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Unravelling Urban Religious Landscapes: Visualizing the Impact of Commerce on Religious Movement at Ostia

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Abstract

Ritual activity constitutes one religious practice that pervaded ancient cities like Ostia, Rome's ancient port. Despite the extensive surviving evidence at Ostia for religious practice, the ways in which the urban landscape shaped religious movement has not received previous attention. This article focuses on how economic activity may have helped to structure areas of ritual movement throughout the city. Using the Urban Network Analysis Toolbox developed for ArcGIS, areas of economic activity are studied by applying betweenness centrality to determine 'hotspots' of movement. These 'hotspots' can be used as nodes for undertaking further study of processional movement. The preliminary results suggest that the proposed methodology can enrich archaeological investigations into ritual movement and religious landscapes.

Keywords: urban network analysis, GIS, human movement, spatial analysis

Introduction

The idea that urban and social landscapes have an impact on religious activity underlies a number of studies focused on religious movement (e.g., Demarest 2006; Popkin 2016). Scholars have long recognized the relationship that existed between social meaning and the built environment (e.g., Giddens 1984) and the ways in which these shaped patterns of interaction (Lawrence and Low 1990; Rapoport 1977). The spatial organization of a city not only structured daily exchanges between people but affected how ritual or religious activities interacted with the cityscape and its inhabitants (Moore 1996). The potential of studying ritual movement has only recently garnered attention. Early research into past landscapes saw movement as secondary in importance within phenomenological based studies (Tilley 1994) whereas movement is now recognized as a central component for a city's organization and its subsequent analysis (Álvarez and Oubiña 2007; Paliou, Lieberwirth, & Polla 2014). Movement within the cityscape was shaped by a variety of different factors, ranging from the pre- existing street network, movement intent, urban activity, and the built environment (Giddens 1984; Russell 2016). How movement can be studied within the context of an ancient city and the ways in which it informs our understanding of social practices has resulted in an influx of recent studies (Laurence 1994; Östenberg, Malmberg, & Bjørnebye 2015; Poehler 2017). Current methods for examining movement and the reciprocal relationship that exists with the built environment provides the context for undertaking the present study of ritual movement.

Considering the city of Ostia, Rome's ancient port, this paper explores how a specific aspect of the built environment, indicative of different types of social activity, may have impacted processional movement. In particular, it discusses the potential of applying an urban network-based approach using betweenness centrality measures to investigate the possible correlation between Ostia's commercial spaces and ritual movement. Specific processional routes at Ostia are unknown within the archaeological and historical record. By questioning how one form of social activity influences ritual movement, which is represented within the built environment through recognizable architectural structures, "influences ritual movement" can hypothesize about which areas of Ostia may have seen processional activity if influenced by commercial activity. This builds upon previous pedestrian-based studies, like Hillier and Hanson's (1984) model of space syntax, in order to provide new insight into a religious landscape that encompassed the entire cityscape.

Research Background: Ritual Activity at Ostia and Movement Studies

Ostia's Religious Landscape

The temples, shrines, and religious artefacts uncovered at Ostia provide a rich source of information about the city's religious life. Inquiry into temples and cultic practices remains one of the most contested areas of Ostian scholarship over the past decade (Pavolini 2016: 201). Until recently, studies were predominantly confined to individual temples or cults without considering their placement within the total cityscape (Squarciapino 1962; Taylor 1912). Recent scholarship has attempted more general investigations into the city's religious space (Arnhold 2015; Rieger 2004; Steuernagel 2004), while acknowledging the importance of Ostian rituals and their need for further study (Bruun 2009). How ritual activities, like processions, contribute to our understanding of Ostia's religious environment have not been adequately addressed. The numerous debates about the identification of individual temples do not shed light on the ways in which religious practices intersected with the city's residents (Van der Meer 2009).

The lack of existing information, either archaeological or literary, alluding to the nature of processional rituals at Ostia has resulted in minimal discussion of their presence within the city. While processions constituted a regular component of ritual practices, ancient authors rarely describe processions in detail, likely because they formed a standard part of the city's landscape and did not necessitate further commentary (Flower 1996: 97). Processions were ephemeral events, with their occurrence predominantly held in the memories of those who attended or heard about the event while leaving little to no lasting impression within the archaeological record (Connelly 2011: 314; Russell 2014). Existing discussions of Ostian processions focus on either the construction of a processional route that was structured by the spatial location of early temples (DeLaine 2008: 101) or their probable occurrence along Ostia's major streets (Boin 2013: 75). Undertaking new study of processional movement presents an unexplored method of looking at how religious practices were disseminated across the city. Directing enquiry away from identifying particular Ostian rituals and movement routes to considering what influenced processional movement more generally is one way to address the issues inherent in Ostian processional studies.

Movement Studies within Roman Archaeology

The formal study of human movement has been a popular avenue for archaeological research. Within studies of Roman urbanism, approaches to movement have predominately developed out of Pompeian research. These studies consider urban movement either in terms of proxy data or through the application of urban theories like space syntax. Early research focused on archaeological indicators of movement such as the presence of wheel ruts (Poehler 2006; Tsujimura 1991) or how architectural structures like street-side benches helped to structure pedestrian movement (Hartnett 2008). An alternative approach widely used is space syntax, which consists of a set of theories and methods initially developed for urban planning to explore the relationship between space and human society (Hillier 1996; Hillier and Hanson 1984). In relation to a street network, their methodology contends that a street's spatial arrangement is related to various social phenomena including movement flows. In particular, space is defined by its position in relation to other spaces within a city. Space syntax has been applied to archaeological contexts to explore the characteristic of both individual buildings as well as urban street systems (Grahame 2000; Laurence 1994; Stöger 2011).

Axial analysis, developed by Hillier and Hanson (1984), has commonly been applied in order to study the spatial configuration and movement potential of ancient street systems (Kaiser 2011; Stöger 2011). In this instance, the street network is modelled topologically in order to identify which street segments are more accessible and therefore saw greater use (Hillier and Hanson 1984: 82–142). The analysis first represents the street in terms of axial lines, which consist of the longest and fewest lines that can be drawn within the open spaces of a street that often correlates to lines of sight. These lines are then converted to a connectivity map where nodes represent streets and links represent intersections (Porta, Crucitti, & Latora 2006b: 854). The distance between each node provides an index of its connectivity to every other node in the system and which can be used to calculate various space syntax metrics. The outcome of axial analysis is a visualization produced on a colour scale of red to blue that indicates which axial lines, corresponding to streets, are most integrated within the network, providing an indication into likely areas of movement.

While space syntax is useful in determining how a city's street network design promoted movement, it does not account for how the space was actually used or other urban or social activities that influenced movement (Batty 2003; Benedikt 1979; Ratti 2004; Steadman 2004). Furthermore, it cannot account for specific types of movement or movement intent within a street network. This poses issues when trying to address how processional movement can be studied within the ancient city when routes are unknown. Processions have a particular purpose when traveling through the streets of a city, an intent that cannot be properly accounted for within space syntax models.

One way to address the difficulties of movement intent is to question what factors influenced movement directionality. Processional movement had an underlying purpose, to move from point A to point B. And while movement was not the only purpose of a procession, this allowed the ritual to be seen and experienced (Grimes 1992: 72). Current studies of ritual movement highlight that a close relationship existed between urban space and the construction of sacred routes (Lawrence and Low 1990; Popkin 2016). In many instances, a landscape or city had certain attractors that helped to guide and structure processional routes (Kristensen and Friese 2017; Malville and Malville 2001; Morton et al. 2014). In particular, looking at how commercial activity affected ritual movement, or vice versa, enables us to question how a specific form of urban activity may have structured possible areas of ritual movement. This is far from the only factor that would have impacted ritual movement, but the focus on commercial activity is used as a way to think about how processional routes were formulated within the city and how this form of movement can be studied.

By the 2nd century AD Ostia had a rich commercial landscape, ranging from large warehouses (*horrea*), areas of production like granaries, and small shops (*tabernae*). Ostia's streetscape in particular was characterized by shop fronts, with an estimated 800 *tabernae* located across the city (DeLaine 2005; Ellis 2011). Shops, warehouses, and areas of production define Ostia's commercial spaces, reflecting three distinct types of commercial activity. Three categories are used within this study for the purposes of simplicity and to show the potential of the proposed method. The complexity of defining commercial space at Ostia cannot be negated. Consideration of how these different commercial spaces either encouraged or deterred movement sheds new light on possible areas of processional movement at Ostia. While the potential of undertaking a movement-based study at Ostia has previously been addressed through space syntax analyses (Kaiser 2011; Stöger 2011), it has yet to be applied to the study of processional movement. The street network and existing architectural landscape at Ostia provides a unique opportunity to consider how commercial activities, structured by the built environment, may have regulated processional movement. This presents a novel approach to examining a specific form of movement within the ancient cityscape.

Urban Network Analysis of Commercial Spaces at Ostia

The application of network science approaches to archaeological studies has seen considerable attention in recent years (Brughmans 2013; Brughmans, Collar, & Coward 2016; Knappett 2013). In particular, network analysis has been applied as a quantitative approach to study the topology and movement structure of cities using methods like space syntax (Hillier and Hanson 1984; Porta, Crucitti, and Latora 2006a). As previously discussed, however, several issues limit its application to the study of processional movement. As a result, a new form of network analysis is employed as a way to address some of the issues implicit within space syntax by focusing on how commercial activity, recognizable by specific architectural structures, effects movement.

Urban Network Analysis Toolbox & Betweenness Centrality

Recognizing the above limitations for studying processions, the present study applies an innovative approach to studying urban movement patterns using the Urban Network Analysis (UNA) toolbox in ArcGIS, created by Sevtsuk and Mekonnen (2012). Unlike axial analysis within space syntax which only looks at the geometric design of a city's street network, this toolbox implements a third metric for considering movement patterns along a street network, the built environment. The urban landscape is modelled using three elements within the ArcGIS toolbox: edges (streets), nodes (intersections), and buildings. This tripartite network enables buildings to become the focus of analysis, enabling a new understanding about the fundamental relationship that existed between urban activities and the study of movement along a city's street network. Buildings can be prescribed various attributes that range from their total size to their urban function. This enables the different properties of individual buildings to be studied within the context of both their spatial position within the city as well as how they may have affected movement along a street network. The size of the study area can also be specified, correlating to different forms of movement (e.g., pedestrian or vehicular).

Additionally, innovative is the fact that all calculations occur within ArcGIS 10.0–10.3, presenting new possibilities for undertaking various urban spatial analyses. This negates previous issues of having to undertake network analysis in a separate software program (e.g., Pajek, Visone, Gephi) and importing the results into a GIS platform in order to visualize the results (Andris 2016). This toolbox allows for the calculation of the most common network centrality measurements directly within ArcGIS: reach, gravity, closeness, betweenness, and straightness (Sevtsuk, Mekonnen, & Kalvo 2016).

Centrality measurements are one of the primary network analysis functions used by urban planners to determine areas that are related to increased pedestrian access (Wilson 2000). For considering movement potential in relation to commercial spaces at Ostia, the present article applies betweenness centrality, which computes the probability that a certain node or building will be passed when travelling the shortest distance between two points (Isaksen 2013: 61). While this is not the only measure that can be used to address movement along a city's street network, it presents a visual indication into potential movement patterns corresponding to passing specific commercial structures. Since the actual processional routes are unknown, this specific centrality measurement provides an indication into certain areas that may have been passed, regardless of the start point or destination, rather than attempting to define actual routes. The UNA toolbox applies a betweenness centrality equation adapted from Freeman (1977) whereby commercial buildings are considered based on their likelihood of being passed by movement along Ostia's street network (Sevtsuk, Mekonnen, & Kalvo 2016: 14).

Betweenness is not an indication of the ease of a potential movement route, but indicates whether or not a building will be passed (Isaksen 2012: 62). Assessment of betweenness centrality is important because it provides an indication of which commercial structures had greater control over structuring movement within Ostia's street system within the framework of the present study (Freeman 1977: 35). In terms of movement patterns, betweenness is often associated with higher traffic volume or bottlenecks; meaning that a building with a higher betweenness value indicates that it had a more important role within the city's total infrastructure. More importantly for the present study, it presents the potential of being passed by through-traffic, providing insight into how commercial structures have the potential for generating movement.

The application of betweenness centrality in relation to Ostia's different commercial buildings presents an innovative approach to looking at how commercial activity may have helped to structure areas of ritual movement. As the commercial structures are weighted relative to their assumed importance, betweenness measures provide an indication of areas most likely to be passed. The resulting values constitute 'hotspots', or areas that can be used to help inform our understanding about commer-

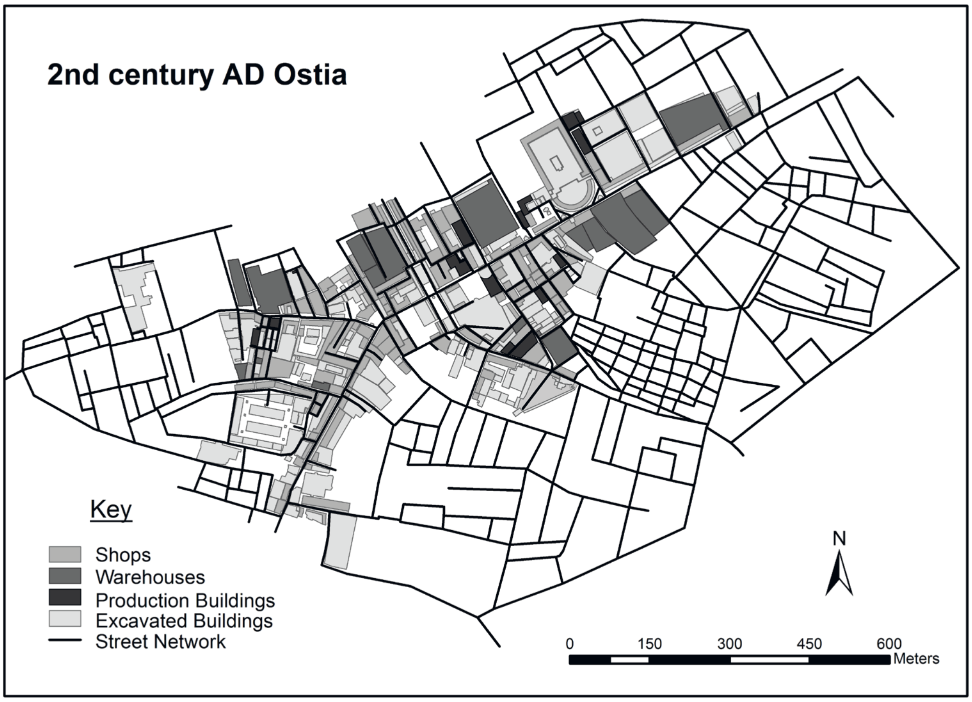

Figure 1. Ostia's 2nd century AD built environment showing commercial building classifications and the extended street network (after Calza 1953; Mannucci 1995).

cial areas of the city possibly passed by processional rituals.

The Model

In order to examine what impact commercial spaces may have had on ritual movement, a model (Figure 1) of the city during the late 2nd century AD was first digitized within ArcGIS following the original plans of Calza (1953) and the updated map created by Mannucci (1995). The street network that extends beyond the excavated city is additionally included after the preliminarily geophysical survey results undertaken by Heinzelmann (1998; Martin and Heinzelmann 2000) and the space syntax axial graph produced by Stöger (2011) following these results. It needs to be noted that portions of this extended street network likely postdate the period under consideration, however, since the final results are still awaiting final publication it was not possible to differentiate all the streets specific to the late 2nd century AD from the current plan. The extended street network's inclusion accounts for the potential of movement travelling in and out of the city rather than confining analysis to only the excavated city, helping to negate the issue of edge effects.

Three different types of commercial spaces (shops, warehouses, production spaces) were then classified within the late 2nd century AD city. Regarding these classifications, the complexity of trying to define individual spaces within the ancient city cannot be discounted. This presents just one interpretation following previous scholarship on the definition of commercial spaces throughout the city (DeLaine 2005; Rickman 1971). Due to how the city has been excavated and studied, it is difficult to identify each commercial space with accuracy. In many instances, the size and location of a structure along the street network has informed our definition of a commercial space where there is limited existing archaeological material. The different space classifications serve as the focus of analysis within the UNA toolbox applying betweenness centrality measurements as an exploratory approach for studying ritual movement.

Metric Radius

The study radius must first be determined in order to set the scale at which movement will be assessed within the city. The input radius specifies the network radius for which the betweenness calculations occur (Sevtsuk and Mekonnen 2012: 292). If a radius is not specified, then the measurements are computed for an infinite radius that can reach all structures within the graph. For example, if a 100 m radius is used, then movement will be calculated for each building relative to every other building located within a 100 m network radius. To determine what

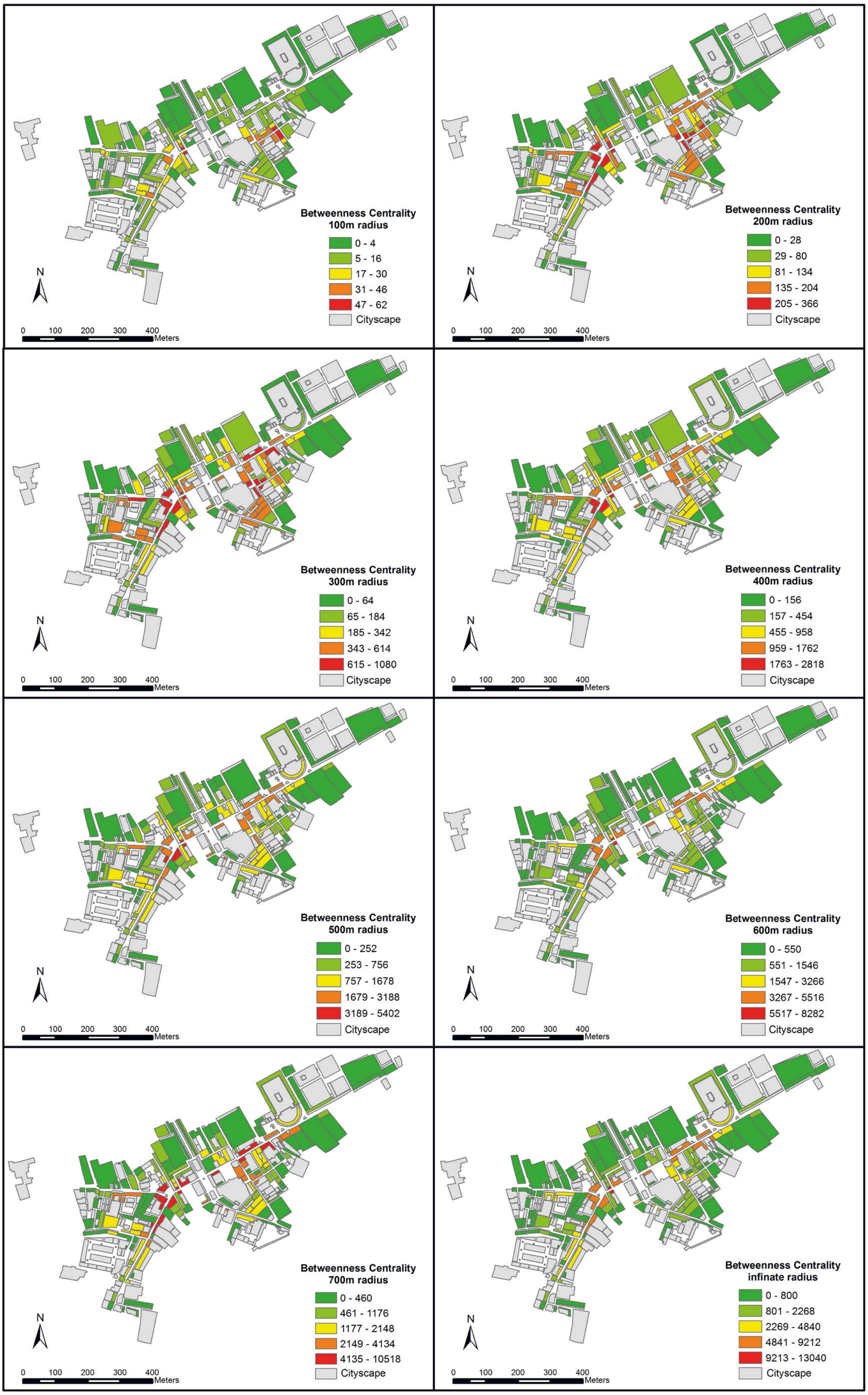

Figure 2. Image showing change in betweenness centrality with different radii values.

radius should be applied to the present study, Ostia's commercial landscape and extended street network was examined with eight different metrical radii (100–700 meters and infinite). Betweenness centrality was calculated in relation to each radius based on unweighted buildings to address the correlation between betweenness centrality and movement radius. The radius affects the network calculations in that each commercial space is considered only if it is an equal or less geodesic distance than the specified radius from every other building within the network (Sevtsuk and Mekonnen 2012: 292). The difference in radii is shown below (Figure 2) in relation to the 182 commercial spaces. The graphs are represented on a colour scale from red to dark green, with red indicating spaces of the highest betweenness centrality or areas most likely to be passed and dark green as areas of the lowest betweenness centrality.

Figure 2 shows that there is considerable variation in betweenness centrality values when the radius is adjusted. Local pedestrian movement is generally best accounted for with a 400 m radius, while a 800 m radius tends to correlate to vehicular movement (Omer, Rofè, and Lerman 2015). Within the present calculations, a 300–400 m radius shows the best average of the two highest betweenness centrality measures, displayed in red and orange (Figure 2), located throughout the city. A 400 m radius is ultimately used throughout this study because it accounts for movement within a greater portion of the cityscape. In relation to pedestrian movement, this associates to movement potential across the majority of Ostia's excavated environs. The application of a smaller radius (e.g., 100–300 m), alternatively, could be used for exploring smaller ritual movement areas, such as those confined to neighbourhoods rather than city-wide processions.

Weighting of Commercial Buildings

One of the most innovative features of the UNA toolbox is the ability to weight commercial spaces based on pre-determined values such as occupancy, importance, or size. The present study attributed each commercial space a weighted importance value 0, 50, or 100. The exact combination of weighted values is arbitrary. The choice to use intervals of 50 serves to more clearly differentiate between the three different commercial space classifications. The resulting betweenness calculations present a visualization of which commercial areas of Ostia had the highest movement potential weighted by building importance. Since the extent to which different commercial spaces influenced processional movement is unknown, three different iterations of building weights are run to determine how weighting the three commercial spaces in different ways effected movement potential across the cityscape. The highest betweenness values are displayed in red, indicating the greatest movement potential while dark green indicates the lowest movement potential areas. The following graphs (Figures 3–5) illustrate the difference in betweenness centrality for weighting shops, warehouses, and production areas each with an importance value of 100 while the other two classifications are given lower values.

The results indicate that the alteration of weights for different commercial classifications has a significant impact on the betweenness calculations and movement potential. The greatest difference in movement potential is shown with the last figure (Figure 5), where production areas were weighted highest and shops lowest. This is important because it indicates how areas of processional movement could change based on attraction or aversion to going past differing commercial spaces. While all possible weighted combinations are not presented, the three images above (Figures 3–5) show that weighting commercial structures in different ways following their importance for ritual movement illustrates differentiation in areas of likely movement passage throughout the city. This provides an initial indication into how activity occurring within the built environment impacted where ritual movement may have travelled.

Discussion and Conclusions

The calculation of betweenness centrality in relation to commercial structures begins to address the issue of how movement intent can be studied within the ancient city. The present focus has questioned how different commercial spaces may have played a role in structuring ritual movement patterns at Ostia. This moves beyond previous studies of movement at Ostia focused solely on how the street network design generated movement (Kaiser 2011; Stöger 2011). The

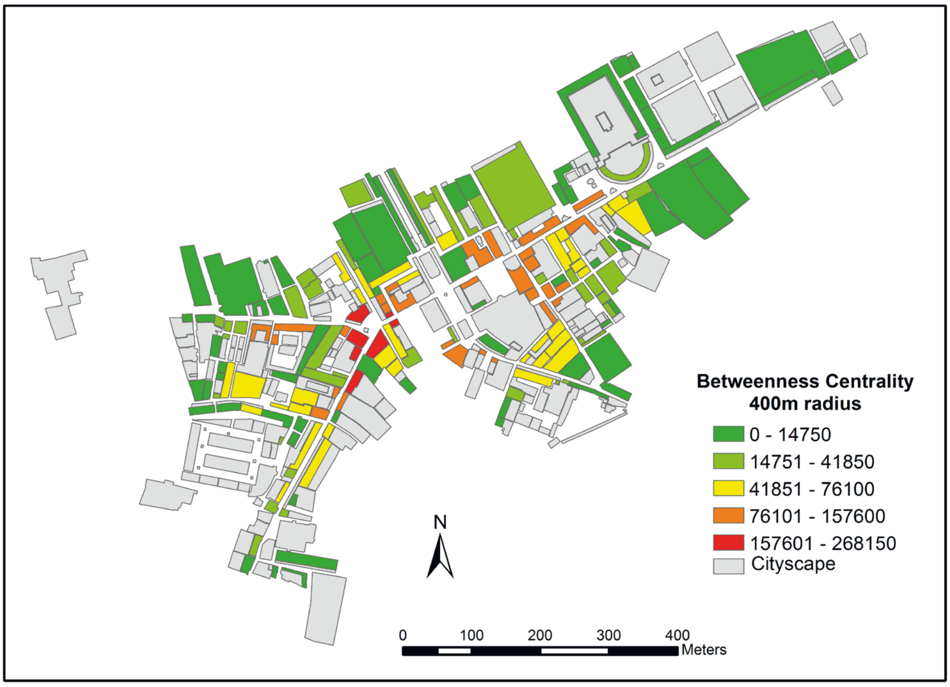

Figure 3. Betweenness centrality of commercial spaces within a 400m radius with the following building weights:
shops – 100;
warehouses – 50
production – 0.

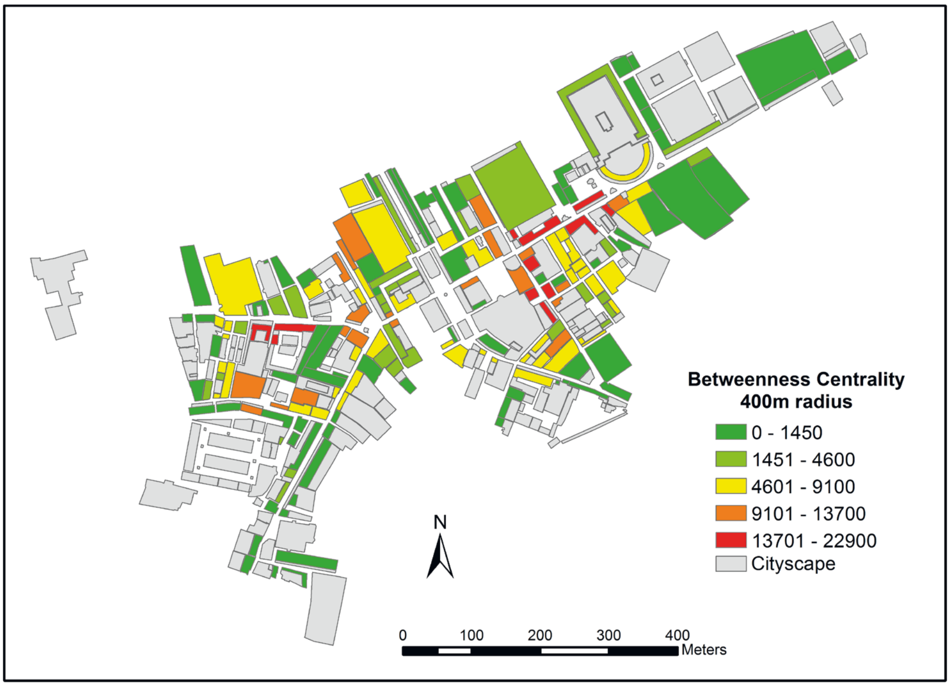

Figure 4. Betweenness centrality of commercial spaces within a 400m radius with the following building weights:
warehouses – 100;
production – 50;
shops – 0.

results of the weighted betweenness centrality calculations illustrate that changes in how commercial buildings were weighted based on their supposed importance for ritual activity had a visible correlation to movement potential. The most important aspect is that multiple types of commercial buildings can be included, an aspect that can broaden future analyses to include other types of urban spaces.

The implications of these betweenness calculations results in what can be termed 'hotspots' of movement. The two highest betweenness centrality measures shown in Figures 3–5 indicate areas with a high degree of movement potential relative to different commercial spaces. In relation to ritual movement, these hotspots indicate certain areas that would have been passed if the highest weighted space was important for a specific ritual. The results do not indicate full areas of movement, rather, they indicate

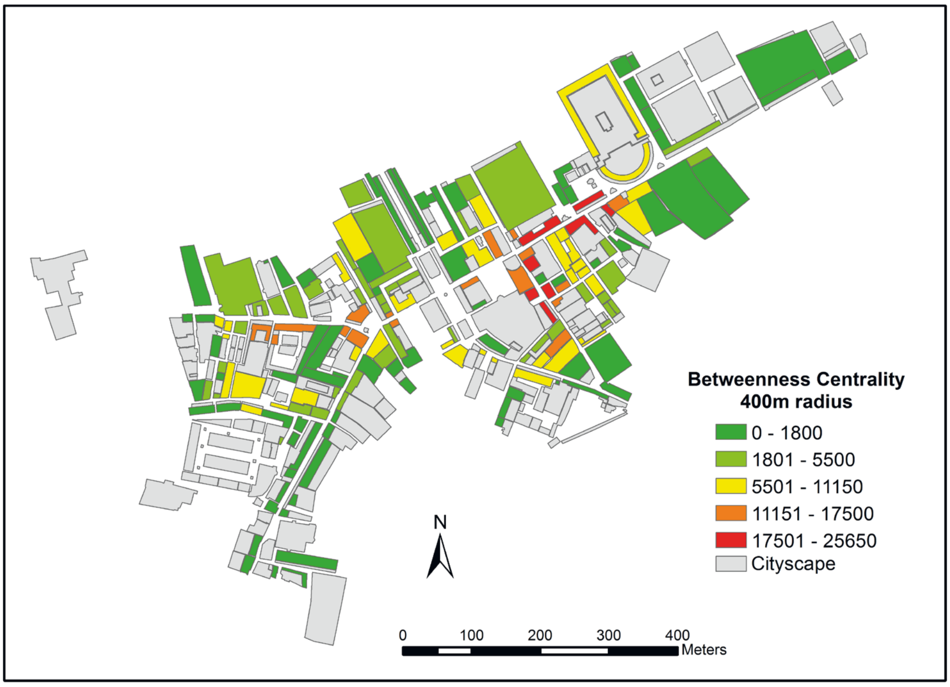

Figure 5. Betweenness centrality of commercial spaces within a 400m radius with the following building weights: production – 100; warehouses – 50; shops – 0.

possible nodes within the city that could have been passed by a procession, providing a framework for future study about the influence of commercial activity on processional movement at Ostia. By taking into account the specifics required for a particular procession, such as avoiding a specific temple or area within the city, the movement potential results can be adapted for individual routes. The examination of different iterations of building weights enables various models to be generated that visualize the ways in which commercial activities affected movement routes. Most importantly, this creates a way to begin to think about how ritual movement can be studied by questioning what affects different movement routes.

The network analysis computed in relation to commercial spaces at Ostia presents the first attempt at visualizing how commercial activity affected religious movement. The understanding of how urban and social factors structured ritual movement furthers our understanding of both processional routes and the larger religious landscapes they constructed at Ostia. While the specific routes are not detailed, potential areas are visualized that set the foundation for future more focused studies of ritual movement. The benefit of this method is that it considers how movement intent can be approached, moving away from more general models of pedestrian activity. The dynamics of the built environment and social activity are accounted for within the model, allowing new insights that expand upon previous space syntax results of movement directionality at Ostia. This presents just one method for exploring the potential of studying a specific form of pedestrian movement. An advantage of applying betweenness centrality within the UNA toolbox is not only the compatibility with ArcGIS, but also the addition of the built environment within the model. It provides a visualization of how urban structures shaped movement potential.

The study of processional movement and commercial spaces at Ostia adds a new dimension to ritual studies. The methodology not only forces the researcher to think about how urban activity can be classified in relation to the built environment, but it allows us to ask questions about how this activity helped to shape ritual movement practices. The UNA toolbox for applying betweenness centrality has significant implications for not only studying ritual movement but allows for other spatial questions to be addressed. The ability to adjust the model to different focuses of analysis enables many new questions to be raised, not just specific to ritual movement.

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