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Image-based 3D models as tools for critically analyzing the architectural composition of Pompeian intersections

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ABSTRACT OF THE THESIS

Image-based 3D models as tools for critically analyzing the

architectural composition of Pompeian intersections

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Image-based 3D models are powerful resources providing exceptional means, by which the lived qualities of urban environments can be discovered. Traditional means of studying ancient urban features, such as 2D drawings, small physical replications, and even 3D reconstructions, lack characteristics and qualities that greatly diminish architectural historians' ability to analyze these spaces. Therefore, it is paramount to deploy technology such as photogrammetry that rapidly produces detailed 3D models that can address these deficiencies. Issues such as movement within and through spaces, their communicative qualities, and their ability to cater to a multitude of activities are key to our understanding of how urban environments are perceived and experienced kinetically. At the forefront of this study is the development of an efficient and accurate process for producing image-based 3D models of Pompeian intersections. By eliminating traditionally labor and time intensive processes, one can dedicate more resources to onsite analysis, as well as drastically lowering the costs of traditionally expensive techniques.

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1.. Introduction

1.A Statement of the Problem

While operating in separate and distinct fields of study with different approaches to the understanding of human history, architectural historians and archaeologists are allies and share certain techniques of documentation and methodologies. Both traditions prioritize the documentation and analysis of standing remains and other architectural elements; the means by which accurate records are achieved is constantly evolving. Traditional methods such as drawing and photography provide a 2D image of spaces and structures in their current state. While providing accurate means to record scale, size, spatial composition, etc., they lack the ability to convey the experienced qualities of these spaces. Image-based 3D models on the other hand provide a greater sense of verism in the models they produce, which can lead to a more realistic interaction with them. Features such as realistic light and shadows assist people in making more accurate assessments of an environment they are experiencing virtually.[1] Intersections provide an ideal location to exhibit the analytical qualities of photogrammetry because they are spaces where services and commodities are sought by travelers, as well as navigational hubs. This study will shed light on the efficacy of the architectural layout of Roman intersections to accommodate both types of activities and uncover the ways in which design attempted to program pedestrian movement.

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[1] On the impact of lighting and increased realism in 3D models see Paul Michael Zimmons, Frederick P. Brooks Jr, and Mary C. Whitton. "The influence of lighting quality on presence and task performance in virtual environments." PhD diss., University of North Carolina at Chapel Hill, 2004, and Mel Slater, Anthony Steed, and Yiorgos Chrysanthou. *Computer graphics and virtual environments: from realism to real-time*. Pearson Education, 2002.

New technologies and approaches, many developed in the field of architecture, are expanding the methods, data, and evaluations of past urban environments, as well as the objects of analysis. These new innovations produce enhanced documents, such as photorealistic 3D models and interactive maps, but it can be quite expensive and time consuming to produce, and often requires equipment and software that can be challenging to procure and difficult to preserve. Therefore, this project aims to establish a method by which ancient urban environments can be efficiently, accurately and economically documented using readily available photogrammetric technologies. This methodology will be applied to a small sample of Pompeian intersections to highlight its ability to enhance our understanding of design's impact on perception of these particular spaces which must be understood experientially, from multiple perspectives, through mobility, and rapid comparison. These models also provide a user the ability to section objects within the intersection, providing vantage points unachievable on site, while also arming them with a tool that can be continuously studied off site. This study investigates the urban environment at the micro level focusing primarily on the individual or small groups of travelers, instead of investigating the spaces to determine their impact on larger socio-economic groups. By analyzing the individual architectural elements in intersections, it alleviates any class distinction and focuses solely on how their composition directly affects pedestrians' movement through the space.

1.A.i Previous Studies

1.A.i.a 3D technologies in Architectural History

Digital technologies for rendering objects in three-dimensions were developed in 1963 by Ivan Sutherland. His software, known as Sketchpad, paved the way for a 3D revolution in the 1970s with many fields quickly realizing the benefits of 3D visualization.[2] CAD (computer-aided design) and other 3D model generating software provide the opportunity for architectural historians to produce and disseminate multiple iterations of structures and spaces, allowing scholars to posit different theories regarding how buildings are conceived aesthetically, their various structural changes, and how a user might interact with a space visually. Oftentimes though the final products are reduced down, by decreasing certains qualities such as polycount and texture quality, so the model can be more easily distributed, failing to realize the full potential of 3D applications. However, in the last couple of decades projects have begun to harness the inherent ability in 3D models to visually express the various phases of ancient complexes, highlighting the architectural changes throughout. Projects such as the Digital Roman Forum project by Bernard Frischer et. al., and the Digital Karnak project by Diane Favro, Willeke Wendrich, et. al. are two projects by UCLA's Experiential Technologies Center, which utilize timeline technology to visually illustrate the architectural changes over a lengthy period of time at a specific place in antiquity. These projects exemplify the use of new technology to

[2] Steven A. Coons, "An outline of the requirements for a computer-aided design system." in *Proceedings* of the Spring Joint Computer Conference, AFIPS (Washington, DC, USA, 1963), 299–304.

efficiently convey criteria, such as time, that was much more difficult to do using traditional methods such as 2D drawings.

More recently, in the last ten years, photogrammetry has made it possible to accurately produce photo-realistic 3D models of ancient sites and structures. New studies in the fields of archaeology and cultural heritage have arisen, with both the intent of documentation of ancient and historical sites and buildings, and a dedication towards the monitoring and restoration of large monuments.[3] The various survey systems employed throughout these studies are typically a combination of techniques including both active platforms, such as terrestrial laser scanning, as well as passive ones such as photogrammetry mapping.[4] Recently, producing image-based 3D models of ancient Roman sites has become more commonplace, such as the Herculaneum 3D scan being undertaken in collaboration with the Herculaneum Conservation Project and the Pompeii Quadriporticus Project.[5] These projects exemplify the use of new technology to efficiently convey criteria, such as time, that was much more difficult to do using traditional methods such as 2D drawings. However, both of these projects employ more costly methods such as laser and CT scanning, as well as using drones, which require obtaining a permit from the sites. These projects do illustrate the extensive capacity that image-based models have for things such as virtual tourism, in the case of the Herculaneum 3D Scan project, as well as highly detailed documentation, the aim behind the Pompeii Quadriporticus Project, but there is not as much emphasis on the use of these models as tools for deeper investigation.These projects are

[3] Massimiliano Campi, Antonella di Luggo, and Simona Scandurra. "3D modeling for the knowledge of architectural heritage and virtual reconstruction of its historical memory." *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* 42 (2017): 133.
[4] Fabio Remondino, "Heritage recording and 3D modeling with photogrammetry and 3D scanning." *Remote sensing* 3.6 (2011): 1106.
[5] https://ercolano.beniculturali.it/herculaneum-3d-scanaccelera-la-rivoluzione-digitale-di-tutte-le-attivita-del-parco-nuovi-strumenti-online-per-esperti-e-appassionati-e-tutte-le-attivita-sono-smart/ and https://mediterraneanworld.wordpress.com/2013/10/24/photogrammetry-on-the-pompeii-quadriporticus-project/

committed to producing highly detailed, scientifically accurate models that both provide a visual representation of the existing environment and structure, as well as crucial metadata that can be accessed at a later period for restoration and conservation purposes. This study utilizes similar technologies, but shifts the focus away from individual structures, monuments and topographical surveys, to open urban spaces.

1.A.i.b Pompeii's Urban Environment

Pompeii's urban environment has been the subject of numerous research projects, many recently focusing on topics that are in some way connected with the street and roads, as well as the individual elements associated with these spaces. Specific projects interrogating the streets, curbstones, stepping-stones, and epigraphy have contributed to our understanding of larger issues of urbanism, such as the political and social life, and the city's economy.[6] There are also numerous works that elaborate upon the urban fabric of Pompeii and investigate the design of the city.[7] However, even with this increase in research focusing on roads and their surrounding environs, there are few publications that focus on intersections as distinct spaces. While aspects of intersections appear in some studies, most tend to emphasize their impact on vehicular traffic, particularly in regards to direction. Others draw information from a single component of an

[6] Ray Laurence, *Roman Pompeii: space and society*. (Routledge, 2010). For information on streets and the traffic system see Sumiyo Tsujimura, "Ruts in Pompeii: the traffic system in the Roman city." *Opuscula pompeiana* 1 (1991): 58-90. On the streets, traffic systems and stepping-stones see Eric E.Poehler, *The traffic systems of Pompeii*. (Oxford University Press, 2017). On graffiti and its implications on social life see Helen Henrietta Tanzer, *The Common people of Pompeii: A study of graffiti*. (The Johns Hopkins Press, 1939).

[7] Fausto Zevi, "Pompei dalla città sannitica alla colonia sillana: per un'interpretazione dei dati archeologici." *Publications de l'École Française de Rome* 215, no.1 (1996): 125-138. & Herman Geertman, "The urban development of the pre-Roman city." in *The world of Pompeii*, eds. John Joseph Dobbins and Pedar William Foss (London: Routledge, 2009), 124-139.

intersection in support of larger arguments, but again do not focus on intersections in a comprehensive or comparative manner; none emphasize embodiment.[8]

In recent years a few works have begun to consider movement through Pompeii from the vantage point of a pedestrian. These investigate how ancient observers might have perceived the city as they traveled to specific destinations, and along predetermined routes.[9] Studies also exist that document how the distribution of a specific object or building type impacts the perception of streets.[10] There has also been a renewed interest in space syntax theory, which is traditionally applied to the study of urban environments on the macro level, and now investigating the micro-level, observing the relationship between building and street, specifically the space that connects them.[11] This research is providing a better understanding of how the architectural makeup of the urban environment impacts the individual moving through space.

1.A.ii Parameters of Analysis: Pompeii in the first century AD

The catastrophic event that led to the complete destruction of Pompeii and many of the surrounding cities of the Campanian region left the urban infrastructure of a medium sized Roman town largely intact. This study, not being an archaeological excavation, harnesses the advantageous state of Pompeii during the last year of its existence and focuses solely on the condition of intersections in 79 AD. There are limitations in being restricted to a single snapshot

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[8] Eric Poehler, *The traffic systems of Pompeii*. (Oxford University Press, 2017)., Alan Kaiser, *Roman urban street networks: Streets and the organization of space in four cities*. Vol. 2. (Routledge, 2011)., Jeremy Hartnett, *The Roman Street: Urban Life and Society in Pompeii, Herculaneum, and Rome*. (Cambridge University Press, 2017)

[9] Marina Weilguni, "Streets, spaces and places: three Pompeiian movement axes analysed. PhD diss., Institutionen för arkeologi och antik historia, 2011.

[10] Jeremy Hartnett, "Si quis hic sederit: streetside benches and urban society in Pompeii." *American Journal of Archaeology* (2008): 91-119. & Steven JR Ellis, "The distribution of bars at Pompeii: archaeological, spatial and viewshed analyses," *Journal of Roman Archaeology* 17 (2004): 371-384.

[11] Akkelies Van Nes, "Measuring Spatial Visibility, Adjacency, Permeability and Degrees of Street Life Pompeii," in *Rome, Ostia, Pompeii: Movement and Space,* eds. Ray Laurence and David J. Newsome (Oxford University Press, 2011), 100-118.

of Pompeii, for example tracking the architectural evolution of an intersection is difficult without revealing the layers of activity below. Being able to see how an intersection changed over time would certainly provide further insight concerning the impact intersections have on pedestrians' perception and understanding of their urban environs, but doing so is a complicated and extremely time consuming process, which goes against this study's goal of rapid and efficient documentation.

Similarly, a comprehensive analysis of all Pompeian intersections, beyond the scope of this project, would be valuable, but is time consuming. As a result, this project focuses on a sampling of representative intersections to validate the methodology and results. Careful thought went into selecting a diverse collection of intersections. Diversity regarding size, type, location, adjacent buildings, and physical elements provides a comparative sampling detailing the various ways in which intersections address issues relating to pedestrian traffic. For instance, a large intersection containing a water fountain, multiple stepping-stones and heavily frequented buildings facilitates foot traffic differently than a small intersection possessing few physical elements. For example, intersections C and D are both large intersections situated along major thoroughfares and those intersections contain a water fountain and tower, as well as numerous elements to assist pedestrian traffic, such as stepping-stones across all branches of the intersections, sets of steps in at least one corner, and severely raised curbstones upon approach. Whereas, in smaller intersections such as A, B, E and F, there are a limited number of stepping-stones and their arrangement does not seem as orderly.

Location is also an important determinant in selecting the sample intersections. The site of an intersection within the larger urban network has a direct impact on things such as occupancy rate, nearby visual references, ability or inability to support large crowds, and inclusion in ceremonies (processions, rituals, speeches, etc.). The selected intersections are representative, including examples situated along major thoroughfares and smaller secondary streets, as well as minor tertiary roads and alleys. Some contemporary factors constrained the selection of intersections in the study. For example, only those open to the general public are included in the case-sample; those in restricted areas are not considered. The desire to examine intersections that visually communicate with each other further narrows the field of eligible intersections. Regardless of the limitations, the sample represents a highly diverse collection of intersections, capable of validating the conclusions drawn from the research. (Figure 1)

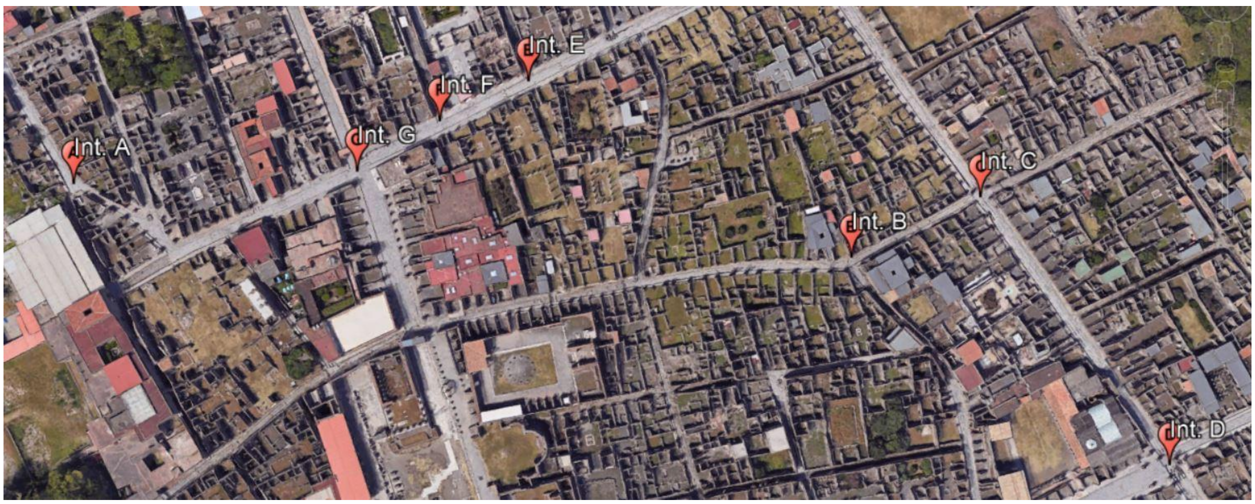

Figure 1 - Intersections A - G plotted on a Google Earth image of Pompeii. Intersection A is the only intersection that does not communicate with another intersection in the case study. While intersections B and C, C and D, and E - G all visually communicate with each other.

Intersections	Stepping Stones	Water Fountain	Water Tower	Steps	Monumental Structures	Misc.
Intersection A	1 SS in the SW branch of the intersection	NA	NA	Set of steps along the W sidewalk.	NA	Small vehicle free zone where Y occurs.
Intersection B	2 SS in the center of the intersection.	NA	NA	NA	NA	Lares shrine located in the SE corner
Intersection C	Sets of SS in all four branches of the intersection	Water fountain in the SW corner	Water Tower in the NW corner.	Set of steps in the NW corner adjacent to the water tower.	NA	Medium sized arcade in SE corner.
Intersection D	Sets of SS in N, E, and S branches of the intersection.	Water fountain in SE corner.	Water fountain in SE corner adjacent to fountain.	One step in the SE corner just behind the water fountain.	Arch of Marcus Holconius Rufus in the western branch.	Vehicular traffic is completely blocked in the western branch. The Stabian Baths occupy the NW corner.
Intersection E	Set in the northern branch.	NA	NA	Set of steps accessing the NW corner.	NA	House of the Faun occupies the entire block.
Intersection F	Set in the northern branch.	NA	NA	NA	NA	Series of hitching holes and narrowing stones along the NW curbstones.
Intersection G	Sets in the eastern and western branches.	Basinless water fountain at the foot of the E pier of the Arch of Caligula.	NA	Two sets of steps leading up the the Temple of Fortuna Augusta	Arch of Caligula in the northern branch and the Temple of Fortuna Augusta in the SE corner.	The Forum Baths in the SW corner. The baths also have a public bench on the northern facade.

Table 1. Significant architectural elements for each intersection.

1.B Methodology: Tools and Approach

Developing a methodology is paramount to the success of this project and it requires some prior knowledge of both the software available, as well as the process involved in effectively photographing the space. The following two sections discuss the softwares currently available for producing structure from motion (SFM) models and briefly describe the development of the photograph capturing methodology. Due to the technical aspect of SFM software, especially when discussing the properties of the models it is necessary to provide some information regarding terminology commonly found in studies involving SFM. While software platforms are constantly evolving, this discussion highlights the underlying structures significant to research about spatial history.

LIST OF TERMS

Structure from Motion (SFM): Progress that uses a series of two-dimensional photographs to estimate the 3D structure of a scene, i.e. to create structure from moving snapshots.

Photogrammetry: The science of obtaining information about physical objects based on measurements from photographic images.

Polycount: The total number of polygons in a 3D model.

UV Islands: Smaller pieces of a 3D model used for texturing.

UV Mapping: The process of mapping a 2D image onto a 3D model. “U” and “V” are the names of the axes of a plane since “X”, “Y” and “Z” are already used to map the coordinates of 3D objects.

Key Point: A key point is an “interesting” point that the software identifies as important in assisting with producing the sparse point cloud.

Key Point Limit: The key point limit is the upper threshold for how many points the software samples and uses in the alignment process. In Photoscan the recommended number is 40,000, but running alignment with a higher limit allows the software to sample more points and can sometimes lead to more accurate alignment. For this research the standard was typically a 60,00 key point limit.

Tie Point: Tie points are points that the software identifies on two or more images. These are used to help create the 3D properties of an object.

Tie Point Limit: Similar to key point limit, tie point limit is the upper number of tie points that are used to make connections between images. Photoscan's default is 4,000 ties points and increasing the number of tie points can greatly increase processing time with little improvement on accuracy. This project uses tie point limits ranging from 4,000 - 6,000 points.

Polycount: The total number of polygons created during 3D model production. Higher levels of polygons can lead to more accurate textures, but also slow down processing speed.

1.B.i Image-Based 3D Models and Structure from Motion: An enhanced close reading of intersections

The goal of this project is to identify rapid and economical tools for the accurate and efficient production of photorealistic 3D models of ancient urban spaces to enhance historic insight, using methods that can be employed irrespective of one's technological background. There is a variety of software currently available that can rapidly produce a 3D model by matching individual pixels shared across a series of photographs. However, no two software are the same and they all have their proficiencies and limitations. Therefore, it is best to begin with a brief review of some of the existing technologies, highlighting strengths and weaknesses. Structure from motion software became commercially available in 2006 when Agisoft released its all-in-one software Photoscan, which photogrammetrically aligns the photos, constructs both a normal and dense point cloud, builds a mesh, and textures the model. In the non-commercial sector, VisualSFM is a popular, open-source alternative to Photoscan for aligning the points, and then deploying a separate software, PMVS/CMVS to create the dense point cloud and the mesh. Due to the popularity of SFM for a number of diverse applications some larger companies, such as Autodesk and Microsoft released their own SFM software, which made SFM technology even more readily available and led to SFM becoming a regular part of toolkits in many disciplines. Studies detailing the intricacies between the various software are available and provide a thorough analysis of the strengths and weaknesses of each platform.[12] For this research the review focuses on the specific features for documenting ancient sites.

Specific criteria are crucial for successful image-based modeling of ancient urban spaces. Chief among these is capacity, regarding specifically how many images the software can process at a given time, and the direct impact on processing speeds. This is particularly true for image-based 3D models of ancient environments, because quite often image collections of ancient spaces can easily exceed 500+ photos; in the related fieldwork for this project, collections often surpassed 700 images. The large number of images eliminated many of the cloud-based services, such as Autodesk Recap, because they typically have an image threshold of 250-300, and therefore cannot handle processing so many images. It is also worth noting that cloud based services possess the ability for rapid data acquisition and model production, often much faster than desktop applications, but they provide little to no capability for users to provide input during the process and are also severely limited in the size of projects they can undertake. Therefore, these pieces of software gravitate towards inexperienced users and are mainly used for visualization purposes. Due to these limitations cloud-based services were not considered for this project, but they may be appropriate in other cases.

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[12] Joel Forsmoo, Karen Anderson, Christopher JA MacLeod, Mark E. Wilkinson, Leon DeBell, and Richard A. Brazier, "Structure from motion photogrammetry in ecology: Does the choice of software matter?." *Ecology and evolution* 9, no. 23 (2019): 12964-12979. doi:10.1002/ece3.5443
Anestis Koutsoudis, Blaž Vidmar, and Fotis Arnaoutoglou. "Performance evaluation of a multi-image 3D reconstruction software on a low-feature artefact." *Journal of Archaeological Science* 40, no.12 (2013): 4450-4456.

Besides possessing superior image capacity, Photoscan provides other benefits that cater to ancient site 3D documentation that are unavailable in other platforms. Notably, it allows users to align photos manually, which allows a user to identify photos that Photoscan could not align and manually align them, thereby filling in missing areas after alignment. The mesh process is quite fast and there is no polycount limit. In addition the meshes generated by Photoscan can easily be exported, allowing for more refinement in the accurate mapping of the mesh, as well as fixing issues, such as holes in the mesh. These are processes that Photoscan cannot address with nearly the same precision as software designed for mesh analysis, such as Meshlab.[13] Finally, Photoscan's desktop interface is expansive allowing for control over the minutiae of all processes. These are all key aspects to being able to generate accurate models of ancient Roman sites, because they allow for efficient production for onsite testing, and provide higher end capabilities offsite.

Image-based 3D models have rapidly become a vital part of architectural documentation, especially with regards to the ancient world. The advancement in structure from motion technology, mainly the widespread accessibility of SFM software, enhancements in performance and increased processing speeds, creates a process that rivals more traditional methods of 3D documentation, primarily laser scanning, as well as traditional 2D forms of documentation, such as hand drawing.[14] Studies have highlighted their ability to not only create aesthetically pleasing models, but also to produce research tools with sub-centimeter accuracy.[15] Image-based 3D

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[13] Meshlab is an open source system that caters to the editing and processing of 3D meshes. Particularly it provides the ability to clean a mesh, removing unwanted and inaccurate sections, as well as closing holes in the model that Photoscan could not.

[14] Brandon R. Olson, and Ryan A. Placchetti. "A discussion of the analytical benefits of image based modeling in archaeology," *Visions of substance: 3D imaging in Mediterranean archaeology* (2015): 17-25.

[15] Maurizio Forte, "3D archaeology: new perspectives and challenges—the example of Çatalhöyük." *Journal of Eastern Mediterranean Archaeology & Heritage Studies* 2, no.1 (2014): 1-29. &

models, in contrast to 3D reconstructions, provide digital replicas that most resemble the current space and experience, because they are textured with high-resolution photos as opposed to procedural textures or non image-based textures, which lack a realistic quality. Certain characteristics such as physical wear seen on stepping-stones, curbstones and fountains enhance the immersive experience of photorealistic models. Furthermore, image-based models provide a much more accurate depiction of materials and their surfaces, highlighting the various haptic qualities in the space, in turn creating a deeper sensorial experience.[16] Therefore, the resulting models possess qualities that other forms of documentation lack. In general they capture the ephemeral aspects of a specific space preserving the surface of the object or area in its most original form, allowing for research of the unadulterated site.[17] This is particularly relevant for ancient Roman sites because there are constant efforts to conserve and preserve them. Specifically, the city of Pompeii has seen a recent surge over the last decade in the number of buildings collapsing, due to lack of preservation and conservation efforts and also because of heavy rains that threaten their structural stability. Therefore, possessing image-based models of Pompeii's urban environment and structures can assist in restoration projects and lead to more accurate physical reconstructions.

Image-based models not only provide a means for restoration in the case of unforeseen future destruction, but also give researchers powerful analytical tools. They also allow for accurate, offsite analysis of ancient Roman streets and urban environments, as well as efficient site mapping, which again, is traditionally a time intensive process. Finally, image-based 3D

Jeroen De Reu, Gertjan Pletz, Geert Verhoeven, Philippe De Smedt, Machteld Bats, Bart Cherrette, Wouter De Maeyer, et. al, "Towards a three-dimensional cost-effective registration of the archaeological heritage." *Journal of archaeological science* 40, no.2 (2013): 1108-1121.

[16] Sarah Pink, *The future of visual anthropology: Engaging the senses*. (Taylor & Francis, 2006): 5-6.

[17] While Pompeii is an extremely well preserved archaeological in comparison to many other Roman sites, it is worth noting that the excavated remains are only fragmented parts of the city. Only two-thirds of the city has been excavated, so a 100% accurate depiction of the urban fabric does not exist.

models provide a means by which one can document, analyze, and display the more ephemeral and experiential qualities highlighting the embodied characteristics of Roman urban spaces. With image-based models it is possible to record spaces during different times, which only enhances their ability to have a greater impact on certain senses. It is not difficult to imagine the higher level of sensorial stimulation that would occur if a model of a street in Pompeii was generated during or after a rainstorm and then rain sounds were added to a real time model. The wet paving stones glistening in the sunlight, revealing their slippery quality would most certainly heighten one's perception of the space and allow them to envision how travel through the city changes under certain circumstances. Sense of space and the nature of a place change depending on the way it is conveyed and when different senses are engaged, different perceptions are generated.[18]

Two-dimensional maps convey the location of individual objects, their distribution throughout Roman urban environments, and the spatial relationships that exist between them and the surrounding area. However, image-based three-dimensional models possess the ability to conduct examinations not possible with two-dimensional imagery, that complement and enhance the information gathered through more traditional 2D studies, including light and wind studies, sightline and viewshed observations, as well as experiential studies. Investigations such as these, and others in a similar vein, shed light upon previously overlooked research possibilities. They enhance our understanding of ancient urban sites by injecting them with the animated quality that dominated Roman urban environments.[19] This is particularly true of image-based 3D models, because they are digital replicas of the actual lived-in space (even if fragmentary), whereas more

[18] David Howes, "Architecture of the Senses." *Sense of the city: An alternate approach to urbanism* (2005): 323.
[19] Jeremy Hartnett, "The power of nuisances on the Roman street." in *Rome, Ostia, Pompeii: Movement and Space,* eds. Ray Laurence and David J. Newsome (Oxford University Press, 2011): 135-36.

traditional 3D reconstructions are hypothetical models based on measurements, plans, literary commentary, etc.

Traditional three-dimensional reconstructions, conceived after painstakingly researching multiple sources, and creating what one believes is the most accurate representation of the original urban environment, are still just that, "a knowledge representation," a tool used to convey the results of research as opposed to tools for research.[20] They, as Diane Favro states, "usually depict Rome as clean, spacious, and tranquil."[21] That statement can be applied to reconstructions of various Roman sites, not just Rome, and even when populated with "people" they tend to have an abstract quality to them that detracts from the fact that these were vibrant spaces bustling with people performing a variety of activities. Image-based 3D models emphasize the lived in qualities of these sites, because one can witness the actual mark these ancient civilizations left on the physical spaces they occupied nearly two thousand years ago.

This is particularly true of Pompeian intersections where evidence of ancient activities are witnessed throughout these transitional spaces. Whether it be significant wear on a stepping-stone or curbstone, wheel ruts running across the roads and turning through the intersections, or the graffiti scrawled across the walls, there is a visceral reminder that these spaces hosted visitors well before we rediscovered them. Furthermore, 3D models provide architectural historians with the ability to experience all of these sensations contemporaneously, as opposed to flipping through a series of images, one can simply move the viewpoint, to simulate, for example, turning a corner, to witness their surroundings.

[20] Diane Favro, "Se non é vero, é ben trovato (If Not True, It Is Well Conceived) Digital Immersive Reconstructions of Historical Environments." *Journal of the Society of Architectural Historians* 71, no. 3 (2012): 275.
[21] Diane Favro. "Construction Traffic in Imperial Rome," in *Rome, Ostia, Pompeii: Movement and Space,* eds. Ray Laurence and David J. Newsome (Oxford University Press, 2011): 332.

1.B.ii Method Development

There are limitations and pitfalls to SFM software, and it needs to be stressed that many problems that arise when using photogrammetry can be avoided or lessened with proper understanding of the fundamentals behind image-based modeling, which can help develop strategies tailored for specific projects.[22] For this project that meant modifying proven techniques to create an image capturing procedure geared specifically towards ancient Roman urban spaces. Ancient urban environments present a new set of challenges, specific to these spaces, that requires a unique approach crafted specifically for ancient sites. Roman intersections, especially those at Pompeii contain a myriad of elements that are fairly unique to Roman towns but are integral to understanding the complexities associated with movement. This is especially true when considering the degree of planning that went into Roman cities, particularly the street and the number of preserved Roman towns available for research. Other towns from other cultures may have possessed similar features, but the degree of planning was not nearly as rigorous as that of the Romans, and many of these towns are still occupied today meaning multiple modern modifications have taken place. The addition of objects within the intersection makes producing image-based models more challenging, because they do not fit neatly into any of the prescribed methods, which are geared towards individual objects, enclosed spaces, and large terrains. Instead past urban sites are *open* spaces in an uncontrolled environment comprising large horizontal planes (sidewalks, and roads), smaller individual elements (stepping-stones, curbstones, fountains, water towers, etc.), and larger vertical fixtures (facades, commemorative arches, and colonnades). Therefore, this method provides a means of documenting such spaces

[22] Brandon R. Olson, and Ryan A. Placchetti, "A discussion of the analytical benefits of image-based modeling in archaeology." *Visions of substance: 3D imaging in Mediterranean archaeology* (2015): 18-19.

while providing flexibility for combining both horizontal and vertical elements, while adhering to criteria at the core of successful image-based models.

It is best practice in structure from motion modeling that more images are always better, allowing for a degree of forgiveness in the case of bad or blurry photos. Therefore, an 80% overlap between photos is the goal during any photo sequence.[23] This threshold is sometimes difficult to achieve in instances where an object, such as an arch, or water fountain forces a larger gap between sequential images. Besides an 80% overlap the other guideline is to ensure sequential image capture, which should happen naturally if one is maintaining an 80% overlap, but the sequence of images is extremely important for accurate photo alignment. If image sequence is strictly adhered to, this new method allows a photographer to move freely within an environment, as well as move in for detail shots and then return to the main sequence capture.

In order to determine the best, most reliable method, ten techniques were tested at Pompeii. The paths were a combination of suggested techniques developed by Agisoft, and new paths developed specifically for this project that attempt to provide as much coverage as possible and capture a high enough level of detail.[24] While some early testing was performed at intersections in Los Angeles prior to entering the field, it became apparent that final testing had to be performed at Pompeii. Pompeian intersections possess complexities and intricacies that are not replicable at contemporary intersections, such as the inclusion of smaller architectural details like water fountains, stepping-stones, and narrowing stones.

During initial testing it became clear that certain arrangements were not conducive to surveying ancient Pompeian intersections for various reasons, such as high degree of difficulty

[23] Agisoft recommends a minimum of 60% overlap, but for this study it was found that closer to 80% overlap provided more accurate models and provided some leniency for blurry photos.
[24] https://www.agisoft.com/pdf/metashape-pro_1_6_en.pdf, 9-10

achieving complete coverage with efficient overlap, obscured detail due to image angles, and challenges maintaining sequential photos. However, a model was still generated using each of the initial patterns, in order to compare their individual statistics, and eliminate ones that fell below a quality threshold. In certain formations such as trials 1-3, the deficiencies are obvious when viewing the models, such as the large void in the middle of test 1, due to camera location (Figure 2). While certain inefficiencies are easily observed causing immediate dismissal of those trials, others require an in-depth analysis of the statistics associated with each model, such as key points, tie points, polycount, and mesh accuracy to accurately determine which method is the best suited for these spaces. There are no standard values for these figures as they can vary widely from model to model, but previous studies show that there is a desirable range for them.[25] Ranges also vary depending on the model's ultimate objective. Models strictly for display purposes, that prohibit users from interacting with them are possible at a much lower quality, because masking errors is more easily achieved. Conversely, a model that provides users with unlimited access, presenting itself to more intense scrutiny, requires a higher level of detail, and minimal errors. The current project's necessary level of detail gravitates towards the high end, because ultimately users will have open access to the models while at the same time annotated videos will be produced. The annotated models will be hosted and shared publicly via Sketchfab, a platform designed with the sole purpose of hosting 3D content. Table 2 highlights the specific statistics for each trial, which clarifies the different criteria, as well as the value range across all trials.

[25] Mauro Lo Brutto and Paola Meli, "Computer vision tools for 3D modelling in archaeology." *International Journal of Heritage in the Digital Era* 1, no. 1_suppl (2012): 4-5.

Ten Initial Test Trials

1. *Interior Shooting Outward:* This trial was conducted by standing in the center of the intersection and aiming the camera towards the periphery of the intersection.

2. *Exterior Shooting Inward:* User stands along the exterior of the intersection and aims the camera towards the interior, working their way around the entire exterior of the intersection while taking photographs across it. (This is the technique Agisoft recommends)

3. *Strafing Outward:* In this trial the camera does not move while the user walks around the intersection in a linear fashion positioning the camera towards the exterior.

4. *Snaking Strafe Horizontally:* User snakes up and down the branches of the intersection while the camera pivots in a horizontal fashion.

5. *Combination of Interior shooting Outward and Exterior shooting Inward:* This technique combines both the inward and outward photographing used in trials 1 and 2.

6. *Strafing Inward:* This technique is the reverse of trial number 3. The user walks the perimeter of the intersection in a linear fashion while photographing across the intersection.

7. *Random Snaking Pattern:* This technique involves the photographer to snake around the intersection moving the camera vertically in an attempt to capture all angles of the intersection. There is no set program of movement, as in the other techniques, the only requirement is that the photos must be sequential and have 80% overlap.

8. *Snaking Strafe Vertically:* While moving laterally around the intersection the camera is pivoted in a vertical fashion.

9. *Roadway Only:* This technique focuses solely on capturing the roadway and sidewalk, so the photographer positions the camera so that it frames just the roadway and sidewalk and then moves laterally around the intersection.

10. *Combination of Inward and Outward Strafing:* For this technique the user moves around the intersection in a lateral motion, photographing towards the interior and then repeating the movement, but now positioning the camera to shoot towards the exterior.

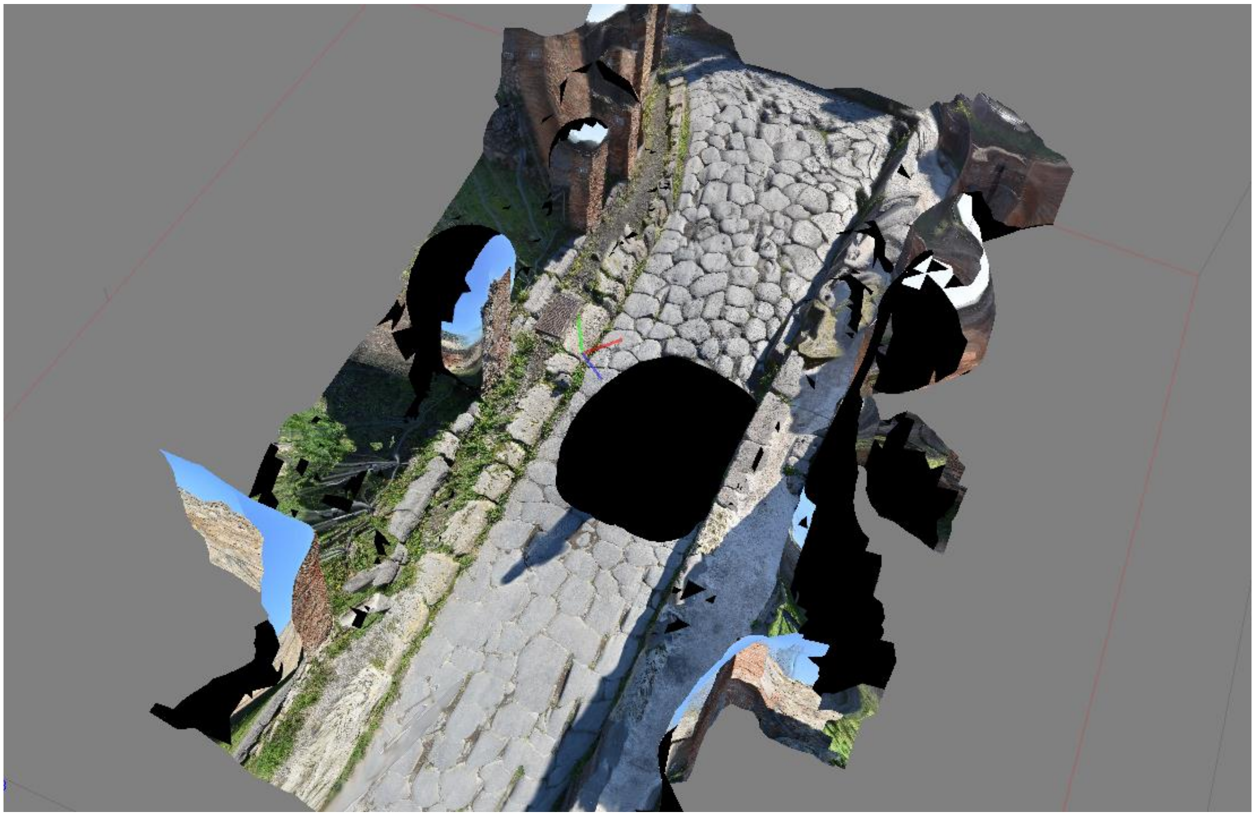

Figure 2 - Photogrammetric model displaying the inherent errors in technique one, specifically the missing portion in the middle of the intersection represented by the large black circle.

Table 1
Statistics for Photo Capture Techniques

Image Capture Method	Cameras	# Aligned	Points	Tie Points	RMS Reprojection Error	Max Reprojection Error	Mean Key point size	Effective Overlap	Faces	Vertices
1. Interior Shooting Out	63	63	37,009	32,821	.119507 (.601332 pix)	.359492 (15.5447 pix)	4.82697 pix	7.14686	23,011	11,733
2. Exterior Shooting Across	36	36	35,679	19,171	.390534 (1.96804 pix)	1.22383 (37.0768 pix)	4.8563 pix	4.15777	30,000	15,528
3. Strafing Outward	56	20	79,098	26,337	.0851307 (.470487 pix)	.255758 (10.4922 pix)	5.1975 pix	2.92876	30,000	15,422
4. Snake Strafing	163	92	126,933	64,511	.138016 (.831982 pix)	.416485 (23.86323 pix)	5.74102 pix	5.61527	30,000	15,234
5. Combination 1 & 2	70	70	72,776	63,875	.0937131 (.477228 pix)	.282336 (19.783 pix)	4.86521 pix	4.02515	29,999	15,302
6. Strafing Inward	78	33	97,558	36,373	.0916868 (.660203 pix)	.277534 (26.1433 pix)	6.01917 pix	3.30218	29,999	15,380
7. Random Snaking pattern	683	683	1,214,141	1,054,977	.143926 (.99197 pix)	.910122 (39.0878 pix)	6.31585 pix	4.72904	57,210	29,079
8. Snake Strafing Vertical	590	590	508,945	458,843	0.131571 (.837951 pix)	.397871 (52.7933 pix)	5.63028 pix)	5.79033	29,999	15,188
9. Roadway only	88	88	123,766	117,561	.0854405 (.661709 pix)	.257076 (25.9596 pix)	6.21745 pix	2.96114	29,999	15,155
10. Combination 3 & 6	153	153	180,351	168,157	.0958358 (.72368 pix)	.288432 (32.5539 pix)	6.39035 pix	3.57097	29,999	15,225

Table 2 - Statistics for initial ten tests.

Ultimately, based upon the statistics, techniques seven and nine are the best for image collection, because they possess a high percentage of tie points to total points (86.89% for #7 and 94.99% for #9), they have reprojection errors below a .20 threshold, the recommended ceiling for reprojection error, according to a forum on Agisoft's website is 1.0, and they have a high mean key point size.[26] While some of the other tests show higher results in particular categories, these two perform best after compiling all the statistics. It is worth noting that these statistics are generated using medium to low settings in Photoscan and with minimal adjustment, simply to determine the best technique for the project. Therefore, certain data, such as reprojection error can improve through proper filtering and camera optimization.

Technique 9 focuses solely on capturing the roadway, curbstones, and stepping-stones by having the camera moving laterally with the camera constantly pointed down towards the roadway. The resulting models allow a thorough investigation of the relationship between curbstones and pavers, and analyze the configuration of stepping-stones throughout the intersection, noting how they collaborate to impact pedestrian movement across the space. This method is highly effective because the camera does not move along more than one axis, a desired feature, and the shooter moves around the intersection, aligning the upper extent of the scene with the top of the curbstones in each subsequent image. The resulting model is a detailed replica of the intersection minus the adjacent sidewalks and façades. (Figure 3) Technique 7 captures the entire urban environment of intersections, including sidewalks, facades, water fountains and towers, arches, etc., to produce a robust model that highlights the entire built environment (Fig 13). This technique allows for investigations into the impact of, and relationships between all

[26] Agisoft does not actually provided a recommended ceiling for reprojection error, but a forum on there site discusses the 1.0 threshold found here https://www.agisoft.com/forum/index.php?topic=3393.0, and notes from a conference in

objects occupying the space. However, since the camera, as well as the photographer is moving in this method certain qualities suffer slightly, such as alignment, and texturing, due to the various angles of each picture. Instances also arise when it is necessary to capture individual elements vital to a detailed analysis, therefore they must be photographed individually. They can then be investigated independently, or inserted into the larger model, post initial processing.

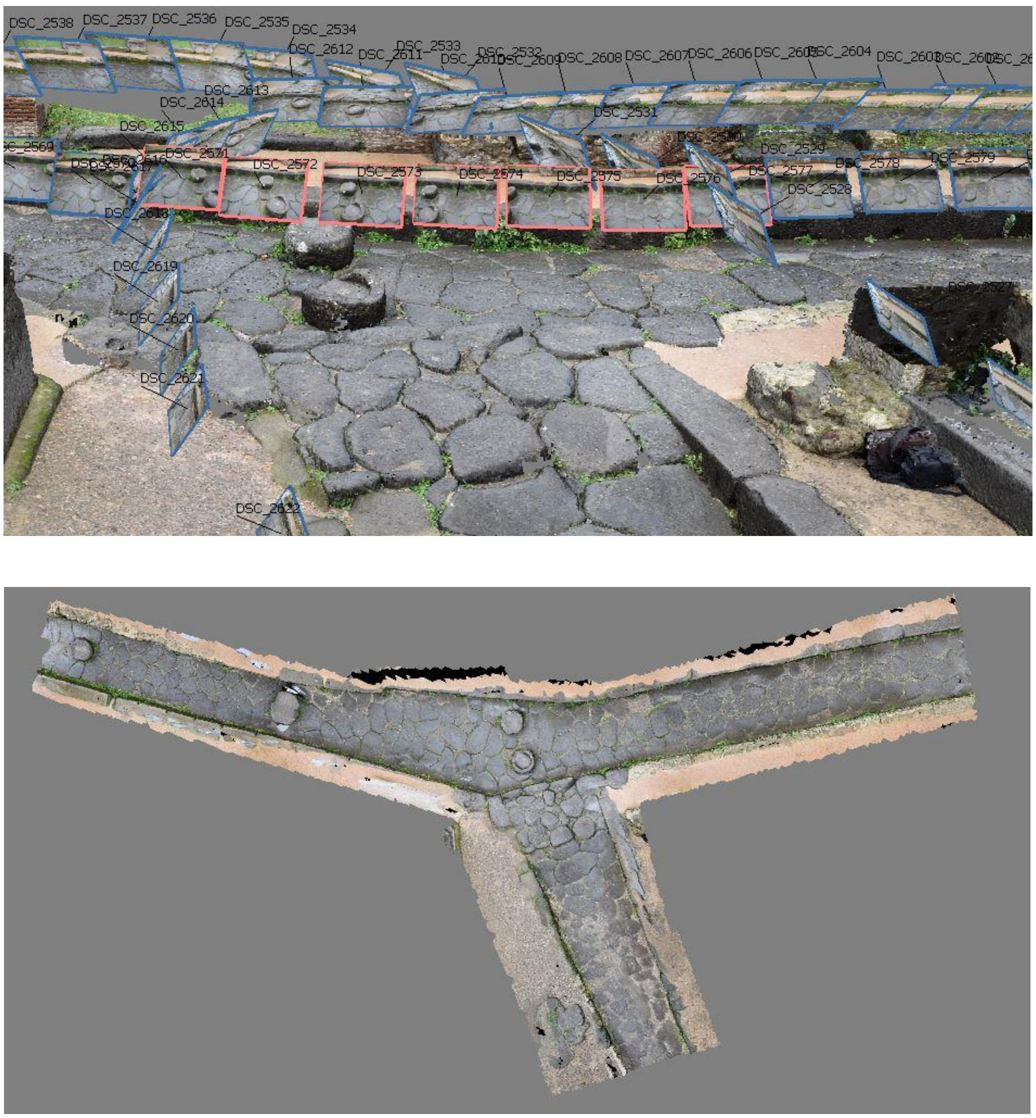

Figure 3 - Image overlay showing roadway only technique and resulting model displaying only the roadway and curbstones. Notice the lack of vertical movement in the series of red highlighted photos as well as the downward angle of the camera.

Figure 4 - Image overlay illustrating horizontal movement and vertical strafe, creating a snaking pattern throughout the intersection. Images in red are in sequential order. You can see the snake like pattern created by moving laterally while the camera moves vertically.

Overall, both techniques prove to consistently produce models with a high degree of quality and detail. However, there are some drawbacks to this method, which might make it unfit for other studies involving urban environments. One challenge that presents itself is the inability to capture orthorectified photos of the upper limits of the adjoined facades, which can create some skewing in the final model, due to the stretching of the image. Furthermore, because this project aims to create a methodology that can be employed quickly and economically, it will not produce models at the highest quality. This is mainly due to the upper thresholds of most affordable laptops specifications not possessing enough processing speed. This issue can be remedied by processing the images on either a high end desktop with more computing capacity or by having access to a computer cluster that can greatly increase processing speed.[27] It also is difficult to control the environment during this process and one may encounter issues with shadows and crowds, but this can typically be mitigated through some patience. Despite these

[27] For information on the advantages of High Speed Computer Clusters see V.N. Adrov, M. A. Drakin, and A. Yu Sechin. "High Performance photogrammetric processing on computer clusters." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 39 (2012): B4, and Guangchen Ruan, Eric Wernert, Tassie Gniady, Esen Tuna, and William Sherman. "High Performance Photogrammetry for Academic Research." In *Proceedings of the Practice and Experience on Advanced Research Computing*, pp. 1-8. 2018.

drawbacks, this study provides a workable method that allows researchers to produce models suitable for various studies, while providing a degree of flexibility that allows it to easily be modified accordingly.

1.C Chapter Preview

The remainder of this research will be presented in the following three chapters which will elaborate on life in Pompeian intersections and discuss the analytical sources, provide a close reading of the sample intersections, and finally present the results of the overall project and future work. Many of the images throughout the paper contain links to the actual model itself and this is stated in the figure description. These models are annotated models that allow users to see how certain programs of movement, and all of the annotated models can also be freely navigated by users. The annotated models are all stored at Sketchfab, which is an online platform for the storage, annotation, publishing and sharing of 3D content. (Link for annotated models)(Link for models on Open Science Foundation)

Chapter two details typical activities that occur in intersections, activities that contribute to the perception of intersections due to their proclivity for congregations. Identifying the actions performed by pedestrians on a regular basis helps identify how the architectural arrangement of intersections cater to these activities, as well as help individuals navigate areas of crowding in an efficient manner. This provides a general sense of how movement both into and through intersections is more complex than traditional linear movement along a street, intersections create spaces where decisions need to be made and any assistance making those decisions is beneficial. Each intersection is a unique space and their architectural compositions vary widely, however certain elements appear more frequently and have a significant impact. The final section of chapter two identifies the objects most important to understanding intersection traffic and details precisely how these individual objects contribute to the overall program. Recognizing which elements are key contributors to intersection traffic allows for a broader comparative study, making it possible to analyze how these specific elements are utilized in a more universal sense.

Chapter three is the most analytical section, taking the individual elements covered in chapter two and using them to provide a comprehensive review of pedestrian traffic in and around intersections. A brief description of each intersection, including location, type, and major architectural elements introduces the sampling and sheds light on the objects that are substantial during the deeper analysis. The intersections are examined by investigating particular elements and observing the various ways in which they are arranged to impact movement. Curbstones and sidewalks, stepping-stone placement, delineation of space and visual cues, and adjacent structures are the techniques that inform the ways in which movement is manipulated. Beginning with curbstone height and sidewalk width, which are frequently used to program movement while approaching an intersection, and then using the other components to encourage and discourage certain routes of travel. Finally, a similar process is conducted on the two Herculaneum intersections to illustrate that this method is viable in other Roman towns, as well as shed light on some of the different ways traffic is managed.

Chapter four reveals the results of the case-study and highlights many of the significant findings, indicating that there was indeed an attempt, via the architectural arrangement, to influence pedestrian movement into and through intersections. These results also validate the need for further research on this topic, which is addressed at the end of chapter four. There are also brief discussions on both the methodology as well as the approach to interpret intersections through their architecture. In this section the efficacy of the methodology and approach are considered, leading to some suggestions on how they can both be improved for future studies. Finally, ideas for future research are addressed, which include more extensive research in Pompeii, such as a comprehensive study of all intersections, and ways in which the models produced can be utilized apart from close analytical readings. This will clarify the next steps for this research to proceed in the hopes of shedding light on these spaces and providing a deeper understanding of the significance of intersections.

2. Pompeian Intersections

2.A Life at Intersections

Pompeii's urban environment was a vibrant atmosphere, and the lively street life it catered to was at the crux of Roman daily life.[28] Livy colorfully describes the scene in Tusculum, a small Roman town in the Alban Hills:

> "....[one] entered the city and beheld the doors open, the shops with their shutters off and all their wares exposed, the craftsman all busy at their respective trades, the schools buzzing with the voices of the scholars, crowds in the streets, and women and

[28] James C. Anderson, *Roman Architecture and Society*, (Baltimore: John Hopkins University Press, 1997), 326-29.

children going about amongst the rest, this way and that, as their several occasions called them."[29]

Streets are densely occupied spaces that cater to multifarious activities carried out by a diverse group of people, including slaves, residents of all classes, and visitors from across the Roman world.[30] Due to Pompeii's state of preservation it is the subject of numerous studies focusing on Roman street life and the urban environment, many of them investigating the public spaces that dot the urban environment. Early studies on Roman public spaces postulated a lack of notable planning or zoning for spaces like commercial properties outside of the larger public spaces such as the forum, and the theater and entertainment districts.[31] While initially widely accepted, this notion came under intense scrutiny nearly two decades later, and studies emerged that highlighted urban patterns throughout the city, not just large public districts.[32] However, even these later studies tend to focus on larger urban spaces such as major thoroughfares, and large elite homes, all the while still neglecting smaller, more discrete spaces. There is no denying the significance of large public spaces such as fora, theaters, and arenas; they are all essential to urban development within a Roman city. However, focusing predominantly on spaces such as these, or those reserved for the wealthy and elite, prohibits a complete understanding of the urban environment's impact on its entire range of occupants.

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[29] Livy 6.25.8-11, Foster, B.O. trans. 284-187

[30] Cornelius Van Tilburg, *Traffic and Congestion in the Roman Empire*, (New York: Routledge 2007), 10.

[31] R. A. Raper, "The analysis of the urban structure of Pompeii: a sociological examination of land use (semi-micro)," in *Spatial archaeology,* ed. David L. Clarke (Academic Press, 1977): 193.

[32] Ray Laurence, *Roman Pompeii Space and Society*, London: Routledge (1994).
Damian Robinson, "The Social Texture of Pompeii," in *Sequence and Space in Pompeii*, eds. Sara E. Bon, Sara E. & Rick Jones, (Oxford: Oxbow Books, 1996): 135-144.
Mark Grahame, *Reading Space: Social Interaction and Identity in the Houses of Pompeii*, BAR International Series 886, (Oxford: Archaeopress, 2000).

Intersections at Pompeii, in particular, are extremely complex locations, filled with facilities and shops catering to a large portion of the population. Ray Laurence calculated that thirty-nine percent of all places serving food, and sixty percent of bakeries are located at intersections, while shrines to neighborhood Lares, the main deities of space and place, and water fountains also have a preference for intersections.[33] The Compitalia was the Roman state holiday dedicated to neighborhoods' protective spirits, and festivals were held at crossroads containing shrines to the Lares.[34] Therefore, crossroads containing shrines to the neighborhood Lares are significant to neighborhoods and function, to a certain degree, as boundary markers for neighborhoods.[35] Furthermore, intersections also tend to be the location for various items that visually engage a passerby, enticing them to linger.[36] At an intersection travelers are forced to make decisions regarding their course of travel and typically slow down their pace, which makes intersections an ideal place to visually capture attention. Consequently, the overwhelming amount of activity occurring converts intersections, especially ones between two major thoroughfares, into individual, highly active, nodes. Nodes, which require attention regarding their design in order to effectively and efficiently accommodate the diverse activities taking place within the space, as well as controlling the movement through the space.[37]

2.A.i Users and Activities

[33] Ray Laurence, "City Traffic and the Archaeology of Roman Streets from Pompeii to Rome. The Nature of Traffic in the Ancient City." in ed. Dieter Mertens Stadtverkehr in der antiken Welt : Internationales Kolloquium zur 175-Jahrfeier des Deutschen Archaologischen Instituts Rom, Palilia 18 (2008): 91.
[34] Bert Lott, *The Neighborhoods of Augustan Rome*. (Cambridge University Press, 2004): 14
[35] Ibid., 4.
[36] Hanna Stöger, "The ancient city and Huizinga's Homo Ludens." *Spatial Cultures*. Routledge, 2016. 49.
[37] Kevin Lynch, *The image of the city*. Vol. 11. (MIT press, 1960): 72-78.

The vast majority of Pompeians conducted a large portion of their daily routine outside, and more specifically in the streets and their adjoining spaces.[38] There Romans could acquire goods and services, transport commodities, observe teachers instructing their pupils, visit with locals, scrutinize graffiti and political propaganda, view festivals, and many other activities. The second century poet Juvenal is well versed in the chaotic nature of Roman streets, and often cites the maelstrom that was Roman street-life, including suffocating crowds that kick and elbow, loud carts with precarious loads that can crush, litters that temporarily part the densely packed crowd, and smoke filling the air from local street side vendors.[39] Therefore, street life, at the very least, was an active process requiring a certain degree of awareness to avoid potential disaster. Therefore, street life, at the very least, was an active process that required a certain degree of awareness to avoid potential disaster.

While it is apparent that navigating such crowded spaces, especially for a visitor, may be an arduous task, it is not unreasonable to expect that certain steps were taken to control and assist these congested areas. Furthermore, the arrangement of these elements had an impact on the way one perceived and experienced a site, and therefore some thoughtful design decisions must have been implemented. Intersections functioned as hubs that were multimodal, and at any given time both filled with people performing a certain daily routine, and others wanting to efficiently cross the space to continue their travels. The intent of the case-studies is to investigate how exactly the various arrangements of similar architectural elements, specifically within intersections, affected the ways in which a visitor both traversed and occupied the space. Examining a small selection of intersections, while by no means providing a comprehensive understanding of Roman

[38] Jeremy Hartnett, *The Roman Street: Urban Life and Society in Pompeii, Herculaneum, and Rome*. (Cambridge University Press, 2017): 47.
[39] Juv. 3.232-267

intersections, provides a taste of what can be gleaned through a detailed examination of the individual components, concerning pedestrian movement and perception.

2.B Traffic and Movement

Pompeian intersections are multi-faceted spaces, each specific architectural element serving an individual purpose, but also the team of elements working together as a unit to accomplish specific aims. Paramount among these is the ability of intersections to funnel traffic both through the space, as well as to a particular destination, in an efficient manner. Moderate to large intersections frequently possess attractions important to the well-being of citizens, such as water fountains, altars and places for food procurement. Many of these partially impede both pedestrian and vehicular traffic and the architectural design must assist in navigating pedestrians through the intersection, while limiting the interference on the activities occurring within. There are other objects within an intersection that, while not necessarily providing a service, occasionally function as a loci for congregation, such as arches and propaganda boards, which also have a direct impact on traffic circulation.

The purpose of the next two sections is to observe the various architectural components that exist within Pompeian intersections and discuss the means by which they contribute to traffic flow. After a brief discussion on the general topic of pedestrian traffic, highlighting the reasons for why tight control and programmed movement is necessary to maintain a sense of order, focus will shift to two major utilizations: “movement through” denoting a desire to simply navigate through the intersection in order to continue a journey, and “movement into” designating a final destination within the intersection. These two aspects are separate and distinct from each other, but their functions frequently overlap, and here the similarities and differences of how various types of intersections accommodate such movement are observed. Finally, a detailed investigation concerning the specific type of architectural elements provides insight into how their arrangement within intersections impacts pedestrians' perception.

2.B.i Pedestrian Traffic

As an important port town on the Sarno river in the Campania region, Pompeii was responsible for the distribution of goods to many of the surrounding towns, such as Nuceria, Nola and Acerra.[40] Therefore, the streets of Pompeii were often heavily congested with vehicular traffic, large ox drawn carriages transporting goods throughout the city, as well as pedestrian traffic, both assisting with the transportation of goods, as well as conducting their daily lives. The crowding and overcrowding of streets is well documented, in Rome at least, by ancient authors, often painting the commotion on the streets as dangerous and chaotic, one that should be avoided if possible.[41] So much so, that in Rome, Julius Caesar banned heavy vehicular traffic, except for that conducting state affairs, from entering the city between sunrise and the tenth hour after sunrise, coinciding with the time people would begin returning to their homes for the night.[42]

In Pompeii, it is uncertain if a similar ban was enacted, but undoubtedly steps were taken to ensure safe and efficient movement throughout the town, particularly in regard to pedestrian traffic. There were numerous laws pertaining to the streets with a particular interest in keeping streets clean and free of obstruction as well as controlling cart traffic, and maintaining this order fell to both the civic government as well as to property owners who were responsible for

[40] Alex Butterworth and Ray Laurence. *Pompeii: the living city*. (Macmillan, 2006): 117.
[41] Sen. epist. 7, Hor. sat. 2, Juv. sat. 3
[42] Michael Crawford, *Roman statutes*. Vol. 1. Institute of Classical Studies, School of Advanced Study, (University of London, 1996): 358-62

managing their street frontage.[43] Due to the danger presented to pedestrians by the large carts lumbering along the roadways, pedestrian traffic is most likely restricted to the sidewalks, especially along major avenues.[44] Therefore, it is expected that the more bars, homes, shops, etc. that lined a street the busier that street is, but when it comes to pedestrian movement that may not necessarily be true, because as noted in studies of the vehicular traffic, many roads in Pompeii are completely blocked to vehicular traffic.[45] Roads that are completely free of vehicular traffic are excellent avenues for pedestrian movement due to the elimination of vehicular obstruction.

Blockages of various roads throughout Pompeii are an example of efforts made by the administration to accommodate efficient and safe movement through the city. Blocking multiple roads throughout the city only limits the number of paths available for transporting large goods and puts extra burden on the streets that are open to vehicular traffic. Various reasons for these blockages have been suggested, such as a demand by the building trade to control movement of large goods, especially during a time of extensive renovation following the earthquake of 62 CE.[46] However, the number of blockages throughout the city, especially in certain regions, such as VIII and VII, where vehicular traffic is limited to a few access points, creates a situation there are limited paths for large carts to travel. Instead, what may be occurring is the administration, realizing an increase in vehicular traffic, that a need to ensure safe pedestrian movement is

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[43] Alan Kaiser, *Roman urban street networks: Streets and the organization of space in four cities*. Vol. 2. (Routledge, 2011): 21-24

[44] Ray Laurence, "City Traffic and the Archaeology of Roman Streets from Pompeii to Rome. The Nature of Traffic in the Ancient City." in ed. Dieter Mertens Stadtverkehr in der antiken Welt : Internationales Kolloquium zur 175-Jahrfeier des Deutschen Archaologischen Instituts Rom, Palilia 18 (2008): 87

[45] Sumiyo Tsujimura, "Ruts in Pompeii: the traffic system in the Roman city." *Opuscula pompeiana* 1 (1991): 66.

[46] Ray Laurence, "City Traffic and the Archaeology of Roman Streets from Pompeii to Rome. The Nature of Traffic in the Ancient City." in ed. Dieter Mertens Stadtverkehr in der antiken Welt : Internationales Kolloquium zur 175-Jahrfeier des Deutschen Archaologischen Instituts Rom, Palilia 18 (2008): 90

paramount and one way of accomplishing this is providing a number of vehicular free zones, while concurrently funneling vehicular traffic onto major thoroughfares where the larger spaces allow for more architectural elements to program pedestrian movement. The blockage of the entire forum to wheeled traffic by 79 CE, exemplifies the ability the civic government possesses to limit access to wheeled traffic regardless of the difficulty it may have posed to cart drivers.

Furthermore, there also appears to be a certain amount of ability for individual residents to block or alter the paths of wheeled traffic to improve street conditions around their homes.[47] Ancient authors do not shy away from expressing their disdain for cart traffic, bringing with them dirt and disruption, both physically and aurally.[48] Therefore, it comes at no surprise that residents in Roman cities, especially those like Pompeii that are fairly large trade hubs and therefore are prone to increased vehicular traffic, would choose to prevent carts from traveling roads that flank their homes. One example of this occurs in Intersection E, where during the repaving of the streets surrounding the residence, the owner decided to add a blocking stone at Vicolo del Labirinto, preventing wheeled traffic from entering the street. There are other instances of similar blockages or disruptions to wheeled traffic occurring throughout Pompeii, whether it be completely blocking traffic or altering the paths upon which they traveled.[49] Eliminating wheeled traffic removes the noise and inconvenience caused by large ox drawn carts passing in front of a home or homes and grants a more liberated sense of movement through the roadways.[50] Ancient authors do not shy away from expressing their disdain towards carts Surely,

[47] Poehler, *The Organization of Pompeii's*, 63

[48] For sources on the disruption caused by cart traffic see Horace *Epist*.1.17.6-8; id. Sat. 1.6.41-4; Sen. *Ep.* 56.4.

[49] On how the owner of the Casa del Marinaio placed a fountain at the end of the street to block wheeled traffic in response to the forum being blocking see David Newsome, "Traffic, space and legal change around the Casa del Marinaio at Pompeii (VII 15.1-2)." *BABesch* 84 (2009): 125-130. On how the owner of the House of the Vettis placed a stepping-stone directly in front of the entrance to his home, impacting the movement of carts, pushing them away from his door see Poehler, *The Organization of Pompeii's*, 70.

[50] Julian *Dig*. 8.4.14.

these obstacles are not part of a civic plan and display the potential individuals or groups of individuals had to disrupt traffic flow.[51] By allowing such disruptions to happen at the behest of individuals, despite the less than desired impact they had on vehicular traffic demonstrates the high priority of pedestrian mobility. Therefore, it is not without reason to believe that many of the design elements and decisions within intersections are made based on the impact on pedestrian traffic.

2.B.ii Movement through versus Movement To

The first step in understanding how architectural arrangements cater to both "movement through" and "movement to" is accomplished by observing aerial views of each model, specifically with regards to how the streets and sidewalks enter the space. This helps identify locations that are conducive to the production of occupiable spaces or those that constrain occupation and are designed to facilitate traffic flow. For instance, a Y intersection, such as Intersection A, typically tends to have open space near the crux of the Y, because there is traditionally a void created here to accommodate the gradual convergence of the two roads. (Figure 5) Whereas, with a 4-Way intersection, these voids do not occur as frequently due to the sharp ninety degree turn of the roads and sidewalks at the juncture. (Figure 6) Studies have shown that the angle of a road's turn can be more, or less conducive to vehicular traffic moving across an intersection. An acute or ninety degree angle, requiring a harder turn, is more difficult to navigate around then an obtuse angle, requiring a soft turn motion.[52] Furthermore, an obtuse

[51] Alan Kaiser, "Cart traffic flow in Pompeii and Rome." in *Rome, Ostia, Pompeii: Movement and Space*, eds. Ray Laurence and David J. Newsome (Oxford University Press, 2011): 184.
[52] Eric Poehler, *The Organization of Pompeii's System of Traffic: An Analysis of the Evidence and Its Impact on the Infrastructure, Economy and Urbanism of the Ancient City*. ProQuest, 2009: 112-113.

angle may also provide the opportunity for space to be created that is more susceptible to crowd gatherings. (Figure 7)

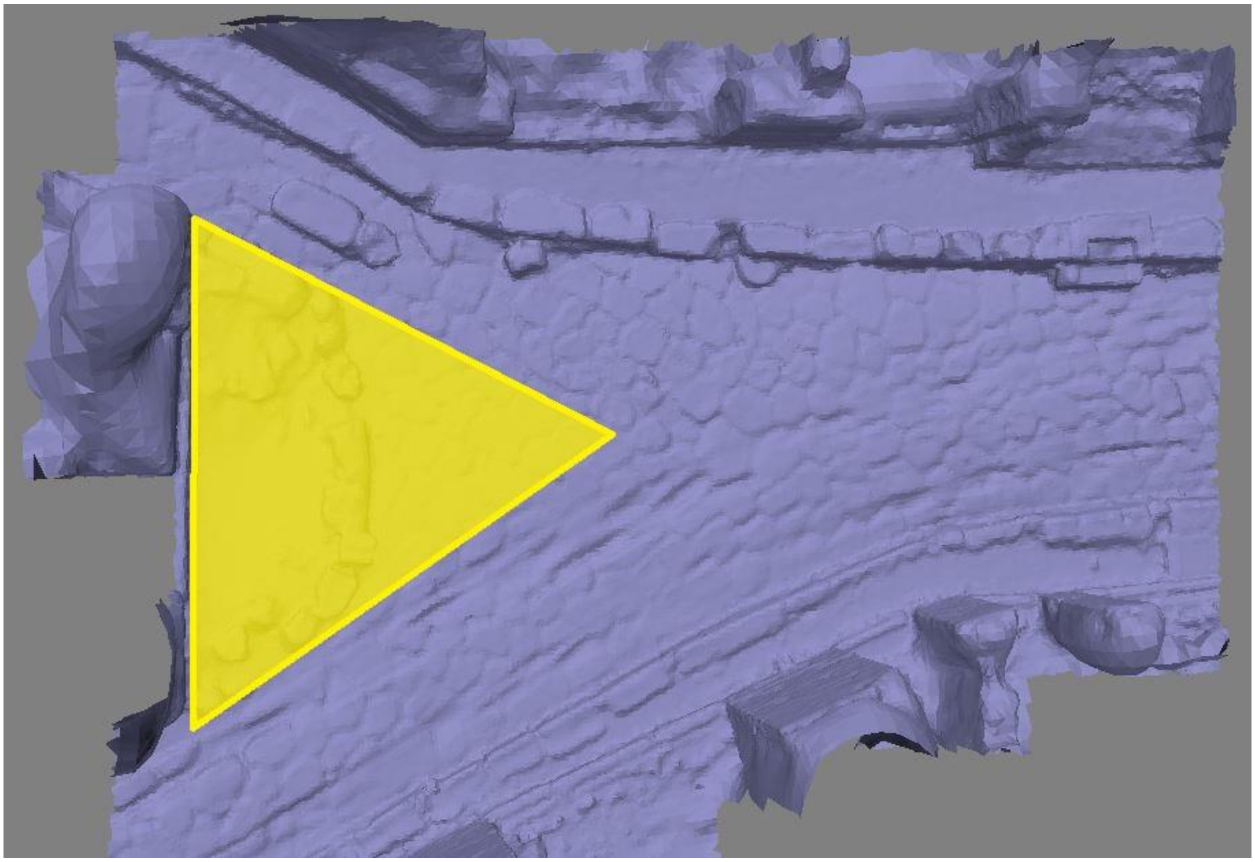

Figure 5 - Intersection A: Y-Intersection with open, vehicular-free zone highlighted due to the divergence of Via Consolare and Vicolo dei Farmacista. Taberna is located on the left side of image adjacent to vehicular-free zone.

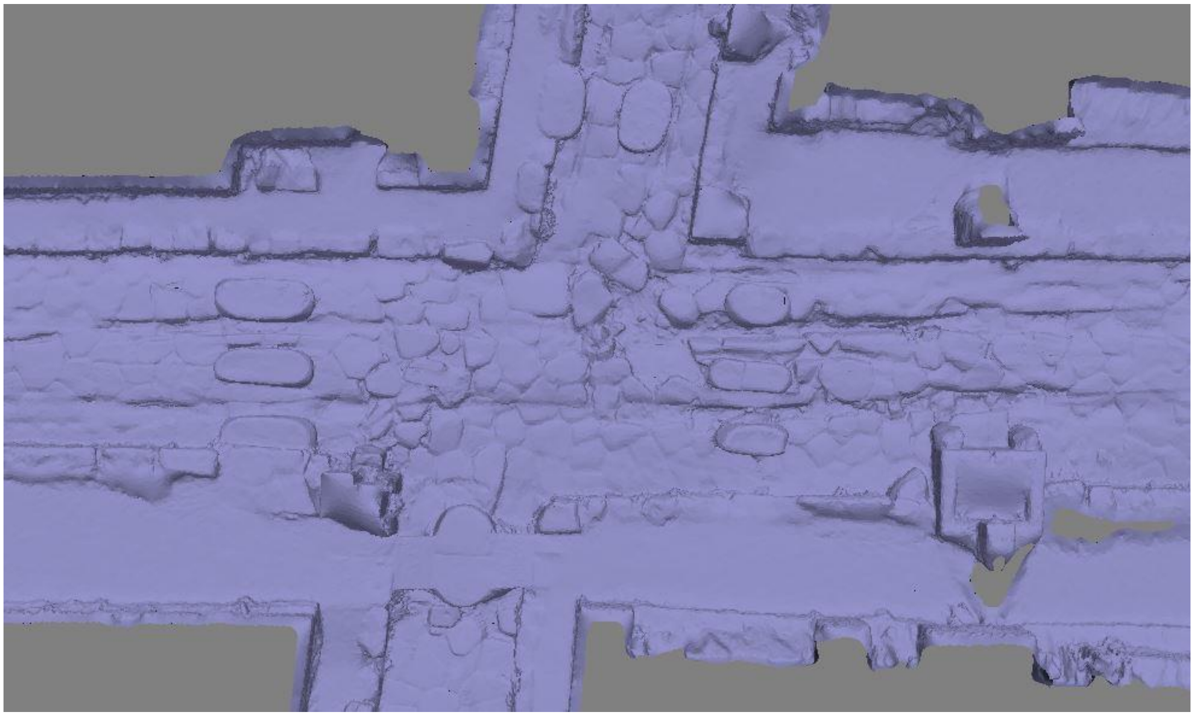

Figure 6 - Photogrammetric model, mesh only, of Intersection C displaying hard right angles at the intersection both making turning difficult for vehicles and discouraging pedestrians to enter into the road.

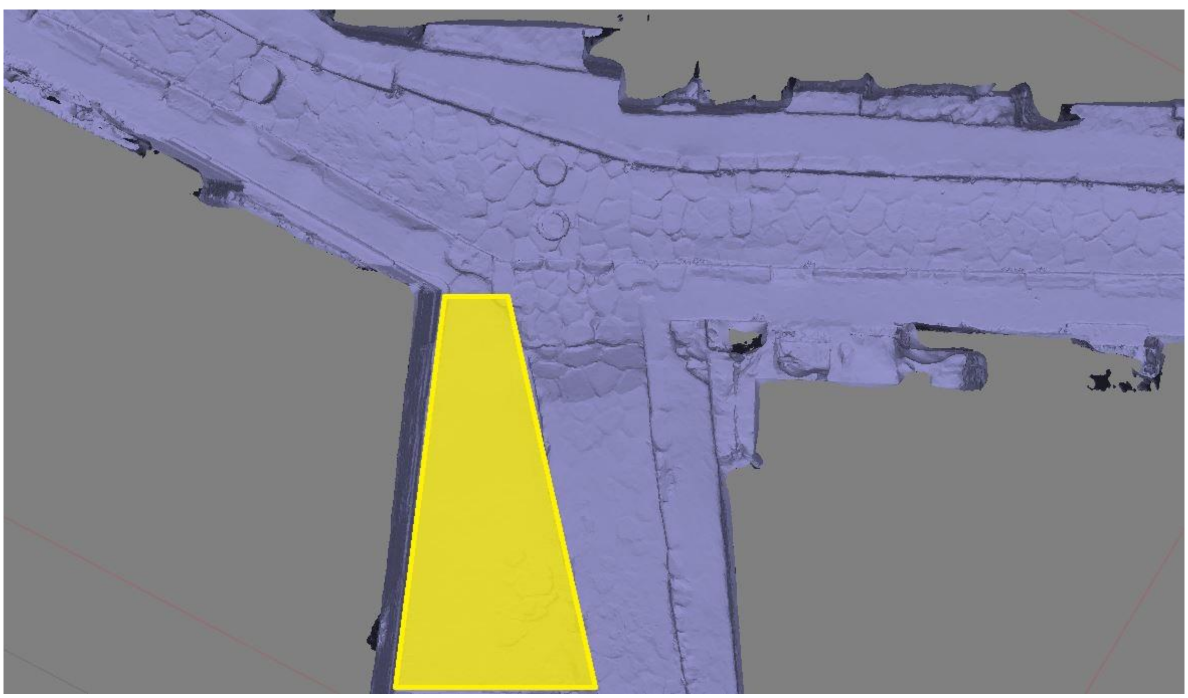

Figure 7 - Photogrammetric model, mesh only, of Intersection C with open space created by obtuse angle between the intersection of Via degli Augustali and Vicolo Lupanare.

Certain architectural elements, such as stepping-stones and elevated curbstones are more suited for movement through intersections, while others, such as fountains and some adjacent structures clearly function more as destinations. Through awareness of this it is possible for the civic government to use the different tools at their disposal in a concerted effort to create programs of movement, to efficiently navigate and occupy intersections. By studying the architectural elements and layouts of intersections it becomes apparent that patterns exist. For example, both water fountains and stepping-stones are generally retracted into one of the branches forming the intersection. This alleviates some of the stress and congestion that occurs when the streets and sidewalks converge, by slightly removing the crowds associated with water fountains and encouraging pedestrians to make navigational decisions prior to entering. Conversely, water towers are nearly universally found at the edge of sidewalks as they converge in the intersection, which enhances their degree of visibility, allowing them to more effectively function as visual wayfinders.

There are other visual cues that are strategically built into certain intersections to encourage either movement to a destination or movement through the space that are less obvious due to the absence of obvious physical cues. Whereas with stepping-stones and water fountains there are tangible objects that visually and physically assist users in perceiving the space and the intentions of the design, other, more subtle techniques are also employed to influence a pedestrian's movement. These techniques are witnessed, quite often, when buildings are vying for the attention of a passerby, whether this be a neighborhood taberna, wealthy residence, or facade used for local propaganda. This can come in the form of a small piece of artwork located on a door jamb, hoping to catch the gaze of a traveler.[53] Other techniques involve the use of

[53] Barbara Kellum, "The spectacle of the street." *Studies in the History of Art* 56 (1999): 284.

material that may catch the attention of a traveler positioned in just the right location, such as the large marble doorway of the bakery on the southeast corner of Intersection D, which is adjacent to the large series of stepping-stones that guide people across Via Stabiana. Techniques such as these, while more subtle, are still quite effective at encouraging or discouraging certain movements in order to achieve an end goal of attracting clientele.

The different intersections offer an excellent sampling of the various ways in which these different techniques are utilized and the multiple combinations that appear around the town. They will provide insight into both how individual elements impact perception, as well as how systems of components working together are utilized in a similar fashion among many intersections. With a better understanding of the systems developed to impact pedestrian movement, a more comprehensive system of pedestrian traffic movement is possible.

2.B.iii Roman Street Administration

Responsibility for maintaining and administering changes to roadways is shared by both the civic government of a Roman city as well as owners of street frontage property.[54] The city administration owned the streets while property owners are responsible for keeping urban space adjacent to their properties clean and well maintained. The *lex Julia Municipalis* is widely cited in regards to street legislation, and while the text discusses the city of Rome, the fact that the tablet containing these laws was discovered at Heraclea makes them applicable to towns outside of Rome.[55] The document states that aediles are responsible for the repair and paving of all streets within their jurisdictions as well as providing a stone or gravel on all lesser paths,

[54] Alan Kaiser, *Roman urban street networks: Streets and the organization of space in four cities*. Vol. 2. (Routledge, 2011): 21.
[55] Michael Crawford, *Roman statutes*. Vol. 1. Institute of Classical Studies, School of Advanced Study, (University of London, 1996): 358-62.

including footpaths or sidewalks.[56] Aediles are responsible for deciding which portions of road are in need of repair and then determine which property owners will pay for the construction.[57] Due to the lack of private property fronting intersections, responsibility for any repairs or modifications must fall to the administration[58] and therefore the majority of the decisions regarding the architectural makeup of intersections is done with the desires of the administration in mind. However, it is not unrealistic to believe that wealthy residents possess the ability to influence the decisions made by the administration and arguments have been made that in certain cases homeowners may take it upon themselves to enact repairs and change to the roadways.[59] The idea that homeowners are capable of enacting change on their own or making modifications that they deemed necessary can readily be seen in the variety of material seen in the curbstones throughout the city.[60] Intersection E and the surrounding area present a situation in this study where the patron of the House of the Faun may have been influential in some of the design decisions and modifications made to the street and intersection. It is clear though, that the majority of the decisions being made regarding the street and particularly intersections are made by local officials, and they are ultimately the people accountable for the programming of pedestrian traffic.

[56] Erice E. Poehler, and Benjamin M. Crowther. "Paving Pompeii: The Archaeology of Stone-Paved Streets." *American Journal of Archaeology* 122, no. 4 (2018): 601.
[57] Poehler discusses how the law details the proportioning of costs to residents owning the building fronting the space being repaired and then the construction itself is supervised by the aedile and quaestor in Erice E. Poehler, and Benjamin M. Crowther. "Paving Pompeii: The Archaeology of Stone-Paved Streets." *American Journal of Archaeology* 122, no. 4 (2018): 601.
[58] Ibid., 603
[59] Kaiser, *Roman urban street networks*, 185-86
[60] Catherine Saliou, "Les trottoirs de Pompéi." *BABesch* 74 (1999): 161-218.

2.C Sources and Approaches

Following the earthquake of 62 CE, in which a large amount of Pompeii suffered extensive damage, there was an effort by the administration to control, and in some cases rearrange the streets and the flow of traffic through them, in order to alleviate some of the stress caused by material transportation into the city.[61] This resulted in the creation of detours around major intersections to facilitate the transport of large stones to repair large public works, such as the many rebuildings undertaken in the forum, as well as the closure of certain streets while major construction occurred.[62] The government exploited the catastrophe to rebuild parts of the city in a more up to date manner.[63] Most notably are the changes made to the forum, and specific to this study, an increase in attention to the northeast entrance to the forum which leads directly to intersection G. A large arched entrance way was constructed during these renovations that framed the southern portion of intersection G and served as one of the three primary entrances to the forum.[64] This brought further attention to the intersection, particularly the pedestrian shopping zone in the southern portion. Intersection G is the only intersection in Pompeii that is framed on two branches by monumental arches, increasing its visual presence in the urban fabric. Furthermore, the Central Baths underwent construction at this time, and attempts were made to create a unified facade of shop fronts across the northern and western fronts of the Via di Nola

[61] Eric Poehler, *The Organization of Pompeii's System of Traffic: An Analysis of the Evidence and Its Impact on the Infrastructure, Economy and Urbanism of the Ancient City*. ProQuest, 2009. Poehler looks at this issue with regards to wheeled traffic specifically.
[62] Ray Laurence, *Roman Pompeii: space and society*. (Routledge, 2010): 52
[63] John J. Dobbins, "Problems of chronology, decoration, and urban design in the Forum at Pompeii." *American Journal of Archaeology* (1994): 630-631.
[64] Ibid., 98

and Via Stabiana.[65] Similar uniformity appears at intersection A along the eastern side of Via Consolare, a section dominated by industrial shops, highlighting the administration's ability to visually delineate properties both economical in nature, and partially under control of the government. Examination of individual intersections and their architectural arrangement reveals how the administration attempted to control and regulate pedestrian traffic as well.

This is particularly important when it comes to the development of space, and part of the initial investigations into intersections is rooted in examining how their arrangement assists in the creation of smaller, semi-defined areas. Smaller identifiable spaces are vital to intersections' ability to cater to a variety of uses, as well as accommodate both vehicular and pedestrian traffic. Certain types of space lend themselves more effectively to sustained and extended gathering of pedestrians, while others are more restrictive and deter pedestrian traffic. Spatial studies concerning the urban environment have determined certain qualities exist that enable social life within a city to flourish.[66] Space syntax, first developed by Hillier and Hanson in 1984, is a scientifically based technique allowing for a better understanding of the potential urban spaces possess for higher levels of activity.[67] One concept of Hillier and Hanson's space syntax applied by scholars to Pompeii is the idea of axial spaces versus convex spaces.[68] Convex spaces cater to occupation, and conversely axial spaces tend to promote movement, convex spaces ideally allow for movement across the space without having to ever leave the space. This study does not investigate axial and convex spaces, but it is worth noting that in many intersections the

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[65] Lawrence Richardson, *Pompeii: an architectural history*. (Johns Hopkins University Press, 1988): 262
[66] Bill Hillier and Laura Vaughan, "The spatial syntax of urban segregation." *Progress in Planning* 67, no.3 (2007): 255.
[67] Bill Hillier and Julienne Hanson. *The social logic of space*. (Cambridge university press, 1989).
[68] Mark Grahame, *Reading Space: Social Interaction and Identity in the Houses of Roman Pompeii: A syntactical approach to the analysis and interpretation of built space*. Vol. 886. British Archaeological Reports Limited, 2000.
Marina Weilguni, *Streets, Spaces and Places: Three Pompeiian Movement Axes Analysed*. Diss. Institutionen för arkeologi och antik historia, 2011.

architectural layout creates convex spaces in ideal locations for congregating. Furthermore, where these spaces do not exist, it will be the intent to understand how the layout of intersections encourages continued movement along certain paths, while avoiding the spaces of congregation that have the ability to impede upon pedestrian movement.

2.C.i Impact of Stepping-Stones and Curbstones

This section investigates the specific type of architectural elements providing insight into how their arrangement within intersections impacts pedestrians' perception. The undeniable effect of stepping-stones and curbstones upon the Pompeian urban environment has been the subject of recent studies, specifically with regards to their impact on vehicular traffic.[69] However, these objects also have significant influence concerning *foot* traffic throughout Pompeii. Massive stepping-stones, generally carved from local lava stone, dot the urban landscape and their location, undoubtedly, impacted pedestrian movement, particularly in conjunction with intersections, where the vast majority are situated. The addition of stepping-stones in Pompeii suggests, that when possible, pedestrians avoided traveling in the roadways, both to mitigate encounters with wheeled traffic, as well as circumvent the grime that flowed through the streets on a regular basis, including fecal matter, both human and animal.[70] Furthermore, Pompeii's topography consists of a fairly severe and consistent slope from north to south, which turns the streets into fairly rapid waterways, especially during large storms that drop a large amount of rain.[71] On a more consistent basis is the overflow of water from the

[69] Eric Poehler, *The traffic systems of Pompeii*. (Oxford University Press, 2017).
Sumiyo Tsujimura, "Ruts in Pompeii: the traffic system in the Roman city." *Opuscula pompeiana* 1 (1991): 58-90.
Cornelis Van Tilburg, *Traffic and congestion in the Roman Empire*. (Routledge, 2007).
[70] Mary Beard, *Pompeii: The life of a Roman town*. (Profile books, 2010): 57.
[71] Eric Poehler, *Romans on the right: the art and archaeology of traffic*. Diss. University of Virginia, 2003: 256

numerous fountains regularly distributed, causing the streets to have a constant flow of water through them, especially near fountains.[72] Therefore, of great primacy is stepping-stones' ability to provide a route through the city that avoids the unpleasantness that lurks in the streets and the rivers, that at times, course through them.

Working in conjunction with elevated curbstones averaging .5m in height, stepping-stones curate a series of passages through the city, across which pedestrians can safely navigate. Furthermore, they provide a valuable tool for analyzing how the administration desired for spaces to be experienced. The placement of stepping-stones, their size and number, distance from curbstones, and elevation change from curbstone to stepping-stone are some of the criteria that assist in understanding desired pedestrian movement through an intersection. A brief analysis of each of the individual criteria provides the basis upon which the case studies in chapter three are formulated.

The location of stepping-stones is significant, both in their proximity to an intersection and their distance from curbstones, factors which can be indicative of desired movement. There are multiple instances throughout Pompeii where stepping-stones are not close to intersections (that is, no closer than 50-75 meters of the intersection). In other instances, stepping-stones are very close to the intersection, usually the last element along the road before entering the actual crossroads. This is done to mitigate the impact pedestrian traffic has on vehicular traffic, particularly when approaching intersections, which tend to be heavily congested spaces. Further reinforcement of this desire comes in the form of elevated curbstones in conjunction with the last set of stepping-stones prior to the intersection, providing an extra obstacle to entering the street. It is important to note the dual purpose of stepping-stones, not only did they help pedestrians to

[72] Gemma Jansen, "The water system: supply and drainage." *The World of Pompeii* (2007): 264.

cross roadways and avoid stepping in streets that were regularly running with water and trash, but they also served as traffic guides for carts that would pass over them during transportation. Therefore, stepping-stone heights had to both be low enough to allow for carts to pass over, and also high enough to accommodate efficient pedestrian crossing. In certain cases elevated curbstones make accessing stepping-stones more difficult, which may be the exact intent of raising the height of the curbstones. By discouraging access to the roadway, pedestrians are forced to stay on one side of the road until they enter the intersection, where they will make navigational decisions. In essence this creates a smaller, more defined space, where architectural elements have a greater capability of influencing movement, because if the majority of foot traffic is approaching an intersection from a particular side of the road or a particular direction, then it is easier to devise a system at the intersection to accommodate traffic flow.

Upon entering the intersection, stepping-stones become tools, facilitating efficient movement throughout the space. This is accomplished through the placement of individual stones considering their proximity to each other and to curbstones, as well as their size and occasionally their angle. Positioning a stepping-stone closer to a curbstones provides easier ingress and egress, especially considering clothing restrictions (i.e. long togas, albeit less common than simple tunics, were formal attire for Roman male citizens, and ease of movement for those who did wear them would have been a priority) that can impact the length of a stride. The typical spacing between two stepping-stones in Pompeii is 45 centimeters, which as Poehler discusses is ideal for allowing two cart wheels to pass, but is also remarkably close to the comfortable distance for a pedestrian's stride.[73] Damage to multiple stepping-stones in Pompeii, caused most likely by cart wheels crashing into them while trying to pass through the narrow

[73] Eric Poehler, *The traffic systems of Pompeii*. (Oxford University Press, 2017): 90.

gap, suggests that spacing between stepping-stones was not determined primarily by cart specifications.[74] However, when stepping-stones are placed at a greater distance from the curbstones, it could be that crossing is not preferred at this location, and instead the stepping-stone is only in place to help guide vehicular traffic. It is worth noting here that the impact stepping-stone spacing has on pedestrians varies depending on the type of clothing worn. Roman male citizens wore togas, which due to the heavy amount of material and the length of the togas, impacted mobility, specifically the length of a stride, more so than males wearing only a tunic, such as slaves. When additional effort is taken to ensure comfortable spacing, it is most likely indicative of an optimal route for crossing. Such efforts include angling one end of a stepping-stone, thereby placing it closer to the curbstone, and more elaborate schemes such as engaging a stepping-stone with the sidewalk closing the gap between the curb and the set of stepping-stones. The latter highlights their desire to create and program pedestrian routes that grant comfortable and efficient access across an intersection, and that stepping-stones utilized to maintain control over vehicular traffic. Conversely the lack of modifications to close the gap at certain intersections and crossings may be indicative of a want to dissuade pedestrians crossing.

Finally, the size of stepping-stones can elicit information pertaining to their desired usage and function, specifically in regard to their ability to facilitate two-way traffic. In order to allow simultaneous two-way traffic, stepping-stones must be wide enough to accommodate two people accessing the stone at the same time. The vast majority of stepping-stones average between 1 - 1.5 meters lengthwise, which is more than adequate for two-way crossing, however there are instances where the width of a stepping-stone is closer to .5 meters, which does not allow for two-way crossing. (Figures 8 and 9) The occurrence of the latter may be indicative of a desire to

[74] Gunther E. Thüry, *Müll und Marmorsäulen: Siedlungshygiene in der römischen Antike*. (Verlag Philipp von Zabern, 2001): 16.

discourage crossing completely at this location, or an attempt to funnel a certain direction across the space, perhaps in an attempt to alleviate congestion. The architectural arrangement and nearby physical elements assist in ascertaining whether this is the case, especially in regard to determining to which direction the stones cater. Conversely, an intersection containing a high number of two-way stones is indicative of a heavily trafficked space allowing pedestrian traffic to travel more freely.

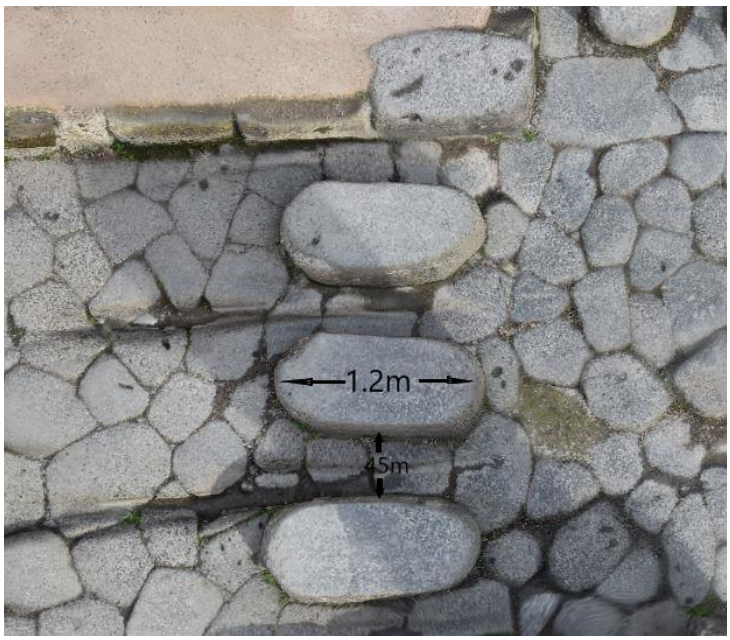

Figure 8 - Image-based model of Intersection D showing both the length of the middle stepping-stone in the northern branch, as well as the distance between them. The length (1.2 m) easily accommodates two-way crossing, while the gap between them (.45 m) is within the comfortable stride of a typical pedestrian.

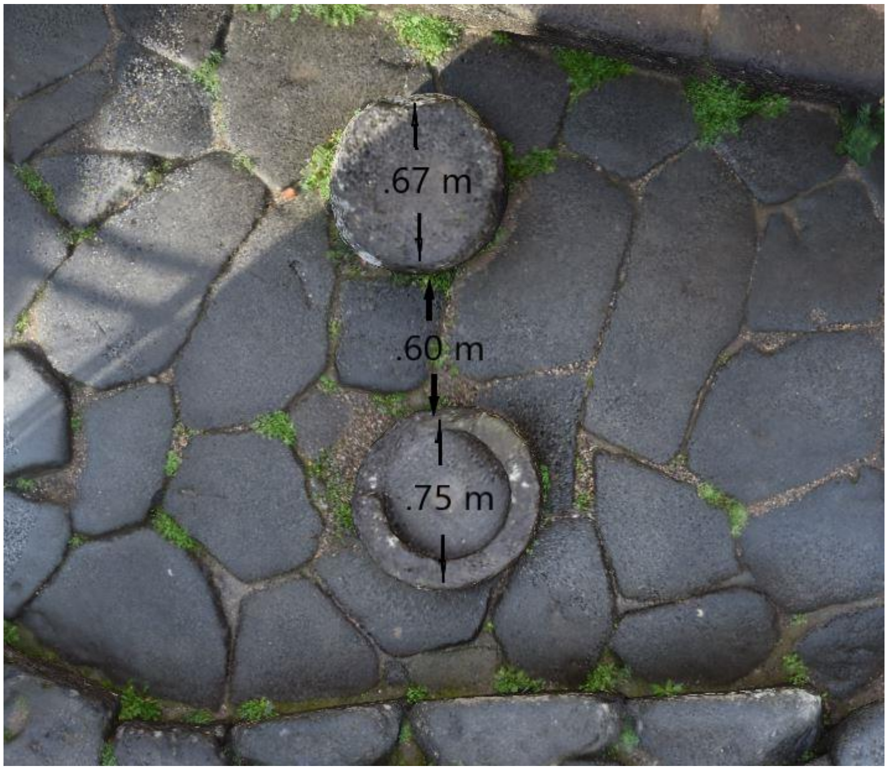

Figure 9 - Image-based model of Intersection C showing the smaller width of the two stepping-stones in the middle of Intersection C. Just a small width would not suffice for two-way crossing. The space between them is also wider than a comfortable crossing length.

Stepping-stones are a crucial element to the Pompeian urban fabric and by analyzing their specific qualities it is possible to further understand their ability to manipulate pedestrian traffic, not solely vehicular traffic. They are an integral component in establishing a means by which the administration can program pedestrian traffic, especially in and around intersections, where navigational decisions become prioritized, and traffic is typically the most congested. Photorealistic models allow for the study of both the placement of stepping-stones in relation to intersections as well as the relationship to each other and other nearby sets. This makes it possible to understand the nuances associated with stepping-stones and their placement and analyze the different methods in which stepping-stones are employed to assist in programming pedestrian movement.

2.C.ii Water Towers and Fountains

It is widely acknowledged that the majority of Pompeian citizens, living both in private homes and insulae, had to make multiple trips to fountains to procure water for a variety of daily activities.[75] During the Augustan period Pompeii's water system was greatly enhanced by running a branch of the Serino aqueduct to the town and the building of the Castellum Aquae to distribute the water through a series of water towers. The Castellum Aquae is responsible for allocating the water to three main entities, the city baths, wealthy residences, and significant to this study, the forty-two water fountains for public use.[76] Water towers are employed throughout the city and tanks at the top of these brick piers were filled with water to help reduce the water pressure on fountain taps to ensure that they didn't burst.[77] There are a total of fourteen water towers in Pompeii and thirteen are located in intersections, so there is clearly a preference to place them in intersections.[78] The water fountains are distributed evenly throughout the city, for most households a fountain exists within 50m of their front doors, providing accessible water sources to the population of Pompeii, and many water fountains are situated in, or nearby, intersections.[79] Water towers are also frequently located in intersections, which makes understanding their impact on pedestrian traffic crucial to this study. They impact movement through an intersection both visually and physically, and water towers in particular, due to their height, can serve as navigational cues when attempting to navigate the town.

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75 Mary Beard, *Pompeii The Life of a Roman Town*, (London: Profile Books, 2008): 58.
76 Lisolette Eschebach, and Jürgen Müller-Trollius. *Gebäudeverzeichnis und Stadtplan der antiken Stadt Pompeji*. Böhlau, 1993. Eschebach was the first to document and map the location and number of water fountains.
77 Trevor A. Hodge, "In Vitruvium Pompeianum: urban water distribution reappraised." *American Journal of Archaeology* (1996): 270.
78 Richard Olsson, *The water-supply system in Roman Pompeii*. Department of Archaeology and Ancient History, (Lund University, 2015): 31.
79 Roger Ling, *Pompeii: history, life & afterlife*. (Tempus Pub Limited, 2005): 341-342.

Thirty-five of the forty-two water fountains typically consist of four stones placed together to form a water basin, the actual water fountain is typically placed on the side of the basin adjacent to the sidewalk.[80] Of the remaining seven public fountains, three contain no basin and may have been drinking fountains, while the other four are of special design and function primarily for decorative purposes.[81] Positioning the fountain on the sidewalk side of the basin discourages people from entering into the street to access the water. However, it does create a crowd on the sidewalk behind the fountain while people wait to access the water. Crowds, that at times, incite arguments and fighting, that undoubtedly pour over into unexpecting passersby. This is exemplified by a quote from Petronius, an ancient Roman author, who, while eating at the home of thea wealthy patron Trimalchio, whose house did have a private water supply, witnessed the following activity:

> "Suddenly two slaves came in who had apparently been fighting at a water tank; at least they still had waterpots on their neck."[82]

Therefore, accommodations were made for these regular and frequent gatherings that potentially restricted pedestrian movement. These accommodations come in the form of sidewalk widening behind fountains, pushing a portion of the fountains into the street, encouraging programs of movement that circumnavigate fountains, and delineating fountain space to discourage unnecessary access.

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[80] Richard Olsson, *The water-supply system in Roman Pompeii*. Department of Archaeology and Ancient History, (Lund University, 2015): 48.
[81] Ibid., 48
[82] Petronius, Sat. 70

Accommodations such as these are easily identified through scrutiny of photorealistic 3D models, because they allow the spaces to be viewed as a whole, as well as from multiple angles and vantage points. Particularly for this use case, it is advantageous to view the intersection from above which reveals how extra space is created behind fountains, including the shifting of adjacent facades, re-angling the sidewalk, and degree to which fountains jut into the street. These multiple aerial views of different intersections can then be compared, allowing the identification of patterns concerning the various efforts by the administration to alleviate stress on the surrounding pedestrian space (Figures 10 and 11).

Figures 10 & 11 - Intersections C (Top) and D (Bottom) showing how strategic placement of fountains in an effort to alleviate traffic congestion. Both are situated at locations where a widening in the sidewalk occurs, intersection C via a shift in the facade directly west of fountain and intersection D by a bending of the curbstones. Spaces also exist that are isolated from the traditional flow of traffic where pedestrians wishing to access the fountain can congregate. Intersection C has a vehicular free zone in the roadway while the bending of the eastern curbstones and the positioning of the water fountain completely in the roadway creates a small space that is removed from the stream of traffic.

Water towers, on the other hand, while not destinations, do have a certain degree of impact on pedestrian movement, both physically and visually. Despite having a small architectural footprint, especially when compared to fountains, water towers function as visual signposts for people moving through the city. Before discussing the visual characteristics of water towers, it is necessary to briefly analyze their physical presence and the impact they have on intersections.

Water towers vary slightly in size, with bases ranging from approximately 1m squares to 1.5m squares, heights are more difficult to determine because many of the water towers are damaged and no longer preserve their original height, but they would have had a maximum height of 8m, anything higher would generate too much pressure on the pipes.[83] The location of

[83] Jens Dybkjaer Larsen, *The water towers in Pompeii*. (Accademia di Danimarca, 1982): 41

water towers within intersections is not uniform, some are found attached to a structure, others are placed back off of the road in a sort of piazzetta, while still others, like the two in this survey, are found in the corner of the sidewalk as it terminates at the intersection. Water towers such as these have the most physical impact at intersections because they affect both pedestrian and vehicular traffic. They are responsible for bottlenecking on the sidewalks due to the space they now occupy, and the narrowing stones they both possess narrow the width of the roadway. This study will interrogate the impact they have on movement further in chapter three.

The visual aspects of water towers are where the 3D models enhance our understanding of how they can function as navigational wayfinders. By georeferencing the models and placing them into a virtual environment, such as Google Earth, it is possible to position a viewpoint from one water tower and observe if other water towers fall into the viewshed. A great example of this occurs between Intersection C: Via degli Augustali and Via Stabiana, and Intersection D: Via Stabiana and Via Dell'Abbondanza. Large water towers occupy corners in both of these intersections and using a viewshed study it will become apparent the efforts made to program movement into a certain position that optimizes the visibility between the two towers.

2.C.iii Adjacent Structures and Monuments

While items like stepping-stones and water fountains directly impact the movement of pedestrians through intersections, other elements such as buildings and monuments in or near an intersection impact movement more indirectly. Intersections contained many buildings such as bars and bakeries, shops that are needed on a regular basis and at times are quite crowded and perhaps in the case of the bars, the crowd might get a bit raucous. Many Roman shops and bars had open facades and during the hours of operation the crowd easily could encroach upon the public space of the street. Therefore, steps may have been taken to accommodate this overflow and encourage pedestrians to circumnavigate such locations, if that is not their ultimate destination. This is accomplished by widening the sidewalks near these structures, delineating the space around them, or encouraging crossing prior to entering these areas.

On the other hand, monuments such as the arches seen in Intersection D and G, while not responsible for the distribution of commodities, still can attract a crowd and their impact on pedestrian traffic warrants consideration. These monuments act as visual wayfinders, meeting places, as well as spots of interest along parade and festival routes, such as the Ludi Apollinares.[84] The beneficiaries of these monuments are often wealthy Pompeian families and therefore there is a strong desire to ensure that they are encountered by as many travelers as possible. By placing them in prominent and congested intersections, benefactors greatly increase the visibility of their investment. Monuments both visually and physically impact pedestrians' movement through and perception of intersections. Visually, their size and location along main thoroughfares sets them apart from surrounding structures, while their architectural footprint can be quite substantial, forcing bottlenecks and slowing traffic down. Understanding how smart design of intersections consider monuments and their impact on traffic provides a better comprehension of how the administration worked with the ambitions of local elites, while maintaining safe and efficient traffic flow.

Adjacent structures and monuments, while not viewed primarily as traffic controllers, possess the ability to greatly influence both pedestrian and vehicular movement. They can manipulate pedestrians both visually and physically, and at times can interfere with and hinder pedestrian movement. They also work in cooperation with other elements to enhance the experience of certain intersections while also vying for the attention of busy travelers. Whether it

[84] Ray Laurence, "City Traffic and the Archaeology of Roman Streets from Pompeii to Rome. The Nature of Traffic in the Ancient City." (2008): 90.

be to enhance a benefactor's reputation or attract a new client for a quick respite and a bite to eat, these structures look to take advantage of their location within intersections, places where pedestrians are forced to scrutinize their surroundings. It is a chance for local businesses, residents, and wealthy citizens to entice pedestrians and distract them temporarily from their original destination. (Figure 12) A close reading of intersections will allow for a better understanding of how the physical layout encourages pedestrian engagement with the adjacent built environment, both physically and visually.

Figure 12 - Intersection E with annotation of the different elements that assist in bringing attention to the House of the Faun. All of the elements labeled assist in bringing attention to the House of the Faun by encouraging people to continue traveling along the northern sidewalk and passing in front of the residence. Click on image to go to model and read individual annotations.

2.D Conclusion

Pompeian intersections are complex spaces filled with individual elements and unique characteristics that cooperate to facilitate a diverse set of activities and various forms of movement. Specific objects such as stepping-stones and curbstones function as physical guides that attempt to encourage certain programs of movement. They possess the ability to both make it difficult for pedestrians to enter into the roadways and assist in funneling people to certain sides of the street as they approach intersections. The models provide a tool that allows for a detailed analysis of characteristics such as elevation change and degree of slope of sidewalks and curbstones. They also serve as a means to analyze the precise positioning of stepping-stones that can be indicative of preferred routes of movement across an intersection in an attempt to avoid points of congestion.

While stepping-stones and curbstones primarily assist in moving traffic into and through intersections, items such as water towers and fountains function as spaces of congregation and aid in delineating space. Water fountains encroach upon pedestrian movement by protruding into the sidewalk, drastically reducing its width and threatening to force a bottleneck. Therefore, solutions are needed to alleviate the impact they have on traffic flow and the models help to visualize these various solutions. It becomes possible to identify the adjustments made in the urban fabric to accommodate the crowds, such as slightly shifting the angle of adjacent facades, or a gradual widening of the sidewalk. These modifications are easier to identify by providing views of intersections that are not readily available, such as high-resolution aerials. Water towers, while not places for congregation, can further help to delineate space and also serve as visual wayfinders for travelers. The models allow for a comprehensive study of how the specific placement of water towers enhance their visibility and effectiveness as navigational aids.

Finally, larger structures such as adjacent buildings, monumental arches and colonnades force certain accommodations to be made based on both their visual and physical impact. Many of these structures vie for the attention of passersby and therefore may lead to a degree of congestion, whether it be people stopping to admire a large commemorative arch or overflow from a crowded taberna. The large footprints some of these structures have, such as the foundations of arches, also presents another challenge to efficient traffic flow, and further accommodations are needed to help alleviate some of this stress. Photorealistic 3D models allow for a comprehensive analysis of how these structures enhance and impact perception. They provide the opportunity to horizontally section objects like colonnades and arches, removing vertical obstructions and granting unprecedented analysis of the impact foundations have on surrounding areas. It is also possible to observe the collaborative effort among such objects in the hopes of manipulating both the movement and vision of pedestrians. Forced lines of sight can be exploited to bring attention to adjacent structures and facades, and they can be explored through immersion in the models, making it possible to see exactly what vantage points create glimpses of particular structures and how certain programs of movement attempt to enhance these views.

The next chapter applies these methods and approaches to the chosen intersections for this study in an effort to identify the various ways in which pedestrian movement is manipulated. A select few examples of each of these techniques clarifies how these architectural elements are regularly installed to ensure efficient movement into and through intersections. The study reveals collaboration between objects within a single intersection, and between individual intersections in an attempt to better understand how studies like this can lead to a better understanding of the comprehensive system of pedestrian movement in Pompeii.

3. Intersection Analysis

3.A Case-Study Intersections

The seven selected case studies approach intersections from the viewpoint of the pedestrian accessing them on foot, and to what extent the design of intersections, or changes made to them directly affected pedestrian traffic and experience. While choosing the intersections it became clear that the sample size had to be small given the time required for photogrammetric analysis, but at the same time needed to be diverse in regard to size, type, location, associated buildings, and physical elements. For example, a large intersection with a water tower and a water fountain has a different approach to guiding and facilitating pedestrian traffic than a small intersection with very few physical features. Location within the city is also vital, because it impacts traffic in a multitude of ways, including frequency rate, nearby visual references, and inclusion in ceremonies (processions, rituals, speeches, etc.). Consequently, the selected intersections represent locations along large thoroughfares, smaller secondary streets, as well as ones that intersect with minor tertiary streets or alleys. The selection was also shaped by the desire to explore how intersections communicate with each other. As a result, many of the examples communicate along urban paths. Given these determinants the selected intersections provide a diverse sampling that generate valid conclusions. (Figure 13)

In observing the location of the intersections, one notices that there are basically two groups of intersections that communicate with each other spatially, intersections B, C and D, and intersections E, F and G, and one, intersection A, that is isolated from the rest. However, within the connected groups themselves, there exists a diversity of intersections, including a mixture of three and four-way intersections, as well as a variance in street size forming the intersections. Intersection A, isolated in the northwest section of the city, is part of the sampling, because it allows an investigation into one of only two Y intersections, the other being due north of intersection A (Via Consolare and Vicolo di Narciso). Intersection A is also situated along the southern portion of the Via Consolare, an area known for late modifications to the traffic system, therefore making an ideal location to observe what simultaneous changes are noticed in the flow of pedestrian traffic.[85] Finally, intersection A runs parallel to the western edge of the city, making it possible to observe, to a certain extent, the relationship between the wealthy homes high on the city wall, and the pedestrian traffic funneled in their direction.

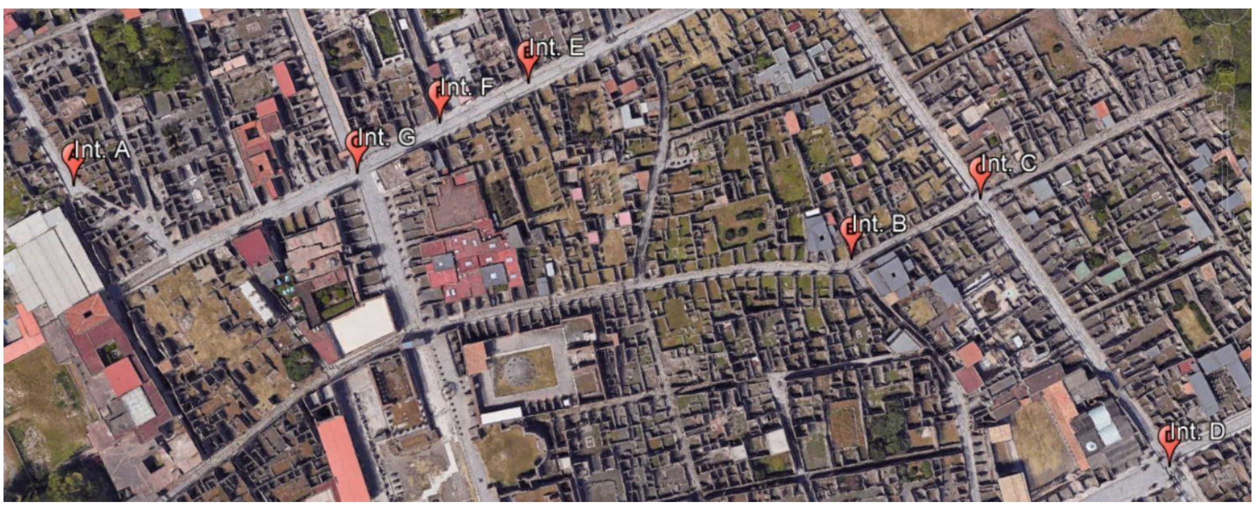


Figure 13 - Location of seven Pompeian Intersections

[85] Eric Poehler, *The Organization of Pompeii's System of Traffic: An Analysis of the Evidence and Its Impact on the Infrastructure, Economy and Urbanism of the Ancient City*. (ProQuest, 2009): 72

3.A.ii Intersection A: Via Consolare, Vico del Farmacista, and Vicolo di Modesto, Regio VI Insula 3, 4 and 7

Located at the southern extent of Via Consolare, intersection A is formed at the divergence of Vico del Farmacista to the south west and the termination of Via Consolare to the southeast as it is absorbed by the Vicolo di Modesto. (Figure 14) Situated within the boundaries of the original city plan, it lacks the typical Roman grid patterning seen throughout the majority of the city, attested by its Y formation as opposed to the more traditional cross pattern. Intersection A, being a remnant of the pre-Roman Pompeii, allows for observations pertaining to Roman adjustments to a pre-existing space in order to better incorporate it into the larger, more ideally Roman, urban network.

The space consists of a single stepping-stone, placed precisely at the point where Vico del Farmacista branches off from Via Consolare, a fairly large taberna at the apex of the Y, and a piazzetta, semicircle in shape, directly north of the taberna. There are also deep wheel ruts running along the eastern portion of Via consolare and continuing along Vicolo di Modesto. Studies have revealed that at this intersection vehicular traffic is one-directional, funneling it along the southeastern branch of Via Consolare, creating a pedestrian corridor along the Vico del Farmacista.[86] Furthermore, the eastern side of Via Consolare is heavily industrialized, as denoted by the uniform facades, and consistent large openings indicated in the

[86] Eric Poehler, *The Organization of Pompeii's System of Traffic: An Analysis of the Evidence and Its Impact on the Infrastructure, Economy and Urbanism of the Ancient City*. (ProQuest, 2009): 71

Figure 14 - Photo of Intersection A, looking south. Notice the absence of rut along the western portion of the intersection, creating a vehicular free zone for pedestrians.

threshold stones.[87] Meanwhile, the parallel western portion of Via Consolare consists of medium to large homes overlooking the western extent of the city. This juxtaposition of industry with primarily residential on opposing sides of the street provides an opportunity to investigate how elements associated with the street, sidewalks, and ultimately the intersection impact a traveler to encourage a more appealing route.

Finally, Via Consolare leads to the Porta Ercolano, the gate entering the city from the west, which is heavily utilized by both vehicular and pedestrian traffic, indicative of the large central opening for vehicles to pass through, as well as the two adjacent, covered pedestrian

[87] Rick Jones and Damian Robinson. "Intensification, heterogeneity and power in the development of insula VI. 1", in *The World of Pompeii,* eds. Pedar Foss and John J. Dobbins (London: Routledge, 2009): 394.

barrel vaulted corridors. Therefore, Via Consolare would have been consistently crowded with people and vehicles entering and exiting the city, and Intersection A provides a unique opportunity to observe how traffic is dealt with when entering a bottleneck, such as the one that presents itself in this space.

Finally, Via Consolare leads to the Porta Ercolano, the gate entering the city from the west, which is heavily utilized by both vehicular and pedestrian traffic, indicative of the large central opening for vehicles to pass through, as well as the two adjacent, covered pedestrian barrel vaulted corridors. Therefore, Via Consolare was regularly crowded with people and vehicles entering and exiting the city, and Intersection A provides a unique opportunity to observe how traffic is dealt with when entering a bottleneck, such as the one that presents itself in this space. (Figure 15)

INTERSECTION A: Via Consoloare, Vico del Farmacista, and Vicolo di Modesto

1. Singular Stepping-Stone in Vicolo Farmacista
2. Small open piazzetta associated with taberna at juncture
3. Taberna
4. Deep wheel ruts indicating wheeled traffic continuing down Vicolo di Modesto

Figure 15: Intersection A with significant elements

3.A.iii Intersection B: Via degli Augustali and Vicolo del Lupanare, Regio VII Insula 1, 2 and 12, located just east of the forum and north of the large lupanare.

Intersection B is another intersection located in the original city plan of Pompeii, before the Romans established the existing grid over the remainder of the city and is located east of the forum and just north of the famous Lupanare. The intersection itself is a modified T intersection, most likely formed in order to connect the space with the formal grid, which lies directly east of Intersection B. (Figure 16) This provides insights into how the Romans accounted for the original layout of the city when adjoining it to the more formal grid. (Figure 17)

Figure 16 - Photo of Intersection B, looking north along Vicolo del Lupanare. Large ramp in the foreground prevents vehicular traffic from entering Vicolo del Lupanare from Via degli Augustali.

Figure 17 - Plan of Pompeii showing the three main phases of city expansion. Circled space is the location of Intersection B, which may explain its unusual style as it served as a connector between the original city and the modifications.

Within this space there are a number of architectural elements that impact how space is utilized and traversed, including a set of stepping-stones located directly in the center of the intersection, a series of curbstones that successfully prohibit wheeled traffic from entering the intersection from Vicolo del Lupanare. There is also a small Lares shrine erected directly in the southeastern corner, as well as a medium size piazzetta in the southwestern corner, both of which are indicative of the fact that this space catered to a local crowd, perhaps one associated with the surrounding neighborhood.[88] Structurally speaking there is a medium sized taberna on the southeastern corner, the Lares shrine is actually attached to its facade, and there is a wealthy home, Casa dell'Orso, slightly northwest of the intersection. A large taberna is adjacent to the home and its large entranceway dominates the street at this juncture, and another taberna opens onto the piazzetta's southern end. Tabernae dominate this intersection highlighting the idea that it serves as a destination for locals to congregate, and therefore businesses wish to take advantage of the increased traffic. It also makes an ideal location to understand how certain design elements catered both to those inhabiting the space, as well as to those wishing to pass through it in an efficient manner. (Figure 18)

[88] On the ideas of Lares serving as markers for neighborhood nodes see Bert J. Lott, *The Neighborhoods of Augustan Rome*. (Cambridge University Press, 2004): 4; on the graffiti on the walls of the piazzetta in the southwest corner serving as notifications to local residents see James L. Franklin, "Games and a Lupanar: prosopography of a neighborhood in ancient Pompeii." *The Classical Journal* 81, no. 4 (1986): 319.

Figure 18 - Intersection B with significant elements

3.A.iv Intersection C: Via degli Augustali and Via Stabiana, Regio VII Insula 1 and 2, and Regio IX Insula 2 and 3.

Directly east of Intersection B is the intersection of Via degli Augustali and Via Stabiana, which brings us officially into the gridded portion of Pompeii. Intersection C takes the more traditional cross pattern and is the third intersection from the north along Via Stabiania, which is the city’s cardo. Therefore this intersection consists of a major thoroughfare, and a secondary street; it encompasses multiple architectural elements that help control an immense flow of pedestrian traffic.[89] This intersection, more so than the previous two, is prone to multiple occupants at any given time, all competing for access to space as well as resources. (Figure 19)

Figure 19 - Photo of Intersection C, looking north along Via Stabiana. A water fountain is in the left foreground and a water tower is in the left background. The medium sized arcade is seen on the right side of the image.

The intersection consists of many architectural elements that all work together to create an efficient, multifunctional space. Stepping-stones are present in every branch of the intersection with the north and south branch of Via Stabiana having sets of three stepping-stones, and the east and west branches of Via degli Augustali each having one stepping-stone. A water tower is situated in the northwest corner, and a water fountain juts into the street south of the southwest corner. There is also an arcade associated with the residential building in the southeast corner, which runs along the southern portion of the Via degli Augustali and wraps to the south

[89] Discussions of various ways to determine primary, secondary, and tertiary streets can be found in Ray Laurence, *Roman Pompeii: space and society*. Routledge, 2010. and Eeva-Maria Viitanen, Laura Nissinen, and Kalle Korhonen. "Street Activity, Dwellings and Wall Inscriptions in Ancient Pompeii: A Holistic Study of Neighbourhood Relations." *Theoretical Roman Archaeology Journal* (2013).

along Via Stabiana. Water fountains are thought to be equally distributed throughout Pompeii serving specific neighborhoods of the city.[90] (Figure 20)

Similar then to Intersection B, where heavy and frequent occupancy by locals is expected, Intersection C also is utilized regularly by locals, in this case to retrieve water from the fountain. However, in addition to being a destination for locals, Intersection C also served as a major transitional space for visitors to the city, and therefore provides additional insight into how the architectural arrangement creates spaces that efficiently cater to both types of visitor. This intersection allows for the examination of how movement through the space can be easily managed by a non-local, while at the same time minimizing the impact it has on residents gathering in the space.

[90] Akkelies Van Nes, "Indicating street vitality in excavated towns: Spatial configurative analyses applied to Pompeii." in *Spatial analysis and social spaces: Interdisciplinary approaches to the interpretation of prehistoric and historic built environments* 18, eds. Eleftheria Paliou, Undine Lieberwirth, and Silvia Polla (Walter de Gruyter, 2014): 281

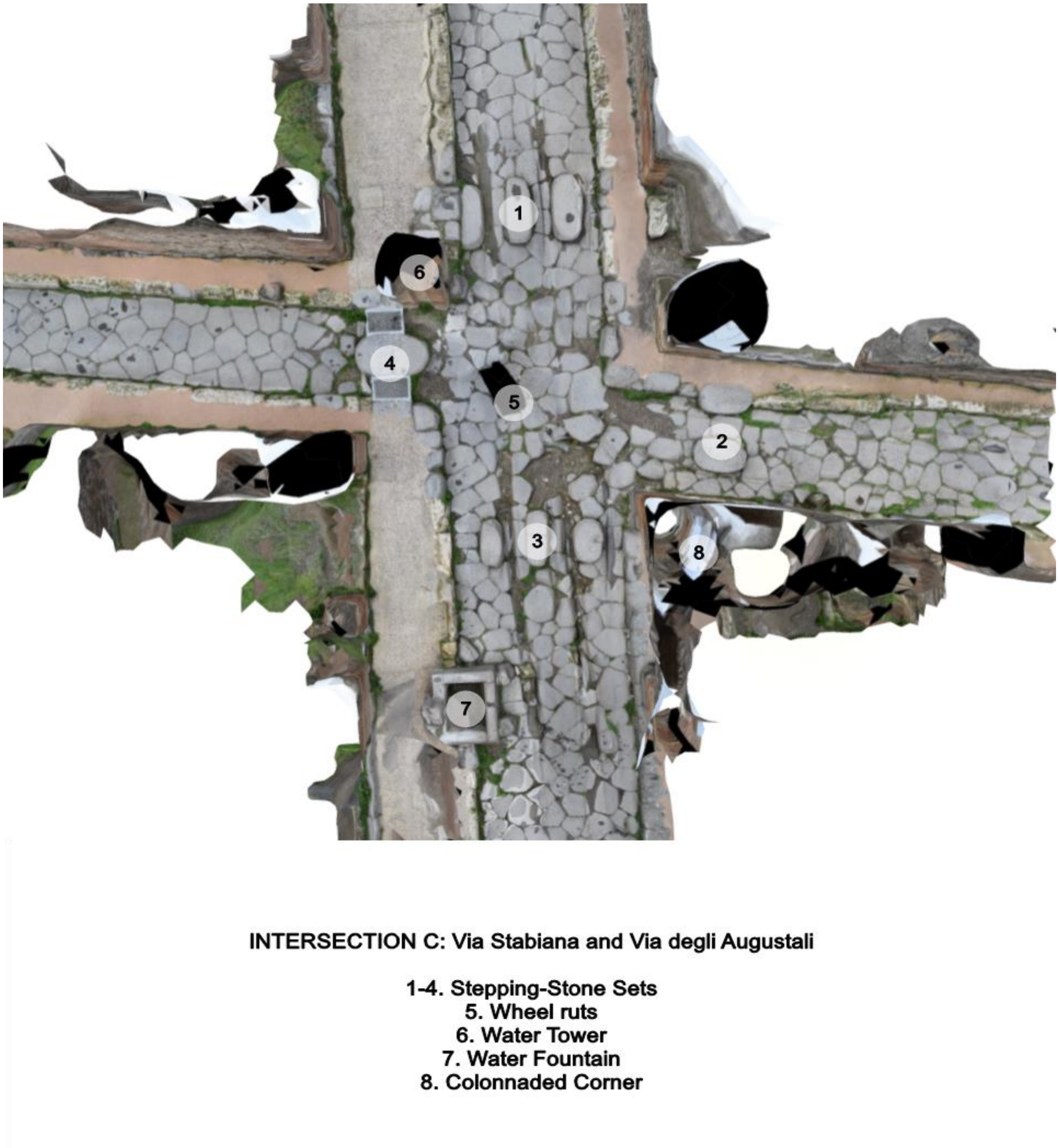


Figure 20: Intersection C with significant elements

3.A.v Intersection D: Via Stabiana and Via dell'Abbondanza, Regio VII Insula 1, Regio IX Insula 1, Regio VIII Insula 4, and Regio I Insula 4

Directly south of Intersection C is the largest and most active intersection in Pompeii, that of Via Stabiana and Via dell'Abbondanza. This is another traditional cross intersection made up of Pompeii's major decumanus, which leads directly to the forum, and the cardo, which runs between two major gates, the Porta Vesuvio and the Porta Stabia. (Figure 21) This intersection is also the location of the only commemorative tetrapylon in Pompeii, the Arch of Marcus Holconius Rufus, indicative of the space's significance. Holconius Rufus was a prominent Pompeian city and based on numerous statue bases found in the city he had multiple prestigious political appointments from the late 1st century BCE until the early 1st century CE. According to the inscription on the statue base attached to the northwest pier of the tetrapylon he received the honor of military tribune, was five times elected duumvir of the law courts and quinquennial twice, served as the priest of Caesar Augustus, and was the patron of the colony.[91] Scholars tend to date the arch to the middle of the first century CE based upon an inscription on the base of the statue dedicated to Marcus Holconius that is attached to one of the piers of the tetrapylon.[92] Therefore, Intersection D is the ultimate example of how architectural design has the ability to direct both pedestrian and vehicular traffic through these spaces, provide ample space for locals to congregate and retrieve goods, and promote the Pompeian wealthy and elite.

[91] Brenda Longfellow, "FEMALE PATRONS AND HONORIFIC STATUES IN POMPEII." *Memoirs of the American Academy in Rome* 59 (2014): 89-90
[92] Longfellow, *FEMALE PATRONS AND HONORIFIC,* 89

Figure 21 - Photo of Intersection D, looking east along Via Abbondanza. The base of the statue to Marcus Holconius Rufus can be seen on the left side of the image.

Intersection D is the richest of all of the intersections in this study in regards to architectural components, which is expected due to its importance, size, and amount of traffic. Similar to intersection C, there is a water fountain and tower, both situated in the southeastern corner, and the water fountain is volumetrically larger than that in intersection C, indicating a higher degree of usage.[93] The eastern branch of Via dell'Abbondanza and the northern branch of Via Stabiana both contain sets of three stepping-stones, while the southern portion of Via Stabiana has a set of four stepping-stones. The western section of Via dell'Abbondanza has no

[93] The fountain in Intersection C is 94 x 120 x 76 for a capacity of 850 liters, and the fountain in Intersection D is 120 x 150 x 76 for a capacity of 1360 liters (L x W X H)(all measurements in centimeters).

stepping-stones, because vehicular traffic is blocked at this juncture with a series of narrowing-stones, curbstones, and a wide set of stairs, creating a large piazza. Accentuating the piazza in the western branch of Via dell'Abbondanza is the aforementioned commemorative tetrapylon of Marcus Holconius Rufus, which spans the entirety of the space from north to south and promotes Holconius and his family. (Figure 22)

The arch of Holconius delineates the space within intersection D, mainly separating the space for congregation from the chaotic daily operations occurring throughout the remainder of the intersection. This is exemplified by examining the structures that flank the various parts of intersection D. In close proximity to the water fountain and tower, on the same southeastern corner is a large bakery, and the Taberna D. Junius Proculus, shops that are typically frequented by the lower to middle class. Whereas, in the western branch of Via dell'Abbondanza associated with the Arch of Holconius stand the Stabian Baths, one of the largest and most elaborate baths in Pompeii with a large marble entrance echoing the marble veneer of the arch. Intersection D highlights the methods by which the organizational qualities of architectural elements assist in delimiting space in a permeable manner, not strictly reliant on physical deterrents.

INTERSECTION D: Via dell'Abbondanza and Via Stabiana

1-3. Stepping-Stone sets
4. Water Fountain
5. Water Tower
6. Blockage of Wheeled Traffic with set of steps entering pedestrian piazza
7. Arch of Holconius, fours existing piers spanning street

Figure 22: Intersection D with significant elements

3.A.vi Intersection E: Via della Fortuna and Vicolo del Labirinto, Regio VI Insula 12 and 13, and Regio VII Insula 4

Intersection E is a small intersection located along Via della Fortuna intersecting with Vicolo del Labirinto, which is the small, tertiary street that defines the eastern extent of the House of the Faun. This is a true T-intersection with the small and narrow Vicolo del Labirinto terminating into the Via della Fortuna, a portion of the secondary decumanus, which is comprised of three sections, from east to west: Via di Nola, Via della Fortuna, and Via delle

Terme. (Figure 23) This intersection illustrates how tertiary streets lacking any vehicular traffic are managed by larger heavily trafficked streets. In addition, it provides insight into the ability of wealthy residents to impact design decisions when their property is directly involved.

Figure 23 - Photo of Intersection E, looking north. The later blocking stone to prevent vehicular traffic from entering Vicolo del Labirinto can be seen in the center left of the image.

This intersection, when compared to previous ones, contains few architectural elements, but the existing ones still allow for an understanding of how the space is controlled and experienced. A set of two stepping-stones lies within the Vicolo del Labirinto situated at the juncture with Via della Fortuna, assisting crossing along the northern side. Associated with this set of stepping-stones are steps carved out of lava stone that comprise the westernmost curbstone, further assisting the movement across Vicolo del Labirinto towards the House of the Faun. Directly between the two stepping-stones and slightly to the north is a large blocking stone that prohibits any vehicular traffic from entering or exiting Vicolo del Labirinto. Finally, the northwestern curbstone that runs parallel to the steps is elevated to a height nearly twice that of other nearby curbstones, which again both protects and guides visitors to the House of the Faun. It is worth noting that the House of the Faun is one of the largest and most elaborate homes in Pompeii, adorned with beautiful mosaics, most notably the Alexander mosaic that consumed the floor of the exedra connecting the first and second peristyles. The house, consisting of two atriums, two peristyles, four dining rooms and multiple smaller rooms flanking these larger rooms, consumes an entire city block measuring 315 by 115 feet.[94] A detailed study of the collaborative nature of these various components exemplifies how a wealthy homeowner can directly impact the perception of an intersection. (Figure 24)

[94] August Mau, *Pompeii, its life and art*. (Good Press, 2019): 281.

Figure 24 - Photogrammetric model of Intersection E with significant elements

3.A.vii Intersection F: Via della Fortuna and Vicolo del Fauno, Regio VI, Insula 10 and 12, and Regio VII, Insula 4.

Intersection F lies directly west of intersection E and the southwest corner of the House of the Faun occupies the southeast corner of the intersection. Similar to intersection E, it is a traditional T-intersection with the smaller Vicolo del Fauno terminating at the juncture with Via della Fortuna. (Figure 25) Whereas intersection E sheds light on how an intersection can manipulate and control experience as one enters into a semi-private space, that of an elite residence, intersection F highlights how a similar space can also influence pedestrians' experience as they progress from the semi-private space and approach a large public space, namely the open marketplace directly north of the forum dominated by the Temple Fortuna Augustus in the northeast corner.

Figure 25 - Photo of Intersection E, looking northeast.

There is a paucity of large architectural elements in this space, but significant information can still be found in the smaller, more subtle details. A pair of stepping-stones, similar to those in intersection E, span the terminal end of Vicolo del Fauno, and another set of two stepping-stones is present in the western branch of Via della Fortuna. The western branch also contains four small circular punch outs in the curbstones, which are most likely hitching places for horses and draught animals.[95] (Figure 26) Evenly spaced narrowing-stones exist throughout the space, both on the northern and southern portions of the western branch, indicative of administrative influence in controlling vehicular traffic and pedestrian safety.[96] The location of these narrowing-stones, or guard stones, is of particular interest, because while typically utilized throughout the city to protect water fountains and towers, here their function is solely the protection of pedestrians.

Figure 26 - Photo of western branch of Intersection F showing a pair of hitching holes and narrowing stones.

[95] Claire Weiss, "Determining function of Pompeian sidewalk features through GIS analysis." *Archaeology* 102, no.4 (1998): 371.
[96] Eric Poehler, *The Traffic Systems of Pompeii*. (Oxford University Press, 2017): 204.

It is apparent in this intersection, especially in the western branch, that there is an abundance of both pedestrian and vehicular traffic, and that an attempt is being made by Pompeian officials to control this congested space. This is most clearly evident in the western portion of the intersection along the Via della Fortuna and may have been an attempt to focus one's attention towards the large public space and the Temple of Fortuna Augusta and away from the House of the Faun. Examinations of intersection F elucidates how the architectural elements and composition of an urban space can help redirect travelers' attention to a wealthy residence. (Figure 27)

Figure 27 - Intersection F with significant elements

3.A.viii Intersection G: Via della Fortuna, Via delle Terme, Via di Mercurio, and Via del Foro, Regio VI Insula 8 and 10, and Regio VII Insula 4 and 5.

The final Pompeian intersection in this study is situated directly north of Pompeii's forum. It is a four-way intersection formed at the crossing of the Via di Mercurio, Via del Foro, Via della Fortuna, and Via delle Terme, and is punctuated by the Temple Fortuna Augustus in the southeast corner. The form of the intersection is slightly irregular due to the jog in the road between the Via della Fortuna and the Via delle Terme to the east and the west of the intersection respectively. Aside from the Temple of Fortuna Augusta, intersection G is dominated by public buildings, such as the Forum Baths in the southwest corner, large shops and tabernae along both the northern and southern portions of Via della Fortuna and Via delle Terme, and the large marketplace that occupies the entire southern branch. Therefore, it allows for a close examination of space management involving multiple public buildings, as well as a large public piazza, and a significant religious monument.

The intersection's physical traits are extensive and indicative of a multimodal space that caters to a large number of both residents of and visitors to Pompeii. The western and eastern branches both contain sets of three stepping-stones (two of which are missing from the western extent), and uniformly placed narrowing-stones are adjacent to both the northern and southern side of the eastern branch. A singular stone remains along the western side of the southern branch, and a small marble stone defines the end of the southeastern sidewalk, which is most likely associated with the Temple Fortuna Augusta, and serves as a way to delineate the sacred space from the pedestrian. The northern portion of Via di Mercurio is accentuated by a Triumphal Arch, perhaps to Caligula, but it may also have been dedicated to Marcus Tullius, which was adorned with a bronze equestrian statue, and spanned the entire width of the street.[97] Marcus Tullius was a prominent figure in Pompeii who personally dedicated the land for the Temple of Fortuna Augusta and supplied all of the funding for its construction. There is a dedicatory inscription on the commemorative stone located above the cult statue in the cella that details all of Marcus Tullius' political appointments and recognizes his contributions.[98] The Arch of Caligula also functioned as a water tower, evident in the lead piping embedded in the masonry, and although in its current state only the brick interior remains, it was originally veneered in marble and made for quite an impressive display. (Figure 28)

[97] Katherine E. Welch, "Pompeian men and women in portrait sculpture." in *The World of Pompeii*, eds. John J. Dobbins and Pedar Foss, (London: Routledge, 2009): 551-554. Welch discusses the possibility that this was not an arch for Caligula, but instead, based on the style of the sculpture, and the close proximity to the Temple Fortuna Augustus, was actually dedicated to Marcus Tullius. He paid for the Temple of Fortuna Augustus, and was given the honorary title of *tribunus militum a populo,* a title given at the recommendation of the emperor.

[98] William Van Andringa, "5."M. Tullius… aedem Fortunae August (ae) solo et peq (unia) sua"." *Private foundation and public cult in a Roman colony. In C. Ando & J. Rüpke (eds.) Public and private in Ancient Mediterranean law and religion. Berlin: De Gruyter* (2015): 101.

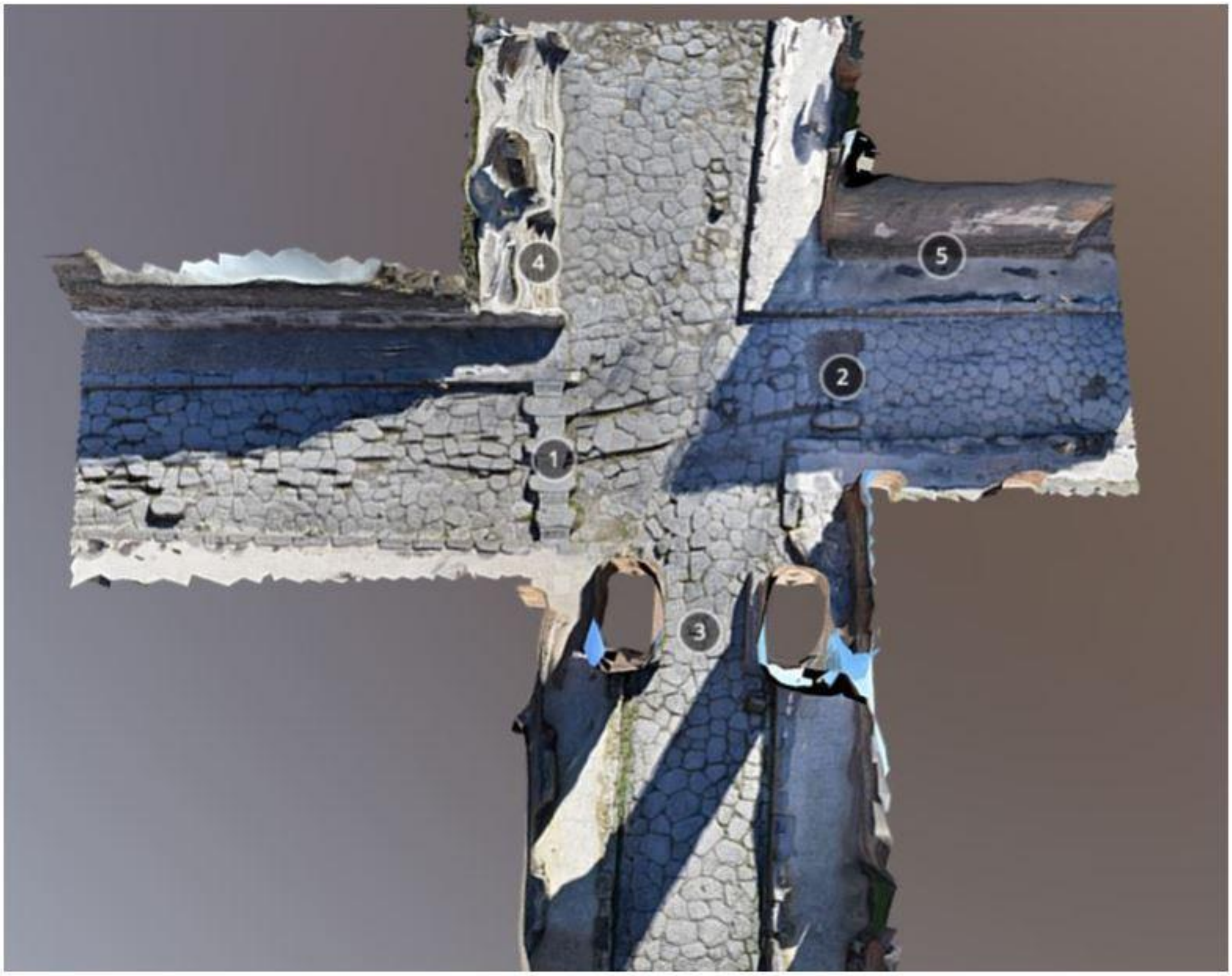
Figure 28 - Arch of Caligula, looking north, with associated pedestrian ramp highlighted.

While intersection G is highlighted by the monumental buildings and structures, it also has several smaller elements that emphasize further qualities of the space. There are two ramps in proximity, one is located along the northwestern sidewalk leading into the northwest corner of the intersection, and the other is south of the Temple Fortuna Augustus, extending from the piazza to the southeastern sidewalk. (Figure 29) Ramps are typically thought to be indicative of wheeled traffic, specifically carts, and most often associated with economic functions, such as stables, inns, and bakeries.[99] While Poehler is mostly correct that the majority of ramps are

[99] Eric Poehler, "Where to park? Carts, stables, and the economics of transport in Pompeii." *Rome, Ostia, Pompeii: Movement and Space* (2011): 196-197.

utilized to transport goods, this does not appear to be the case with the two ramps situated in intersection G. In the case of the ramp just south of the Temple Fortuna Augustus, it is located in a pedestrian zone that is inaccessible by wheeled transport, and the ramp along the northwest sidewalk, again it is difficult to imagine wheeled vehicles utilizing this ramp, both because it does not open onto the road, and it is located in a bottleneck caused by the Arch of Caligula. Therefore, it is more logical that these ramps were installed for pedestrian purposes, perhaps to accommodate large amounts of foot traffic with greater ease, or to assist in moving goods into the shops located in the piazza. Furthermore, a bench runs along the entire northern facade of the Forum Baths, highlighting another design element geared specifically towards pedestrian traffic utilizing this intersection, and the baths. Examining this intersection will provide a better understanding of how architectural details, such as ramps, can be constructed by the administration to handle large pedestrian crowds moving through and occupying transitional spaces. (Figure 30)

Figure 29 - Southern steps of Temple of Fortuna Augustus and adjacent pedestrian ramp.



INTERSECTION G: Via della Fortuna, Via delle Terme, Via di Mercurio, and Via del Foro

1. Set of four stepping stones
2. Set of three stepping stones (two are missing)
3. Location of Arch of Caligula
4. Steps leading to Temple of Fortuna Augustus
5. Bench on northern end of Forum Baths

Figure 30 - Intersection G with significant elements

3.A.ix Herculaneum Intersections: Cardo IV and Decumanus Inferior, and Cardo V and Decumanus Inferior

The final intersections in the case study are two from Herculaneum, which provide comparative material to verify the validity of the methodology and interpretations in another urban context outside of Pompeii, examining similarities and differences between how two Roman cities in the Campania region approach pedestrian traffic in intersections. Due to the limited remains at Herculaneum, compared with Pompeii, there are only six extant intersections, and a third are included in this project. A major difference between Herculaneum and Pompeii, concerning the urban environment, is the lack of stepping-stones at Herculaneum. There is also a significant lessening in curbstone height, a decrease in the number of narrowing-stones, and in general a diminished number of architectural elements focused on wheeled traffic. The limited sampling in Herculaneum creates the possibility that other unexcavated sections of the city catered more heavily to wheeled transport, but for the area of this study pedestrian traffic appears to have been less restricted and controlled than in Pompeian streets.

The intersection of Decumanus Inferior and Cardo IV is a four-way intersection featuring quite low curbstones that do little to prevent pedestrian traffic from entering the street at will, and there is no sidewalk along the eastern end of the southern branch. A small set of steps exists in the south east corner guiding traffic east along Cardo IV, and a large pier abuts the staircase to the south. There are only two shops that communicate with the intersection, and only the taberna in the southwest corner interacts directly with the intersection, which may be indicative of a space that is not heavily occupied by travelers, but instead functions more strictly as a transitional space. (Figure 31)

Figure 31 - Cardo IV and Decumanus Inferior, looking south.

The second Herculaneum intersection, another T-intersection comprising Cardo V and Decumanus Inferior also possesses an architectural arrangement suggestive of reduced vehicular traffic. The intersection contains a water fountain, which runs parallel to the intersection and lacks any physical interventions, such as narrowing or guard stones, a feature of nearly every Pompeian fountain. There is a singular large lava stone in the northeast corner of the intersection situated in the roadway at the termination of the northern sidewalk. The sidewalk at this juncture does not continue to the east along Decumanus Inferior but appears again after a gap of approximately twenty meters. There are also a series of steps in the western portion of the street, as well as the eastern, and there is a third set of steps along the northeast sidewalk to accommodate an elevation change from a higher colonnaded section. (Figure 32)

Figure 32 - Cardo V and Decumanus Inferior, looking west

The Herculaneum intersections provide an ideal counter to those found in Pompeii, because they cater to pedestrian traffic in different ways. Whereas Pompeian streets are littered with the physical remains of extensive vehicular traffic, Herculaneum streets do not possess similar evidence to such a degree. Therefore, it becomes possible to observe the ways in which intersection design varies when protection from large amounts of wheeled transport is not as necessary.

3.B Comprehensive Architectural Analysis

This section presents a comprehensive analysis of the case-study intersections, in particular their architectural elements, and will highlight specific traits among the seven intersections that most effectively impact pedestrian traffic. There are certain techniques, employed in a variety of ways, that are witnessed throughout intersections, which perform tasks that allow pedestrian movement to be managed and to a certain extent programmed. The photorealistic models will be used both in the analysis of these techniques, as well as their presentation, creating a more immersive way of experiencing them.

The specific characteristics documented in this chapter are sidewalk width and curbstone height, stepping-stone placement and position, delineation of space and visual cues, and adjacent structures. These are traits that are witnessed in many intersections and gaining a deeper understanding of how they are employed and the ability they possess to impact and program movement merit analysis. They can encourage and discourage forms of movement in an attempt to both protect pedestrians, as well as bring attention, both physically and visually, to features. Besides stepping-stones, which Pompeii has nearly twenty times as many as another Roman town, these are all objects that can be found universally throughout Roman cities, therefore making the methodology transferable.[100]

[100] Eric Poehler, "Crosstown Traffic Driving the Streets of Pompeii." *Current World Archaeology*, 87 (2018), https://www.world-archaeology.com/features/crosstown-traffic-driving-streets-pompeii/

3.B.i Sidewalk Width and Curbstone Height

Sidewalk widths vary throughout Pompeii, averaging between 2.5 to 4 meters wide, allowing for comfortable two-way pedestrian traffic and in certain cases may accommodate larger crowds to pass efficiently.[101] In many instances sidewalk width is manipulated during the approach into an intersection, the reasons for such manipulations include widening to accommodate movement around elements, such as water fountains, and into spaces. These intentional bottlenecks slow traffic and bring attention to surroundings. Changing widths compel shifts in the speed and density of pedestrian traffic. While the adjustments may be modest at times, a small adjustment to the width of a sidewalk can greatly impact how many people can occupy the area at one time, which in turn impacts the overall movement through and into a space.

Curbstones define sidewalk space, and they work in tandem to create an effective means of programming pedestrian traffic. Curbstones are simple yet effective tools to discourage pedestrians from entering into roadways; one of the most efficient ways to prevent people from entering into the street is by raising the height of the curbstones, which makes ingress quite difficult due to the increased drop. Conversely, decreasing curbstone height may be indicative of a location where entering the streets is once again safe, or at the very least possible. It becomes apparent when analyzing the models that quite often during the approach to an intersection there occurs both a shift in sidewalk width, as well as an increasing or decreasing of curbstone height. There is the possibility that some of the increase in curbstone height is related to drainage throughout the city. The sloping streets provide a natural conduit for rainwater and even today it is not uncommon that during a rainstorm the streets become rapid flowing streams that are

[101] Connolly, Peter. *Pompeii*. (Oxford University Press, 1990): 20.

diverted towards the city's southern gates. The elevated curbstones most certainly provide some sense of security during times of excessive rain and can assist in flooding certain streets while guiding the water away from others.[102] However, this cannot be their sole purpose, particularly when intersections are taken into consideration. Intersections A, C, D and G all display a pattern of raised curbstones while approaching the intersection and then upon entering it a decrease in height to allow pedestrians to access stepping-stones and proceed across the street. Therefore, curbstone height has dual functionality in both programming the flow of rainwater, as well as that of pedestrian movement.

This can be seen at Intersection A where an effort for pedestrian traffic control comes in the form of a rather drastic elevation change of the curbstones bounding the western sidewalk, raising the height of the curbstones to a level making it difficult to enter into the street directly. (Figure 33) This is exemplified by the fact that there are a pair of mirrored set of step cutouts in the western and eastern curbstones to accommodate accessing and crossing the street prior to entering the intersection. Therefore, it appears that an effort was made by the administration to deter pedestrians from accessing the street near the intersection, preventing bottlenecking at a juncture where there already is significant vehicular congestion. A similar configuration exists slightly further south along the Consolare, where a drop in elevation of the eastern curbstones coincides with a pair of steps allowing access to the western sidewalk. This is another attempt to encourage crossing the street from east to west, where the sidewalk is wider, and one is further removed from vehicular traffic proceeding down Vico del Farmacista.

[102] For a more detailed discussion on how the street drainage system worked see Eric E. Poehler, "The drainage system at Pompeii: mechanisms, operation and design." *Journal of Roman Archaeology* 25 (2012): 95-120; Gemma Jansen, "The water system: supply and drainage." *The World of Pompeii* (2007): 257-266.

Figure 33 - Section of western side of the northern branch of Intersection A highlighting the increase in elevation as one approaches the intersection with a pair of steps.

Furthermore, the first step of the aforementioned set actually projects into the street approximately 50 cm, which both simultaneously aids in entering the sidewalk from the street and prevents vehicular traffic from encroaching upon this space. There are other physical qualities present at this location, such as the two areas of narrowing along the western sidewalk. They are caused by the protrusion of a threshold stone and the upper step, decreasing the sidewalk's width by nearly fifty percent. Narrowing the sidewalk ultimately causes a slight bottleneck effect, because two-way traffic is condensed down to one-way traffic, but this ultimately slows the traffic, which perhaps is the desired outcome. Slowing the traffic at this moment heightens the awareness of a traveler, and in turn makes them observe the nearby steps, which introduced new traffic, and adjust their path accordingly. (Figure 34)

Figure 34 - Image-based model of Intersection A: 1) Bottleneck caused by protrusion of threshold 2) Bottleneck caused by upper step narrowing sidewalk.

The western sidewalk remains elevated at this point and only decreases enough to allow access into the street, as it approaches the stepping-stone in Vico del Modesto. While easing the restrictions on street access where vehicular congestion is amplified may seem counterintuitive, in this instance it is more tenable, because the protection provided by the roughly triangular vehicular free zone and the associated two narrowing stones, which further prevents traffic from impinging upon pedestrians entry into the street. (Figure 35) The lack of any visible wheel ruts in the triangular space provides further evidence to the relative scarcity of wheeled traffic. Ultimately, this area allows for safe passage from the western sidewalk, across the street, and into the physically delineated semi-circular space adjacent to the taberna.

Figure 35 - Photogrammetric model highlighting the medium sized pedestrian zone in Intersection a, formed by diverting traffic along the eastern branch of the intersection and extending the entrance of the taberna into the street.

Another example, that strictly uses sidewalk width to manipulate pedestrian traffic, occurs in Intersection B, specifically on Vicolo del Lupanare as one approaches from the south. The architectural configuration along Vicolo del Lupanare, prior to reaching the ramp at the northern extent, presents a traveler with a few options, and unlike Intersection A, there is not the extreme emphasis on avoiding wheeled transport. The road is not completely closed to vehicular traffic, but given the inability to continue at this juncture, wheeled traffic was most likely limited to carts providing commodities to the taberna on the northeast corner, or the workshop adjacent to and opening onto the piazzetta. Prior to the slight eastward bend in Vicolo del Lupanare both the eastern and western sidewalks are quite narrow, and allow for the passage of, at most, one pedestrian, suggesting the majority of pedestrian traffic exists in the roadway. However, concurrent with the bend, is a widening of the eastern sidewalk, allowing for more comfortable pedestrian traffic, and unimpeded upon, until they reach the intersection with Via degli Augustali. The widening of the sidewalk at this junction is most likely done to accommodate the crowds from the taberna at the southeastern corner. Widening the sidewalk at this location provides an avenue of travel for pedestrians that is less impeded upon by the crowds at the taberna. It grants them an efficient path to move into the intersection and continue along their journey. (Figure 36)

There is another example of sidewalk widening in Intersection B, however in this case it is not done to accommodate localized crowds at a taberna, but instead the widening is done to alleviate additional stress on pedestrian traffic due to an increase in northerly crossings. The narrowness, 0.65m, of the stepping-stones at this location prohibits two-way crossing, expressing a desire to funnel northerly headed pedestrians into a portion of the sidewalk, which is conveniently widened at this exact spot. (Figure 37) Pedestrians wishing to cross to the south at this juncture are forced to make an awkward hard turn to the left to continue onto the second crossing-stone, and then would enter into a narrow and constricted sidewalk, that appears more conducive to one-way traffic. Therefore, the sidewalk's widening directly east of Casa dell'Orto Ferito allows for traffic continuing east along Via degli Augustali to navigate this bottleneck with relative efficiency and with little impediment upon fellow travelers crossing north and proceeding west at the same point. However, what is certain here is that any crossing at the central portion of the intersection is limited to a single direction at any given time, necessitating the need for a certain degree of programmed movement. These details are indicative of a semi-programmed route of travel, the architectural layout, while not overtly expressive or visually dominant, being the guiding element.

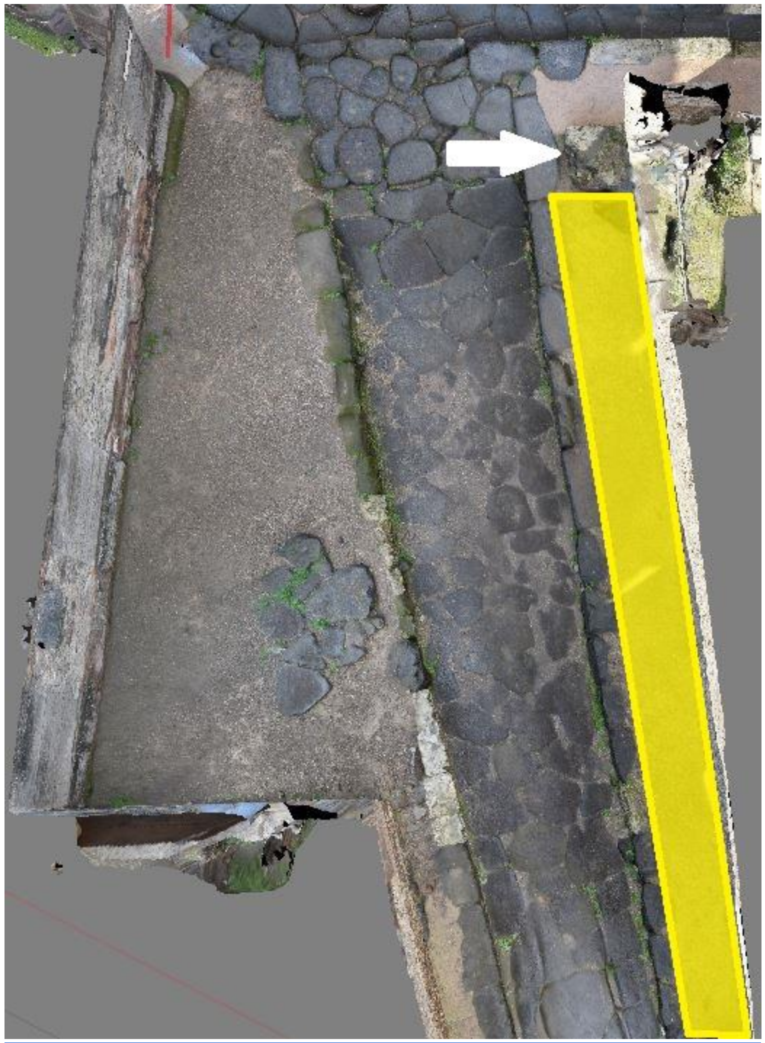


Figure 36 - Image-based model of Intersection B. Highlighted eastern sidewalk widens until reaching the intersection and brick pier of the Lares altar, indicated by the arrow that impedes upon pedestrian traffic. Click to view inside of the model.

Figure 37 - Photogrammetric model showing the sidewalk widening in front of Casa dell'Orto Ferito to accommodate crossing from the south.

Intersection C provides a great example of how sidewalk width and curbstone height work in conjunction to suggest a preferred route of travel. As a traveler approaches Intersection C from the north along Via Stabiana there is a concerted effort to both encourage movement along the western sidewalk, and to discourage entering the street. The first indication of this preference is the fact that the last set of stepping-stones, allowing pedestrians to comfortably cross, is thirty-two meters north of the intersection, and at this exact location the western sidewalk doubles in width from one meter to two meters, while the eastern sidewalk remains one meter in width. This highlights the administration's desire to entice pedestrian traffic to cross to the west at this location and travel more comfortably along the wider western sidewalk until reaching the intersection. Furthermore, it is precisely at the location of the last set of stepping-stones that the height of the curbstones is doubled by adding an additional layer of curbstone, increasing the height from 50 cm to one meter, a significant drop for a pedestrian trying to gain access to the roadway. (Figure 38)

Figure 38 - Photogrammetric model of northern branch of intersection C. Notice the two height curbstones and the difference in sidewalk width between the eastern and western sides. The western sidewalk easily accommodates two-way traffic, while the eastern branch is more suited for one-way traffic.

The western sidewalk continues to function as the preferred route for pedestrian traffic, and further programming for this direction of movement occurs immediately after crossing Via degli Augustali. The fountain situated in the southwestern corner requires thoughtful planning to accommodate for the crowds that tend to gather at these locations. First, approximately 50% of the fountain extends into the roadway, which is significant, because it provides a greater portion of the sidewalk for occupancy. This clearing for pedestrians to gather within is enhanced by a conspicuous westward shift of the facade, directly west of the fountain's spout, further widening the sidewalk. Taking advantage of the facade's westward push at this moment not only increases the occupational space for fountain users, but also provides relief for pedestrians simply wanting to continue traveling southward along the western sidewalk by providing them extra space to circumnavigate the fountain's congestion. In addition, the curbstones directly south of the fountain curve outward slightly, further enlarging the space adjacent to the fountain. (Figure 39)

Figure 39 - Photogrammetric model of the southern branch of Intersection C. Highlighted area is the extra space created by the bending outward of the curbstones and the westerly shift of the facade (indicated by the arrows).

Finally, Intersection D provides another ideal example of sidewalk width and curbstone height working together to program movement. Approaching Intersection D from the north, along Via Stabiana, there are, again, obvious modifications made to the sidewalk that directly impact pedestrian movement. Most significant is the complete blockage of the western sidewalk, which greatly impedes upon foot traffic, by forcing all traffic into the street and onto the eastern sidewalk. (Figure 40) This impediment is the result of the protrusion of the Stabian Baths eastern wall, and it not only greatly diminishes the width of the sidewalk, but also elevates it to more than twice the existing height, making access difficult. The interior of the Stabian Baths corresponding with the facade's extension is the large furnace room, which is accessible from the street, perhaps to restock supplies.[103] This modification is traditionally dated to the early empire, specifically during the rule of Augustus, and highlights the administration's ability to alter the urban environment, regardless of its impingement on pedestrian traffic.[104]

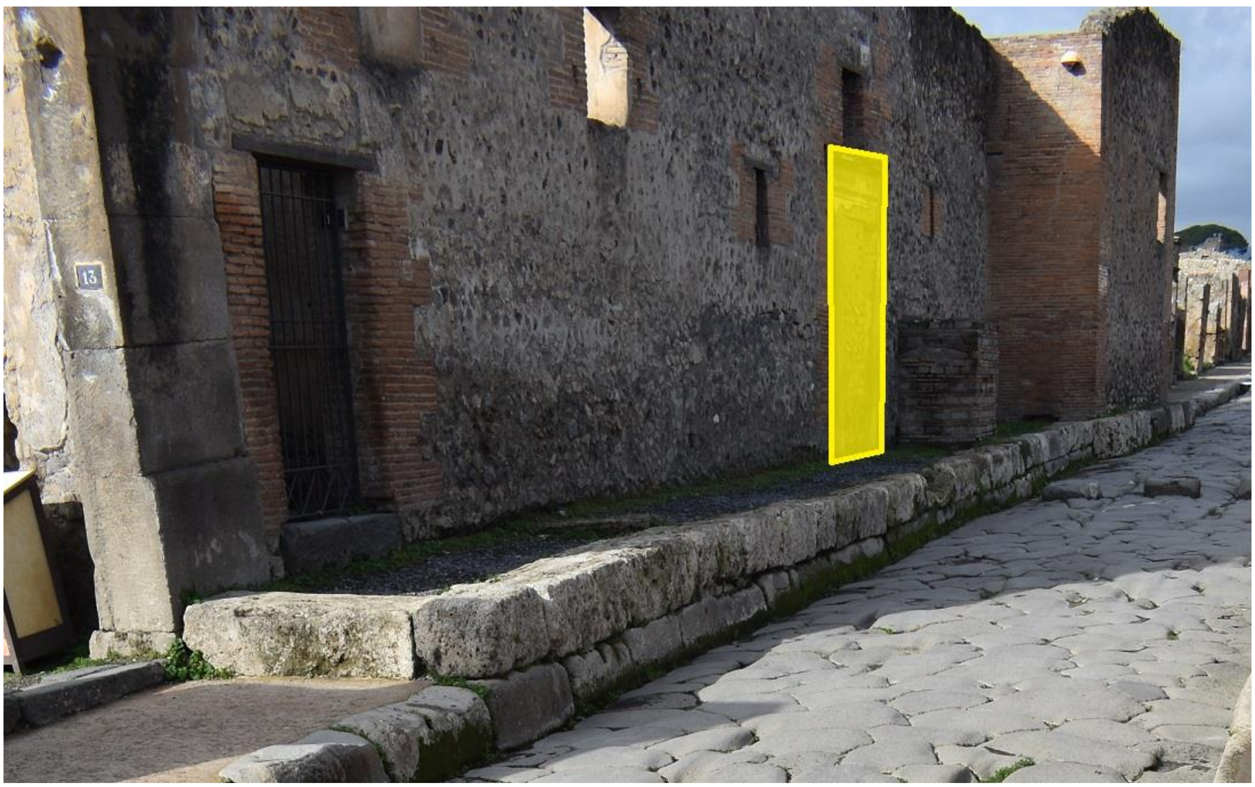


Figure 40 - Image of the Stabian Baths addition that completely blocks western sidewalk seen in the upper right portion of the image, and curbstone elevation achieved with an additional row of pavers. Entrance blocked in antiquity highlighted.

[103] Lawrence Richardson, *Pompeii: an architectural history*. (Johns Hopkins University Press, 1988): 101-5.
[104] Garret G. Fagan, "The genesis of the Roman public bath: recent approaches and future directions." *American Journal of Archaeology* (2001): 411-14.

Accommodations for this occur directly north of the blockage and comes in the form of a series of stepping-stones spanning Via Stabiana, allowing pedestrians to safely cross to the eastern side. Slightly south of this initial set of stepping-stones is another set that communicates directly with an earlier point of egress and ingress to the Stabian Baths. However, since this entrance is most likely used by people restocking the supply rooms situated on the eastern end of the baths, and therefore is not heavily utilized by pedestrians, the configuration does not help alleviate the increased foot traffic along the eastern sidewalk. This entrance was actually blocked in antiquity, and a subsequential entrance was opened directly to the south, which has no associated series of stepping-stones to assist with accessing the doorway. This reiterates the fact that the doorway situated on the eastern side of the baths is most likely reserved for more industrial purposes and does not cater to the establishment's patrons.

The majority of the pedestrian traffic approaching from the north, therefore, is doing so utilizing the eastern sidewalk across from the Stabian Baths, and the sidewalk's width attest to this, easily allowing efficient passage for 2-3 people, accommodating two-way traffic when necessary. The curbstones at this juncture are quite high, and once again discourage ingress into the roadway, establishing the intersection as the next opportunity to amend one's path of travel. It is clear that the majority of pedestrian traffic approaching the intersection of Via Stabian and Via dell'Abbondanza from the north, is moving along the eastern sidewalk.

Sidewalk widths and curbstone heights are simple, yet proficient techniques that allow that administration to encourage certain paths of movement and avoid pedestrians wandering into the streets at some of the town's busiest locations. There are instances of isolated practice, which tend to occur at or near lesser intersections, but at busier intersections it is common to employ both approaches, routinely working in cooperation. This is most likely due to the fact that intersections of two major thoroughfares possess an increase in both pedestrian and vehicular traffic, and therefore attempts to program movement require more rigorous and overt efforts. At these extremely busy locations, which often contain many amenities such as bars, water fountains, bakeries, bath complexes, etc., movement through such congested spaces becomes more complicated, especially to those unfamiliar with the environment. Therefore, it is necessary to initiate programmed movement prior to accessing the intersection, in order to already have a sense of order upon entering the intersection. The combination of elevating curbstones and widening or narrowing sidewalks serves as a very effective tool to establish a preferred path prior to entering the space.

3.B.ii Stepping-Stone Placement

Stepping-stones are found throughout Pompeian streets and regularly impact the way in which one navigates, particularly in close proximity to and in an intersection. The placement of stepping-stones can provide clues to understanding the desires of the administration in regard to pedestrian traffic. Using the models, it becomes possible to study both the location of the stepping-stones and the relationship they have to each other and the curbstones they are adjoining. Specific characteristics regarding the location and placement of stepping-stones, such as distance from curbstone, angle of approach, and height and width can help determine the impact they have on overall pedestrian movement. Specifically, they can help clarify direction of pedestrian traffic, one-way or two-way crossings, and desired direction and location of crossings.

Intersection D provides the first example whereby investigating two specific sets of stepping-stones, those in the northern and eastern branches, it is possible to postulate the paths of movement across these two roads. The inquiry begins at the northeast corner, due to the fact that the majority of pedestrian traffic that approaches Via dell’Abbondanza from the north enters via the eastern sidewalk. Programming movement prior to entering the intersection allows for effective design decisions to handle the increased flow of traffic along the eastern sidewalk.

Upon reaching the intersection travelers are presented with a variety of navigational decisions, they may choose to enter the taberna that dominates the southeastern corner, which is accessible both, from Via Stabiana and Via dell'Abbondanza. However, if the taberna is not the final destination then they have to quickly decide whether to continue south along Via Stabiana or turn and proceed either east or west down Via dell'Abbondanza. A careful observation of the curbstone wear and the position of the stepping-stones elicits further evidence that an attempt is made to once again program how pedestrian traffic moved through the intersection.

There is significant wear on the northernmost portion of the curbstone directly east of the last stepping-stone of the series spanning Via Stabiana, which is indicative of an angled access from the eastern sidewalk proceeding west across the northern stepping-stones. (Figure 41) Furthermore, the position of the stepping-stones across the northern section and the eastern section is indicative of a pedestrian traffic flow consisting of eastbound travelers traversing along the southern half of the stepping-stones, and conversely westbound pedestrians utilizing the northern half. It also appears as if a great majority of the eastbound travelers immediately headed south across the intersection's eastern branch in an attempt to funnel eastbound traffic to the southern side of Via dell"Abbondanza.

The stepping-stones' overall size immediately suggest that they comfortably accommodate cross traffic, a necessity at such a congested intersection. There is certainly a degree of cooperation between these two sets of stepping-stones, which is not necessarily unique, but the degree of collaboration is higher than what is traditionally observed. First, both sets are positioned extremely close to the mouth of the intersection, more so than is typically witnessed, as stepping-stones are traditionally slightly further down the branch. Positioning them in such a manner makes communication between the two sets more efficient, because it alleviates travelers congesting the sidewalks, only to cross at the next set of stepping-stones. Instead, they can continue across to the south without ever exiting from the stones. This cooperation is further promoted by the addition of a transition stone in the northeast corner, extending further into the intersection, allowing for a seamless transition from the northern to the eastern stepping-stones, especially for travelers heading east and then crossing to the south. This appears to be a concerted effort to encourage eastbound traffic to cross to the south at this juncture, perhaps to alleviate congestion near the large tabernae situated on the northeast corner, or to accommodate traffic wishing to access the drinking well located in the southeastern corner. (Figure 42)

Figure 41 - Image-based model of detail of curbstone in the northern branch of wear showing a significant amount of usage, accommodating crossing to the west along the northern side of the stepping-stones.

Upon examination of the eastern intersection this collaboration is fortified through other techniques, specifically in the placement of the southernmost stepping-stones, and the large stepping-stone/curbstone that partially protrudes into the street. This stone highlights a couple of features happening at this juncture, the first of which is right side walking, due to the angle of the stone, slightly bending to the north on the eastern end, effectively narrowing the gap one's stride must cover. Furthermore, there is a small step carved out of this stone, which greatly facilitates exiting the stepping-stones to the south. Therefore, by angling the eastern end of the curbstone closer to the next stepping-stone it appears to accommodate right side pedestrian traffic entering into the intersection from the south, and the small step is the counter accommodation to right side traffic exiting the intersection from the north. (Figure 43)

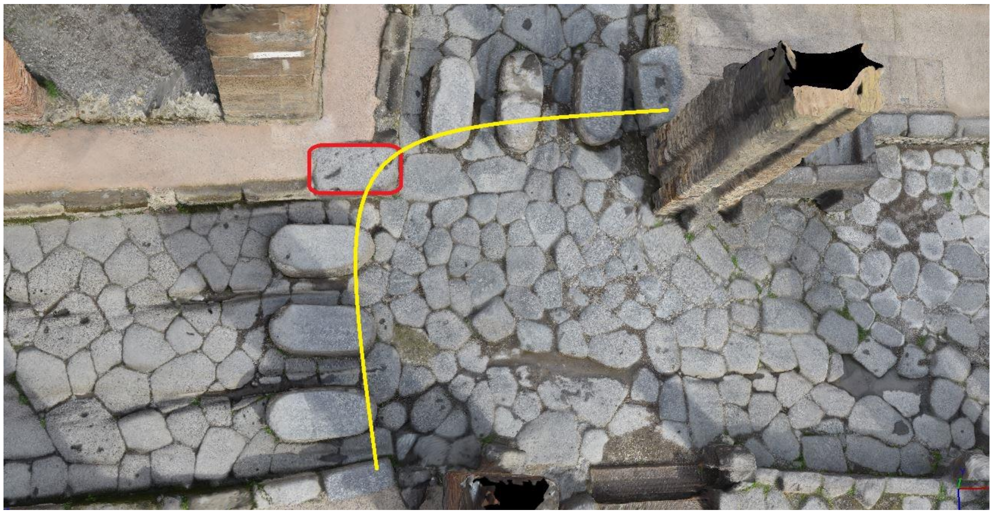


Figure 42 - Image-based aerial of model with preferred path of travel highlighted in yellow and transition stepping-stone in red. Also, notice the angling of the hybrid curbstone/stepping-stone that is directly behind the water tower. This angling encourages people to move away from the water fountain as they enter the southern sidewalk.

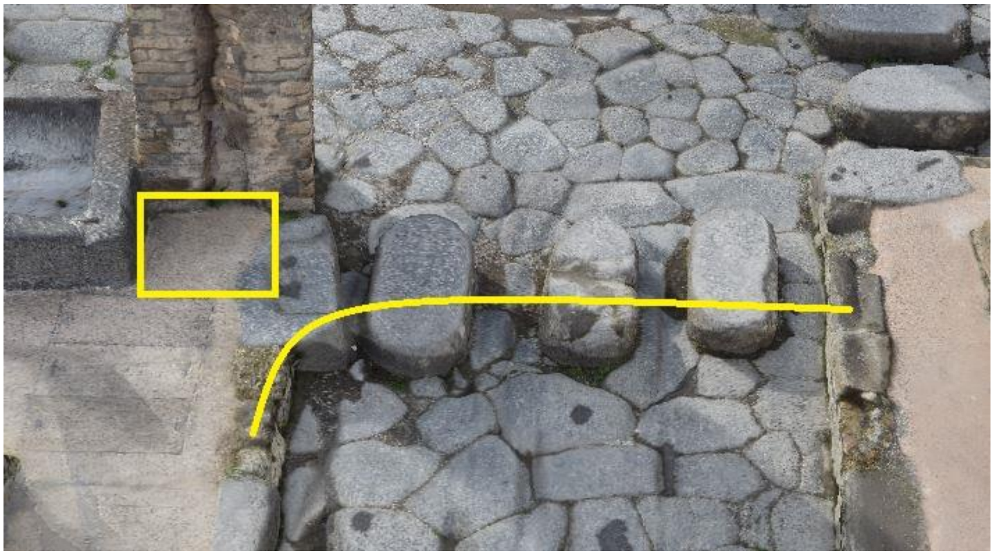


Figure 43 - Image-based aerial of model showing southern branch of Intersection G with additional space created by pushing the entire water tower into the intersection and preferred movement for northerly crossing.

Returning to Intersection C, we recall that an attempt is made using curbstone height and sidewalk width to channel pedestrian traffic to the western side of Via Stabiana. The traits of the intersection's stepping-stones support this theory. Continuing along the western sidewalk toward Intersection C, the next element one encounters is the water tower in the northwest corner. With the construction of the water tower, and its associated elements, the administration continues its desire to route pedestrian traffic to the western sidewalk. Highlighting this attempt to focus traffic to the western sidewalk is the entrance that physically adjoins the water tower to the north, that consists of a small set of steps and a large marble landing providing access to the sidewalk. Furthermore, there are four more large flat lava stone pavers extending west of the marble paver that in essence create a landing upon entering the space. The incorporation of the westernmost stepping-stone into the curbstones, essentially creates the set of steps leading to the landing and greatly facilitates crossing to the west at this location. In addition, the height of the curbstones decreases at this point, allowing for easier access, and the entrance is delineated by elevated lava stones, visually alerting pedestrians to the ingress. (Figure 44)

Figure 44 - Photogrammetric model of Intersection C looking west across Via Stabiana in the northern branch.

(Click to enter model)

1) Decrease height of curbstones (Half of their previous height)
2) Landing directly west of stepping-stones
3) Incorporation of western most stepping-stone, creating step into western sidewalk

The elements work together to draw attention to this point of ingress and egress and also make accessing the stepping-stones easier.

The location of the stepping-stones in the eastern branch also reinforces the theory that a preference exists for southbound traffic on the western side of Via Stabiana at this juncture. While the sets of stepping-stones in the northern and western branches are clearly visible to travelers heading south along Via Stabiana, the eastern branches stepping-stones are hidden from the view of pedestrians heading south due to how they are slightly pushed back into the intersection. The fact that a second stepping-stone is incorporated into the northern sidewalk indicates that this set of stones is indeed for crossing and not just meant to control vehicular traffic. It is clear that the road is not wide enough at this point for two stepping-stones, but wide enough that it cannot be comfortably crossed via a sole stepping-stone in the middle. Therefore, the second one is added to provide a reasonable distance for crossing, which suggests that pedestrian crossing is necessary at this juncture, but not for the people traveling south on Via Stabiana. Instead this crossing seems to cater to residents of an upper scale apartment building on the southeastern corner. A small arcade surrounds the sidewalk adjacent to the apartment building, greatly diminishing the amount of sidewalk available to pedestrians and discouraging unwanted pedestrian traffic from entering, while the stepping stone directly aligns itself with the center of one of the colonnade's arches, allowing comfortable crossing for the apartment's occupants.(Figure 45)

Figure 45 - Photogrammetric model of eastern branch of Intersection C. Stepping-stones are hidden from view if approaching from the north along Via Stabiana and align directly with an opening in the small arcade, suggesting that these stepping-stones are not meant to be frequently used by southbound travelers, but instead catered to a smaller percentage of people heading north. (Click to enter model)

Stepping-stones prove to be vital when attempting to convey the more nuanced desires of the government, particularly regarding traffic flow and direction. They possess the ability to encourage crossing streets and assist in programming specific paths of movement. They are especially effective when coupled with other techniques already discussed, such as curbstone height, and other practices, yet to be examined, such as delineating space.

Stepping-stones are an integral element because at times they are the only locations for travelers to cross the street and therefore they possess a great deal of influence over pedestrian movement. They become particularly influential during times when entering the streets is challenging, such as when torrential rains or overflow from fountains flood the streets, or at busy intersections where accessing the street at ill-advised locations may put a traveler in the path of heavy vehicles towed by large draught animals. Their presence signals to people areas where crossing the street is safe and conversely their absence is an attempt to discourage crossing, providing a means by which pedestrian traffic flow can be manipulated.

3.B.iii Delineation of Space and Visual Cues

Sidewalks, curbstones and stepping-stones directly and physically impact pedestrian movement while delineating spaces and visual cues have a more indirect influence on how someone perceives intersections. The indirect cues that they provide enhance safety in intersections by creating vehicular free zones in streets, specifically in locations where sidewalk crowds may overflow into the roadways. They also create spaces where pedestrians as well as adjacent structures can have a sense of ownership, allowing them to freely occupy the space. Visual cues function as wayfinders, both within a singular intersection, as well as between intersections over long distances. This is particularly important to non-locals, who may not possess the urban acuity of locals. Therefore, visual cues help navigate the city in a more efficient manner. Intersections are the most sensible places for such visual cues are intersections, because they are well-lit, open spaces where tall objects such as water towers or large arches are easily spotted.

At Intersection E a case of delineation highlights wealthy homeowners' ability to declare ownership over the sidewalk and perhaps roadways surrounding their homes, inviting passersby to notice their success. Pompeians had a propensity to unsystematically change the streets, occasionally placing impediments that altered cart access, altering the traffic system, and ultimately impacting pedestrians' experiences.[105] One such example occurs at Intersection E, where cart travel north along Vicolo Labirinto is blocked by a large rectangular stone. Wear on the stepping-stones as well as deep ruts along Vicolo Labirinto indicate that prior to the blockage, carts were able to travel along Vico del Labirinto between Via Fortuna and Via Mercurio.[106] The blockage of wheeled-traffic along Vico del Labirinto subsequently forces vehicular traffic to continue along Via Fortuna causing further congestion in front of the House of the Faun. Deep wheel ruts along Via Fortuna confirm this. Increased traffic could impact the patron of the House of the Faun negatively or positively and depending on their perception could indicate who was responsible for the blockage of Vico del Labirinto. The congestion caused by such an influx could be quite loud and disruptive to the residents, but on the other hand it brings a heightened visibility to their homes, forcing more Romans to observe their wealth, and in turn increasing their status.[107]

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[105] For studies that cite various changes that occur along roadways that significantly alter vehicular traffic, which in turn ultimately impact the way in which a pedestrian interacts with the space see, David J. Newsome, "Centrality in its Place: Defining Urban Space in." (2009): 25-38.
Alan Kaiser, "Cart traffic flow in Pompeii and Rome." in *Rome, Ostia, Pompeii: Movement and Space*, eds. Ray Laurence and David J. Newsome (Oxford University Press, 2011): 174-193.
Eric Poehler, *The traffic systems of Pompeii*. Oxford University Press, 2017.

[106] Poehler, *The Organization of Pompeii's System*, 63

[107] David Newsome, "Traffic, space and legal change around the Casa del Marinaio at Pompeii (VII 15.1-2)." *BABesch* 84 (2009): 125-130.

Furthermore, architectural elements entice pedestrians to continue traveling along the northern side of Via Fortuna, passing directly in front of the House of the Faun. Elevated curbstones demarcate both the east and west corners of the intersection, discouraging pedestrians from entering the street. Further testament to this solicitation by the patron comes in the form of two steps, replacing what typically is a simple curbstone, which only makes the journey more appealing physically, and visually aids in programming movement. Exiting the steps and continuing west along Via Fortuna a pedestrian encounters a steep increase in the sidewalk's elevation, nearly doubling in height from 30 cm to 55 cm, which again has both a visual and kinetic impact. A traveler may not visually notice the rise in elevation, especially if they are not actively paying attention to the sidewalk, but they will, however, feel the elevation change. Ultimately, noticing this change, one becomes aware of their surroundings, in this case, the House of the Faun. The elevation change is more acutely visible from the street where the doubling of curbstone height is clearly discernible. If indeed, the homeowner is responsible for blocking Vico del Labirinto, causing a surge in vehicular traffic, then encouraging pedestrians to continue along the northern side of Via Fortuna both keeps travelers safe and further promotes their reputation.

Intersection B showcases another example of visual manipulation of a traveler in an attempt to give prominence to a specific location, in this case a medium sized piazzetta in the southwestern corner. This piazzetta is particularly important because its western wall appears to have functioned as a billboard for local propaganda. James L. Franklin Jr. discusses how the nine electoral programmata (CIL IV. 817-25), four painted notices (CIL IV. 820a, 1190b-c, 2166), and five graffiti (CIL IV. 2167-70, 3101) are "vying for the eye of the passer-by," highlighting the importance of this space. Even though it is not along any major thoroughfare, the locus is along a well-traveled route to the forum.[108] If the intent of this space is to capture the gaze of passers-by, then perhaps it is possible to examine how the architectural arrangement of Intersection B assisted in promoting this space.

The placement of a brick pillar at the furthest northern extent of the eastern sidewalk, directly opposite the inscribed wall, prohibits the visual continuity along the eastern sidewalk, directing it towards the piazzetta instead. Placing the pillar directly in the sidewalk, at the intersection of Augustali and Lupanare, delineates the space associated with the piazzetta both visually and physically. Intensifying this effect is the obtuse angle at which Vicolo del Lupanare and Via degli Augustali intersect, because it naturally opens up the space occupied by the western wall. Conversely, while the obtuse angle of intersection creates a larger space for the southwest corner to occupy, the complementary acute angle diminishes the area of the southeast corner. By placing the pillar in the southeast corner, this already greatly reduced space is lessened, essentially leaving no space for occupation and increasing desire to cross into the larger piazzetta. The pier also serves to delineate the space outside of the taberna, providing both a place for patrons to congregate if the tavern is full, and creates a semi-enclosed space that provides its occupants with a certain sense of ownership.[109]

In addition, the piazzetta forms a medium sized space of convexity, ideally suited for occupation and congregation, where interaction amongst participants is expedited. In convex spaces lack any concavity, therefore the shortest distance between any two points stays within the space, and all people within the convex space can see each other.[110] Convex spaces are also

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[108] James L. Franklin, "Games and a Lupanar: prosopography of a neighborhood in ancient Pompeii." *The Classical Journal* 81, no. 44 (1986): 319
[109] Marina Weilguni, "Streets, Spaces and Places: Three Pompeiian Movement Axes Analysed." PhD diss., Institutionen för arkeologi och antik historia, (2011): 23-26
[110] Ibid., 23-26

easier to demarcate, due to their continuous border, and in the case of the triangular piazzetta, it is clearly defined by the large western wall, the southern opening to the taberna, and the curbstones along the eastern, open end. This medium sized piazzetta is clearly the focal point within Intersection B, dominating the intersection physically, and visually attracting attention. (Figure 46)

Subtle adjustments and strategic placement of objects in intersections and along the approach to intersections seek to attract travelers' attention. This can be done to highlight a wealthy residence, increasing the owner's status in society, to bring attention to public propaganda and to help pedestrians efficiently navigate congested spaces. While not as overt as larger physical elements, and typically requiring more nuance to understand, they still prove to be effective means of programming movement.

Figure 46 - Photogrammetric model of Intersection B showing approach from the east, looking west. Due to the obtuse angle of the intersection the southwest corner dominates physically and visually. The two openings in the taberna on the southeast corner also provides visual access of the large wall that was used for propaganda and local graffiti. 1) The brick pier that discourages pedestrians from traveling down the east side of Vicolo del Lupanare, instead pushing them towards the piazetta. 2) The ramp across Vicolo del Lupanare encourages crossing to the

western side. 3) Stepping-stones allow crossing to the south to avoid the bottleneck directly to the west. (Click to access model)

3.B.iv Adjacent Structures

Structures situated in or near intersections influence programs of movement, take advantage of crowds, and grant places for respite and congregation. Many of the structures associated with intersections provide goods, such as taberna and bakeries, increasing the number of people frequenting these spaces on a regular basis.[111] Intersections are also the primary location of bath complexes, temples, and commemorative arches.[112]

The Arch of Caligula straddles Via di Mercurio as one enters the intersection from the north, and while visually striking, the disruption caused by its footprint creates a bottleneck for both vehicular and pedestrian traffic. The piers of the arch project into both sidewalks, decreasing the width by fifty percent, forcing pedestrians to pass in a singular fashion. A similar fate awaits vehicular traffic, Via Mercurio permits two-way traffic, but the width of the arch permits only one vehicle to pass. (Figure 47) Vehicular traffic on Via Mercurio is predominantly southbound leading to the intersection, which helps alleviate some of the congestion at the arch, but there still is the dilemma of two-wide traffic reducing to one in an orderly fashion. This ultimately slows down traffic as people and vehicles deal with navigating the situation, which may be intentional to force people to take notice of their surroundings, in particular of the Temple of Fortuna Augustus on the southeastern corner.

[111] Ray Laurence, "City Traffic and the Archaeology of Roman Streets from Pompeii to Rome. The Nature of Traffic in the Ancient City." (2008): 87-106.
[112] 60% of bath complexes are at intersections and all 2 arches that are not delineating entrances to the forum are at intersections, and if the forum is considered an intersection, which it easily could be, then all monumental arches are either at intersections or entrances.

Figure 47 - Image-based model of Intersection G with a horizontal section through the Arch of Caligula, highlighting the severe bottleneck to pedestrian and vehicular traffic caused by the piers of the arch..

In order to control this congestion, there are efforts made to discourage pedestrian traffic from entering or crossing Via di Mercurio upon reaching the intersection. A fountain blocks pedestrian movement on the eastern sidewalk and there are no stepping-stones across the northern branch. Furthermore, the western and eastern intersections are equipped with stepping-stones that are conducive to pedestrian crossing, due to their proximity to adjacent sidewalks, the width of the individual stones, and the decreased height of the curbstones. The eastern crossing consists of four stepping-stones that are virtually in line with the northeastern sidewalk and are readily accessible for traffic traveling both north and south. Comparatively, in the western crossing, where the width of the road decreases by a little more than a meter (5.28 to 4.23), three stepping-stones are more than adequate to provide comfortable two-way crossing. Furthermore, by lowering the elevation of the curbstones to match with the height of the stepping-stones, a seamless transition from sidewalk to stepping-stone is possible. The physical layout of the northern section of the intersection along with the eastern and western crossing exhibit a desire to prevent pedestrians from entering the roadway, while at the same time encouraging a north to south crossing, with the intent to funnel pedestrian traffic along Via del Foro, through the small marketplace, and finally into the forum.

The Temple of Fortuna Augusta, erected in the early 1st c. CE and paid for by the duumvir Marcus Tullius, dominates the entrance into a pedestrian zone in the southern branch and assists in setting the program for traffic at this juncture. One major contribution the Temple of Fortuna Augusta makes to the overall program relates directly to the temple's alignment. Running parallel to Via del Foro, the temple's entrance projects into the street, the majority of the stairs and associated landing situated entirely in the roadway. The projecting platform, upon which the altar presides, and the double set of steps leading to this platform function are key elements to the temple's impact on circulation at the northern entrance. They provide a place for pedestrians to congregate or rest away from the congestion along the roadway, and their orientation directly influences traffic entering the space. (Figure 48)

Figure 48 - Image-based model of the steps leading to the Temple of Fortuna Augusta that functioned as places for pedestrians to rest adjacent to the large vehicular free zone in the southern branch of intersection G.

The placement of the platform for the altar in public space makes the Temple Fortuna Augusta unique in that regard, and also contributes to an increase in activity by creating a public place of worship for cult followers.[113] There are further attempts at this location to delineate this space from the greater public space, in particular the erection of an iron fence around the perimeter of the platform, which further protected worshippers from the busy street activity. Two gates in the fence, one associated with each set of steps, allow access to the altar. Such an intrusion upon public space almost certainly necessitated a corporation between the benefactor and the administration.[114] Furthermore, limiting the fencing to the altar platform essentially creates two separate spaces, one for worshippers to participate in the rituals associated with the Temple of Fortuna Augusta, and another accessible to the entirety of the population to congregate and rest. The two sets of steps are further delineated by narrowing stones at the two corners facing the street, which also helped prevent traffic from entering into the space.

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[113] William Van Andringa, "5.“M. Tullius… aedem Fortunae August (ae) solo et peq (unia) sua”." *Private foundation and public cult in a Roman colony, in Public and private in Ancient Mediterranean law and religion,* eds. Clifford Ando and Jorg Rupke (Berlin: De Gruyter, 2015): 103-104.
[114] Ibid., 104

Besides creating a highly demarcated space providing pedestrians relief from the crowded street, the alignment of the Temple of Fortuna Augusta also influences navigational decisions upon entering the space. The decision to extend the altar platform and set of steps entirely into the roadway significantly narrows the roadway at the entrance to the space, creating a slight bottleneck, slowing traffic upon entrance. However, the platform's perpendicular extension from Via della Fortuna, and the slightly obtuse angle of the eastern edge of Via del Foro result in a widening of the road directly south of the altar platform. Immediately south of the steps, concurrent with the widening of Via del Foro, there is a small ramp leading to the colonnaded sidewalk that runs along the entire length of the eastern sidewalk. This pedestrian entrance is further delineated by a series of large, vertical narrowing stones that are flush against each other and essentially form a small wall around the northern corner of the colonnade. The southern section of the colonnade mirrors this composition, consisting of another ramp leading to the roadway and a set of vertical narrowing stones around the corner. There is also evidence that each of the compound piers possessed a similar series of vertical narrowing stones, further demarcating this space, and discouraging pedestrians from randomly entering the street. Instead, there is a concerted effort to delineate this space in an attempt to program movement into and along the sidewalk that is fronted by a number of shops that one can frequent. Furthermore, the space between the ramps contains a high frequency of hitching holes, nine along a 32.5 meters length (1 less than every 4 meters), indicative of a highly active street, including multiple animals. Therefore, avoiding this congested, and possibly dangerous, area may have been a concern of the administration, meriting the construction of the colonnade.

The lack of stepping-stones spanning the intersection's southern portion is indicative of a more open space lacking strict rules for traffic, particularly wheeled traffic, and instead functions as an open space, more appropriate for congregating, shopping, and observing festivities. The architectural elements in the southwestern corner and along the subsequent sidewalk support this theory. The Forum Baths on the southeastern corner and its adjacent shops along the south and western sidewalks add to the already high number of shops on the eastern sidewalk. The presence of a large bench fronting the northern side of the Forum Baths is further indication that civic intervention at this location aims towards creating a dynamic space catering to a high degree of pedestrian activity. So much so that the local government deemed necessary the construction of the rare public bench, providing the populace with a place to rest and converse, conveniently placed in nearly constant full shade, providing respite on sunny days. In fact, this bench is one of only two benches in the entirety of Pompeii that connect to civic buildings, emphasizing this area's energetic quality.[115]

It is clear that the southern portion of intersection G is designed to create an open space catering to a high degree of activity relating to various functions including religious rituals, commercial interests, and social congregations. Furthermore, this space provides direct access to the forum, and therefore, also is responsible for the efficient flow of pedestrian traffic, while concurrently furnishing the general populace prone to linger, with adequate accommodations. The ability to use architectural elements to create dynamic spaces that effectively satisfy the needs of a diverse community, with diverse needs, is once again highlighted in this area.

[115] Jeremy Hartnett, "Si quis hic sederit: streetside benches and urban society in Pompeii." *American Journal of Archaeology* (2008): 104

3.C Comparative Study: Herculaneum Intersections

Pompeii's neighbor Herculaneum, while possessing a comparatively diminutive urban environment, provides an ideal site to investigate how techniques used to analyze Pompeian intersections are applied to other Roman towns in southern Italy. The proximity to Pompeii means that the builders of Herculaneum had access to similar building materials, and therefore a similar design for the roads and sidewalks is apparent. There appears to be less rigid traffic guidelines in Herculaneum, with far fewer precautions preventing pedestrian access to certain streets, however it is still relatively clear that certain precautions are taken to ensure safe and efficient pedestrian movement. Fewer physical deterrents appear along the sidewalks and curbstones are typically much lower comparatively, perhaps allowing for a freer program of movement. However, the following two intersections display some ways by which the administration can influence pedestrian movement.

3.C.i Intersection 1: Cardo IV and Decumanus Inferior

Intersection 1 consists of one of three cardos traversing the city from north to south and the lower decumanus, known as Decumanus Inferior. The House of the Wooden Partition and the Samnite House occupying the eastern and western corners respectively are indicative of the wealthy homes that dominate Herculaneum's urban landscape. The Central Baths consume the northern corner, while the southwest corner contains a discreet shop and small apartment. The roadways are constructed in an identical manner to those in Pompeii, using large lava stone pavers and curbstones, but the absence of stepping-stones contrasts strikingly with Pompeian intersections, the stepping-stone.

Herculaneum's less commercially centric character, generally viewed as more of a wealthy resort town, may be a major reason for the lack of stepping-stones, something so crucial to efficient traffic flow in Pompeii, particularly vehicular.[116] However, as noted in examining Pompeian intersections, stepping-stones also play a key role in pedestrian movement, and facilitate successful navigation of spaces, explicitly intersections. Perhaps, a lack of stepping-stones is indicative of less wheeled traffic, negating the need for an extensive traffic system, such as the one present in Pompeii. The shortage of stepping-stones may also be a result of less water running through the streets on a regular basis. Pompeian streets, due to the city's extreme slope from north to south can run like rivers during a rainstorm, whereas Herculaneum does not have such a steep pitch. However, even if the topography of Herculaneum lessened the degree of rushing water during rainstorms, there most certainly still was water runoff from fountains and waste water in the streets. Further evidence for a decrease in wheeled traffic is the smaller size of curbstones, which lack the height of their Pompeian counterparts. The need may not be as great to discourage pedestrians from entering the street, because there is significantly less danger from wheeled traffic. This theory of less restricted pedestrian traffic is supported by the lack of a sidewalk along the eastern end of the southern branch. Therefore, pedestrians either solely used the western sidewalk at this location, and then crossed east, or they utilized the roadway when traveling along the easterly route.

The significant wear on some of the curbstones at the intersection provides some clues as to how pedestrians navigated this intersection, or at the very least, what the preferred paths are. Elimination of the sidewalk on the eastern end of the southern branch encourages pedestrians to travel along the western sidewalk, and then, if desired, cross to the east at the intersection.

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[116] C. Bisel, "The human skeletons of Herculaneum." *International Journal of Anthropology* 6, no.1 (1991): 2.

Substantial wear on the corner stone that faces a set of steps adjacent to the Samnite House illustrates a higher degree of usage at this juncture, most likely caused by crossing from the eastern side to the western, perhaps to attend to business at the Samnite House. Two large benches flanking the entrance to the Samnite House indicate that its owner had a fair number of clients. Furthermore, a large brick pier abuts the steps on their southern side, thereby blocking the steps visually if approaching along the eastern side, perhaps further encouraging an approach from the western sidewalk. Considerable wear on curbstones in the western branch suggest a high degree of crossing at this juncture, especially when compared with the significantly lesser wear observed on curbstones in the eastern and northern branches. Therefore, it appears as if a notable amount of pedestrian traffic at this intersection is funneling towards one of the two wealthy homes occupying the northwest and southeast corners. Furthermore, the facades of the buildings occupying the northeast and southwest corners are completely closed off at the intersection, which may discourage pedestrian traffic.[117]

Despite the lack of stepping-stones and larger physical indicators, we are still able to witness an attempt at directing pedestrian traffic, as well as discern a certain degree of programmed movement throughout the space, with particular focus on the wealthy homes. This is especially noticeable when observing the Samnite House and the efforts made to delineate this home from the roadway. Approaching along the southern branch we notice two things that assist in drawing attention to and demarcating the property. The first of which is the widening of the roadway visually drawing attention to the southern facade of the residence. The removal of the sidewalk concurrent with the widening of the road, kinesthetically alerts pedestrians, and forces them to acknowledge their surroundings, particularly the southern facade of the Samnite House,

[117] Weilguni, *Streets, Spaces and Places*, 27-31.

which has abruptly impacted their course of travel. The aforementioned brick pier brings further attention to the home by forcing vehicle traffic to move away from the home, creating a small pedestrian zone along the southern facade of the home, where a bench conveniently awaits travelers along the southern facade. Elevated stones in each corner of the intersection, something not traditionally seen at Pompeian intersections, further assist in programming pedestrian traffic by discouraging crossing the street diagonally. Placing an elevated stone precisely at each corner making entering the intersection on the diagonal much more challenging than simply crossing perpendicularly, therein impelling pedestrians, irrespective of final destination, to at the very least acknowledge the wealthy homes. Finally, the curbstones defining the facades of these homes are higher and more substantial than the other curbstones throughout the intersection, which again helps to enhance the overall physical and visual presence of these two households. (Figure 49)

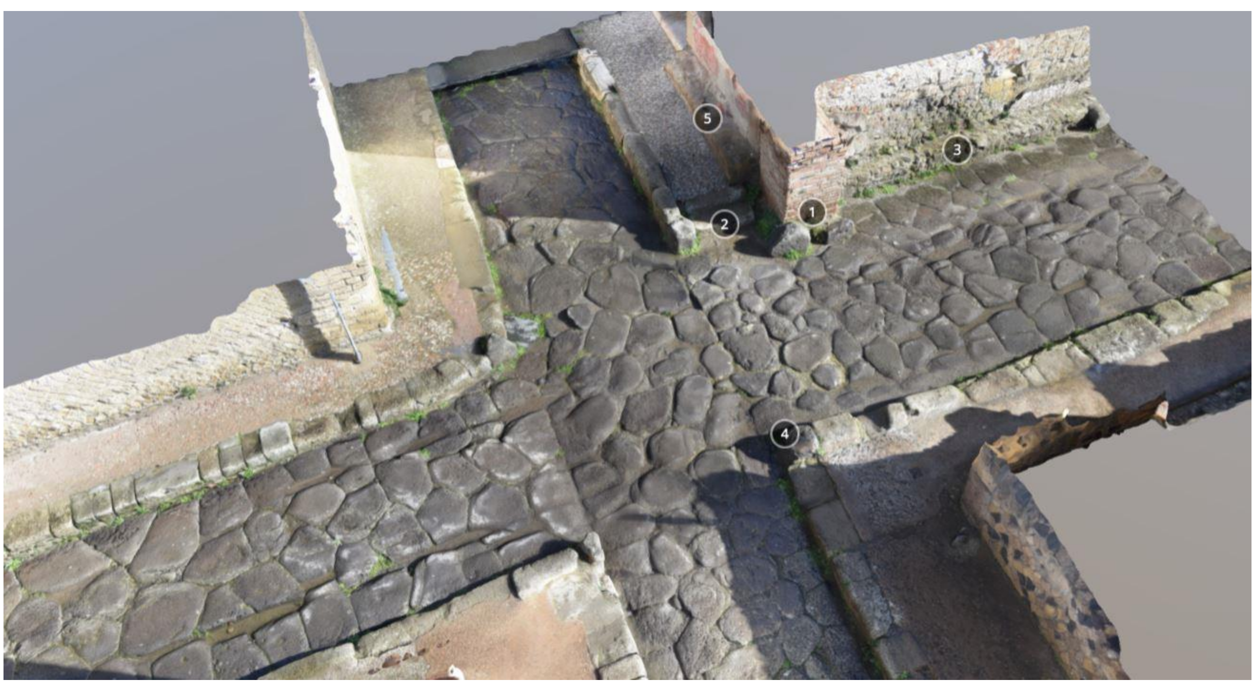


Figure 49 - Image-based model of the intersection of Cardo IV and the Decumanus Inferior in Herculaneum. 1) Brick pier that helps delineate the steps leading to the Samnite House. 2) The steps leading to the Samnite House. 3) The bench along the western facade of the Samnite House along with the adjacent vehicle free zone. 4) Areas of

significant wear on both curbstone in the southern corner of the intersection, indicating increased usage. 5) One of the two benches that flanked that main entrance to the Samnite House. Click to go inside the model.

Initially the absence of stepping-stones at this location may present a challenge to understanding how pedestrian traffic is programmed in order to provide efficient passage. However, it becomes clear that attempts are being made at influencing the ways in which pedestrians move through this space, particularly with regards to the large wealthy homes occupying the northwest and southeast corners. It strengthens the argument that highly visible signage, or overtly obstructive physical impediments are not necessary in order to influence the paths upon which pedestrians choose to navigate an intersection. It also illustrates the ability of this process of intersection analysis via photogrammetrically produced models is viable in cities besides Pompeii, especially those that lack some of the more obvious traffic control elements, such as stepping-stones.

3.C.ii Intersection 2: Cardo V and Decumanus Inferior

Turning our attention to a second intersection at Herculaneum, that of the Decumanus Inferior and Cardo V, it again is apparent that vehicular traffic is not a major concern. The lack of stepping-stones in the previous intersection highlighted the apparent indifference towards vehicular traffic, a trend that continues here, but another element, commonly seen in Pompeian streets, is absent here as well, narrowing stones. Narrowing stones dot the urban landscape of Pompeii and are typically deployed as a means to either manipulate vehicular traffic or prevent damage to property or injuries to people. Therefore, the apparent absence of narrowing stones in Herculaneum supports the theory that the amount of vehicular traffic in Herculaneum is far less than that of Pompeii, so much so that necessary means taken in Pompeii to protect property and citizens is unnecessary.

At Intersection 2 there is a particular interesting example highlighting the lack of necessity for narrowing stones. Located on the northwest corner of the intersection is a water fountain, quite similar to those found in Pompeii, albeit from a different, more expensive white limestone, but there are a couple of peculiarities. The placement of this particular fountain is interesting, because while all of the water fountains found in Pompeii run perpendicular to the sidewalk, forcing approximately half of the fountain into the roadway, this fountain, as do many of the others in Herculaneum, runs parallel to the street. While this may not seem significant at first, it is because the reason for a parallel fountain may be due to the narrowness of the road, which is considerably less than most roadways in Pompeii. A narrow street is less accommodating to a high volume of wheeled traffic, the width of this road already prevents two-way traffic. The addition of a water fountain further restricts the road at this juncture, and if the fountain is placed perpendicularly, as is conventional practice in Pompeii, it would severely limit any sort of access to wheeled transportation. Therefore, the decision was made to position the fountain parallel to the street providing enough of an expanse for a single lane of wheeled traffic. It is clear though through the slender width of the street and the absence of narrowing stones to protect both the fountain and the people using it that vehicular traffic is not as prevalent in Herculaneum as it is in Pompeii, which makes pedestrian navigation slightly easier.

However, it is still possible to discern some navigational patterns by analyzing the intersection's architectural composition. There is evidence of navigational management found in the northeast corner of the intersection, where a large volcanic stone is situated in conjunction with the termination of the sidewalk along the northern end of the eastern branch. This stone functions both as a means to deter any vehicular traffic from encroaching upon the sidewalk, as well as discourage pedestrians from entering the street. Further elements exist that tend to highlight an attempt to funnel pedestrians to the southern sidewalk and limit crossing at the northern intersection. There is a step directly in front of the bakery of Patulcius Felix inviting effortless access to the southern sidewalk, and slightly further to the west there is a cutout on a curbstone that projects slightly into the sidewalk, again encouraging entering the sidewalk prior to the intersection. Accompanying these two points of entry is an increased elevation of the curbstones, clearly visible in a section of the curbstones along the southern sidewalk, created by adding an additional layer of lava stone to the existing *opus incertum* foundation. This elevation begins just east of the intersection to both match the height of the curbstones to the west, and it makes entering the street at this point more difficult. This is indicative of a preferred flow of traffic across the intersection along the southern portion, as opposed to crossing the street at the northern juncture. The majority of the activity at this intersection occurs along the southern portion, which is why attempts are being made to channel traffic in that direction, instead of traveling along the northern sidewalk. The northwest corner is also completely closed off to the intersection with no homes or shops opening onto it, which may be why there is little access to the sidewalk, and most navigational aids tend to steer people towards the southern sidewalk.

It would appear then that Herculaneum in general is more walker friendly than Pompeii with a high frequency of areas of ingress that communicate between the sidewalks and the street, some of them quite impressive stairways leading to elevated sidewalks, covered with elaborate awnings, and arcades. However, it is apparent that efforts were still made to efficiently navigate pedestrian traffic through intersections with specific destinations in mind, despite the lack of vehicular traffic that impinges upon movement in Pompeii. Whereas in Pompeii there is more attention being applied to safe passage of pedestrians and effective movement of supplies and goods via wheeled transport, in Herculaneum there appears to be a slightly more relaxed approach to pedestrian traffic, while still ensuring access to wheeled transport.

3.D Conclusion

While the seven intersections selected for this study represent only a small portion of Pompeian intersections, the representational experiments with photogrammetry make it clear that regardless of size, location, and functionality, a certain degree of planning is present in each. This is done in an attempt to provide efficient passage through or into these spaces. Furthermore, at times an effort is taken to program movements through the space in order to highlight certain elements, while at the same time alleviating congestion, and avoiding bottlenecking. It is clear that one of the major components assisting with programmed movement are the stepping-stones, which appear in each of the case studies, and play a significant role in movement management. They are the most substantial and consistent object throughout the Pompeian urban environment in regard to traffic, both vehicular and pedestrian, and as illustrated throughout this study, their placement, scale, and number all impact how a pedestrian navigates an intersection in the most effective manner.

However, in Roman towns and cities that lack stepping-stones, such as Herculaneum, there are other elements that encourage specific movements, and assist in efficient navigation. For example, increasing the elevation of a series of curbstones makes accessing the roadway at that juncture more challenging, and consequently limits the amount of pedestrian entering the street. Conversely, lowering curbstones' height presents a location where entering the street is deemed safer, and therefore pedestrians entering the street is encouraged, perhaps in an attempt to alleviate congestion at a nearby location. There are also several instances of intentional sidewalk widening concurrent with areas and objects conducive to crowd gathering, such as water fountains, tabernae and shops, allowing for larger crowds to gather. Furthermore, objects are present that, while not providing any tangible service or commodity, impact movement along certain axes. These come in the form of water towers, archways, colonnades, etc., and steps are taken to alleviate the amount of negative impact, such as bottlenecking, that these items have on pedestrian movement.

It is apparent that the administration in Roman towns and cities was not only concerned with designing systematic routes for vehicular traffic, but there was also a concerted effort to dictate pedestrian movement through carefully orchestrated decisions. Many of these conventions are witnessed in the various intersections highlighted in this study and are reiterated across the various spaces. For example, there is a consistent emphasis on walking on the right side, a designation that is pivotal to traffic management, because it makes avoiding issues such as bottlenecking and congestion easier to avoid.[118] Furthermore, there tends to be a strong preference to encourage crossing the street prior to reaching the intersection, again in an effort to create as little unnecessary congestion in these spaces, especially when heavy vehicular traffic is present. By placing easily accessible crossing stones 30 - 40 m prior to entering an intersection, and then immediately elevating the height of the curbstones, crossing at this location is encouraged. There is also a good deal of evidence suggesting that during the design process consideration is given to some of the adjacent structures, and numerous instances suggest routes of travel that highlight specific buildings and spaces that flank intersections, such as wealthy homes, tabernae, and shrines. At times this even appears to have been at the behest of the wealthy homeowner, or taberna's proprietor. Aside from buildings that help define an intersection, certain elements such as water towers and fountains, and small piazzettas are

[118] Poehler, *Organization of Pompeii's System,* 96

consistently semi-delineated, creating spaces where their occupants feel a certain sense of ownership and security. There are other intersections that possess more unique design elements, especially ones associated with large monumental structures, such as intersections D and G (Via Stabiana and Via dell'Abbondanza, and Via della Fortuna, Via delle Terme, Via di Mercurio and Via del Foro respectively). However, even in more unique circumstances such as these, the administration's prerogative is discernible through the architectural layout of the intersection.

These individual objects and spaces coalesce to form systems of movement across and into intersections that efficiently guide travelers to their final destination. Furthermore, they do not operate in isolation, but instead, often channel traffic with respect to upcoming buildings and intersections, and in this way form an urban network catering to a diverse group of users. Understanding the nuances of such a network of spaces is an ideal area for future study regarding Pompeian intersections, and one that will only further enrich our understanding of the Pompeian urban environment. It is clear from the analysis of these seven junctions that their architectural layout informs the degree to which the administration went to ensure intersections' functional practicality, while at the same time occasionally allowing slight deviations to enhance the surrounding spaces and structures.

4. Conclusion and Future Research

After producing image-based models of nine intersections in Pompeii and Herculaneum, and then employing them as analytical tools, safe and efficient pedestrian movement through crossroads was a key factor when designing these spaces. Furthermore, the layout and composition of intersections also promoted certain visual preferences and movement programs to both highlight adjacent structures, as well as create distinct spaces that pedestrians can comfortably occupy in order to accomplish specific tasks. This final chapter discusses the success of the models as analytical tools and suggests both technical and methodological areas for improvement, dealing both with image capture and processing. At the end there is a brief discussion concerning why more work in this area is necessary and possible future avenues for research on this subject.

4.A Findings Analysis

After analyzing seven Pompeian intersections it is clear that attempts were made to influence pedestrian movement into and through intersections in the most efficient manner possible. Many of these efforts came at the behest of the municipality, while others developed more organically as the urban fabric around areas evolved over time. There also may have been efforts at certain locations to influence the views and movements of visitors, as local businesses, residents and billboards vied for attention. Techniques for controlling and manipulating movement ranged from overtly physical elements, such as elevating curbstones, preventing free access to the streets, to more subtle maneuvers, pushing stepping-stones back into the branch of an intersection, visually removing them from certain travelers. It is not only movement that is impacted by the architectural layout of intersections, but there is also attention put towards creating spaces within intersections that pedestrians can comfortably occupy, many times in association with objects such as water fountains or taberna that frequently have crowds. Crowding also occurs in intersections containing graffiti announcing political ambitions and propaganda as well as those that entertained residents during festivals and celebrations, such as the Lares Compitales.[119]

Efforts are also made to begin controlling movement well before one enters an intersection, which makes it easier to program movement through these congested spaces. Persuading travelers to prefer a certain side of the street or discouraging them to enter into the roadway prior to entering an intersection allows for more efficient movement upon entering the intersection, because design choices are made with knowledge that the majority of people entering a space are doing so from a certain direction or in a certain manner. Programming movement prior to an intersection allows for implements to be put in place that can further manipulate this movement and allow someone to continue their journey or reach their desired location.

Furthermore, controlled programming of movement tends to be more aggressively undertaken at larger more congested intersections than at smaller intersections. This is evident at intersections B and C, which are both large intersections containing two major roads in Pompeii.

[119] On political graffiti at intersections see Franklin, *"Games and a Lupanar"*, 319 and for intersections hosting the Lares Compitales festival see Lott, *The Neighborhoods of Augustan*, 14.

Conspicuous efforts exist at both intersections that drastically impact pedestrian movement. The scale of such interventions implies they were almost certainly initiatives enacted by the local government. Blocking entire sidewalks and adding additional curbstones along a lengthy stretch of roadway would require the approval and most likely funding by the administration to accomplish such feats. Larger intersections such as B and C necessitate more controlled pedestrian traffic due to the large amount of vehicular traffic crossing these intersections, maximizing efficiency of traffic movement and avoiding unwanted congestion.

Conversely, at smaller intersections there tends to be less of a comprehensive design strategy and more of a piecemeal approach. This is not to say that smaller intersections lacked planning entirely, but rather that in these spaces there is a tendency to avoid top-down interventions and instead allow free movement with limited effort to control users' actions. For example, intersection B has awkwardly placed stepping-stones in the middle of the intersection that only accommodate one user at a time and the addition of a Lares shrine in the southeast corner that substantially impedes upon pedestrian traffic. Elements of this sort may lead to a sort of bottleneck effect, but due to the fact that Vicolo del Lupanare had little vehicular traffic, pedestrians are more apt to use the roadway to avoid congestion. There is evidence of modifications to the traffic system that resulted in more one-way roads, as well as complete blockage of wheeled traffic, despite the fact that there would have been a surge in heavy vehicles following the earthquake in 62 CE.[120] Considering the immense need for materials to repair damaged properties it may be surprising that the government would choose to limit areas of passage for the vehicles supplying those materials, but it does illustrate the priority placed on

[120] Poehler, *The Organization of Pompeii's*, 69-72

pedestrian safety. Blocking wheeled traffic to certain streets provides pedestrians safe passage along roads void of vehicular traffic.

4.B Methodology Evaluation

Central to this study was the development of photorealistic 3D models that allowed for a more robust analysis of Pompeian intersections and for the development of methods allowing for rapid application to other sites. In the following section the two methods created for this study are reviewed, discussing their effectiveness and identifying areas of improvement. The 3D model process will be analyzed first, followed by a brief review of how intersections and their architectural elements can be more thoroughly interrogated to provide a deeper understanding of how these spaces are perceived.

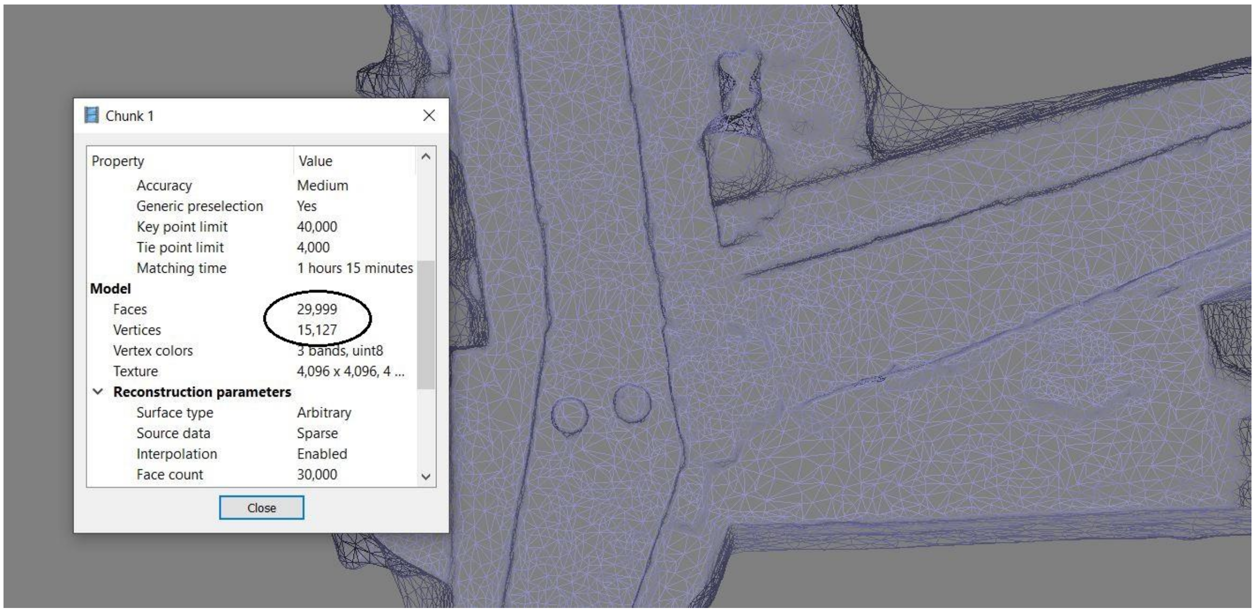
4.B.i Photorealistic Model Process

The process for producing photorealistic models proved to be efficient and the resulting models served as effective analytical tools that enhanced the understanding of Pompeian intersections. The snaking method for photo capture (as seen in figure 4) led to the most comprehensive models, including the roadways, sidewalks and facades, while the method focusing solely on capturing the roadway created highly detailed models where individual elements are easily identifiable.(as seen in figure 3) Models generated using the snaking method allow for greater analysis concerning relationships between peripheral objects, such as adjacent structures and larger monuments, i.e. water towers, arches, colonnades, etc. However, those models focusing solely on the roadway and sidewalk only provide a means to analyze the minutiae of particular elements, such as the angle and position of stepping-stones and wear on curbstones and stepping-stones. These two methods are the most widely used in this study and provide the best series of photos for model production. Image-based models such as these allow for manipulation of these spaces that is otherwise not possible, such as sectioning solid stone elements or walls, accessing views unattainable in person, analyzing the spaces under different conditions, i.e. time of day/year and specific weather conditions, and the ability to rapidly compare intersections.

Improvements exist in the production process that could lead to models that both contain a higher level of detail, as well as function as better analytical tools. Overall, processing is constrained to a certain extent because of equipment, mainly a laptop's processing speed. It proved challenging to process some of the larger collection of photos in an expedient manner due to technological limitations. The biggest challenge proved to be generating meshes using dense clouds as opposed to the sparse clouds that are initially created by Agisoft, many times causing the software to crash due to lack of memory. This issue could be remedied through access to a high speed computer cluster, which would allow for much faster processing speeds as well as more detailed models by using the dense point cloud for mesh production.[121] Using the dense cloud for mesh production generates models that are more accurate and detailed due to the much higher face count of the resulting meshes. (Figure 50) This by far is the greatest area of improvement for the production of the photorealistic models. Meshing a model using the dense cloud as opposed to a sparse crowd leads to meshes that have fewer holes or errors and possess greater detail once textured with the photos. However, your average laptop does not possess the

[121] For examples of the advantages of High Speed Computer Clusters see, Guangchen Ruan, Guangchen, Eric Wernert, Tassie Gniady, Esen Tuna, and William Sherman. "High Performance Photogrammetry for Academic Research." In *Proceedings of the Practice and Experience on Advanced Research Computing*, pp. 1-8. 2018, and V. N. Adrov, M. A. Drakin, and A. Yu Sechin. "High Performance photogrammetric processing on computer clusters." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 39 (2012): B4.

RAM necessary to generate such large point clouds and the subsequent meshes, which is why accessing a computer cluster is paramount to producing better models.



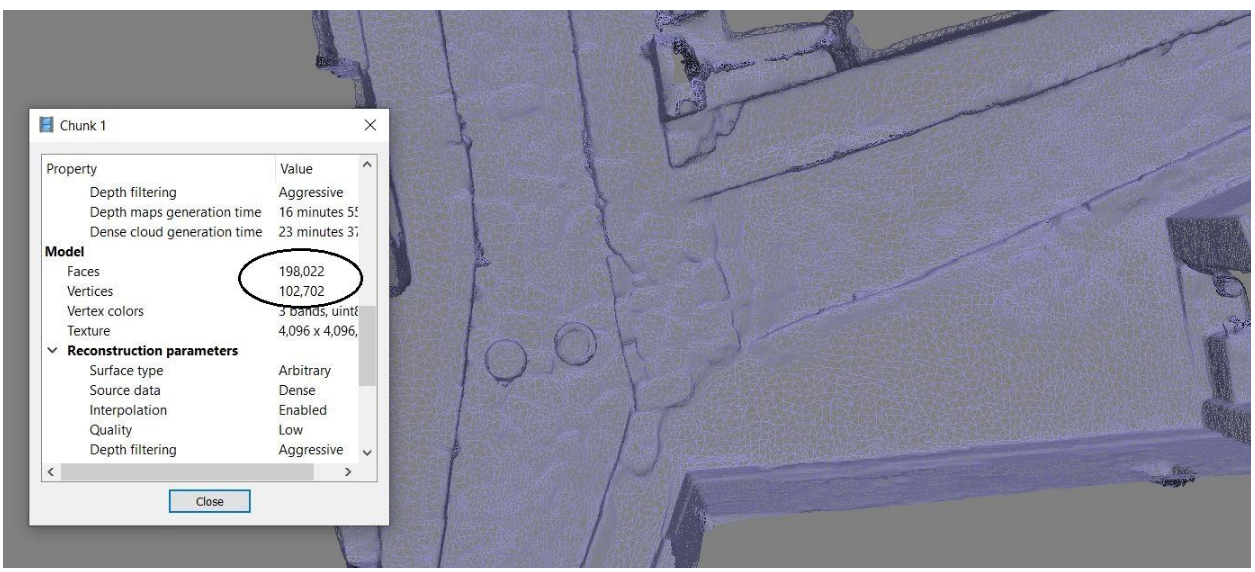


Figure 50 - Top image shows mesh generation using sparse cloud with a max total face count of 29,999, while the bottom image shows the same mesh production using the dense cloud, achieving a max face count of 198,022. You can notice the greater detail in the dense cloud mesh as well, particularly on the surface of the road.

However, in general the methodology established for rapid and accurate production of photorealistic models of ancient Pompeian intersections was successful. Inherent in the models are certain qualities that enhance our ability to understand these spaces and this methodology can easily be employed in a variety of instances without needing to obtain expensive equipment or extensive permissions. They grant a user the ability to achieve new vantage points, section large objects such as curbstones and stepping-stones on multiple planes, present information in a more interactive manner and provide a means for continued study away from the field in a more controlled environment. As noted throughout the research, the models enhance research possibilities beyond what can be accomplished on site, such as providing the ability to achieve high resolution aerial views which can then expose relationships among elements within an intersection, as well as rapidly compare intersections. They also allow for a detailed study on the sightlines achieved between intersections in order to investigate what sort of communication exists between them. Furthermore, possessing the ability to section these models, removing existing material, provides unprecedented views of both the spaces and individual elements. Finally, they can serve as a vital tool in assisting with the constant efforts of conserving and preserving Roman sites, by providing conservationists with detailed, image-based models that can be used to assist in restoring damaged sites.

4.B.ii Impact of Architectural Elements

The approach to analyzing the case-study intersections is rooted in an architectural survey of these spaces, specifically observing the various elements that are traditionally seen in intersections and the overall composition of these spaces and the surrounding structures. Conducting the research in this manner puts the focus on objects that are somewhat universal throughout the city, allowing for more comparison across all intersections. This is not to say that unique items, such as the Arch of Caligula and the Arch of Marcus Holconius Rufus, are not taken into consideration, but instead of focusing on the significance of the arch in a historical sense, in this study it is simply another object in the intersection that has an impact on movement.

Stepping-stones are one of the key factors in many of these individual intersections, and they revealed the most information when examined as a cooperative unit. Therefore, it became clear that the best way to investigate the stepping-stones is by manipulating the model to provide tight aerial views of the sets of stones that spanned the branches of intersections. Views such as these, which are impossible to achieve without the photorealistic model, allow for slight variations, such as angling of one end of the stones and communication with adjacent sets of stones.[122] It is also possible to examine how visually present certain sets of stepping-stones are as one approaches an intersection from various directions. A more visible set of stones may suggest a greater degree of crossing than ones that are tucked away. The models also allow for individual sets of stepping-stones to be removed from an intersection and overlaid across another set to examine similarities and differences between traits such as spacing, distancing, angle, etc. This can be done for multiple sets and can help establish what sort of uniformity exists to assist in pedestrian movement.

Curbstones are another significant element, one that is also more universal than stepping-stones in Roman towns, and therefore important to systematically analyze them. One issue present throughout this study in regard to curbstones is height and specifically the increase in height as one approaches certain intersections. The models allow for the length of curbstones preceding an intersection to be sectioned, further defining both the increase in height as well as the decrease upon entering to accommodate crossing. Another capability the models provide, which will be a focus of research work, is a detailed study of the wear on curbstones, which perhaps may be able to indicate which direction of travel is more likely across certain stones. It is notable that many curbstones associated with intersections, and more specifically with crossing, show substantial wear.

Sectioning of the models can also be done with a horizontal plane, which allows for the removal of extraneous material that can interfere with interpretations. This method can be particularly insightful when analyzing sidewalks, especially at occurrences of narrowing. By horizontally sectioning the model it becomes much clearer how much of the sidewalk space is eliminated due to certain elements, such as water towers or arches. The section eliminates any

[122] Tools, such as Google Earth, where aerial views are possible do not have near the detail of those obtained using the models.

distortion caused by the vertical aspects of the structures, revealing only the portions that directly impact pedestrian analysis. This can provide a better understanding of the impact these objects have on movement through a space and what sort of accommodations are made to alleviate some of this congestion. (Figure 51)

It is also important in the study of the architectural composition of intersections to investigate the less obvious spaces that may be created, perhaps not intentionally, that can cater to pedestrians. These spaces may be harder to identify because they are typically not well defined physically, but one form of assistance can be to view the models in their untextured format. Similar to how sectioning certain elements such as curbstones, arches and arcades help to remove extraneous parts of the space, allowing for (Figure 52) It is important to identify these spaces because many of them can function as space food pedestrians to congregate that are safe from vehicular traffic. Viewing the model minus the texture can also shed light on certain physical characteristics that may be difficult to recognize when textured. For example when we compare the mesh versus texture model of Intersection B a large wear pattern running along the southern curbstones of the western branch of the intersection is clearly visible in the mesh only model, while is more difficult to identify in the texture model, specifically along the northern edge. Intersection B also reveals smoothed stones along the southern side of the western roadway, due to the significant water flow along this route. The mesh only models emphasize the physicality of the surfaces, which can then lead to surface qualities that may be overlooked after the model is textured.

Figure 51 - Top image: Intersection C aerial view with no horizontal section. Bottom Image: Intersection C aerial view with horizontal section highlighting that by eliminating some of the vertical noise via the section, it becomes easier to analyze the sidewalk space and the encroachment upon it that certain elements have. It becomes much clearer how much of the sidewalk is actually impacted by the piers of the arcaded when it is sectioned on a horizontal plane.

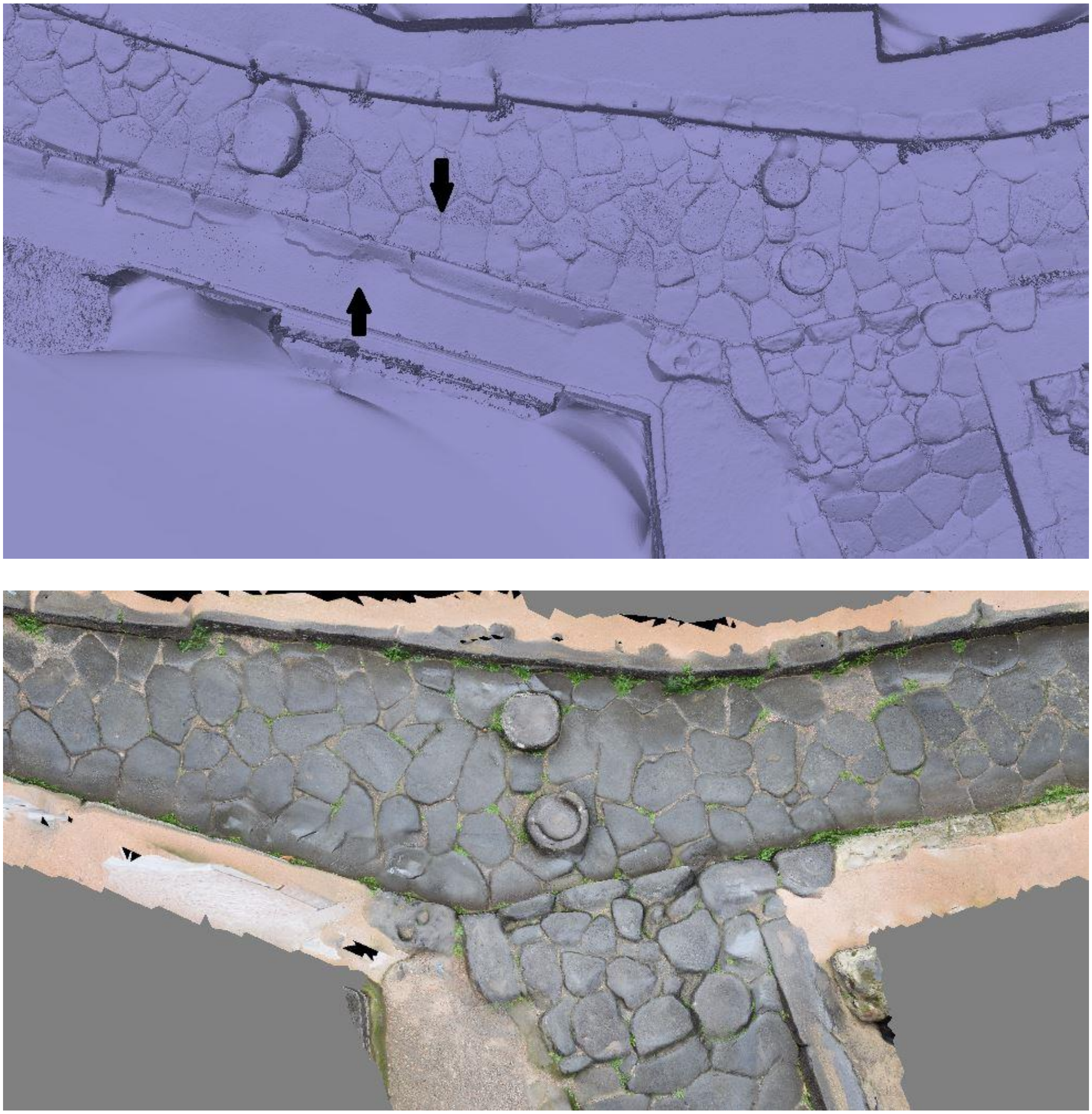


Figure 52 - Top: Photogrammetrically produced mesh model of intersection B, with two sections of wear indicated. Bottom: Image-based model of Intersection B, textured view where the sections of wear are not nearly as conspicuous.

The method developed during this study attempts to study intersections both on the micro and macro scale. Small individual elements and characteristics can reveal information pertaining to the desired direction of crossing, side of the road that is preferred, points for ingress and egress into the roadway. Aside from the physical aspects, they can also identify attempts to persuade the gaze of a pedestrian to manipulate their movement. Observing all these individual elements as a whole can help us understand the suggested program of movement.

4.C Future Research

The amount of information uncovered by studying a small sampling of Pompeian intersections merits future work on this topic. Paramount to further research is a more expansive analysis of intersections, both at a micro and macro level. Previous studies, particularly ones focusing on Pompeii, reveal that comprehensive studies of individual objects and spaces found regularly in the urban environment, greatly increase our understanding of ancient urban life. Stepping-stones and curbstones, benches, doorways and graffiti, and bars are just a few of the examples of such objects that have proven effective in generating theories on both the urban fabric of Pompeii, as well as pedestrians' perception of spaces.[123] Therefore, a similar investigation pertaining to Pompeian intersections has the capability of yielding similar results and warrants further study.

As with the initial case-study intersections, the first step in a more comprehensive analysis is to create photorealistic 3D models of the remaining intersections via the methodology

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[123] On stepping-stones and curbstones see Eric E. Poehler, *The traffic systems of Pompeii*. (Oxford University Press, 2017), on benches see Jeremy Hartnett, "Si quis hic sederit: streetside benches and urban society in Pompeii." *American Journal of Archaeology* (2008): 91-119, on doorways and graffiti see Ray Laurence, *Roman Pompeii: space and society*. (Routledge, 2010), on bars see Steven JR Ellis, "The distribution of bars at Pompeii: archaeological, spatial and viewshed analyses." *Journal of Roman Archaeology* 17 (2004): 371-384.

established in this study. Minor adjustments made to the methodology will allow for a more efficient photo collection process, expediting the most time consuming activity. Processing the models offsite, using computer clusters, will also greatly decrease the amount of time allotted to model production. Enhancements to the model production become possible by using high speed computer clusters, such as dense point clouds, higher face count meshes and high-resolution photo texturing.

Post model production, intersections will be categorized based on a variety of elements, such as size of roads, presence of particular objects, distance from gates, etc.[124] By separating intersections into groups, a focal point of future research will be to investigate the similarities in design among similar intersections. It is clear from the case-studies that certain characteristics are shared among intersections that are similar in scale and form, as well as those that contain similar objects. For example, intersections that possess a water fountain tend to have accommodations allowing for crowds to gather around it more comfortably. These come in the form of widening sidewalks and/or pushing a large percentage of the fountain basin into the street. Furthermore, large intersections traditionally crowded with both vehicular and pedestrian traffic tend to use elevated curbstones in an attempt to reduce the amount of pedestrian traffic entering the street. A comprehensive investigation will hopefully confirm the belief that these accommodations occur on a nearly universal scale, as well as shed light on other characteristics not present in the current study.

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[124] The models can be sized and scaled through a couple of different techniques. One is to place an object such as a meter stick, or you can place a series of marking stickers throughout the space and then take the measurements between them. Once the model has been processed the meter stick or the marking stickers will appear in the model and then either the length of the meter stick or the measurements between the stickers can be used to size and scale the model.

A second phase of research also involves a more thorough study of how intersections cooperate with each other both through visual communication and physical program. After producing photorealistic 3D models of each intersection, it will be possible to observe the relationships between intersections, such as programming pedestrian traffic to certain sides of the road that make traveling between intersections more efficient. Furthermore, by geolocating the intersections it will become possible to see what visual references can be seen between intersections, allowing them to function as visual navigational guides. Due to the lack of signage evident throughout the city, and in the archaeological record, intersections may have functioned as nodes that assisted visitors in moving more effectively throughout the city.[125] They are one of the few spaces, in an otherwise dense urban fabric, that are open enough to contain objects that are visible from a distance.[126] By understanding how intersections communicate and cooperate together it will become possible to see the intent behind the overall traffic scheme in regards to pedestrian movement.

[125] Jeremy Hartnett, *The Roman street: urban life and society in Pompeii, Herculaneum, and Rome*. Cambridge University Press, 2017.
[126] Sam Griffiths and Alexander von Lünen, eds. *Spatial Cultures: Towards a new social morphology of cities past and present*. (Routledge, 2016).

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