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Measuring the Movement Economy: A Network Analysis of Pompeii

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Part III

Economic Life and its Contexts
Measuring the Movement Economy

A Network Analysis of Pompeii

Eric Poehler

Even if our own approach to things is necessarily conditioned by the view that things have no meanings apart from those that human transactions, attributions, and motivations endow them with, the anthropological problem is that this formal truth does not illuminate the concrete, historical circulation of things. For that we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories. It is only through analysis of these trajectories that we can interpret the human transactions and calculations that enliven things. Thus, even though from a theoretical point of view human actors encode things with significance, from a methodological point of view it is the things-in-motion that illuminate their human and social context.1

For a long time I have been enamoured of this quotation from Arjun Appadurai’s The Social Life of Things. In this passage, Appadurai first succinctly articulates and embraces the broader modern notions of meaning-making before denying such theories the power to say anything meaningful about specific objects. At the heart of Appadurai’s argument (a part of a larger argument for commodity theory) is the metaphor of economic exchange—that in the moment of exchange an object’s value is temporarily reified and becomes observable. In transposing the word ‘value’ with ‘meaning’, commodity theory shifts from a tool for examining economic exchange, to a tool for examining social transactions, including deeply socialized economic behaviours.

For just as long, however, I have been challenged by its implications for the field of classical archaeology. It is easy to imagine the great volumes of materials flowing through the streets of Pompeii, and ancient literature helps to add detail to that picture. But how do we answer Appadurai’s challenge and

1 Appadurai (1986: 5).
Figure 6.1 Pompeian street names.
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say anything specific, anything meaningful, about that circulation of material? We must follow the objects in motion, as he says, but the archaeological record is both static and incomplete. What objects we have exist only at their final destination, with rare evidence for their origins and even rarer information on the moment of their exchange. How then, if we cannot work at the level of specificity of the object, can the methodological implications of commodity theory meaningfully be deployed at Pompeii? The way forward may well be to step back to a more general level; to model movement as a wider flow and to compare it with a broader category of objects. To use an analogy: if we cannot observe fish in migration, perhaps we can use the volume, speed, and direction of the ocean currents that carry them as a proxy. The purpose of this chapter is to explore ways to measure that current in the context of a particular Roman city, first by examining previous attempts at modelling movement in Pompeii, then by suggesting a new model of movement—one of many that might be built—and considering what utility it has for understanding the city’s socio-economic landscape.

I will address the final point first, the utility of the model. At its most basic, the purpose of building such a model is to offer a new abstraction of the city to compare with other such abstractions. Consider, for example the famous (or infamous) map by Eschebach of Pompeian property types.\(^2\) Constructed from the identification of property function, and despite its faults, this map is often the first place Pompeianists turn to examine the abstract categories of Pompeii’s social texture, especially its economic landscape. We are also familiar with the standard formulas of how abstractions such as property types are further used to explore the urban environment. Andrew Wallace-Hadrill’s work on residential properties provides one of the best examples.\(^3\) An elite house can be defined by being more than a certain number of square metres in area and containing an atrium and/or a peristyle. These elements provide a metric by which to compare one house with other houses and justify terming such properties as ‘elite’ houses. Similarly, Steven Ellis’ definition of a property as a bar by the existence of a masonry counter, its limited size, and its wide door defines another category of space.\(^4\) Brothels, most confidently identified by the presence of masonry beds in cramped cellae, are a third example.\(^5\) In this act of definition, spaces are (temporarily) reified into abstractions—‘elite house’, the ‘bar’, and ‘brothel’—that can then be plugged into formulas. The operands of these formulas, most often distance (e.g. how far an elite house is from a bar or brothel) create a relationship between the property types in

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\(^2\) Eschebach’s colour-coded map is based on the identifications in Eschebach (1970) and the later elaborations in Eschebach, Eschebach, and Müller-Trollius (1993).

\(^3\) Wallace-Hadrill (1994: 81–7); see also Robinson (1997).


\(^5\) McGinn (2002).
order to find social rules and norms in the output. Building a model of movement in Pompeii produces yet another abstraction to combine with residential and entertainment variables, among others.

More specifically, accurately modeling movement is a step closer to defining some of the economic principles underlying the shape of space in the city. Recent scholarship has fully dismissed Maiuri’s long distrusted image of Pompeii as a city in decline following the great earthquake of AD 62/3.\(^6\) Elites did not flee the city at this time, leaving it to freedmen and the lower classes to invade their former homes and transform them to vulgar commerce. Archaeological research on fullonicae has shown that these businesses were deliberately inserted into atrium-style residences prior to the great earthquake, co-opting the space of the salutatio for a different clientele.\(^7\) More specifically, excavation within tabernae has revealed a consistent sequence and chronology for the shift in the investment strategy of property owners during the Augustan age from household-level fish-processing industry to retail sale of food and drink.\(^8\) In this new image of the Pompeian economy of the imperial period, elites invested in urban property and commerce, adjusting their investment in both to respond to the dwindling of one market and the opening of another, flipping an axis of the urban economy, at least as seen through the lens of property investment, from industry to service. The creation of these bars and their architectural formats demonstrate that, in the first century AD, there was money to be made through high-volume, low-price transactions if one could entice the passer-by to stop and spend some of the small denomination coins from his/her pockets.

From a theoretical perspective, the preceding archaeological interpretation relies on a rather broad and broadly shared underlying principle: that there is a correlation between the number of people moving through a particular area and the economic potential for that area. This is most succinctly put in the real estate mantra ‘location, location, location’. The idea is not new, but it is now fashionable to use Bill Hillier’s more specific term ‘movement economy’. Hillier defines the movement economy as:

\[ \text{[T]he reciprocal effects of space and movement on each other […]}, \text{and the multiplier effects on both that arise from patterns of land use and building densities, which are themselves influenced by the space-movement relation, that give cities their characteristic structures} . . . \] \(^9\)

\(^6\) The most recent challenges to Mauri’s (1942) model have offered a more nuanced model of what was occurring in both residences (Anderson [2011]) and in production spaces (e.g. Kastenmeier [2007] and at Herculaneum, Monteix [2010]) in the final decades of Pompeii’s existence. Wallace-Hadrill’s (1994: 122–31) critique of Maiuri is still a worthy starting point.

\(^7\) Flohr (2011; 2012).

\(^8\) Ellis (2011b, 76–83); Chapter 10 (this volume, PAGES).

Like Appadurai’s quotation, Hillier’s statement is broad and it is hard to operationalize the theory it expresses. Moreover, the reciprocal relationship between space and movement makes it difficult to separate cause and effect. That these forces have ‘multiplier effects’, however, does suggest that we can at least identify areas of greatest or least intensity, where movement and spatial development, particular of an economic variety, combine most clearly to shape the city.

On the space side of the equation, a great deal of work has been done to improve the ever- and over-relied upon Eschebach map of property types. Some of the best work has been done by the contributors to this volume. Pompeian scholars have also made a number of arguments about the reaction of space to movement, largely from the point of view of space, that is, from the inside the building looking out to the street. The identification of purpose-built commercial complexes has been a particularly fruitful area of interest. On the movement side of the equation, however, progress has been limited and, in my opinion, largely unsuccessful. To realize the potential of the movement economy theory (and the metaphor of commodity theory), we must balance this equation and build a more robust method to model movement.

CRITIQUE OF PREVIOUS APPROACHES

In the early 1990s, Pompeian studies were revolutionized by the advent of quantitative and spatial approaches towards the ancient city. Though now thoroughly critiqued, Ray Laurence’s seminal metric of counting the number of doorways along a street and dividing the length of that street by the number of doorways remains one of the most commonly deployed means to measure the intensity of the use of space along the street frontages. To express these data, Laurence divided the city streets into four categories—streets with doorways every 0–5 m, 6–10 m, 11–15 m, and streets with over 15 m between doorways on average—and produced a map for each category (Figure 6.2).
Figure 6.2 Occurrences of doorways at Pompeii. After Laurence (1994: maps 6.1-4). Doorways 0–5 m, black; doorways 6–10 m, dark grey; doorways 11–15 m, light grey; doorways 15+ m, cross-hatching.
These four maps (here combined into one) offered the first quantified expression of the variability of human movement in the city and, for two decades, Laurence’s ‘occurrence of doorways’ method (hereafter, ODM) has rightly been one of the premier abstractions describing potential movement in Pompeii.

There have been, however, many critiques of Laurence’s book in general and with this method specifically. Two issues are relevant to this discussion: (i) the method’s general lack of sensitivity to nuance in the dataset of doorways and (ii) the lack of continuity among those data. The first problem with the ODM approach—its lack of sensitivity—is created by the manner in which the data were calculated and expressed, precluding finer grained interpretation. For example, because the doorway counts from both façades of a street were combined and averaged, the unique histories of each block facing a street are obscured. This mode of calculation obscures the evidence for the movement of people and skews the results in the maps, which are the only data available to the reader. In fact, the maps themselves amplify this problem by dividing the doorway occurrences into only four groups, carving out categories too broad to find the more detailed patterns in the data.

Interestingly, in a single paragraph, Laurence inadvertently highlights both problems of sensitivity (place) and continuity (path) in his method. Two streets leading to gates, Via Marina and Via del Vesuvio (for the location of these streets see Figure 6.1), have doorway spacings between 3.1 m and 5.9 m, placing them in the first division of doorway occurrences, but into the second subset of that division. Laurence argues that mitigating factors skew the data on these two streets and they should be considered as part of the first subset (2.0–3.0 m) along with the other streets connecting to the forum and the major through-routes. On Via Marina, there are only two doors on the south side of the street, while the north side has twenty. The two southern doors, however, open onto the Basilica and the Sanctuary of Venus, two of the largest and most important destinations in all of Pompeii. Laurence rightly reasons that these two doors would have attracted far more people than their number can represent. Embedded within this interpretation, however, is the criticism that the quantification of doors masks the quality of the place that door leads to: place matters.

Similarly, the lower-than-expected doorway density of Via del Vesuvio, despite its connection to both the Porta del Vesuvio and one of the most important crossroads in the city, is a pattern to be explained by the special

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15 For example, Vicolo di Eumachia is placed in the highest category and Vicolo del Labirinto is placed in the third highest category, despite entire blocks of each street having no doors at all. Other streets with no doors, such as the street between Insula I 1 and Insula I 5, are ignored entirely in the mapped data.


17 Laurence (1994: 101–3) attempts to address this issue in a related analysis, breaking doorways into two types to represent shops (wide doors) and domestic space (narrow doors).
circumstances in the area. Because Vicolo dei Vettii flanks Via del Vesuvio and also connects to the Porta del Vesuvio (if indirectly), Laurence again rightly concludes that the lower density of doorways on Via del Vesuvio is a function of the bifurcation of traffic entering and leaving the city. On this basis, Laurence moved Via del Vesuvio into his highest density category to reflect more accurately the movement potential of this street. Explaining the historical factors affecting these data, however, reveals another weakness of the method. Counting doorways on a street segment can only model the activity within that segment and cannot consider the impact these doorways could have on the activity levels of adjacent street segments and vice versa. Movement is thus unrealistically bound to the unit of analysis, ignoring the paths Pompeians took across the city, both in moving to these doors and moving past them. As the following discussion will demonstrate, paths matter.

Several years ago I attempted to revise Laurence’s ODM in order to understand the impact of wheeled transport in the city. The first step was to shift the unit of analysis from the street to the individual insula façade and recalculate the number of doorways by the length of that façade. In addition to giving each side of the street its own history, this change also detached the doorway data from the street as a unit defined in length by the names given by excavators (Figure 6.3). The second modification of Laurence’s method was to divide the doorway data into ten categories rather than only four. The result of these adjustments is an instrument more sensitive to the fluctuations in the urban social and economic landscape, capable of illustrating the various impacts of different places and even the variable impact of a specific place. That is, the map used to express these ten categories of doorway densities can be used not only to compare very specific locations with one another, but also can show the differential effect of an individual building, such as the ‘pockets’ of low doorway densities on the façades of many monumental buildings and the higher incidence of doorways on the façades facing those monumental buildings.

I have felt it necessary to include my own modifications to Laurence’s method here, not only because they are an attempt to improve the sensitivity of the doorway occurrences model to more localized variability within the data, but also because it is necessary to admit that my own previous attempts to use doorways to define movement in Pompeii are equally inadequate to address the second and greater problem: the lack of connectivity (path) within the data. It is also necessary because Laurence’s choice to have particularly long street segments does a better job of masking the issue. My maps, however, reveal this failing rather starkly. Consider the frontage of the House of the

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19 Although Laurence did subdivide the longer streets, his unit of analysis still varied from one block in length to as many as seven (in the case of Via di Castricio).
Figure 6.3 Occurrences of doorways at Pompeii. After Poehler (2009: maps 6.23–7).
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Faun on Via della Fortuna (Figure 6.4). The six doorways along the 32.45 m façade length places it into my third category of density (very high), at 5.41 m of façade per doorway. Across the street, the roughly equivalent section of insula VII 4, has an approximately equivalent density (5.76 m/doorway). In several of the street sections to the east and west of the House of the Faun, however, the densities of doorways are appreciably higher (in this case, producing a lower number of metres per doorway). If doorway density along a street is a proxy for movement density within that street, then how do we understand this drop in density in the middle of a major thoroughfare in terms of movement? Since the connecting streets at this location—Vicolo del Fauno and Vicolo del Labirinto—show the lowest density of doors or no doorways at all, these streets offered little to pull people away from Via della Fortuna. Where then, did the people go? Did some of them simply turn around and go back upon reaching the House of the Faun? Being one of the largest atrium houses in the city, with two atria and two peristyles, it is commonly expected that this location would witness throngs of clients, slaves, delivery men, dinner guests, and others. Clearly, this is another example of the insensitivity of the ODM, in both Laurence’s use and mine, to the importance of place. More importantly, this example demonstrates the method’s inability to model the connectivity and interdependence among the data of adjacent street sections. To put it another way, each façade segment in my model or each street section in Laurence’s has no way of showing how a higher or lower number of doorways further down the street might be influencing the number of people within a street at a given location or how it might therefore impact the number of doorways in those façades. Translating this into human experience, these methods treat people as if they teleport rather than transport themselves around the city.

An escape from this problem would seem to come from the space syntax method, a method explicitly interested in the issue of spatial connectivity. Space syntax is a package of theoretical and practical tools designed to test the organizing effects of architectural designs on human actors without having to build the architecture or engage the human actors. In the context of large cities, analysis of street networks shows how these grids create the basic structure of urban movement and suggests how those patterns might be interpreted as the locations along the streets exploit the movement within the streets. Although space syntax techniques have been used regularly in the

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20 Note also that the number of tethering holes in the sidewalk also precipitously declines in front of the House of the Faun. See Weiss (2010: 368, figure 9).
Figure 6.4 Occurrences of doorways at Pompeii, detail. After Pfeiffer (2009: maps 6.23–7).
study of ancient buildings, few researchers have published attempts to examine the entire city. Recently, Alan Kaiser used the space syntax analysis called ‘depth’ to explore the underlying spatial structure of Pompeii and to compare it to other Roman towns. Depth is a measure of an individual street’s level of connectivity, quantified as the number of other streets or plazas one must pass through from the edge of the city to reach that street. Thus, streets that lead to a gate have a Depth of 1 from the gates, while streets that intersect such a street have a depth of 2 from the gates, and so on (see Figure 6.5). To implement the Depth analysis, Kaiser divided the street network into segments based on the linearity of the streets rather than their length, ignoring any bend less than 45 degrees. His units of analysis were therefore, in many cases, exceptionally long, which, when combined with the grid patterns across most of the city, meant that no street was topologically deeper than four steps from a gate. Kaiser also cleverly reversed the analysis, counting street Depth from the forum.

On their own, the results of such space syntax analysis are rather prosaic: the longest and widest streets connect directly to the city gates, most of the city’s streets cross these main streets (at a Depth of 2), and the most isolated streets are in the shadow of the forum. To be fair to Kaiser, these results were expected, indeed desired, and were intended as a kind of control group for two related projects: the consideration of Latin terms for urban streets and the examination of the kinds of properties that lined these streets. It is the second project that is of interest here, as Kaiser made statistically relevant correlations between the locations of different categories of properties and the Depth of the streets onto which they open. In a series of tables, the account of property types—Commercial (i.e. retail), Health, Production, Residential, Administrative, Entertainment, and Religious—are given for the streets of each Depth category and compared against the number of such properties that would exist if their distribution across the Depth categories were completely random. While Kaiser’s approach is to be lauded as an interesting and important attempt to bring together data from different analytical techniques into a single interpretive framework, the general results of this pairing of space syntax analysis of the streets and statistical examination of the

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23 Graham (1997; 2000); Fridell-Anter and Weilguni (2003); Anderson (2005; 2011); Stöger (2008). Laurence (1994: 115–21) and Newsome (2009), however, have attempted to connect their space syntax analyses to the adjacent streets, or to model a section of the city, respectively.
27 Kaiser (2011a: 84–9; map 3.4).
29 Of the ten widest streets in Pompeii, seven are depth one from the gates.
Figure 6.5 Depth from gates at Pompeii. After Kaiser (2011a: map 3.3). Depth 1, white; Depth 2, light grey; Depth 3, dark grey; Depth 4, black.

Map: Eric Poehler.
properties sited along them, however, is equally prosaic: commercial, production, and residential properties tend to be found along streets with low Depth from both the gates and the forum. Simply looking at the map will reveal most of these same patterns. When one considers the logic behind the implementation of the method and the interpretation of its results, the value of those results shifts from accurate but uninteresting to potentially misleading.32

The first problem with Kaiser’s method is that it employs only ‘to-movement’, or movement toward, which measures only the value of movement between a limited number of origins and any particular destination. Although he tried to add nuance to the method by integrating the number of intersections along a street, this does not actually model the impact of the use of streets by those whose destination is not on that street, or ‘through-movement’. “To-movement’ models only a tiny fraction of the connectivity that the streets actually create.33 To illustrate the difference, imagine drawing the most direct route between any of the city gates and any location, for example the forum. Now imagine all the other possible paths across the city that might use a portion of our first route, but never reach either the gate or the forum. The difference is literally millions of unacknowledged paths.

A second methodological concern leads to one of the greatest interpretive problems with Kaiser’s use of space syntax analysis. In order to determine the statistical significance in the counts of observed and expected property types along streets of different Depths, Kaiser employs a chi-square test and identifies those instances in which the distribution of property types varies significantly from a pattern of random distribution. Randomness, however, is not a meaningful variable to exclude from statistics on an urban environment. A city is a concatenation of behaviour, active, passive, constrained, conscious, or unconscious, but never random.34 Randomness is, of course, analytically useful, but to exclude it is simply to point out that whatever caused the pattern to be created is observable in the data correlating streets and property types. The correlation in this case, Depth, has, however, no ability to identify its cause. Kaiser sometimes seems not to be confused on this, and in several instances makes a more nuanced general statement or takes a more particularist

32 For example, Kaiser (2011a: 77) notes that the only pathway that is at a Depth of 4 from the city gates is the stairway between the Triangular Forum and the Quadriporticus, making it ‘the most remote part of the street network in the entire city’. Such Depth value suggests that this stairway is the least-likely travelled path in the city. This conclusion is difficult to countenance given the stairway’s monumentality, its great width (3.4 m), and the locations that it connects.

33 That is, ‘to-movement’ models only one path, which, translated to ‘through-movement’, equals only 1/total number of nodes. In the case of Pompeii, this is 1/2467th or 0.04% of all possible movement that the network creates. By treating all seven gates equally as one single node, this use of depth analysis still further simplifies its results, which is why the level Depth 2 covers so much of the city.

approach to subsets of the data.\textsuperscript{35} On the other hand, there are as many instances in which he conflates Depth itself with the cause of a property type’s distribution along streets.\textsuperscript{36} In several other occasions, it is stated that the Romans themselves understood and employed the concept of Depth in their decision-making processes.\textsuperscript{37}

There is, of course, a fundamental difference between the terms of an analysis and the translation of the results of that analysis into a description of historical forces. Bound up within correlations of a street’s Depth and the properties along its length are a number of interdependent historical forces. Social factors, such as the idea of moral geographies, create zones of inclusion and exclusion of activities. The relative isolation of brothels away from main thoroughfares and the exclusion of wheeled traffic from the forum have been explained by such moral zoning.\textsuperscript{38} Additionally, urban landscapes and their varying architectural environments impose a wide array of psychological impacts on human beings using those environments. The width of streets, the height, quality, and types of buildings, and the amount of pedestrian and vehicular traffic as well as the proportion of these two traffic types, all influence the decisions about activities within and along the streets.\textsuperscript{39}

Economics, of course, also played a crucial role in determining the location of property types and it is this factor that we are attempting to isolate in the present analysis. There is also the simple fact that, although we examine Pompeii at a specific moment in time, that does not mean we can treat the forces that acted upon it as equally synchronic. The position of any property along any street is contingent upon all these factors and upon their specific expression within a particular time period. For example, the insulae east of the forum were not always disconnected from it and therefore most of the buildings here relate to a time when their Depth from the forum was 1 and not 3. The Depth of property types is an effect of all these intersecting historical forces, which is why it correlates with them. Yet Depth is too blunt an instrument to dissect these individual forces nor can it stand in for all of them collectively. For example, Depth 2 not only covers 54 per cent of all streets (by length) in Pompeii, but also overlaps all of Laurence’s categories of doorway density (Figure 6.6). That a single analytical unit (Depth 2) covers so much of the city’s space and encapsulated so great a diversity of the intensity of its use clearly undermines the value of Depth to explain forces of urbanism at Pompeii. Depth, metaphorically, is not the distance the ancients walked, it is

\textsuperscript{35} Kaiser (2011a: 82, 85, 104).
\textsuperscript{36} Kaiser (2011a: 58, 78, 79).
\textsuperscript{37} Kaiser (2011a: 54, 55, 105).
\textsuperscript{38} Laurence (1995); Wallace-Hadrill (1995); McGinn (2002). Although I disagree that wheel ruts can be used as supporting evidence for moral geographies, I do agree that such informal zones exist and had real-world effects.
\textsuperscript{39} Lynch (1960); MacDonald (1992).
Figure 6.6 Doorway occurrences with Depth 2 from gates. After Kaiser (2011a: map 3.3) and Laurence (1994: maps 6.1–4). All streets, Depth 2. Doorways 0–5 m, black; doorways, 6–10 m, dark grey; doorways 11–15 m, light grey; doorways 15+ m, cross-hatching. Map: Eric Poehler.
the ruler we can use to measure that distance, and while the reason for walking might be unknown, that reason was certainly not the ruler.

A NEW MODEL: GIS NETWORK ANALYSIS

Taking the criticisms of these methods together, we can define the general problem that a new model of movement must overcome: because we use an image of the city as a proxy for movement and then compare it against another image of the city as a proxy for economic behaviour, the results hang dangerously close to a tautology (if not reach it). Put most plainly, we count doors to measure movement and then we use that movement to explain the presence of the doors and functions of the space they access. Moreover, none of the previous methods has given due consideration to the impact that people moving through, rather than to, an area had upon the development of the urban landscape, and consequently, the range of economic responses to that movement. The absence of this volume of people is critical because all movement is conducted between origin and destination.

In what follows, I outline and discuss a more accurate, but still imperfect model to quantify and visualize pedestrian movement in order to understand better how movement patterns might relate to the variable intensities of economic behaviour we see along the frontages. At the heart of this model are the network analysis tools in geographical information systems (GIS) software. Network analysis in GIS is a set of tools based on graph theory and informed by the topological constraints of a specific network to describe the behaviour of flows within that network. As in space syntax, network analysis stresses the understanding of the shape of the network, as it has a far greater impact on movement than does any individual or group of destinations.

The Network

The basic network dataset is a series of points (nodes) that represent doorways into properties and lines (edges) that describe the street network and connect the points to it. Because the city is not fully excavated, it was necessary to extend the street network between the extant streets. These street extensions are shown in Figure 6.7 in dark grey. The streets in the unexcavated areas in regions I, III, and IX can be confidently reconstructed based on recent geophysical work and the known sections of these streets. Greater caution

40 The city gates are also nodes. 41 Fiore and Chianese (2008).
Figure 6.7 Street network of Pompeii. Excavated streets, grey; extrapolated streets, black; unexcavated areas, diagonal hatching. Map: Eric Poehler.
is warranted in regions IV and V, especially in tracing the inner pomerial street between Porta del Vesuvio and Porta di Nola. Excavations at the once-called Porta di Capua have shown the continued presence of a street (if atop debris) midway between the gates, as well as doorways opening into this space.\textsuperscript{42} The presence of an inner pomerial street between Porta di Nola and Porta di Sarno further strengthens the reconstruction of its continuation all the way to the Porta del Vesuvio. Reconstructing the complete street network is essential to the accurate modelling of movement, as the exclusion of possible routes from the analysis will bias other routes, skewing the results of potential movement.\textsuperscript{43}

For the same reasons, though with less impact on the model, it was also necessary to extrapolate the number of doorways that would exit from the unexcavated insulae and their distribution around these blocks. To accomplish the extrapolation, calculations of the doorway distributions in the excavated parts of the city were made by counting the doorways around the perimeter of all excavated insulae. The area of the insula was then divided by the total doorway count to find the average number of square metres served by each door. The lower the number, the greater density of penetration into the space and the greater the overall façade use. Visualizing these data reveals several general trends (Figure 6.8). The overall trend among these data confirms the long-held and well-established observation that the intensity of the use of space reduces as one moves east across the city. Within this overarching trend, however, more localized effects can be observed, such as increased intensity of use in the area east of the forum,\textsuperscript{44} along Via del Vesuvio–Via Stabiana axis, and at the city gates. Less intense use of space can be seen to occur among the insulae that abut the city walls, and (unsurprisingly) those blocks that are partially or fully composed of monumental public buildings.\textsuperscript{45} These trends are themselves intensified or mitigated by the effects of important streets—those that connect to gates, the forum, cut wide transects across the city, and/or are more than a single lane in width.

Once the profile of the doorway density in the excavated insulae was known, this was used as a baseline for doorway densities in the unexcavated insulae of the city (Figure 6.9). A density value, however, does not explain where the doorways should be placed around each unexcavated insula. To make this

\textsuperscript{42} Etani, Sakai, and Ueno (1996).

\textsuperscript{43} For example, Kaiser (2011a: map 3.4; 2011b: fig. 8.2) does not consider the continuation of Via Mediana eastward, which would change at least three of his twenty-three Depth 3 streets (13\%) to Depth 2 from the forum. Because Kaiser did not publish the data on property identifications, it is not possible to assess if this would alter his results of correlation between Depth and property function.

\textsuperscript{44} The insula ‘behind’ the forum to the east include Insulae VII 9 to VII 14.

\textsuperscript{45} Two monumental buildings with significant shop space built into them, the Forum Baths and the Macellum, are exceptions to this observation.
Figure 6.8 Doorway densities, excavated areas. Map: Eric Poehler.
Figure 6.9 Doorway densities, excavated and extrapolated areas. Map: Eric Poehler.
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approximation therefore required an equally careful consideration of the
distribution of doorways in excavated insulae. Laurence had already done
much of this work, showing that doorways tend to cluster on one or two
sides, confirming the expectations that they would populate the façades of
wider streets. Such clustering by side can equally be seen in my own map of
façade doorway densities (Figure 6.3). The shapes and sizes of buildings within
insulae also tend to compound the focus upon one or two sides. Thus, the side
facing a wide street tends to have not only more doors, but also doors that
open into rather shallow spaces—the ubiquitous retail shop. These smaller
spaces also tend to have no other entrances. Larger properties that take up the
interior space of the block also tend to have a doorway onto the wide street,
but, despite their size, have only one additional door on another side of the
block, if they have a need for a back door at all. These observations were
paramount when the distribution of doorways around the unexcavated insulae
was determined. I am under no illusion as to the precise reality of these
doorway locations; but to be used in the network, the nodes had to be placed
somewhere. Placing doorways in locations informed by the broad patterns
found in the excavated parts of the city, however imprecise, does serve as an
antidote to the rigidity of a purely numerical approach to doorway distribu-
tions. Figure 6.9 shows the great local variation in the excavated insulae that
might be flattened by strictly mathematical extrapolations.

Of course, even if carefully reconstructed, the character of the unexcavated
area will remain necessarily speculative. On the other hand, that speculation is
on a spectrum. Thus, we can have great confidence in the position of the street
network; we can also be sure that the extrapolation of the total number of
doorways in the unexcavated insulae is not far off; the exact distribution
of those doorways around the insulae is less certain; the specific locations of
doorways along a particular façade is least secure of all. The strength of this
network model is that it relies primarily on the street grid and the aggregated
results of the number of doorways. The primacy of the street grid means that
where along an insula façade a doorway is placed is far less important than
that it exists at all. Moreover, the aggregation of all doorways reduces the value
of any given door’s existence: at nearly 2,500 total doorway nodes, a single
doorway has only a 0.04 per cent impact on the model. The 454 doorway
nodes placed in the unexcavated areas are only 18.5 per cent of the total,
meaning that even if 25 per cent of all extrapolated doorways are wrongly
placed or should be removed or duplicated, the impact on the full model is
only 4.60 per cent. Thus, for the calculation of paths, the specific location of a
doorway is of relatively little value. The preceding paragraphs are intended to
present the data and assumptions that constitute these reconstructions of

46 Laurence (1994: 104–13, map. 7.2).
47 Proudfoot (2013) has challenged the primacy of the fauces entrance.
unexcavated Pompeii because, whatever the reader’s assessment of their accuracy, not to make such an extrapolation would ensure the failure of any network analysis of the ancient city.

In total, the network built for Pompeii consists of 2,467 nodes (doorways) and 2,434 edges (street network segments) that generate and carry 3.25 million paths (Figure 6.10). With the network structure complete and the full complement of destinations placed, it becomes possible to compute the path a person would take from any point in the city (an origin) to any other and every other point (the destinations). Figure 6.11 visualizes this concept for a single location, showing all paths to the Temple of Apollo from all other destinations. The paths closest to the temple were used in nearly all trips, those further away being used least. By running a route analysis from every point in Pompeii to every other point it is possible to add all routes together, producing a composite plan of all potential movement at Pompeii as distributed by the ancient city’s particular network of streets (Figure 6.12).

Such a plan returns us to Appadurai’s challenge to use ‘things-in-motion [to] illuminate their human and social context’, as quoted at the start of this chapter. Individual paths in the network model are of limited value. We cannot know the purpose of travel and the particular motivations that might have informed how that travel was conducted. These are the motivations that encode individual items and actions with their meaning. Together, however, the sum of all paths effectively averages out motivation by expressing all possible intentions for movement as subjected to the confines of the network. Returning to the metaphor that opened this chapter, we still cannot observe fish in the ocean and divine what was driving their migration. Using network analysis, however, it is possible to reconstruct what currents might have carried them, where those currents were strongest, in what direction they flowed, and what kinds of places they passed along the way. Still, it must be remembered that this model itself is incomplete and flawed in its own ways. The interpretation’s movement intensities and the correlations with building types that follow should be understood as preliminary and in need of refinement. Some of those flaws and refinements are known and admitted in the conclusion of this chapter.

Figure 6.11 represents the intensity of use along these paths, the currents, through colour and line thickness. As is immediately apparent, movement in

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48 There are 4,905 total edge segments, including those connecting a node to the street network. The connecting edges were excluded when finding highest percentages of use. I am deeply grateful to Alexander Stepanov for his help in running the network analysis.

49 The model was run using Python and the NetworkX library. Due to computational speed, the node pairs were broken into eight groups and run simultaneously on eight machines. Each process took approximately ten hours to calculate.

50 Appadurai (1986: 5).

51 The map is visualized as path weight divided into ten classes using quantiles to get sufficient sensitivity to local changes.
Figure 6.10: Network of excavated (black dots and lines) and extrapolated (grey diamonds and lines) doorways and streets at Pompeii. Map: Eric Poehler.
Figure 6.11  Intensity of movement through the network; all paths to the Temple of Apollo. Map: Eric Poehler.
Figure 6.12 Total intensity of movement through the network; aggregation of all paths to all locations. Map: Eric Poehler.
Pompeii was most likely to occur along a few routes that were crucial to the network. Three street segments form an elongated ‘Z’ pattern and integrate the network: Via degli Augustali, Via Stabiana between Via Mediana and Via dell’Abbondanza, and Via dell’Abbondanza east of its intersection with Via Stabiana. The importance of these streets is not surprising and the heavy use of Via Castricio, Via Mediana, and the Via della Fortuna/Via di Nola line is also to be expected. Other streets, however, carried much more traffic than might have been anticipated. For example, the intersection of Via Consolare, Vicolo di Modesto, and Via delle Terme generated a short but intense confluence of movement. Because of their connection to Via del Vesuvio, Vicolo di Mercurio and Vicolo delle Nozze d’Argento were surprisingly busy streets. As Laurence suspected, Vicolo dei Vettii was a well-used street and part of a longer route that provided an alternative to Via Stabiana. Similarly, the streets that connect through region I’s unexcavated areas—Via delle Concipelle and Via della Palaestra—reveal an important southern route across the city, taking pressure off Via dell’Abbondanza and Via di Castricio. Perhaps the most unexpected of all are the various north–south routes in the eastern half of the city, including several segments in the unexcavated areas of regions III and IX, the exceptionally strong integrating role played by the narrow and unpaved Vicolo di Paquius Proculus, and, finally, a meandering minor route between the Porta di Nola and Amphitheatre area using a portion of the eastern interior pomerial road.

The other pomerial streets, however, are remarkable for having little to no importance in the network. Other streets are also surprisingly undertravelled. Via Mercurio, which connects to the forum and gives access to a number of large residences in its northern segment, diminishes in intensity of use as precipitously as do the other, much narrower streets in the north of region VI. On the other hand, the position and size of the House of the Faun appears to have nearly completely quieted the non-integrating streets that border it: Vicolo del Fauno and Vicolo del Labirinto. Ostensibly one of the most important routes in the city, the section of Via dell’Abbondanza between Via Stabiana and the forum is, surprisingly, not one of the most used routes in Pompeii despite its connection to the forum. The reason is equally non-intuitive: the position of Pompeii’s forum in the far south-west of the city and the blockage of many streets that formerly reached the forum undercut its expected distributive function.

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52 This route is composed of Vicolo dei Vettii, Vicolo Storto, Vicolo di Eumachia, and Vicolo dei Dodici Dei.
53 Vicolo della Fullonica also is reduced in this manner, though slightly less so due to the number of doors opening onto the street.
54 For a diachronic consideration on the area west of the forum, see Newsome (2009: 123–5).
Finally, because the street network ends at the city gates, these exceptionally important nodes are treated only as a door to a building rather than as a door to the city itself. The effect of this is an unrealistic diminishing of street use as the gates are approached. Certainly both scholarship and common sense underscore the problem.55 The problem can be overcome by giving a population ‘weight’ to the nodes at the gates. There is no reason to lose confidence in the present model, however, as the added number at the gates will raise the importance of the streets leading to the gates, but will not fundamentally change the overall distribution of movement across the city. Because the network of streets remains unchanged, new paths will not now become of greater value, but the increase in population moving through the gates will create greater proportional distance between the most and least used paths in the city. How such ‘weighting’ might be accomplished is discussed in detail in the section entitled ‘Improving the Model: Place’.

Two specific examples serve to illustrate the value of the GIS network analysis approach to understanding movement in Pompeii and to considering its impact of that movement on the economy. Insula VII 12 has thirty-four doorways distributed mainly on its northern (14) and southern (14) sides. The northern façade, however, witnessed 23 times more traffic along the Via degli Augustali than did the Via del Balcone Pensile to the south. Even the eastern and western streets,56 which have only six doors total opening onto them, were 7.5 and 8.7 times busier than the southern street. Such a distinction is completely absent from the doorway occurrence model: all four streets are identically lumped into the highest use category. The space syntax concept of Depth does a far better job of finding distinction between these streets, particularly in Depth from the forum. It is impossible, however, to find nuance within these topological Depths: Is the topological distance of two steps in Depth the same everywhere? That is, while both Via degli Augustali and Via dell’Abbondanza are at Depth 1 from the forum, and both Vicolo del Balcone Pensile and Vicolo degli Scheletri are at Depth 3, Via degli Augustali (519,467 paths) saw 3.7 times more traffic than Via dell’Abbondanza (140,438 paths), and Vicolo del Balcone Pensile (22,559 paths) witnessed 10.3 times more movement than Vicolo degli Scheletri (2,191 paths).57 Such equivocation in category by the ORM and Depth methods is deeply misleading, as the network model shows exceptional variability amongst all of these streets.58

which made a trip through the forum slightly longer. Whether this distance calculation would also be made by most ancient Pompeians is discussed in ‘Improving the Model: Human Actors’.

55 On gates as generators of space, see Malmberg and Bjur (2011); Poehler (2011).
56 These are Vicolo del Lupanare and Vicolo di Eumachia, respectively.
57 Because of the larger numbers in the fluctuation of path frequencies on Via degli Augustali, the lowest path frequency count on each street was used in order to create the fairest possible comparison.
58 A future project using these results will examine the notion of moral geography at Pompeii as it relates to this section of region VII.
A second example returns us to the area of the House of the Faun and to the previous critiques of counting doors and counting turns. Where Laurence’s doorway density method left us to guess at the apparent reduction street activity at the House of the Faun and Depth analysis did not suggest any difference at all, the quantification of paths allows us to see that this area as one part of a trend of diminishing use from east to west on Via della Fortuna. The reason for the diminishing use is the presence of several important routes nearby—especially Via del Foro/Via di Mercurio, Vicolo dei Vettii/Vicolo del Storto—that steered away much potential traffic that was not destined for the House of the Faun itself. Being able to see the siphoning off of ‘through-movement’ traffic by alternative routes allows us to escape the tautology of basing our interpretations of the development of façades on traffic flows that rely on ‘to-movement’ alone. That is, we no longer have to ignore the underlying circularity of saying that the busyness of a street, as measured by the number doors that open onto it, is the cause of the number of doorways on that street. Instead, we can produce a nuanced and quantifiable figure of a street’s busyness that is based on the average of all potential movement paths within the city. What is more, we can now ask if such busyness had an impact on the number and functions of doorways along a street without falling into the trap of circular reasoning, which hold enormous potential for our understanding of Pompeii’s commercial landscape.

So, what was the impact of through-movement on the number and function of properties? Again, this model is incomplete. Additionally, this model cannot speak to specific properties and their particular histories, but rather to the broader trends of how property owners, by AD 79, might have reacted to the variable intensities of people on the move. Table 6.1 expresses the associations of four property types—Public Buildings, Houses, Shops, and Bars—to four categories of movement intensity. The movement intensity categories are the top 10 per cent, 20 per cent, and 25 per cent of busiest streets in Pompeii (Figure 6.13) as well as the bottom 25 per cent (Figure 6.14). These percentages, however, are based on values of the frequency of use for each segment and not on the length of that segment. Therefore, the total length of the segments of each category and its percentage of all street segments is also listed. As the table shows, there is a vast difference in the total length of streets used in each movement intensity category: the top 10 per cent of busiest streets make up less than one tenth of the distance of the bottom 25 per cent. The impact of this is to

59 From Eschebach (1970); Eschebach, Eschebach, and Müller-Trollius (1993).
60 Ellis (2004; 2005).
61 The total number of street segments is 2,343 and their total length amounts to 18,201.76 metres,
Table 6.1 Association of property type with movement intensity

<table>
<thead>
<tr>
<th>Movement intensity</th>
<th>Count of segments</th>
<th>Length of segments</th>
<th>Percentage of segments</th>
<th>Public buildings</th>
<th>Houses</th>
<th>Shops</th>
<th>Bars (Ellis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 10%</td>
<td>243</td>
<td>756.30</td>
<td>4.2%</td>
<td>8</td>
<td>17.0%</td>
<td>50</td>
<td>135</td>
</tr>
<tr>
<td>Top 20%</td>
<td>486</td>
<td>1,494.60</td>
<td>8.2%</td>
<td>12</td>
<td>25.5%</td>
<td>82</td>
<td>253</td>
</tr>
<tr>
<td>Top 25%</td>
<td>609</td>
<td>1,953.93</td>
<td>10.7%</td>
<td>15</td>
<td>31.9%</td>
<td>102</td>
<td>318</td>
</tr>
<tr>
<td>Bottom 25%</td>
<td>609</td>
<td>8,537.22</td>
<td>46.9%</td>
<td>6</td>
<td>10.6%</td>
<td>87</td>
<td>30</td>
</tr>
</tbody>
</table>
Figure 6.13 Street segments with the greatest movement intensity. Map: Eric Poehler.
Figure 6.14 Street segments with the least movement intensity. Map: Eric Poehler.
further intensify the association or dissociation of property types with movement, which is included in the following discussion.62

The results show that the forty-seven public buildings (including temples) are somewhat correlated with busy locations, with nearly one-third being found along the top 25 per cent of busiest streets (10.7 per cent of total street length). The dissociation with the least used streets further supports the weak correlation. Houses, however, show no correlation with the intensity of movement passing their front doors. Indeed, the top and bottom 25 per cent of movement intensities have nearly the same proportion of the 440 houses at Pompeii. Conversely, shops have an exceptionally strong correlation with number of people using a street: 54.1 per cent of all shops are found on the busiest 10.7 per cent of street lengths (top 25 per cent), while only 5.1 per cent exist on the quietest 46.9 per cent of street lengths (bottom 25 per cent). These three of Eschebach’s property types were chosen not only for their variability in kind (public space, residential space, and retail space), but also for the likelihood that they could produce reliable results. Public spaces are easily identifiable, and the high number of houses (440) and shops (588) meant that individual errors in identification would not skew the calculations. The final category relies on the data from Ellis’ comprehensive archaeological survey of 158 properties containing masonry counters, which he used to define the Pompeian bar. The identification of these properties, therefore, is the most reliable, despite the variability of their architectural forms and their relative rarity. Bars, interestingly, are both strongly related to the busiest locales and also have an important profile in the least trafficked areas. That is, 37.5 per cent of all bars are found on the busiest 25 per cent of locations, but are also found with the same regularity as houses (20.4 per cent) in the least trafficked 25 per cent of streets.

How might we interpret these results (bearing in mind the flaws of this iteration of the model)? As I have argued, no single variable explains the collective forces that generate the urban topography, and the intensity of movement defined by this analysis will not be the exception. For example, when deciding the location for a residence, the number of people passing that location was not a deciding factor for Pompeians, except for where to put the front door. The slight correlation of public buildings and busy streets is best interpreted as historical: as the forum became monumentalized and as sacred precincts and entertainment districts were enlarged and enclosed, access through and around these places was diminished. Retail businesses, however,

62 It is obvious that the absence of strong movement at the gates is skewing these results, making associations with the top percentages weaker and the bottom percentages stronger. Similarly, the lack of attractiveness of public buildings—and to a lesser degree, houses and shops—is also skewing the results. Resolving these issues will be discussed in the section 'Improving the Model: Place'.

clearly were opened on the busiest streets in Pompeii and assiduously avoided placement (or failed) on the least busy streets. The process of locating a bar also gave important consideration to the number of passers-by, showing their engagement with the movement economy.63 Bars, however, also were successful in limited numbers on the city’s backstreets. These examples point to the importance of neighbourhood economics—a variety of hyperlocalism in retail consumption—that underlies and complements the overall movement economy.64

IMPROVING THE MODEL

Compared to both the occurrence of doorways and space syntax methods, the sensitivity of the model to change in the network analysis is significantly improved. The impact of a greater number of destinations can be observed within the length of a single city block, such as the section of Via Stabiana between insulae VIII 4 and I 4. Simultaneously, the network model shows the additive effect of through-movement on a street (e.g. Via degli Augustali), as well as the subtractive effect on a section of street (e.g. Via della Fortuna) of nearby streets that offer alternate routes. These results, though an exponential improvement over previous approaches, must be still further refined for future research on the movement at Pompeii. This section addresses three areas to be improved: variability in the importance of individual nodes (place), simulating Roman movement behaviour, and the evolving network of the Pompeian street grid. The discussion of these topics is intended to both expose to scrutiny and feedback the weaknesses of the present iteration of a network analysis as well as publicly to explore potential solutions.

Place

The first problem to examine is that the present model—like those critiqued—does not fully address the question of place; that not all doorways are equal indicators of movement. The model can, however, can incorporate

63 Ellis (2004; 2005). The neighbourhood model of consumption and the broader model of the movement economy have a rough equivalency to the household and commercial modes of transport economics. See Poehler (2011).

64 Neighbourhood movement of this kind relies on ‘to-movement’ rather than ‘through-movement’, which is why previous analyses could find some correlation with economic behaviours.
information about the number of people to be anticipated at any doorway. Each node can be weighed against the number of inhabitants of a property that would use each door. The difficulty, of course, is not technical, but historical: How many people lived in Pompeii, how many lived in each building, and of those buildings that had multiple doors, how many would use each door? Chapter 2, discussing the possible number of inhabitants per room, offers a first solution to this topic for private properties, particularly residences. Public buildings will require further consideration as there are no inhabitants at this class of structure. Moreover, these buildings raise the issue that a doorway has not only ‘weight’ but also gravity; both outflow and inflow. Thus, the value of a building’s movement potential is a function of both the number of inhabitants and the number of visitors. Shops, for example, will have far fewer inhabitants than visitors, but so too might large atrium houses. One way to model this might be to generate a ‘visitors expected per property type, per 10 m²’. Thus, an average shop (39.3 m²) could be said to see ten visitors per day for every 10 m² of its size, while a workshop might only receive only one per 10 m². The Temple of Apollo might be assigned ninety-five visitors, or 0.5 per 10 m². In this way, the relative attraction to visitors of the different sizes of different property types in the city might be combined with the value of inhabitants entering and exiting each doorway. These values are all open for debate.

Similarly, the city itself saw a high volume of visitors each day that must be factored into a future model. How can we know how many people might have come through the gates? There are no data that I know of that speak to this question for Pompeii. We can, however, narrow in from a series of estimates to imagine what those numbers would mean in terms of people actually walking through the gates and what range therefore seems reasonable. Table 6.2 shows this concept. If we consider a very high-volume influx of visitors as a maximum, 50 per cent of the population for example, we must imagine that more than 850 people entered through the each of the seven city gates, equalling over seventy per hour. Passage through the gates did not occur evenly through the day, or during the year for that matter, but rather was concentrated in peak morning and afternoon hours. If half of the visitors entered during only three morning hours, the rate per hour doubles. Of course, the gates themselves did not see an equal number of visitors and it seems appropriate that the largest and most important gate, Porta Ercolano, might have carried as much as 25 per cent of the daily traffic, if not more. Taking these

65 A day is calculated as being 12 hours, whether those hours are preferred during daylight or regulated to overnight. Thus, total number people, divided by seven gates, divided by 12 hours.
66 Thus, total number of people, divided by 2 (half arriving at ‘rush hour’), divided by 3 (hours).
Table 6.2 Extrapolations of visitors to Pompeii by gate and time

<table>
<thead>
<tr>
<th>Total Number entering</th>
<th>Percentage of population</th>
<th>Each gate, per day</th>
<th>Each gate, per hour</th>
<th>Each gate, per rush hour</th>
<th>Porta Ercolano, per day (25%)</th>
<th>Porta Ercolano, per rush hour (25%)</th>
<th>Porta Ercolano, per rush minute (25%)</th>
<th>Porta Sarno, per day (10%)</th>
<th>Porta Sarno, per rush hour (10%)</th>
<th>Porta Sarno, per rush minute (10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,500</td>
<td>250</td>
<td>4</td>
<td>600</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>6,000</td>
<td>50%</td>
<td>857</td>
<td>71</td>
<td>143</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,000</td>
<td>33%</td>
<td>571</td>
<td>48</td>
<td>95</td>
<td>1,000</td>
<td>167</td>
<td>3</td>
<td>400</td>
<td>67</td>
<td>1</td>
</tr>
<tr>
<td>2,000</td>
<td>17%</td>
<td>286</td>
<td>24</td>
<td>48</td>
<td>500</td>
<td>83</td>
<td>1</td>
<td>200</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>1,000</td>
<td>8%</td>
<td>143</td>
<td>12</td>
<td>24</td>
<td>250</td>
<td>42</td>
<td>1</td>
<td>100</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>500</td>
<td>4%</td>
<td>71</td>
<td>6</td>
<td>12</td>
<td>125</td>
<td>21</td>
<td>0</td>
<td>50</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>
suppositions and figures together means that if we are to entertain the idea that 4,000 people came to Pompeii in a single day, we must accept that someone sitting at the Porta Ercolano in the morning hours would have seen on average three people per minute entering the city during peak morning hours, including their animals, vehicles, or carried articles.\(^{67}\) Surely one traveller every 20 seconds is an unrealistic rate. At 2,000 visitors, only a single person per minute on average would have entered the Porta Ercolano; still a high, but perhaps more reasonable rate. Conversely, is it reasonable under the lowest estimates that only fifty people per day entered through the Sarno gate? There are no facts to be found here; we do not know the actual ebb and flow Pompeii’s daily population. Still, this excursion into supposition and number play offers a way to visualize those numbers as an experience we can imagine, replicate, and compare with historical parallels.\(^{68}\) And, in turn, this experience can help us choose among a series of possibilities ranging from logistically impractical to historically (and economically) inconsequential.

### Human Actors

If we are concerned to include the value of the number of visitors to Pompeii, we must also be equally concerned with modelling how they would have understood and used the street network. Therefore, another area for improvement is in the way in which human movement is modelled. The algorithm used in this research finds the shortest path between two nodes and therefore presents an ideal kind of movement. There are two problems with using this method. First, it assumes that all actors possess a perfect knowledge of the street network, including knowing both the complete connectivity of all streets and the lengths of each segment. Knowledge of the network at this level, including that of native Pompeians, would be impossible. On the other hand, even first-time visitors would have had their navigation of the city informed by previous experiences. Fortunately, there is evidence in both the literary record,\(^{69}\) and in the architectural articulation of Roman cities,\(^{70}\) that can also be used to replicate the wayfaring knowledge of visitors and inhabitants. For example, in his second-century BC work *Adelphoe*, Terence has two characters, Syrus and Demea, negotiate passage through Athens.

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\(^{67}\) Thus, total number of people, divided by 4 (25% of travellers), divided by 2 (half arriving at ‘rush hour’), divided by 3 (hours), divided by 60 (minutes per hour).

\(^{68}\) For example, contemporary commuters to Manhattan double that area of New York City’s population. See Moss and Qing (2012) and US 2010 Census <http://www.census.gov/hhes/commuting/data/acs2006_2010.html> (accessed 8 June 2016).

\(^{69}\) Ling (1990); van Tilburg (2007: 49–51).

\(^{70}\) MacDonald (1992); Westfall (2007).
The directions imagined by Terence are characterized by a desire to use noteworthy landmarks to establish the location of where changes in directions are to be made. Even without such referential directions, travellers could use the architectural language that overlaid Roman cities and was encoded in its architecture. The urban armature expresses the expectation of Roman urban settings to contain a very limited number of primary routes—often a single street—with important junctions articulated by connective architecture that signals the importance of the intersecting streets. An example from Pompeii, the Tetrapiylon at the intersection of Via dell’Abbondanza and Via Stabiana, serves to illustrate this concept. The monument, built by Marcus Holconius Rufus, not only stands as testament to the man, but also, by its position on the west side of the intersection, as a signal to the forum’s presence, though out of sight, further up Via dell’Abbondanza. Certainly, the smaller tetrapiylon at the crossroads of Via Stabiana and Via degli Augustali/Via Mediana—the second busiest place in Pompeii—now takes on greater meaning.

The literary and architectural evidence also illustrates a second problem with using a shortest path algorithm to model human movement. Human beings, independent of their knowledge of the network, do not usually choose

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72 MacDonald (1992).
73 For an attempt to reconstruct the armature of Pompeii, see Westfall (2007).
74 The busiest location at Pompeii is the intersection of Via degli Augustali and Vicolo Storto/Vicolo di Eumachia.
to zig-zag paths across a city. Instead, we tend to compromise between the most direct and least complex routes. Both of these concerns can be overcome by changing the movement algorithm from one that relies only on the length of an edge to find most direct path, to one in which the shortest path is balanced by the fewest number of turns.

**Chronology**

Future work should also address the necessary synchronicity of the model. Because Pompeii’s street network was a product of multiple stages of evolution—stages still not fully agreed upon—the movement of people throughout the city, and its economic value, were also different. The network built for the city’s final phase can be adjusted to reflect these different phases, including the multiplicity of the interpretations that define them, by simply adding, deleting, or disconnecting streets. While excavation has defined many parts of the evolving street network, only a small percentage of the properties within the early insulae are known. Modelling the doorways that would lead onto these reconstructed networks will therefore prove more difficult. Unlike adding doorways to the unexcavated parts of Pompeii, estimating the number and position of earlier doors will not have the benefit of seventy-seven fully excavated insulae to balance one’s interpretations. Still, the results are likely to reward the efforts.

As David Newsome reminds us, however, there is also much to be gained in considering smaller scale changes:

Pompeii, as elsewhere, had a fluid and evolving—which is not to say expanding—street system until its final day. Indeed, one could argue that the dominant causal factor of urban change is not expansion but the subsequent adaptation of practice within particular infrastructures.

Such incremental changes could have important changes on circulation in the city, changes that could inform and cascade into additional changes. For example, blocking Vicolo del Gallo’s access to the forum by the expansion of the Sanctuary of Apollo had ramifications for the Casa del Marinaio and its neighbourhood. What impact did this closure, by disrupting the distributive nature of the forum, have on movement in Pompeii? We have already seen that the forum’s value for circulation was lower than might be expected because of such disconnections. An important question that can be posed by modelling these changes in a network analysis is whether such a change to Vicolo del Gallo made it easier to countenance the complete closure of the

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75 See Anderson (2013: 581–8) for the most recent consensus on the Pompeii’s development and Ball and Dobbins (2013) for the most recent refutation of that consensus.


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forum’s east side two generations later. Likewise, it can be asked if the construction of the Popidian Colonnade two generations earlier, which blocked at least three streets in the south, made the changes brought by the Temple of Apollo’s expansion more palatable.78

The network analysis method is a way to model those changes, measure their impact, and interpret the choices Pompeians made in light of that impact. To accomplish this work, a chronological series of quantified movement maps might be generated to ‘underlie’ the final, synchronic map of Pompeii and identify the most durable intensities of movement as well as isolating the anomalies that appear in the wake of changes to the network. Moreover, those data expressed in the sequence of maps can be quantitatively rather than merely visually compared.

CONCLUSION

The conclusion to Ray Laurence’s Space and Society is a critique of what he considered to be the over-functional, over-economic, and over-political interpretations of the complex social forces that drove Roman urbanism. It might be summed up in the following, co-opted phrase: ‘It’s the society, stupid.’79

Indeed, Laurence goes on to say that ‘models such as the consumer or service city fail to account for this complexity by reducing all social activity to its economic function’.80 I would agree that these models have failed to explain the complexity of Roman urbanism, but not only because they are too economic and too little social, but also because they are too simple. The same has been true of the methods we have used to study urban forces. While there is elegance to the simplicity of the ‘occurrence of doorways’ and space syntax approaches, they are like the watercolour paintings commissioned by Spinazzola during his excavations along Via dell’Abbondanza: drawn with too broad a brush, creating an image that is too imprecise, too impressionistic. In this analogy, network analysis is the digital camera, able not only to render an image with shaper focus, but also capable of instantly adjusting almost any setting in creating the image. In combination with an earlier literary tradition that minimized the role of elites in the non-agricultural economy, the broad results of these earlier methods lead to broad interpretations, the consequence of which was that many such interpretations relied on social rather than economic forces to explain the patterns.

78 Here I follow the Pompeii Forum Project’s determination of a Sullan date for the Popidian Colonnade. See Ball and Dobbins (2013: 481–6).
79 The original phrase, ‘The economy, stupid’, was coined by James Carville.
these methods revealed. Thus we have moral geographies, but no indices, even relative indices of property value. The maps highlighting the top 10, 20, and 25 per cent of busiest streets can be seen as a first attempt towards this. For the future, we need to continue to explore the power of such social factors in the development of Pompeii, but not at the expense of economic forces. The pendulum must swing back, and we must consider how economic decisions are socially informed and how social decisions are economically constrained or incentivized. The present research and the abstraction of movement generated by it is a step towards remedying that imbalance.

REFERENCES


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