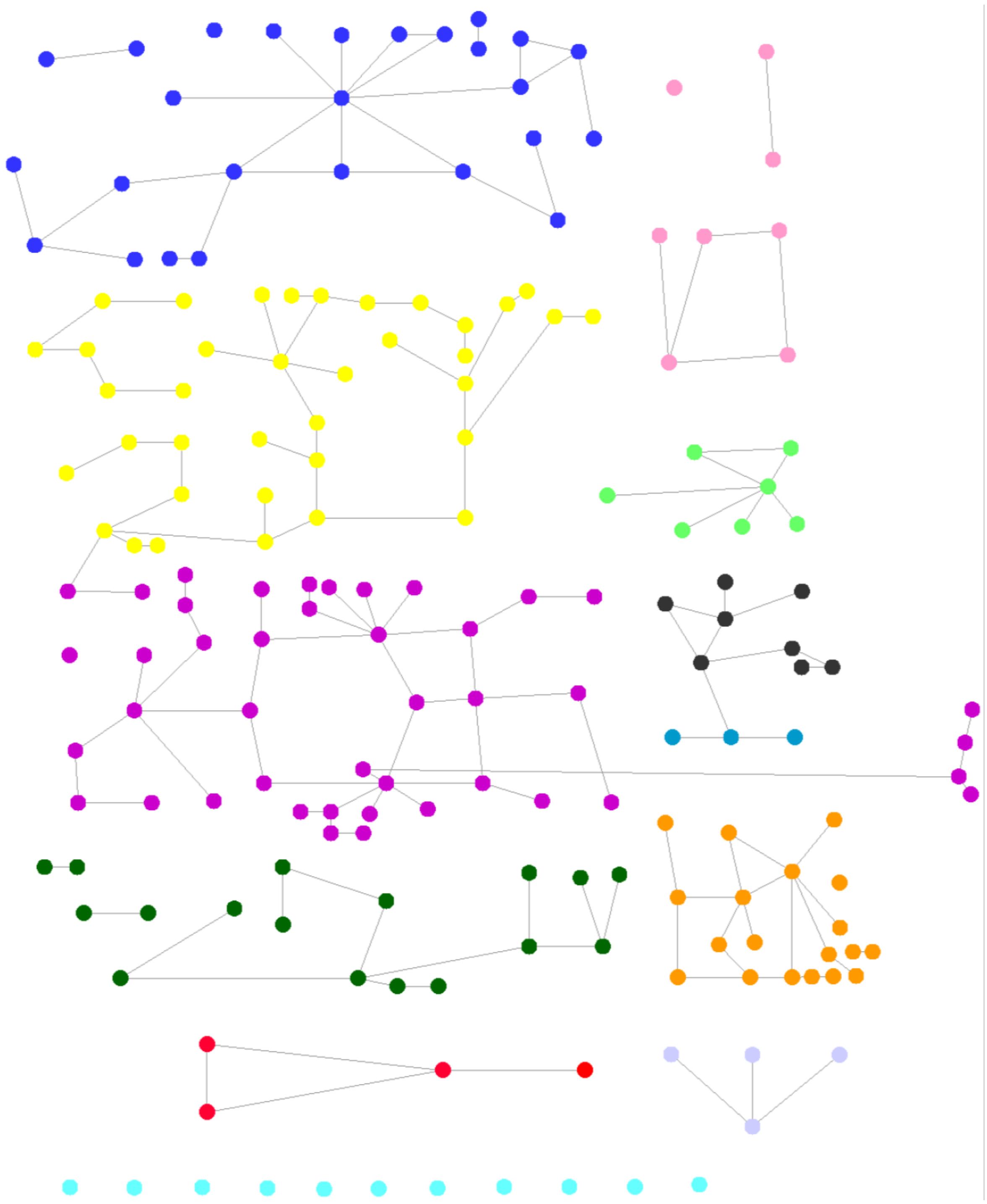
Appendix B5: Justified access graphs of the Severan phase of insula V ii, with the RRA, control and connectivity (for a range of 3) value of every node (by author).



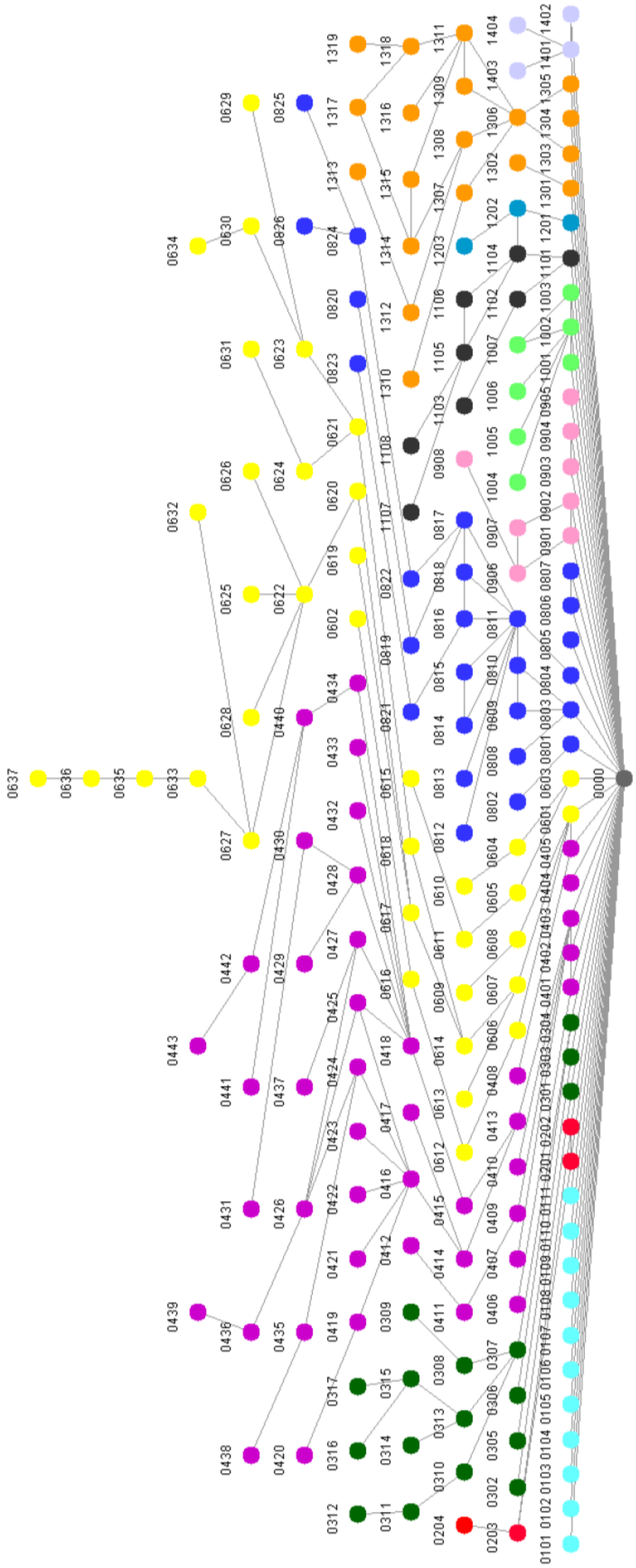
Appendix B6: Topological graph of the final phase of insula V ii shown on top of Boersma's plan. The plan of the underground complex in building V ii 4-5 is displayed next to the insula (background after Boersma 1985, 214, fig. 202 and plan of underground complex after Boersma 1985, 373, fig. 538).



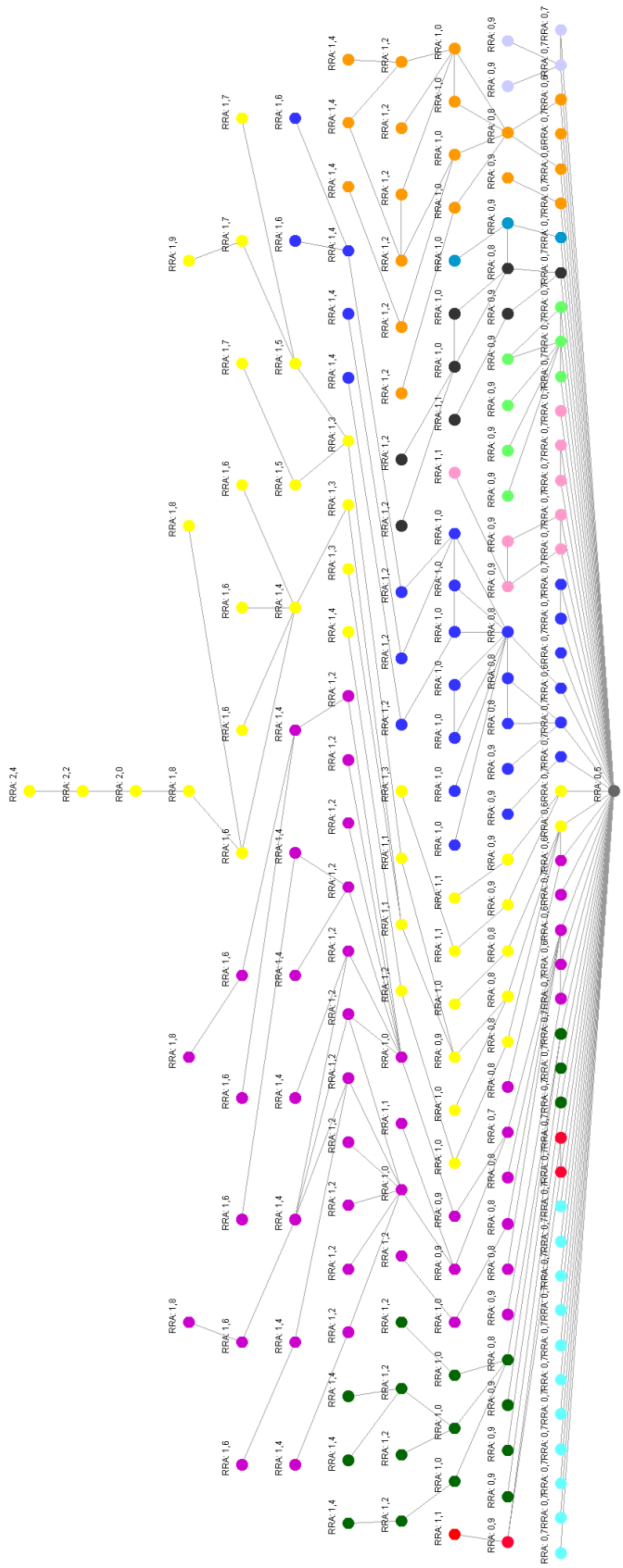
Appendix B7: Topological graph of the final phase of insula V ii, without the root node (by author).



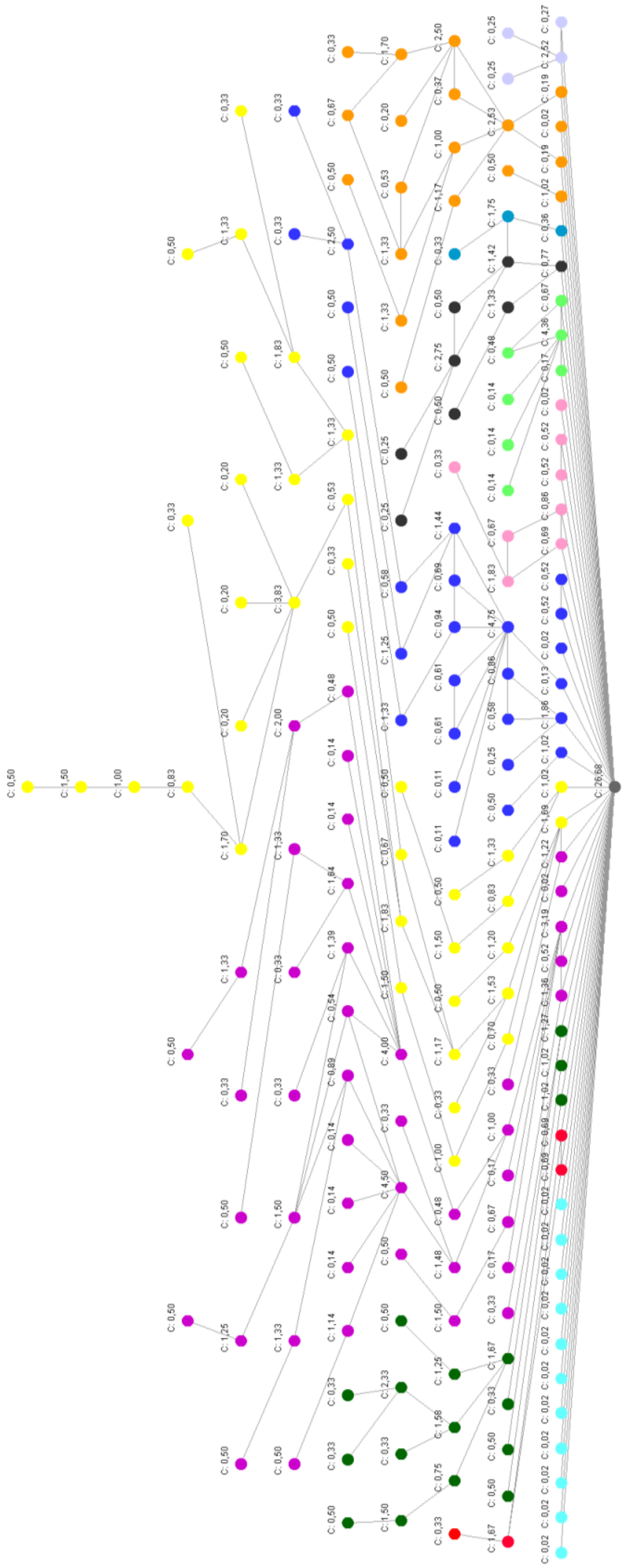
Appendix B8: Justified access graph of the final phase of insula V ii (by author).



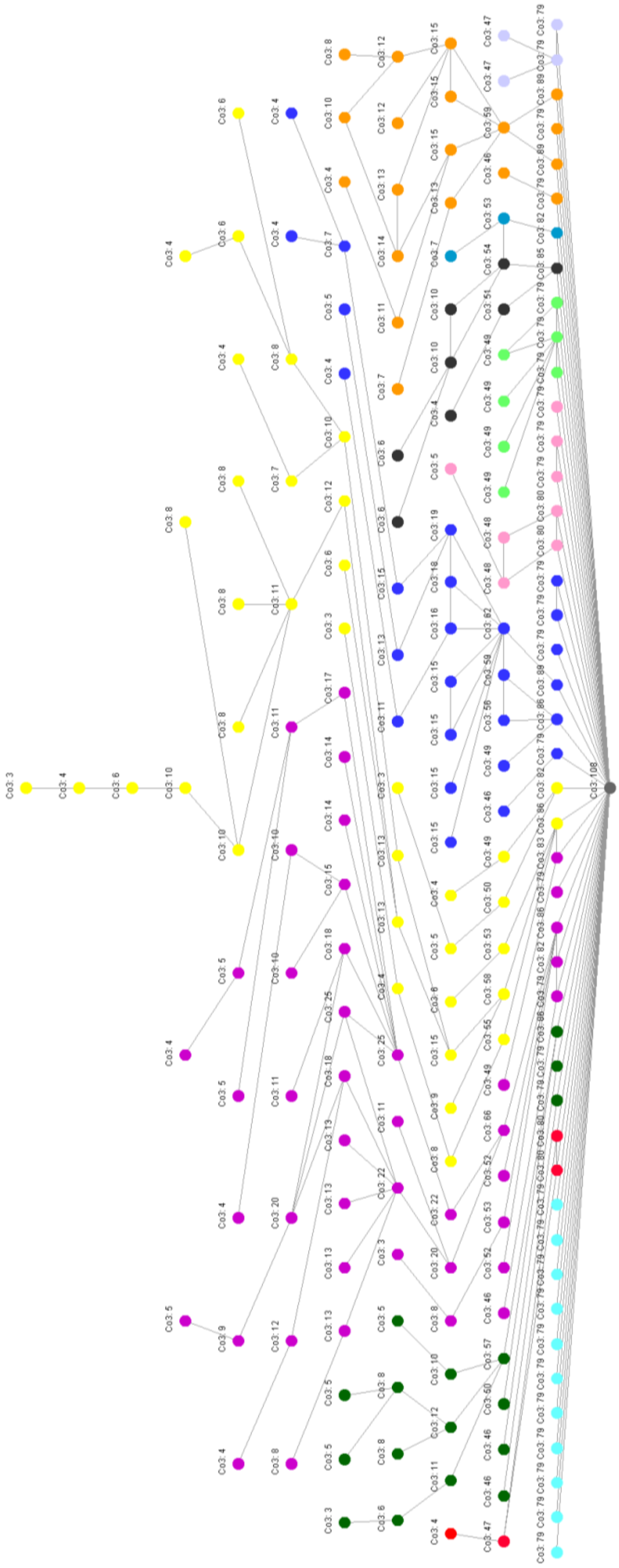
Appendix B9: Justified access graphs of the Severan phase of insula V ii, with the RRA value of every node (by author).



Appendix B10: Justified access graphs of the Severan phase of insula V ii, with the control value of every node (by author).



Appendix B11: Justified access graphs of the Severan phase of insula V ii, with the connectivity value (for a range of 3) of every node (by author).



Appendix B12: Table containing the computed data of every node in the access graph of the Severan phase of insula V ii (by author).

Node	Control	RA	RRA	Depth	Mean Depth	Total Depth	Connectivity (3)
0000	28.78	0.020	0.30	0	2.36	326	109
0101	0.02	0.034	0.51	1	3.36	463	82
0102	0.02	0.034	0.51	1	3.36	463	82
0103	0.02	0.034	0.51	1	3.36	463	82
0104	0.02	0.034	0.51	1	3.36	463	82
0105	0.02	0.034	0.51	1	3.36	463	82
0106	0.02	0.034	0.51	1	3.36	463	82
0107	0.02	0.034	0.51	1	3.36	463	82
0108	0.02	0.034	0.51	1	3.36	463	82
0109	0.02	0.034	0.51	1	3.36	463	82
0110	0.02	0.034	0.51	1	3.36	463	82
0111	0.02	0.034	0.51	1	3.36	463	82
0201	0.69	0.034	0.50	1	3.32	458	83
0202	0.69	0.034	0.50	1	3.32	458	83
0203	1.67	0.048	0.72	2	4.29	592	49
0204	0.33	0.063	0.93	3	5.28	729	4
0301	1.02	0.034	0.51	1	3.34	461	82
0302	0.50	0.049	0.73	2	4.33	598	48
0303	1.27	0.033	0.49	1	3.26	450	85
0304	1.60	0.032	0.48	1	3.20	441	88
0305	0.33	0.047	0.71	2	4.25	587	50
0306	0.25	0.047	0.69	2	4.19	578	53
0307	2.08	0.045	0.67	2	4.07	562	58
0308	1.25	0.059	0.88	3	5.05	697	10
0309	0.50	0.074	1.10	4	6.04	834	5
0310	0.25	0.059	0.88	3	5.07	699	10
0313	1.58	0.058	0.87	3	5.01	691	12
0314	0.33	0.073	1.09	4	6.00	828	8
0315	2.33	0.073	1.08	4	5.97	824	8
0316	0.33	0.087	1.30	5	6.96	961	5
0317	0.33	0.087	1.30	5	6.96	961	5
0401	1.02	0.034	0.51	1	3.33	459	82
0402	0.35	0.034	0.51	1	3.34	461	82
0403	1.48	0.032	0.48	1	3.19	440	89
0404	0.02	0.034	0.51	1	3.36	463	82
0405	0.72	0.033	0.49	1	3.26	450	85

0406	0.67	0.046	0.69	2	4.17	575	57
0407	0.53	0.045	0.67	2	4.09	564	60
0409	0.33	0.046	0.68	2	4.12	569	59
0410	0.83	0.045	0.67	2	4.10	566	59
0415	0.13	0.059	0.88	3	5.05	697	13
0417	0.13	0.059	0.88	3	5.05	697	13
0425	5.37	0.045	0.67	2	4.06	560	59
0435	0.13	0.059	0.88	3	5.05	697	13
0436	2.13	0.059	0.88	3	5.02	693	13
0437	0.13	0.059	0.88	3	5.05	697	13
0438	0.33	0.073	1.09	4	6.01	830	10
0439	0.33	0.073	1.09	4	6.01	830	10
0601	2.19	0.032	0.48	1	3.20	441	87
0602	0.52	0.033	0.49	1	3.27	451	85
0603	0.94	0.032	0.48	1	3.21	443	87
0604	1.50	0.046	0.68	2	4.12	569	57
0605	1.12	0.045	0.67	2	4.06	560	59
0606	0.20	0.047	0.69	2	4.19	578	54
0607	1.40	0.044	0.66	2	4.04	558	61
0608	1.20	0.046	0.69	2	4.17	576	54
0609	0.50	0.061	0.91	3	5.17	713	6
0610	0.33	0.060	0.90	3	5.12	706	6
0611	1.50	0.046	0.68	2	4.12	569	57
0612	0.70	0.045	0.68	2	4.12	568	57
0613	0.33	0.059	0.88	3	5.04	695	11
0615	0.33	0.060	0.90	3	5.12	706	6
0621	2.58	0.056	0.84	3	4.86	671	19
0626	0.20	0.071	1.06	4	5.86	808	12
0690	0.70	0.070	1.05	4	5.83	804	13
0691	1.50	0.085	1.26	5	6.80	939	7
0692	0.50	0.099	1.48	6	7.80	1076	3
0801	1.02	0.034	0.51	1	3.34	461	82
0802	0.50	0.049	0.73	2	4.33	598	48
0803	0.02	0.034	0.51	1	3.36	463	82
0804	0.15	0.031	0.46	1	3.11	429	94
0805	0.02	0.034	0.51	1	3.36	463	82
0806	0.52	0.034	0.51	1	3.35	462	82
0807	0.52	0.034	0.51	1	3.35	462	82
0808	0.50	0.085	1.26	5	6.79	937	4
0809	0.33	0.070	1.05	4	5.81	802	11
0810	1.63	0.056	0.83	3	4.82	665	15
0811	4.75	0.042	0.62	2	3.87	534	64

0812	0.13	0.056	0.84	3	4.86	671	14
0813	0.13	0.056	0.84	3	4.86	671	14
0814	0.13	0.056	0.84	3	4.86	671	14
0815	1.02	0.034	0.51	1	3.34	461	82
0816	0.96	0.056	0.83	3	4.83	666	15
0817	1.46	0.055	0.83	3	4.80	662	16
0818	0.71	0.056	0.83	3	4.80	663	17
0819	1.25	0.070	1.04	4	5.78	797	12
0820	0.50	0.084	1.26	5	6.77	934	5
0821	1.33	0.070	1.05	4	5.80	801	10
0822	1.25	0.070	1.04	4	5.78	797	12
0823	0.50	0.085	1.26	5	6.80	938	4
0824	0.02	0.034	0.51	1	3.36	463	82
0825	0.50	0.084	1.26	5	6.77	934	5
0890	1.33	0.070	1.04	4	5.80	800	11
0891	0.50	0.049	0.73	2	4.33	598	48
0901	0.67	0.048	0.71	2	4.27	589	51
0902	0.77	0.034	0.50	1	3.30	455	84
0903	0.02	0.034	0.51	1	3.36	463	82
0904	0.02	0.034	0.51	1	3.36	463	82
0905	0.27	0.034	0.50	1	3.31	457	84
0906	1.25	0.062	0.92	3	5.22	720	6
0907	1.67	0.047	0.71	2	4.25	586	51
0908	0.58	0.062	0.92	3	5.22	721	6
1001	0.65	0.034	0.50	1	3.30	456	82
1002	5.19	0.033	0.49	1	3.26	450	82
1003	1.15	0.034	0.50	1	3.30	455	82
1004	0.46	0.047	0.71	2	4.25	586	53
1005	0.13	0.047	0.71	2	4.25	587	53
1006	0.13	0.047	0.71	2	4.25	587	53
1007	0.33	0.048	0.72	2	4.29	592	53
1090	0.13	0.047	0.71	2	4.25	587	53
1091	0.13	0.047	0.71	2	4.25	587	53
1101	0.85	0.034	0.50	1	3.31	457	83
1104	1.83	0.048	0.71	2	4.28	591	50
1106	0.33	0.062	0.93	3	5.28	728	4
1107	0.67	0.048	0.72	2	4.29	592	50
1201	0.52	0.034	0.51	1	3.33	459	83
1202	1.50	0.048	0.72	2	4.30	594	49
1203	0.50	0.063	0.94	3	5.30	731	3
1301	1.02	0.034	0.51	1	3.34	461	82
1302	0.50	0.049	0.73	2	4.33	598	48

1303	0.22	0.032	0.47	1	3.18	439	90
1304	0.22	0.032	0.47	1	3.18	439	90
1305	0.22	0.032	0.47	1	3.18	439	90
1306	2.03	0.044	0.65	2	3.99	550	59
1307	0.50	0.086	1.28	5	6.88	950	4
1308	1.03	0.057	0.85	3	4.91	678	14
1309	0.20	0.071	1.06	4	5.88	812	11
1310	1.33	0.071	1.06	4	5.89	813	10
1311	3.20	0.057	0.85	3	4.89	675	14
1314	1.83	0.071	1.05	4	5.84	806	13
1315	0.53	0.071	1.05	4	5.83	805	13
1316	0.20	0.071	1.06	4	5.88	812	11
1317	0.33	0.085	1.27	5	6.83	943	6
1318	1.20	0.071	1.06	4	5.87	810	11
1319	0.50	0.086	1.28	5	6.86	947	6
1401	2.52	0.034	0.50	1	3.32	458	82
1402	0.27	0.034	0.51	1	3.33	460	82
1403	0.25	0.048	0.72	2	4.31	595	49
1404	0.25	0.048	0.72	2	4.31	595	49

Appendix B13: Table containing the computed data of every node in the access graph of the final phase of insula V ii (by author).

Node	Control	RA	RRA	Depth	Mean Depth	Total Depth	Connectivity (3)
0000	26.68	0.026	0.48	0	3.41	638	108
0101	0.02	0.037	0.68	1	4.41	824	79
0102	0.02	0.037	0.68	1	4.41	824	79
0103	0.02	0.037	0.68	1	4.41	824	79
0104	0.02	0.037	0.68	1	4.41	824	79
0105	0.02	0.037	0.68	1	4.41	824	79
0106	0.02	0.037	0.68	1	4.41	824	79
0107	0.02	0.037	0.68	1	4.41	824	79
0108	0.02	0.037	0.68	1	4.41	824	79
0109	0.02	0.037	0.68	1	4.41	824	79
0110	0.02	0.037	0.68	1	4.41	824	79
0111	0.02	0.037	0.68	1	4.41	824	79
0201	0.69	0.036	0.67	1	4.38	819	80
0202	0.69	0.036	0.67	1	4.38	819	80
0203	1.67	0.047	0.87	2	5.36	1002	47
0204	0.33	0.058	1.07	3	6.35	1188	4
0301	1.02	0.037	0.68	1	4.40	822	79
0302	0.50	0.047	0.88	2	5.39	1008	46
0303	1.02	0.037	0.68	1	4.40	822	79
0304	1.27	0.035	0.65	1	4.28	800	86
0305	0.50	0.047	0.88	2	5.39	1008	46
0306	0.33	0.046	0.85	2	5.27	986	50
0307	1.67	0.045	0.83	2	5.17	966	57
0308	1.25	0.055	1.03	3	6.15	1150	10
0309	0.50	0.066	1.22	4	7.14	1336	5
0310	0.75	0.055	1.02	3	6.14	1148	11
0311	1.50	0.066	1.22	4	7.12	1332	6
0312	0.50	0.077	1.42	5	8.12	1518	3
0313	1.58	0.055	1.02	3	6.12	1144	12
0314	0.33	0.066	1.22	4	7.11	1330	8
0315	2.33	0.065	1.21	4	7.09	1326	8
0316	0.33	0.076	1.41	5	8.09	1512	5
0317	0.33	0.076	1.41	5	8.09	1512	5
0401	1.36	0.036	0.68	1	4.39	821	79
0402	0.52	0.034	0.64	1	4.20	785	82
0403	3.19	0.032	0.60	1	4.02	751	86

0404	0.02	0.037	0.68	1	4.41	824	79
0405	1.22	0.035	0.64	1	4.23	791	83
0406	0.33	0.047	0.87	2	5.39	1007	46
0407	0.17	0.043	0.80	2	5.01	937	52
0408	0.33	0.045	0.84	2	5.22	977	49
0409	0.67	0.043	0.80	2	4.99	933	53
0410	0.17	0.043	0.80	2	5.01	937	52
0411	1.50	0.053	0.99	3	5.97	1117	8
0412	0.50	0.064	1.19	4	6.97	1303	3
0413	1.00	0.040	0.74	2	4.69	877	66
0414	1.48	0.049	0.90	3	5.53	1035	20
0415	0.48	0.048	0.90	3	5.49	1027	22
0416	4.50	0.056	1.05	4	6.25	1169	22
0417	0.33	0.059	1.10	4	6.53	1221	11
0418	4.00	0.056	1.04	4	6.21	1161	25
0419	1.14	0.067	1.24	5	7.24	1353	13
0420	0.50	0.078	1.44	6	8.23	1539	8
0421	0.14	0.067	1.24	5	7.25	1355	13
0422	0.14	0.067	1.24	5	7.25	1355	13
0423	0.14	0.067	1.24	5	7.25	1355	13
0424	0.89	0.066	1.23	5	7.17	1341	18
0425	0.54	0.065	1.21	5	7.05	1319	25
0426	1.50	0.075	1.39	6	7.97	1491	20
0427	1.39	0.066	1.22	5	7.13	1333	18
0428	1.64	0.066	1.23	5	7.17	1341	15
0429	0.33	0.077	1.43	6	8.17	1527	10
0430	1.33	0.077	1.43	6	8.16	1525	10
0431	0.50	0.088	1.62	7	9.15	1711	4
0432	0.14	0.067	1.24	5	7.20	1347	14
0433	0.14	0.067	1.24	5	7.20	1347	14
0434	0.48	0.066	1.23	5	7.16	1339	17
0435	1.33	0.077	1.43	6	8.16	1525	12
0436	1.25	0.086	1.59	7	8.96	1675	9
0437	0.33	0.077	1.42	6	8.12	1519	11
0438	0.50	0.088	1.62	7	9.15	1711	4
0439	0.50	0.096	1.78	8	9.95	1861	5
0440	2.00	0.077	1.42	6	8.12	1519	11
0441	0.33	0.087	1.62	7	9.12	1705	5
0442	1.33	0.087	1.62	7	9.11	1703	5
0443	0.50	0.098	1.81	8	10.10	1889	4
0601	1.69	0.033	0.61	1	4.07	762	86
0602	0.50	0.075	1.39	5	7.99	1494	3

0603	1.02	0.036	0.67	1	4.35	814	82
0604	1.33	0.047	0.86	2	5.34	998	49
0605	0.83	0.047	0.86	2	5.33	996	50
0606	0.70	0.043	0.80	2	5.04	942	55
0607	1.53	0.041	0.76	2	4.82	902	58
0608	1.20	0.044	0.81	2	5.06	946	53
0609	0.50	0.054	1.01	3	6.05	1132	6
0610	0.50	0.057	1.06	3	6.33	1184	4
0611	1.50	0.057	1.06	3	6.31	1180	5
0612	1.00	0.054	1.00	3	6.01	1124	8
0613	0.33	0.052	0.96	3	5.82	1088	9
0614	1.17	0.049	0.92	3	5.59	1046	15
0615	0.50	0.068	1.26	4	7.30	1366	3
0616	1.50	0.064	1.19	4	6.99	1308	4
0617	1.83	0.059	1.09	4	6.46	1208	13
0618	0.67	0.059	1.10	4	6.51	1218	13
0619	0.33	0.069	1.29	5	7.45	1394	6
0620	0.53	0.068	1.27	5	7.35	1374	12
0621	1.33	0.069	1.28	5	7.44	1392	10
0622	3.83	0.078	1.44	6	8.25	1542	11
0623	1.83	0.080	1.48	6	8.41	1572	8
0624	1.33	0.080	1.48	6	8.43	1576	7
0625	0.20	0.089	1.64	7	9.24	1728	8
0626	0.20	0.089	1.64	7	9.24	1728	8
0627	1.70	0.088	1.63	7	9.19	1718	10
0628	0.20	0.089	1.64	7	9.24	1728	8
0629	0.33	0.090	1.67	7	9.40	1758	6
0630	1.33	0.090	1.67	7	9.39	1756	6
0631	0.50	0.091	1.68	7	9.42	1762	4
0632	0.33	0.099	1.83	8	10.18	1904	8
0633	0.83	0.098	1.82	8	10.15	1898	10
0634	0.50	0.101	1.87	8	10.39	1942	4
0635	1.00	0.109	2.02	9	11.12	2080	6
0636	1.50	0.119	2.21	10	12.11	2264	4
0637	0.50	0.130	2.41	11	13.10	2450	3
0801	1.02	0.037	0.68	1	4.40	822	79
0802	0.50	0.047	0.88	2	5.39	1008	46
0803	1.86	0.035	0.66	1	4.29	802	86
0804	0.13	0.035	0.64	1	4.23	791	89
0805	0.02	0.037	0.68	1	4.41	824	79
0806	0.52	0.037	0.68	1	4.40	823	79
0807	0.52	0.037	0.68	1	4.40	823	79

0808	0.25	0.046	0.85	2	5.28	988	49
0809	0.58	0.045	0.84	2	5.19	971	56
0810	0.86	0.044	0.82	2	5.10	954	59
0811	4.75	0.043	0.80	2	5.03	941	62
0812	0.11	0.054	1.00	3	6.03	1127	15
0813	0.11	0.054	1.00	3	6.03	1127	15
0814	0.61	0.054	1.00	3	6.02	1126	15
0815	0.61	0.054	1.00	3	6.02	1126	15
0816	0.94	0.054	1.00	3	6.00	1122	16
0817	1.44	0.053	0.99	3	5.96	1114	19
0818	0.69	0.053	0.99	3	5.97	1117	18
0819	1.25	0.064	1.18	4	6.94	1298	13
0820	0.50	0.075	1.38	5	7.94	1484	5
0821	1.33	0.064	1.19	4	6.98	1306	11
0822	0.58	0.064	1.18	4	6.92	1294	15
0823	0.50	0.075	1.39	5	7.98	1492	4
0824	2.50	0.074	1.37	5	7.89	1476	7
0825	0.33	0.085	1.57	6	8.89	1662	4
0826	0.33	0.085	1.57	6	8.89	1662	4
0901	0.69	0.036	0.67	1	4.37	818	80
0902	0.86	0.036	0.67	1	4.38	819	80
0903	0.52	0.037	0.68	1	4.40	823	79
0904	0.52	0.037	0.68	1	4.40	823	79
0905	0.02	0.037	0.68	1	4.41	824	79
0906	1.83	0.047	0.87	2	5.35	1000	48
0907	0.67	0.047	0.87	2	5.35	1001	48
0908	0.33	0.057	1.06	3	6.34	1186	5
1001	0.17	0.036	0.67	1	4.38	819	79
1002	4.36	0.036	0.67	1	4.35	814	79
1003	0.67	0.036	0.67	1	4.37	818	79
1004	0.14	0.047	0.87	2	5.35	1000	49
1005	0.14	0.047	0.87	2	5.35	1000	49
1006	0.14	0.047	0.87	2	5.35	1000	49
1007	0.48	0.047	0.87	2	5.34	999	49
1101	0.77	0.036	0.66	1	4.32	808	85
1102	1.33	0.046	0.86	2	5.30	992	51
1103	0.50	0.057	1.06	3	6.30	1178	4
1104	1.42	0.046	0.85	2	5.25	981	54
1105	2.75	0.056	1.04	3	6.21	1162	10
1106	0.50	0.056	1.04	3	6.22	1164	10
1107	0.25	0.067	1.24	4	7.21	1348	6
1108	0.25	0.067	1.24	4	7.21	1348	6

1201	0.36	0.036	0.67	1	4.36	815	82
1202	1.75	0.046	0.85	2	5.27	986	53
1203	0.33	0.057	1.05	3	6.27	1172	7
1301	1.02	0.037	0.68	1	4.40	822	79
1302	0.50	0.047	0.88	2	5.39	1008	46
1303	0.19	0.035	0.65	1	4.26	796	89
1304	0.02	0.037	0.68	1	4.41	824	79
1305	0.19	0.035	0.65	1	4.26	796	89
1306	2.53	0.044	0.82	2	5.10	954	59
1307	1.17	0.055	1.01	3	6.09	1138	13
1308	1.00	0.054	1.01	3	6.05	1131	15
1309	0.37	0.054	1.01	3	6.06	1134	15
1310	0.50	0.065	1.21	4	7.08	1324	7
1311	2.50	0.054	1.00	3	6.03	1128	15
1312	1.33	0.065	1.20	4	7.03	1315	11
1313	0.50	0.076	1.40	5	8.03	1501	4
1314	1.33	0.064	1.19	4	6.99	1307	14
1315	0.53	0.064	1.19	4	6.99	1308	13
1316	0.20	0.065	1.20	4	7.03	1314	12
1317	0.67	0.075	1.38	5	7.95	1486	10
1318	1.70	0.065	1.20	4	7.00	1309	12
1319	0.33	0.075	1.39	5	7.99	1495	8
1401	2.52	0.036	0.67	1	4.38	819	79
1402	0.27	0.036	0.68	1	4.39	821	79
1403	0.25	0.047	0.87	2	5.37	1005	47
1404	0.25	0.047	0.87	2	5.37	1005	47

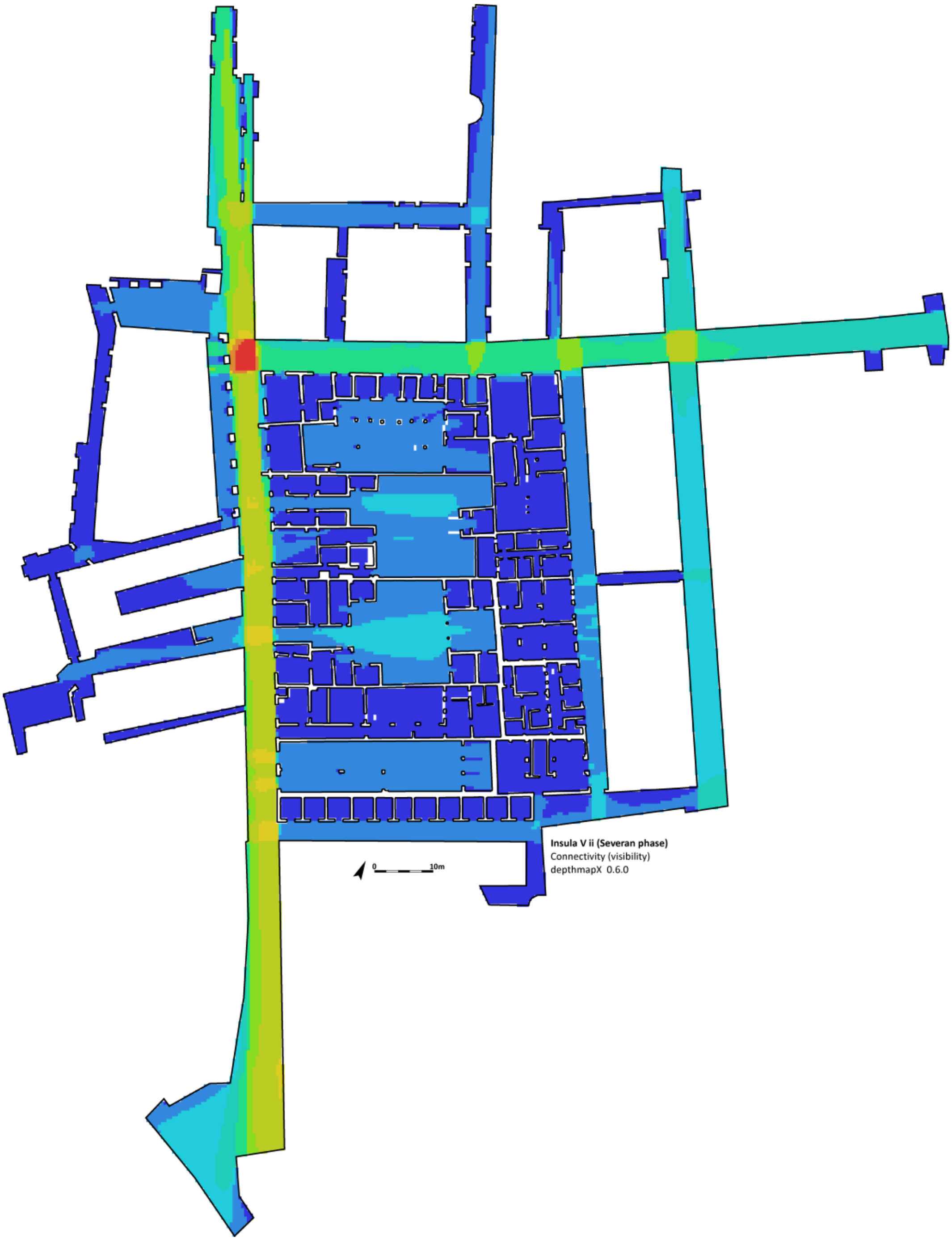
Appendix C: Isovists

Appendix C1: Isovists from all entrances of insula V ii (excluding staircases) during the Severan phase, coloured based on the size of their surface area. The colour distribution begins with blue at a value of 0 and ends with red for values above 200 (by author).

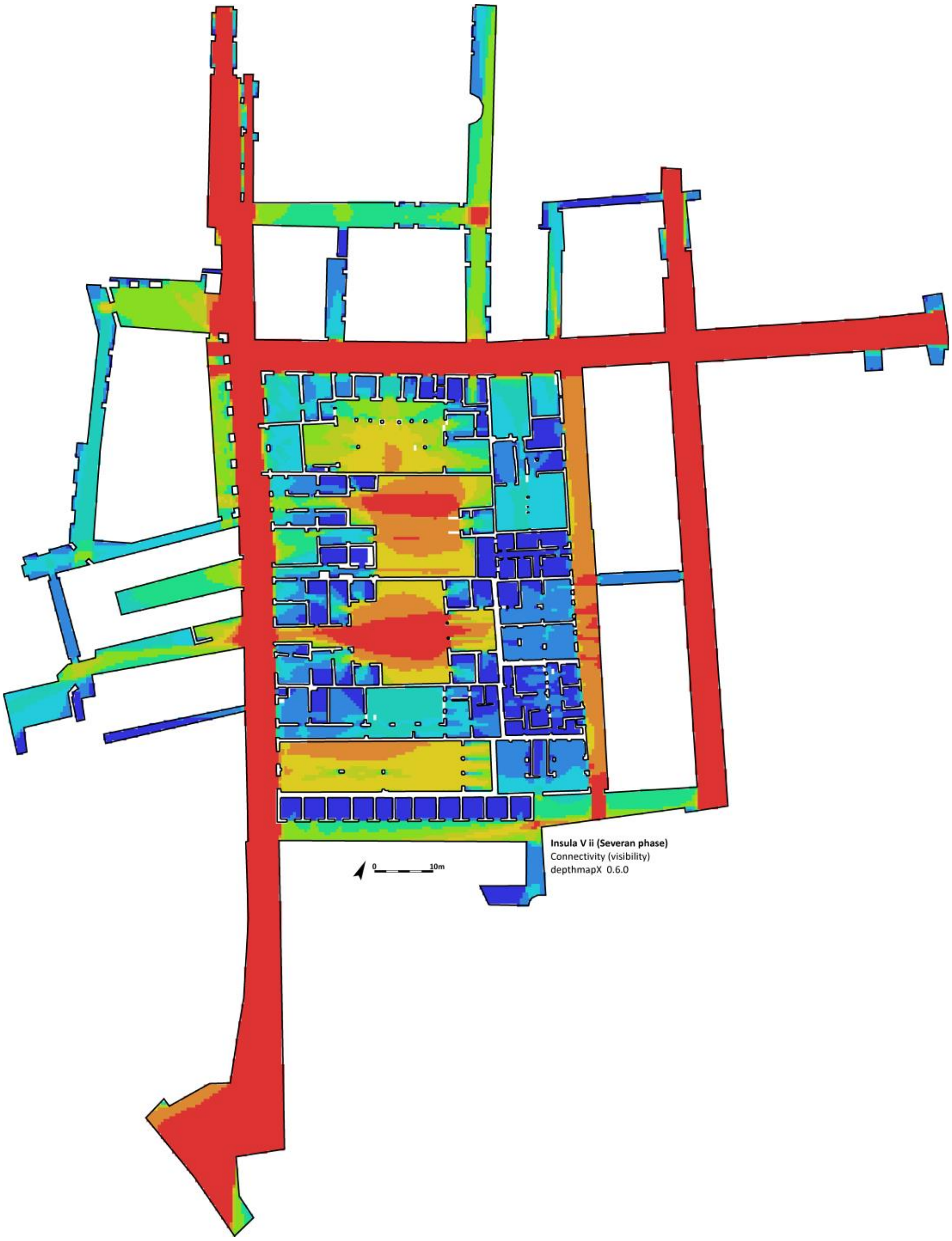
Appendix C2: Isovists from all entrances of insula V ii (excluding staircases) during the final phase, coloured based on the size of their surface area. The colour distribution begins with blue at a value of 0 and ends with red for values above 200 (by author).

Appendix D: Visibility Graph Analysis

Appendix D1: Graph of the connectivity values (visibility) of insula V ii and nearby streets during the Severan phase, with the default colour distribution of 7 (blue) – 7189 (red) (by author).

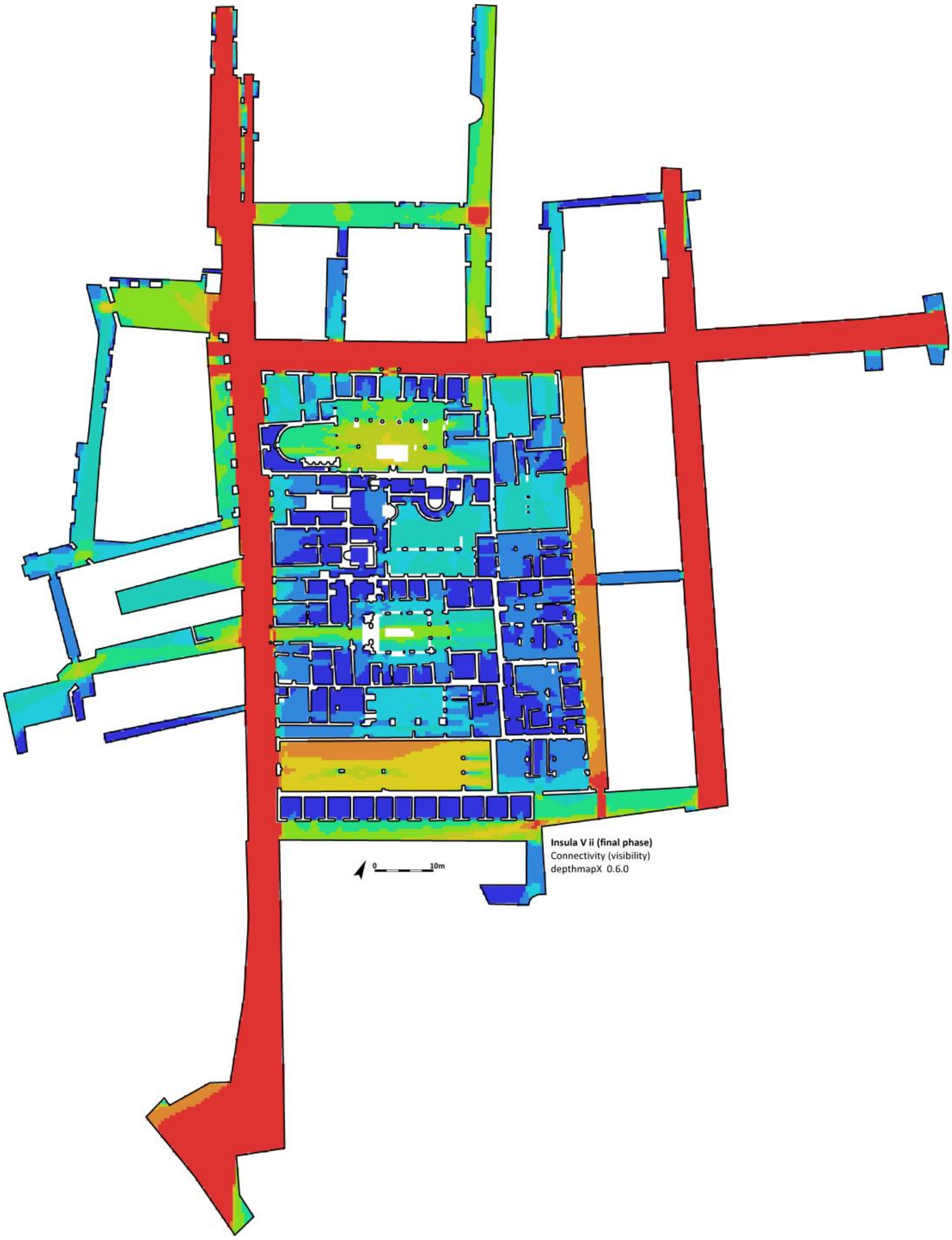


Appendix D2: Graph of the connectivity values (visibility) of insula V ii and nearby streets during the Severan phase, with an alternative colour distribution of 7 (blue) – 1600 (red) (by author).

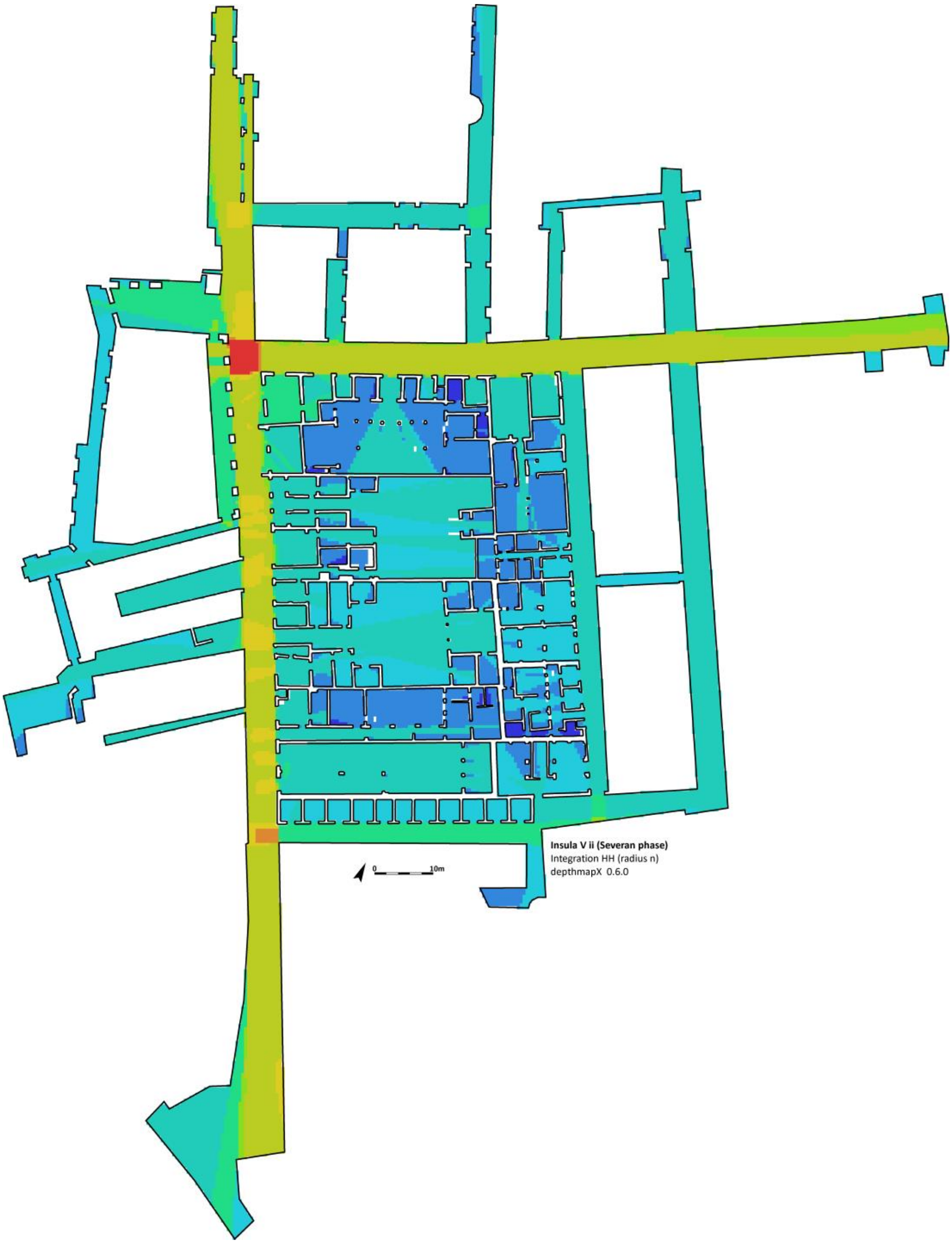


Appendix D3: Graph of the connectivity values (visibility) of insula V ii and nearby streets during the final phase, with the default colour distribution of 7 (blue) – 7046 (red) (by author).

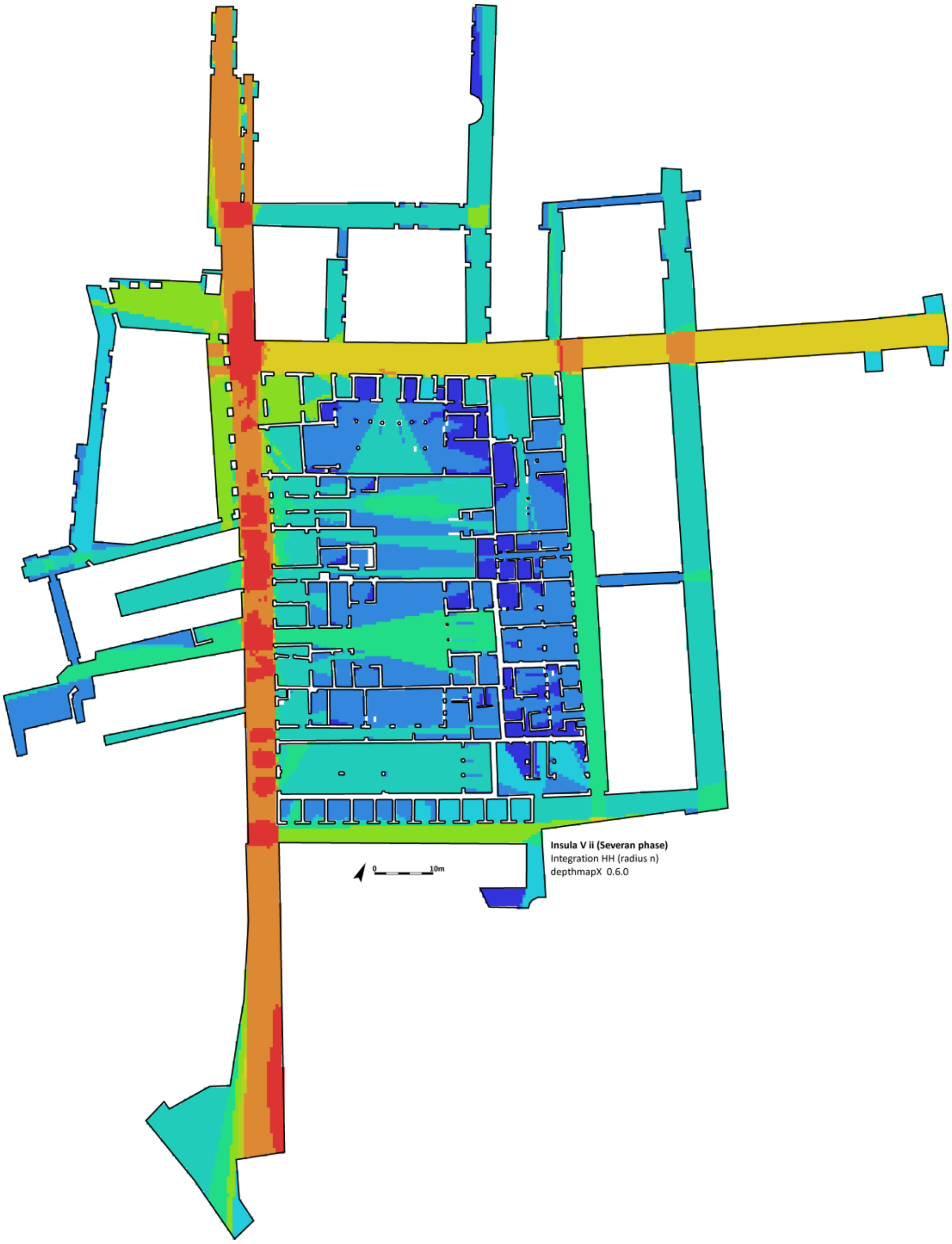
Appendix D4: Graph of the connectivity values (visibility) of insula V ii and nearby streets during the final phase, with an alternative colour distribution of 7 (blue) – 1600 (red) (by author).



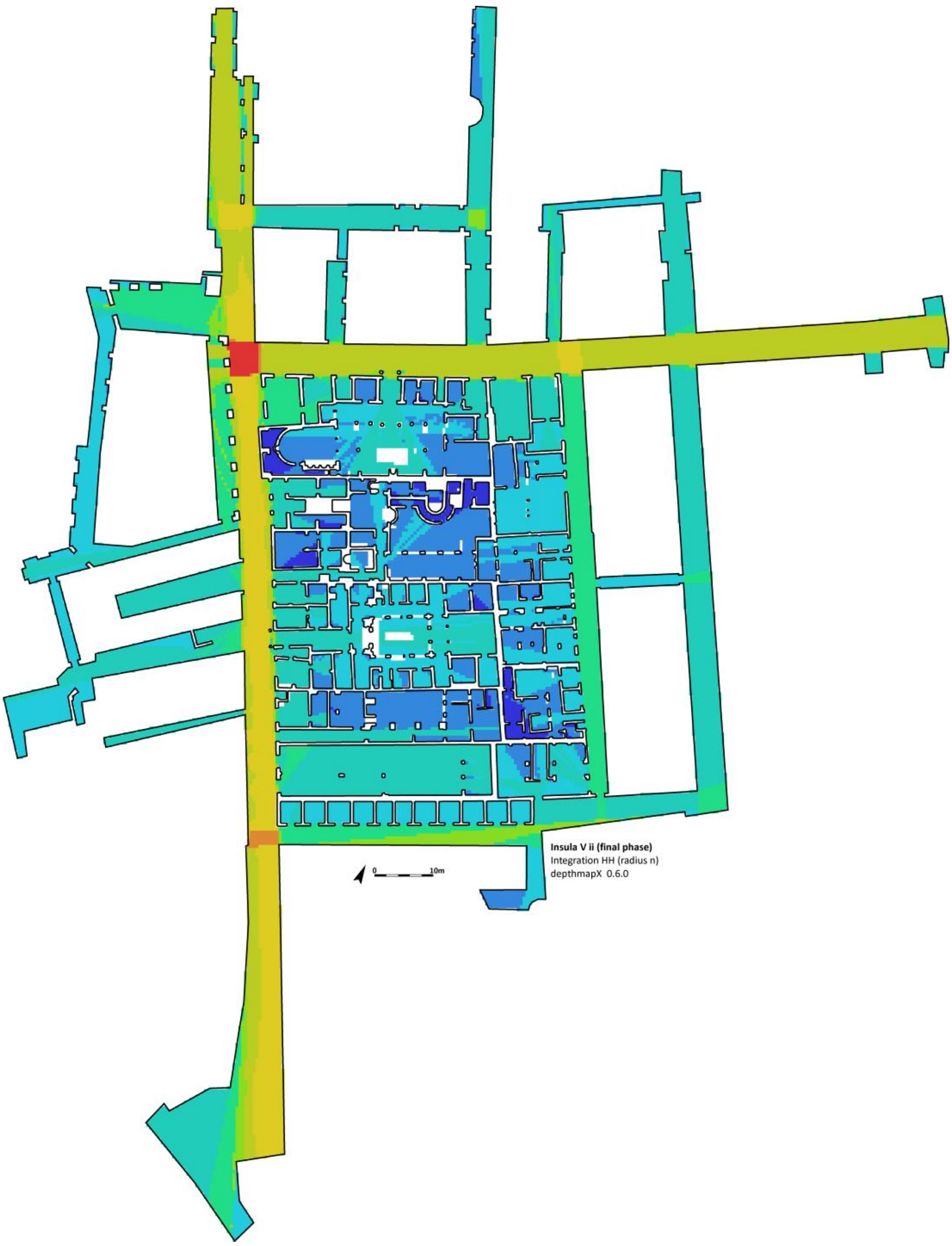
Appendix D5: Graph of the integration values (with radius *n*, or infinite) of insula V ii and nearby streets during the Severan phase, with the default colour distribution of 2,0 (blue) – 11,2 (red) (by author).



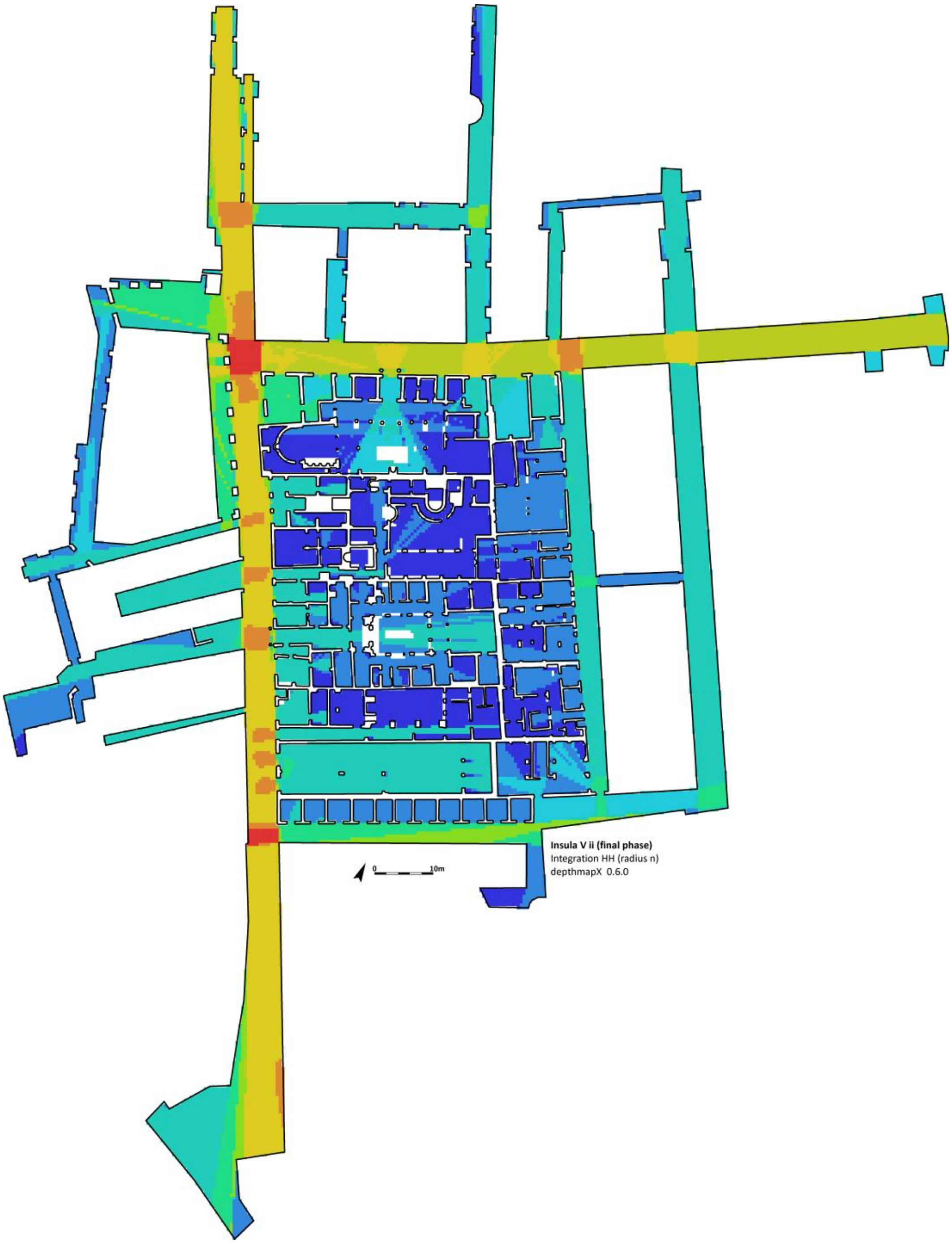
Appendix D6: Graph of the integration values (with radius *n*, or infinite) of insula V ii and nearby streets during the Severan phase, with an alternative colour distribution of 3,0 (blue) – 9,0 (red) (by author).



Appendix D7: Graph of the integration values (with radius *n*, or infinite) of insula V ii and nearby streets during the final phase, with the default colour distribution of 1,9 (blue) – 10,2 (red) (by author).

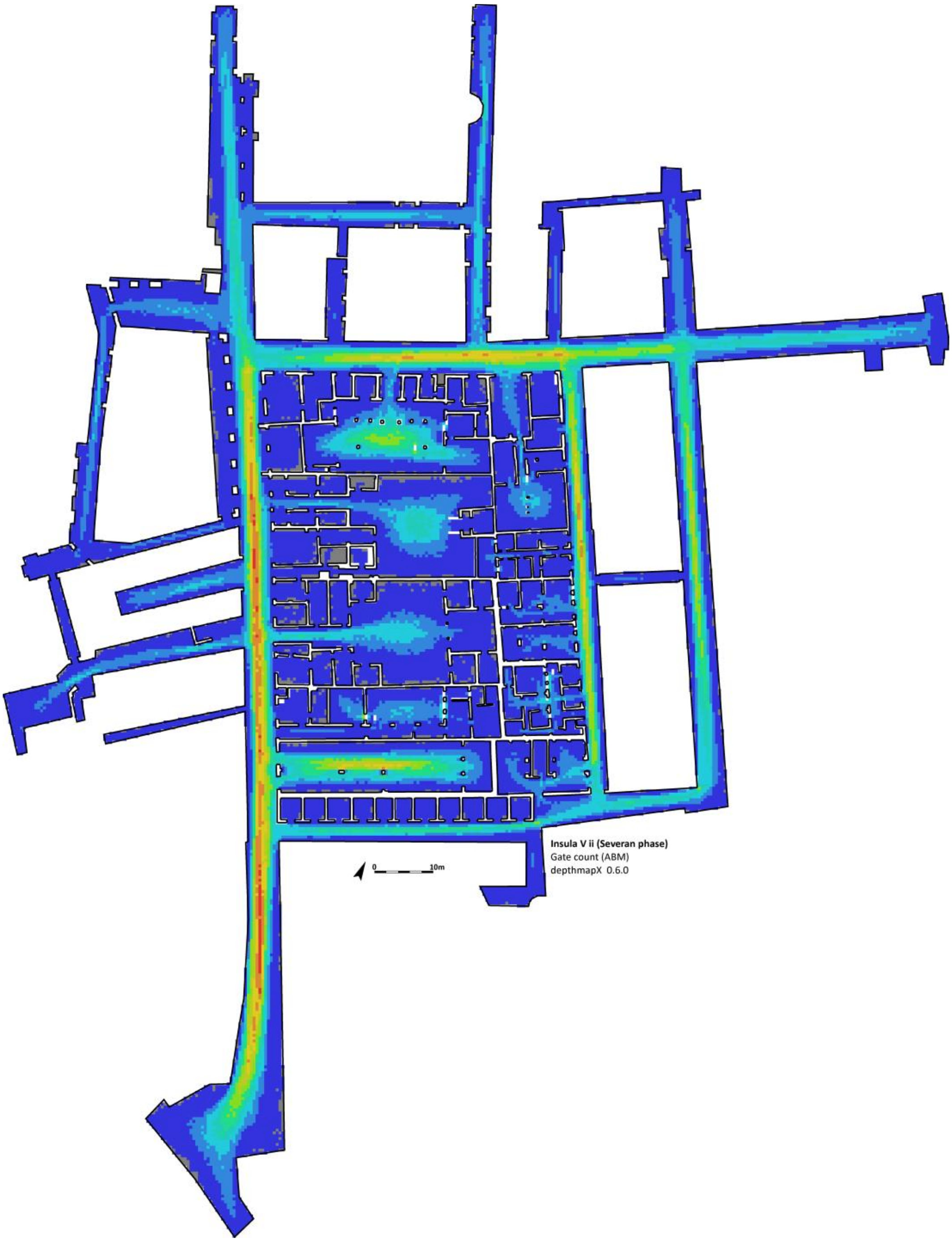


Appendix D8: Graph of the integration values (with radius *n*, or infinite) of insula V ii and nearby streets during the final phase, with an alternative colour distribution of 3,0 (blue) – 9,0 (red) (by author).

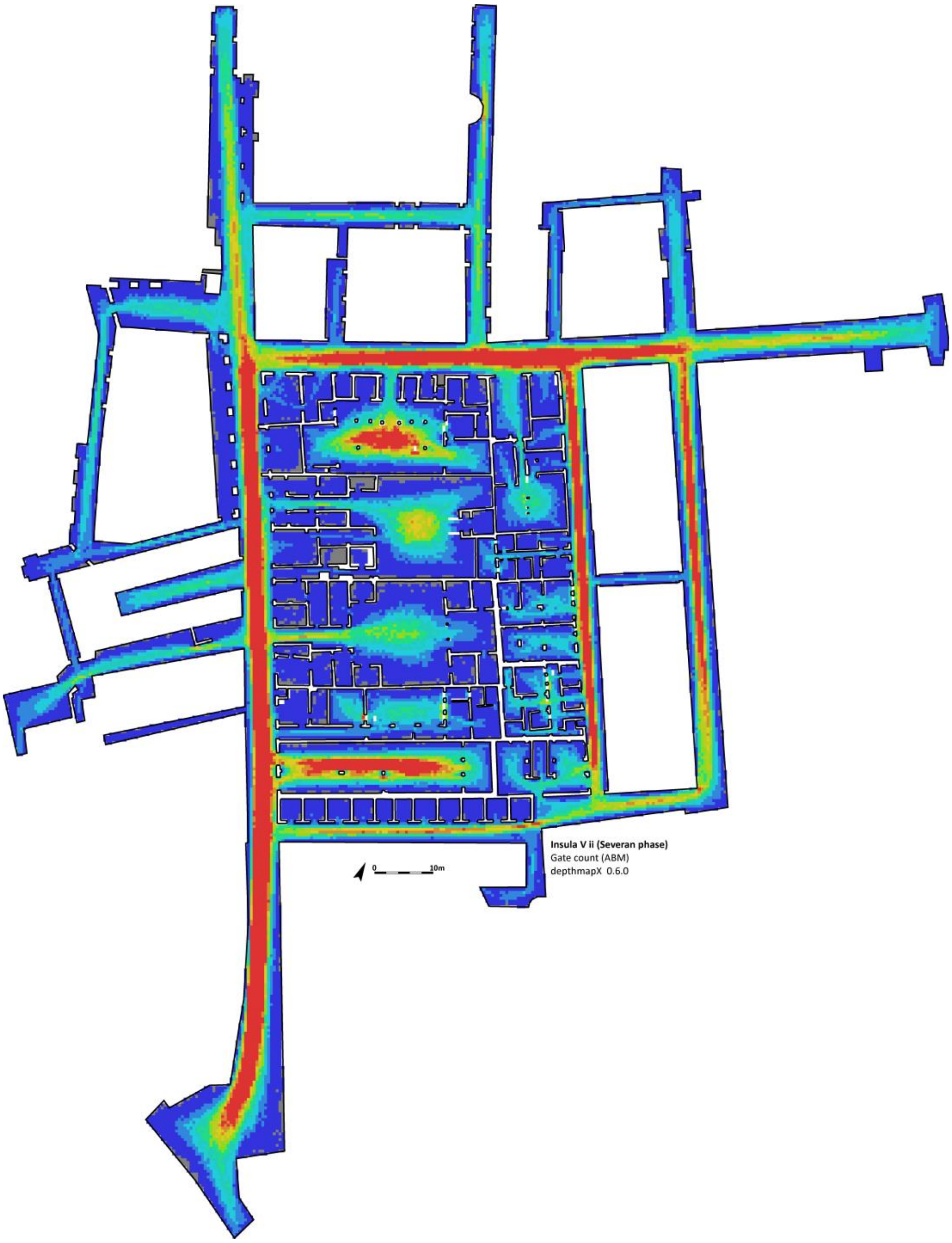


Appendix E: Agent-based models

Appendix E1: Graph of the gate counts (number of visits) of insula V ii and nearby streets during the Severan phase, with the default colour distribution of 1 (blue) – 415 (red). The simulation was run for a duration of 20.000 timesteps (by author).

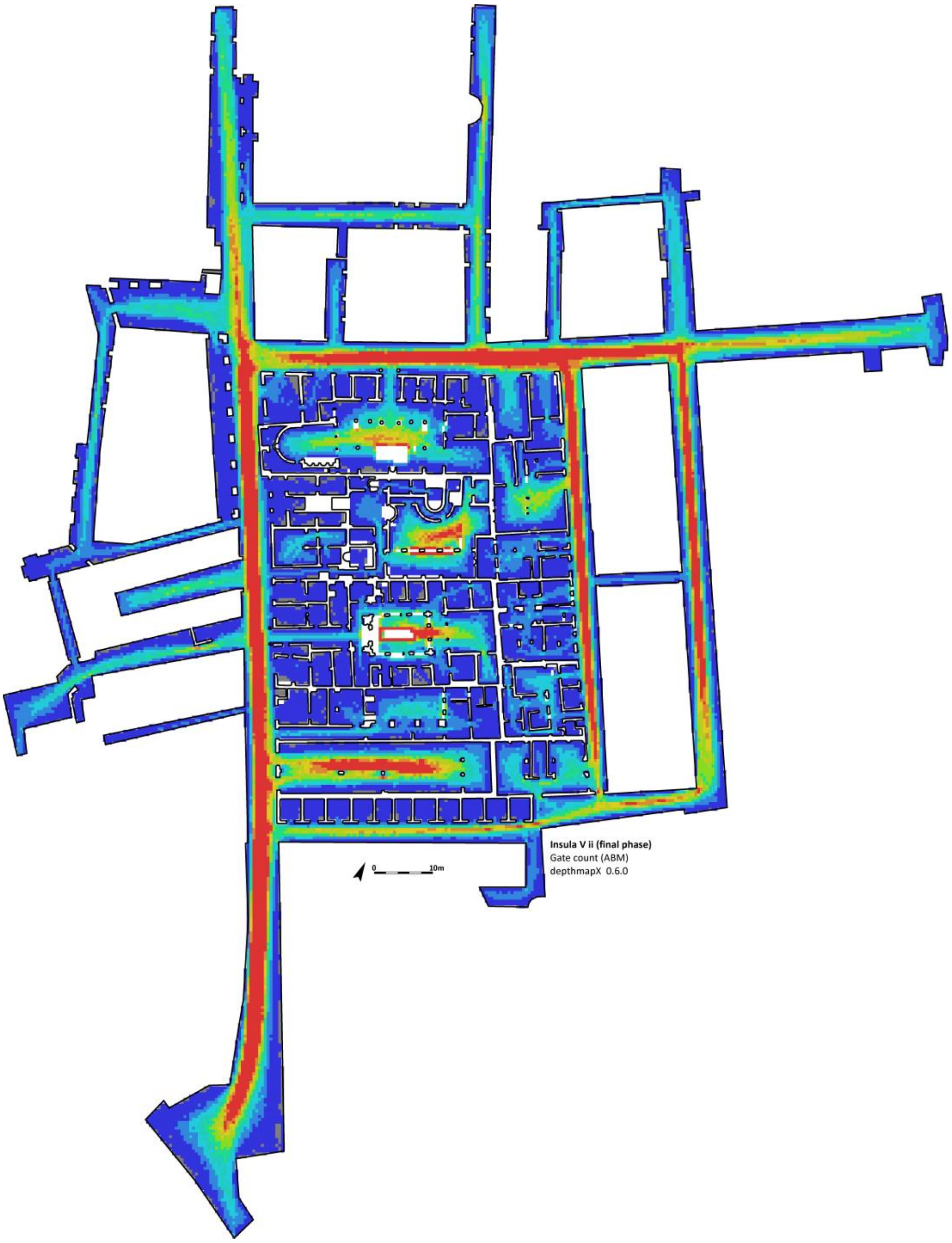


Appendix E2: Graph of the gate counts (number of visits) of insula V ii and nearby streets during the Severan phase, with an alternative colour distribution of 1 (blue) – 200 (red). The simulation was run for a duration of 20.000 timesteps (by author).



Appendix E3: Graph of the gate counts (number of visits) of insula V ii and nearby streets during the final phase, with the default colour distribution of 1 (blue) – 440 (red). The simulation was run for a duration of 20.000 timesteps (by author).

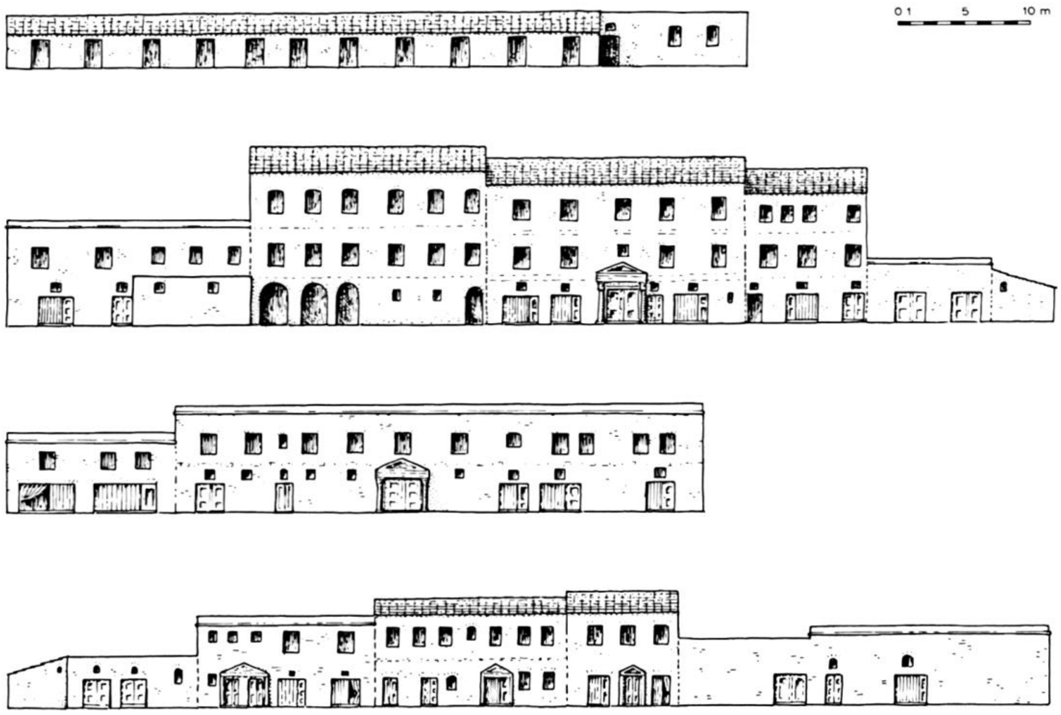
Appendix E4: Graph of the gate counts (number of visits) of insula V ii and nearby streets during the final phase, with an alternative colour distribution of 1 (blue) – 200 (red). The simulation was run for a duration of 20.000 timesteps (by author).



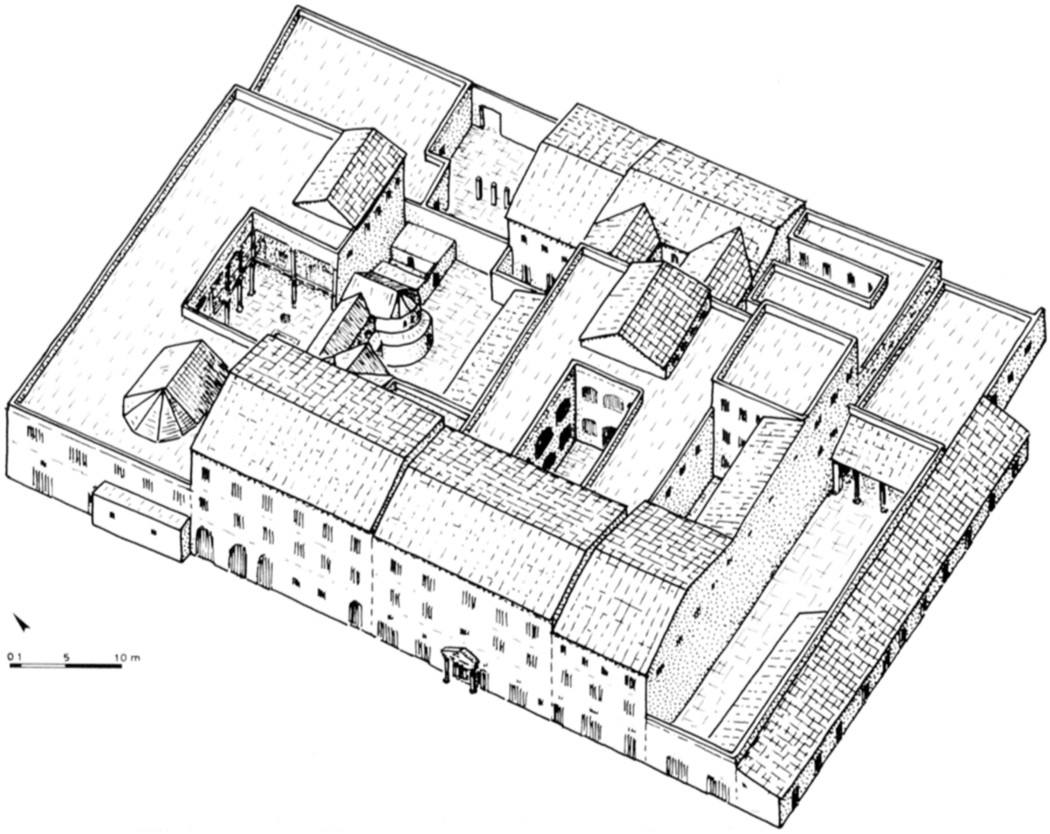
Appendix F: Reconstructions of insula V ii

The 3D models shown in this appendix were made by the author using SketchUp 2016. The reconstruction is of the final phase is based on Boersma's floor plans, isometric reconstruction drawings of the insula as well as the individual buildings, and on the frontal reconstruction drawings of the façades. The 3D model of the architectural remains of building V ii 4-5, was based on the floor plan combined with drawings of the individual walls in the building. The latter model reflects the state of the architectural remains during the fieldwork of Boersma's team. Since then, additional restorations have taken place, and the buildings have also been subject to damage by human activities and nature. Only building V ii 4-5 had its walls fully documented, so complete 3D models of the other buildings could not be created.

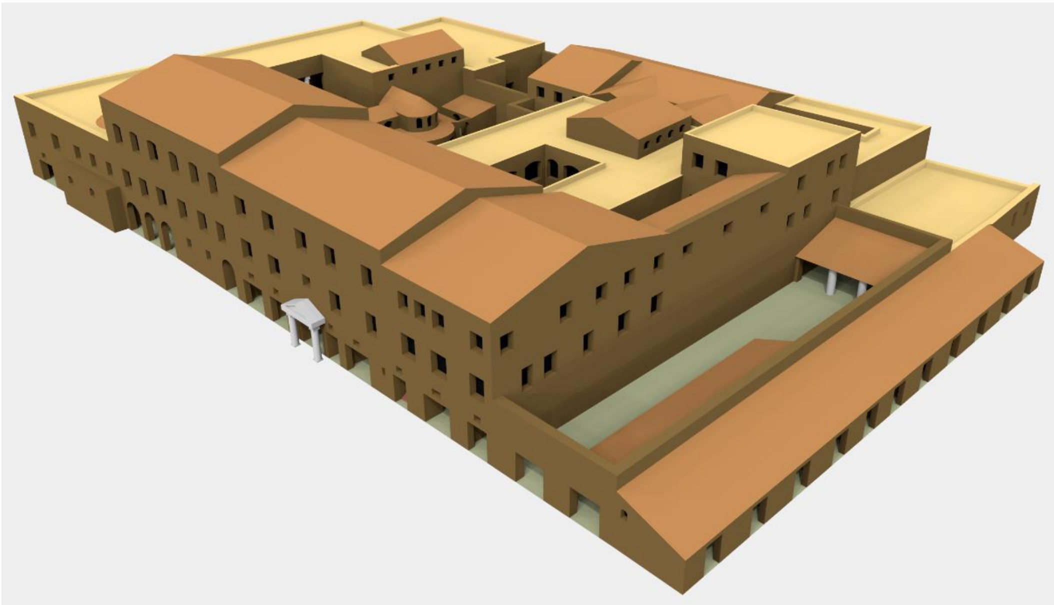
Appendix F1: Reconstructions of the facades of the final phase of insula V ii, c. 400 AD. From top to bottom it depicts the southern, western, northern and eastern facade (Boersma 1985, 224, fig. 207).



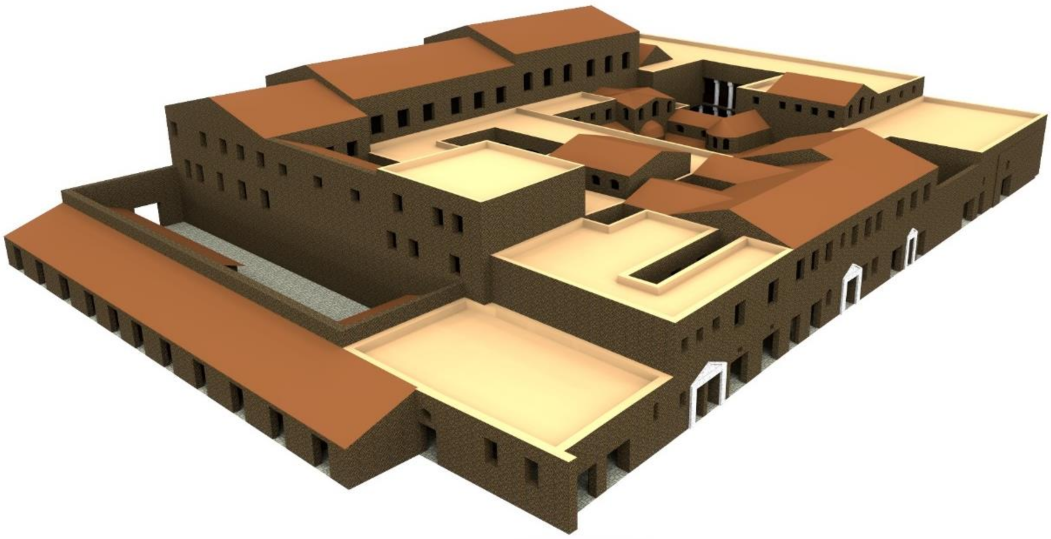
Appendix F2: Isometric reconstruction of the final phase of insula V ii, c. 400 AD (Boersma 1985, 217, fig. 203).



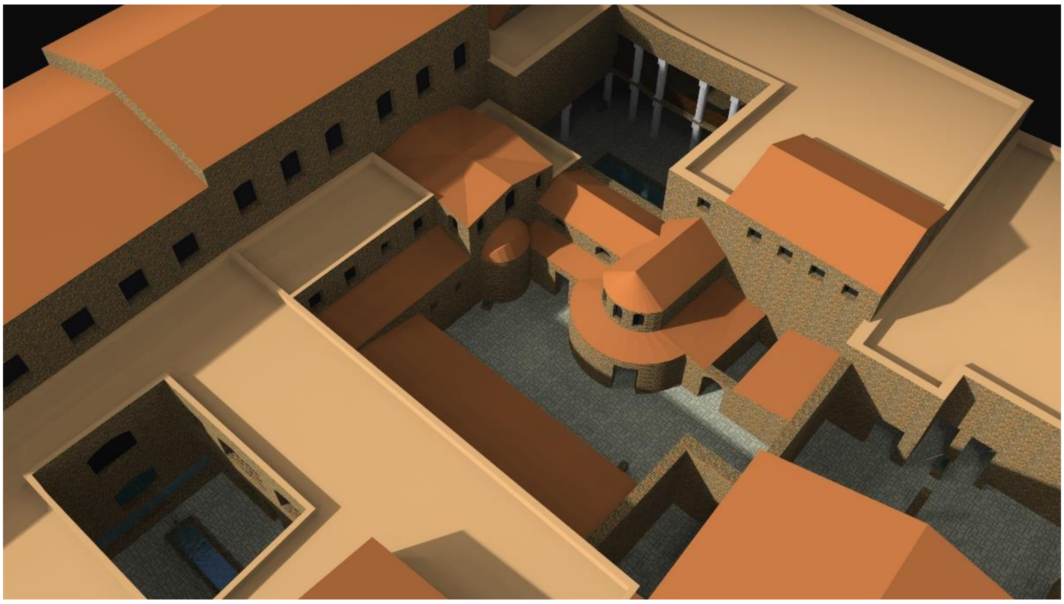
Appendix F3: Untextured three-dimensional reconstruction of the final phase of insula V ii, c. 400 AD. View from the southwest (by author).



Appendix F4: Textured three-dimensional reconstruction of the final phase of insula V ii, c. 400 AD. View from the southeast (by author).

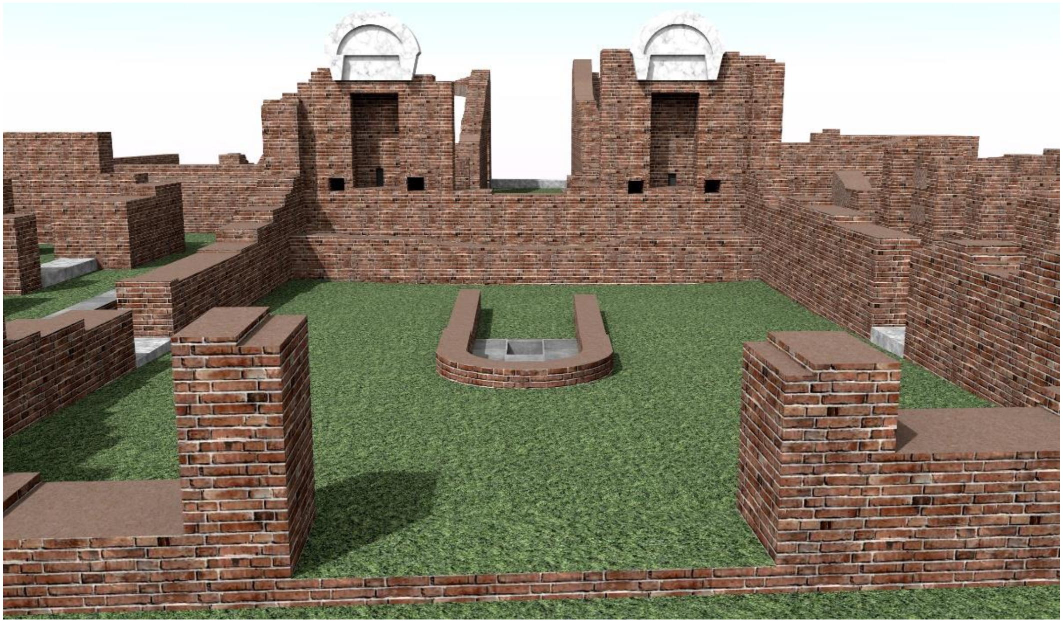


Appendix F5: Textured three-dimensional reconstruction of the final phase of insula V ii, c. 400 AD. View centred on the bathhouse of building V ii 6-7 (by author).



Appendix F6: Textured three-dimensional reconstruction of the final phase of insula V ii, c. 400 AD. View from the entrance of building V ii 8, presenting an alternative for an isovist in a 3D environment (by author).

Appendix F7: Textured three-dimensional model of the architectural remains of building V ii 4-5, showing the courtyard (by author).



Appendix F8: Textured three-dimensional model of the architectural remains of building V ii 4-5 (by author).

Appendix F9: Textured three-dimensional model of the architectural remains of building V ii 4-5. View from the façade of the building (by author).

Appendix G: Table with standard D-values

Appendix G1: Reference table showing the *D-values* (for *k* number of spaces), used when calculating the *Relative Assymetry* of nodes in an access graph (Hillier and Hanson 1984, 112, table 3).

1		51	0.132	101	0.084	151	0.063	201	0.051	251	0.044
2		52	0.130	102	0.083	152	0.063	202	0.051	252	0.043
3		53	0.12	103	0.083	153	0.063	203	0.051	253	0.043
4		54	0.127	104	0.082	154	0.062	204	0.051	254	0.043
5	0.352	55	0.126	105	0.082	155	0.062	205	0.051	255	0.043
6	0.349	56	0.124	106	0.081	156	0.062	206	0.050	256	0.043
7	0.34	57	0.123	107	0.081	157	0.061	207	0.050	257	0.043
8	0.328	58	0.121	108	0.080	158	0.061	208	0.050	258	0.043
9	0.317	59	0.120	109	0.080	159	0.061	209	0.050	259	0.043
10	0.306	60	0.119	110	0.079	160	0.061	210	0.050	260	0.042
11	0.295	61	0.117	111	0.079	161	0.060	211	0.050	261	0.042
12	0.285	62	0.116	112	0.078	162	0.060	212	0.049	262	0.042
13	0.276	63	0.115	113	0.078	163	0.060	213	0.049	263	0.042
14	0.267	64	0.114	114	0.077	164	0.060	214	0.049	264	0.042
15	0.259	65	0.113	115	0.077	165	0.059	215	0.049	265	0.042
16	0.251	66	0.112	116	0.076	166	0.059	216	0.049	266	0.048
17	0.244	67	0.111	117	0.076	167	0.259	217	0.049	267	0.042
18	0.237	68	0.109	118	0.075	168	0.059	218	0.048	268	0.041
19	0.231	69	0.108	119	0.075	169	0.058	219	0.048	269	0.041
20	0.225	70	0.107	120	0.074	170	0.058	220	0.048	270	0.041
21	0.22	71	0.106	121	0.074	171	0.058	221	0.048	271	0.041
22	0.214	72	0.105	122	0.074	172	0.058	222	0.048	272	0.041
23	0.209	73	0.104	123	0.073	173	0.057	223	0.048	273	0.041
24	0.205	74	0.104	124	0.073	174	0.057	224	0.047	274	0.041
25	0.200	75	0.103	125	0.072	175	0.057	225	0.047	275	0.041
26	0.196	76	0.102	126	0.072	176	0.057	226	0.047	276	0.041
27	0.192	77	0.101	127	0.072	177	0.056	227	0.047	277	0.040
28	0.188	78	0.100	128	0.071	178	0.056	228	0.047	278	0.040
29	0.184	79	0.099	129	0.071	179	0.056	229	0.047	279	0.040
30	0.181	80	0.098	130	0.070	180	0.056	230	0.046	280	0.040
31	0.178	81	0.097	131	0.070	181	0.055	231	0.046	281	0.040
32	0.174	82	0.097	132	0.070	182	0.055	232	0.046	282	0.040
33	0.171	83	0.096	133	0.069	183	0.055	233	0.046	283	0.040
34	0.168	84	0.095	134	0.069	184	0.055	234	0.046	284	0.040
35	0.166	85	0.094	135	0.068	185	0.055	235	0.046	285	0.040
36	0.163	86	0.094	136	0.068	186	0.054	236	0.046	286	0.039
37	0.160	87	0.093	137	0.068	187	0.054	237	0.045	287	0.039
38	0.158	88	0.092	138	0.067	188	0.054	238	0.045	288	0.039
39	0.155	89	0.091	139	0.067	189	0.054	239	0.045	289	0.039
40	0.153	90	0.091	140	0.067	190	0.054	240	0.045	290	0.039
41	0.151	91	0.09	141	0.066	191	0.053	241	0.045	291	0.039
42	0.148	92	0.089	142	0.066	192	0.053	242	0.045	292	0.039
43	0.146	93	0.089	143	0.066	193	0.053	243	0.045	293	0.039
44	0.144	94	0.088	144	0.065	194	0.053	244	0.044	294	0.039
45	0.142	95	0.087	145	0.065	195	0.053	245	0.044	295	0.039
46	0.140	96	0.087	146	0.065	196	0.052	246	0.044	296	0.038
47	0.139	97	0.086	147	0.064	197	0.052	247	0.044	297	0.038
48	0.137	98	0.086	148	0.064	198	0.052	248	0.044	298	0.038
49	0.135	99	0.085	149	0.064	199	0.052	249	0.044	299	0.038
50	0.133	100	0.084	150	0.064	200	0.052	250	0.044	300	0.038

Appendix H: Photographs of insula V ii

These photographs were taken by the author of this thesis in 2017, during the month of April.

Appendix H1: Photograph of building V ii 1, as seen from the Semita dei Cippi. The roofed structure to the left is building V ii 2 (by author).

Appendix H2: Photograph of building V ii 2, taken from the western entrances. Most of the remains that can be seen nowadays date from before the Severan phase (by author).

Appendix H3: Photograph of building V ii 3, showing its courtyard, space 0310 (by author).

Appendix H4: Photograph of the main entrance, space 0403, of building V ii 4-5. Space 0402 can be seen through the smaller entrance on the right (by author).

Appendix H5: The courtyard, space 0425, with nymphaeum in building V ii 4-5, as seen from the east (by author).

Appendix H6: Overview the back half of building V ii 4-5 (by author).

Appendix H7: The courtyard, space 0621, of building V ii 6-7, as seen from the west. The tree is located in the middle of the courtyard (by author).

Appendix H8: The portico, space 0618, of building V ii 6-7, as seen from the east (by author).

Appendix H9: Staircase between spaces 0617 and 0622 leading into the bath complex, as seen from the south (by author).

Appendix H10: The main entrance of building V ii 8, showing hallway 0408 and courtyard 0818, as seen from the Via della Fortuna Annonaria (by author).

Appendix H11: The courtyard, space 0818, with peristyle, spaces 0811 and 0817, of building V ii 8, as seen from the east (by author).

Appendix H12: The nymphaeum in space 0822 of building V ii 8, as seen from the north (by author).

Appendix H13: Room 0905 of building V ii 9, as seen from the Via della Fortuna Annonaria (by author).

Appendix H14: The courtyard, spaces 0901 and 0906, of building V ii 9, as seen from the east (by author).

Appendix H15: Hallway 1002 of building V ii 10, as seen from the Via della Casa del Pozzo. Courtyard 1006 can be seen at the end of the corridor (by author).

Appendix H16: Façade of building V ii 11, as seen from the Via della Casa del Pozzo (by author).

Appendix H17: Entrance of building V ii 11, showing rooms 1101 and 1104, as seen from the Via della Casa del Pozzo (by author).

Appendix H18: The two entrances of building V ii 12, showing rooms 1201, 1202 and 1203, as seen from the Via della Casa del Pozzo (by author).

Appendix H19: Hallway 1303 of building V ii 13, as seen from the Via della Casa del Pozzo (by author).

Appendix H20: Courtyard 1306 of building V ii 13, view from the south (by author).

Appendix H21: Room 1402 of building V ii 14, as seen from the from the Via della Casa del Pozzo (by author).