Acoustics of Roman Ostia:
Aural Architecture, Noise and Urban Space in the Second Century CE

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Abstract

This thesis introduces a methodology for the acoustic analysis of Roman urban space, through an in-depth study of Ostia Antica. The archaeological site of Ostia offers the opportunity to analyse the acoustic effects of second century CE building techniques in a variety of spaces. The acoustic analyses introduced are the first application of a quantitative and qualitative sensory study approach to Roman urban space. The original approach draws on digital humanities tools in combination with traditional archaeological site analyses in the interpretation of noise and acoustics.

The thesis is developed in three main parts. First, an exploration of the Roman literary sources through a digital humanities approach, which contextualises the literary urban image of noise in Rome. Noise was a key element in the social perception of urban space. The Latin literary sources display an urban image of noise, especially noise relating to movement. This concern did not manifest itself in legal control of noise, but instead relied on social stigma and moral judgements. Second, an acoustic model was developed and analysed some of the primary building types and streets in second century CE Ostia. Sound isolation was only possible in certain places, a product of other construction techniques and design choices. Third, a social historical investigation of the everyday rhythms of work, which were the background noise of Ostia, was undertaken to develop an approach to urban divisions of space not visible in architecture. These three parts are grounded in spatial and social theory, drawing on work from urban geography and sensory studies.

This thesis shows the importance of acoustic analysis in understanding Roman architecture and urbanism in the second century CE. It develops an original approach to modelling and analysing architecture through acoustics. The application of such a model to the urban arrangement and layout of a Roman site has not been undertaken before. This thesis, therefore, forms an original contribution to the field of classical archaeology through the implementation and interpretation of acoustic modelling of partially preserved buildings, as well as the models application to the urban arrangement of second century CE Ostia.

Contents

List of Figures

List of Tables

Abbreviations

The abbreviations of literary authors and sources follow those in the *Oxford Classical Dictionary*, Fourth Edition, edited by Simon Hornblower and Antony Spawforth. Oxford: Oxford University Press, 2012.

EpiLat	*Épigraphie latine*, edited by Mireille Cébeillac-Gervasoni, Maria Letizia Caldelli, Fausto Zevi. Paris: Armand Colin, 2006.
FOst	*Fasti Ostiense*, edited by Ladislav Vidman. Praha: Nakl. Československé akademie věd, 1957.
LTUR	*Lexicon Topographicum Urbis Romae*, 6 vols, edited by Eva Margareta Steinby. Roma: Edizioni Quasar, 1993-2000.
NSc	*Notizie degli Scavi*
OLD	*Oxford Latin Dictionary*, edited by P.G.W. Glare. Oxford: Oxford University Press, 2012.
PPM	*Pompei: pitture e mosaici*. Five volumes. Roma: Istituto della Enciclopedia italiana, 1995.
Thylander	*Inscriptions du Port d'Ostie*, Thylander, H., Lund: Gleerup, 1952.
TLL	*Thesaurus linguae Latinae*. Munich: K.G. Saur Electronic Publishing, 2006.
Tit. *Ful*.	Titinius *Fullones*

Chapter One
Introduction

"Noises. Noises. Rumours. When rhythms are lived and blend into another, they are difficult to make out. Noise, when chaotic, has no rhythm. Yet, the alert ear begins to separate, to identify sources, bring them together, perceiving interactions."
H. Lefebvre, *Writings on Cities*, 219.

"Movement is an inherently noisy affair, involving as it does the concentration of people in space or the clatter of vehicle wheels on basalt paving stones."
D. Newsome, *Making Movement Meaningful*, 41.

"Our science has always desired to monitor, measure, abstract, and castrate meaning, forgetting that life is full of noise and that death alone is silent: work noise, noise of man, and noise of beast. Noise bought, sold, and prohibited. Nothing essential happens in the absence of noise."
J. Attali, *Noise*, 3.

Noise is everywhere. Today, exposure to increased levels of noise has been linked to a variety of health and well-being issues.[1] Buildings are constructed to isolate traffic noise, while the development of muzak, a particular form of background music often associated with lifts, has brought continuous noise to common places of congregation and interaction.[2] Sound and noise are a fact of life. As Attali reminds us in the opening quotation, noise is a product of life, whether social, economic, or political.[3] Henri Lefebvre, as will be discussed below, was one of the first to theorise an understanding of social space through noise.[4] Listening was Lefebvre's sociological tool to analyse everyday life by separating and critiquing the rhythms of movement.[5] It is within the context of the pervasiveness of noise and its utilisation as an analytical tool that this thesis approaches the architecture and arrangement of space in Ostia.

This thesis argues for the importance of noise as an experience of urban space in second century CE Ostia. It develops a new and original methodology for the

[1] See Gidlöf-Gunnarsson and Öhrström 2007.

[2] Sound design, Maier, Schneider and Schulze 2016; Muzak, Blesser and Salter 2007: 33.

[3] Attali focused, in particular, on the rise of noise in consumerism, Attali 2014.

[4] Lefebvre references noise in passing throughout his works and at the end of his career emphasised listening as central to understanding urban rhythms, see Lefebvre 2013.

[5] Lefebvre 2013: 37.

reconstruction of the acoustic properties of buildings and streets, applying this methodology to a set of case studies that argue for the perception of noise as an element in the design of space. This thesis has two objectives, which incorporate noise, urban space and Roman society. First, it introduces the necessary background for the construction of an appropriate acoustic model, and applies that model to specific spaces. Second, it contextualises the acoustic properties derived from the model within Ostia, and in the development of an image of noise found with the Latin authors. This introduction sets out the argument and structure of the thesis, then the theoretical background and the studies of Ostia that inform it.

1.1 Argument of the Thesis

This thesis goes beyond the simple reconstruction of ancient sounds, an inherently problematic endeavour, and seeks to understand the role of noise in the development of ancient urbanism.

First and foremost, this thesis argues that noise functions as both a tool for the study of space and society, and an object of study in itself. Sound, as a tool, enables the quantification of architectural agency through acoustic analysis. Acoustics are the physical measurements of the auditory field created by physical structures. As will be discussed in the theoretical background (1.4), buildings are the product of social and cultural institutions and norms. Through acoustic analysis, sound becomes a tool for understanding the influence of a built space on social interaction within buildings, streets and public spaces. The thesis here is that in order to understand social interaction in Ostia one needs to account for the acoustics and their influence on different types of interaction. The study of acoustics moves beyond the quantifiable measures, through a grounding in urban theory, to understand the dynamic change that happens outside the destruction and reconstruction of buildings. Acoustics allow for social changes based of activity to be studied over time, as social and cultural perceptions of space.

Noise is an object in the environment, and sound is an object of study, which pervaded the ancient world and appears in a variety of sources from antiquity. Noise is not a product of recent history, as Seneca reminds us. The more frequent complaints made by the ancients reflect the role of noise in their understanding of everyday life. In the most famous, and cited, auditory complaint, Seneca bemoans the noises he hears from the bath complex below his apartment; noises that make him 'hate his very powers

of hearing'.[6] The grunting weightlifter, the scores being called out, the masseur slapping his client's back, the poet who loves to hear his own voice practising, and all the food vendors trying to catch people's attention; all these sounds invade the apartment where Seneca stays, trying his stoic abilities to keep his emotions, spirit and mind in control. The sounds of each individual are brought out in the repetition of the letter S in the weightlifter's description and the masseur's hand in repeated U sounds until the blows come in repeated P sounds.[7] At the centre of this letter is the relationship between Seneca's apartment and the bath complex.[8] Seneca's stoic sensibility is stretched by the noise within his own apartment; the noise of the baths is out of place, not bound by the physical structure of the baths. It is this aspect, the acoustic properties of ancient space that this thesis explores. It is not a thesis on reconstructing ancient sounds, but the relationship between noise, space and society.

Literary discussions and built structures are of primary importance to this thesis, both offering an insight into the nature and perception of noises in antiquity. It must be stressed that both sources are interrelated and dependent on each other, although they offer different types of evidence. The literary sources and material remains are both constituent components of Roman society, while at the same time Roman society produces the literary and building acoustics. It is the interaction of noise, space and society that poses questions to previous interpretations of Roman urbanism. Noise is used to critique and comment on changes to social forms of urbanism, reflecting a growing concern over noise and movement.

A second group of questions revolve around the methodological approach to sensory phenomena in the ancient world. This thesis argues for a rigorous theoretical approach, paired with quantifiable measurements tested in ancient spaces. The methodology draws from the fields of architectural acoustics, further emphasising the need for interdisciplinary research and specialisation. The methodological innovations cannot stand alone, however, and the results must be interpreted properly. These approaches must be founded in the material remains and ancient sources. Theory provides a dual benefit of questioning critically the assumptions about the types of evidence, as well as drawing from the sources critical questions about academic assumptions. In this thesis, method and theory work together to inform and evaluate the academic assumptions about the urban image of noise and its relationship to the built environment of Ostia.

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[6] Sen. *Ep*. 56.1, *quotiens retentum spiritum remiserunt, sibilos et acerbissimas respirations* […] *audio crepitum illisae manus umeris, quae prout plana pervenit aut concave, ita sonum mutat*.

[7] Hartnett 2016: 159.

[8] Cf. Hartnett 2016: 159-61.

The architecture of Ostia displays limited means of dealing with noise, and central to this thesis is the argument that different groups exercised social control of space and spatial practices in an attempt to deal with the issue of noise, apparently a predominantly elite literary concern.

The final hypothesis is that noise was a guide to understanding social interaction in urban space. The acoustic measurements outlined in the methodology demonstrate the experienced properties of space. This thesis argues that the experience of space was central to social interactions in Ostia. Interactions did not determine space, but were made possible by the space. Section 1.4 argues that buildings had agency that enabled, created and influenced the interactions of people and spaces.[9] These interactions were not limited to single rooms or buildings, but were active participants in neighbouring space. Roman buildings display nuanced and small-scale design choices, which isolated spaces acoustically. This thesis proves that Romans did not deal with noise through soundproofing. Instead, social interactions informed by the auditory experience of urbanism were translated into decisions about construction techniques and urban features that began to deal with the issue of noise.

1.2 Structure of the Thesis

This thesis addresses the relationship between noise, space and society through a triad of approaches. The first approach is a theoretically informed engagement with movement, mobility and space, as discussed below (1.4). Roman urbanism needs to be understood as a dynamic process that was influenced by the lived experience of its towns and cities. Sound serves as a heuristic tool for understanding the perception and conception of Roman urban space, as well as an object of study, within the developing theoretical approaches to Roman history. Chapter two considers the literary context of urban noises, whilst chapters three and four analyse particular spaces, and chapter five demonstrates the value of this acoustic approach through case studies of the lived experience of workers in the town.

Chapter two sets out the literary image and topography of urban noise. The anecdotal perception of Rome being full of noise and activity is critically examined through literary references to noise and silence terms (see Appendix 3), using the Packard Humanities Institute Latin library, the associations between noise, silence and urban space across Latin literature (from second century BCE to second century CE, with the inclusion of *The Digest of Justinian*). The chapter begins by looking at the

[9] A point made by various theorists in different ways, Rasmussen 1964; Lefebvre 2014b [1973]; Bourdieu 1977; de Certeau 1984; Pallasmaa 2012.

specific terms used to describe noise and the etymological associations, particularly in relation to movement. Using Truax's typology of noise, the Latin terms are divided into three types: 1) negative responses, 2) obstruction of auditory clarity and 3) unknown sounds. The urban image of noise from the Latin sources is constructed simultaneously from these three definitions of noise. The temporal range of noise and silence terms will be discussed, as well as the term's usage in poetry or prose. The peak periods of usage mirror the peak periods of literary sources, namely the first century BCE to second century CE and, while the terms are used more regularly in prose writings than poetry there are clear emphases on particular terms.

The noise and silence terms associated with urban spaces are discussed in section 2.3. The theatre and courtroom, forum and streets, in particular, displayed three different auditory and urban forms: enclosed space, open space and moving space. Each urban space was associated with particular noises that related to spatial practices and urban perceptions and expectations. These types of spaces form the basis for the specific acoustic analyses in chapter three. This leads to a discussion of movement and noise as intertwined in the perception of urban space, using the movement of rumours as a case study.

Section 2.5 considers the control of noise, drawing on the legal writings of *The Digest of Justinian*. Legal sources indicate damage was measured by visibility, rather than noise limitation (2.5). Social stigma and movement were used to distance individuals from noise. Social stigma and moral judgements are discussed in relation to the announcements of *praecones* and the gathering of *circuli*. The former were integrated into the imperial administration, enabling direct social control, while *circuli* remained outside official forms of communication and remained morally suspect. The urban image of noisy Rome could also be overcome through leaving the city. Mobility provided a way to distance oneself, especially in the literary sources, from the noise and crowds of Rome. Through these examples, the importance of moral judgements and social control comes to the forefront in dealing with the perceived noise of Rome. This urban image of noise was a backdrop to some of the later developments in Roman architecture. Ostia provides one perspective on the relationship of this image of noise to everyday spaces in a town outside of Rome. The elite priorities in the urban image can, therefore, be compared to the practicalities of everyday life in Ostia.

Chapter three presents the methodology for the analysis of acoustic properties (3.2). Historical acoustics have focused on complete structures, and no Roman site has yet been analysed so, this chapter presents an original methodology for the study of acoustics of Roman sites. The second century CE redevelopment of Ostia provides

material remains for a key point in time. In particular, three primary acoustic measures are described (3.2.1-3), namely *absorption coefficient (AC)*, *reverberation time (RT60)* and *transmission loss (TL)*. These measurements provide a basic framework for the acoustic properties of an enclosed space. The mathematical calculations of the measurements were tested against the remains of the Mercati di Traiano in Rome (3.2.4). The correspondence between the calculated predicted measurements and the physically measured acoustic properties validates the acoustic model, as well as validating the comparison of modern acoustic measures with ancient equivalents. The model is then applied to the open space of streets (3.3). Street canyons, façades and paving that frame the street require a variant approach to measuring acoustics, as the space is open, rather than enclosed. The elements that make up the street canyon are discussed to adapt the enclosed space model to an open space.

The analysis of simple rooms precedes the analysis of street canyons. There is a difference in complexity between the two analyses, which requires an understanding of the basic room calculations before moving to street canyons. The two analyses build on each other and the desire is to move from simple to more complex applications of the method. The later chapters continue to follow the same basic arrangement, moving from internal space to street space. It is the analysis of street noise that serves as a guiding question, and it draws on the internal space analysis to formulate an answer.

Chapter three ends with two case studies that apply the acoustic model to specific streets (3.4-5). The north Cardo Maximus and the Via degli Augustali are analysed to contrast two key elements in the development of Ostia. The north Cardo Maximus represents a civic reorganisation of area north of the Forum beginning in 110 CE (3.4). The monumental street served as an entrance to the Forum and its uniformity of shops and porticoes were key to the acoustic differentiation along the street. The Via degli Augustali, in contrast, displayed a series of small-scale interventions by different property owners that reshaped the auditory field at the end of the second century CE (3.5). These two streets highlight different approaches to the shaping of the landscape of noise, whether monumental and organised as a single project or small-scale and dispersed among various local properties.

Using the acoustic methodology developed in chapter three (3.2-3), chapter four analyses commercial and residential enclosed spaces. The overwhelming number of shops in Ostia indicates that these were some of the most widely used spaces in the town and were the primary acoustic experience for the majority of people. The acoustic properties of the shops are examined via the methodology presented in chapter three (4.1.1-2) and compared with '*medianum*' apartments (4.1.3). Both shops and apartments

were oriented towards the street. The acoustic properties of the spaces mean that each had varied interactions with the street. The shops display direct connections, a continuation of street acoustics, while the apartments negotiate forms and levels of social control through acoustic differentiation. A final group of residential structures, *domus*-type houses, are analysed in comparison with the street orientation of shops and apartments. *Domus*-type houses were studied using space syntax, as well as the '*medianum*' apartments, which drew links to Pompeian houses.[10] Space syntax is primarily a visual based analysis, which disconnects the space from its sensory setting. The connections between Pompeian and Ostian residential spaces are critiqued using their acoustic properties to show the way sounds structured the social interactions in space.

In chapter five, human perception of noise is placed within the context of Ostian workers. Several fixed locations are analysed for noises and acoustics that would have created a distinctive soundscape. In particular, fixed commercial spaces, *fullonicae* and bakeries, are discussed, as both share certain characteristics that would define the noises of those jobs. The lack of residential space suggests that movement to and from the premises would have been required, structuring the day.

In section 5.2, particular forms of movement are discussed in terms of the noises associated with them. Pedestrians and carts were the primary modes of transport, both producing distinctive noises that were dependent on the forms of movement. Drawing on the previous chapters, the importance of the street as the site for the majority of social interaction is nuanced further through the human auditory system. Testing the analysis in chapter two, it is argued that it was a social concern, rather than urban noise per se, which influenced the perceptions of these forms of movement. Architectural divisions of movement, such as sidewalks, porticoes and benches, all create distinctive auditory fields relating to movements; even silence differentiates space and movements. Movement, space and social interaction come together in the rhythms of noise in Ostia.

In chapter six, we return to the role of noise in understanding the development of Ostia. The thesis concludes by comparing the urban image of literary Rome with the architectural acoustics of the town and explaining the importance of noise, as representative of social and cultural changes. Noise was not simply a negative response, but was part of the experience of space, which fed into the architectural development of Ostia. Transitions in building style and techniques had auditory affects, which were incorporated into the urban environment. This thesis offers a new methodology which

[10] DeLaine 1999; 2004.

adds nuance to our understanding of the development of Roman urbanism, and demonstrates the importance of noise as a tool for analysis and as an object of study.

1.3 Sound versus Noise

The distinction between sound and noise is a subjective judgement, one based on the perceiver. In its most common-sense definition noise is unwanted sound.[11] The fluidity between sound and noise is in the social perceptions; one person's noise is another's sound. Noise complaints, therefore, cannot be used as indications of sound intensity levels, but do indicate moral judgements on the spatial locations and social status of noise. Discussions of noise are, however, reactions to the social and cultural changes to movement in Rome brought about by technological innovations.

Noise, as unwanted sound, can therefore function as recognisable and meaningful sounds, but ones which carry negative associations, whether subjective judgements of like/dislike or physiological stress, annoyance, or disruption of other activities.[12] Noise can also be defined through the act of obscuring the auditory field in a given location, as a means of lessening the clarity of auditory definition in a given location.[13] Without a quantifiable measure of noise, definitions and word associations created literary images of reduced auditory clarity. One final function of noise is as un-patterned or disordered sound, especially in terms of new information.[14] This is noise in a non-pejorative sense, as sounds that could be *potentially* meaningful, but are unknown at first. This function of noise, although the most useful, is the most subject specific.

Situated at the mouth of the Tiber, Ostia was the port of Rome. The development of the town is connected with the city, a mere 20 km away, and the importation of goods. The large-scale clearance excavations of Ostia have uncovered a site comparable to Pompeii. However, the dense urban space of Ostia, and its slow decline in the seventh and eight centuries, is in contrast to Pompeii. The difference in survival history of Ostia offers insights into later developments beyond Pompeii. As will be discussed, the second century CE marks a transitional period, in terms of architecture and society, which comes to the fore in acoustic analysis of the site. The peak period of development of Ostia was also the peak period for urban noise, as the increase in construction, migration, and urban density produced more noise. Ostia provides a case study for the development, analysis and structure of acoustics following the 64 CE fire in Rome and the architectural transitions that rebuilding brought about. In that period, certain

[11] Truax 2001: 95.

[12] Truax 2001: 96.

[13] Truax 2001: 96.

[14] Truax 2001: 97.

architectural and technological changes shaped the acoustics of urban space, which finds widespread use and application in the expansion of Ostia in the second century CE.

1.4 Theoretical Grounding

The approach of this thesis, grounded in the analysis of noise and acoustics of urban space, is part of an ongoing critical engagement in ancient urban studies on the development of urbanism and spatial cultures.[15] Recent research has begun to examine the role of the senses in ancient sources. In relation to Rome, this tends towards studies of literary sources, or a specific sense, such as smell, although archaeological works on the senses in prehistory already have a notable pedigree.[16] Sound, in particular, has received limited study in the Roman context, especially in a quantifiable and measurable methodological way.[17] Specifically, the combination of urban and sound studies fields have not been applied to the Roman world. In particular, acoustics has only just begun to be explored in Roman urban spaces.[18] Studies in prehistory have a longer tradition of engaging with the senses, although, in terms of acoustics, these are focused on enclosed spaces, especially caves.[19] Acoustics in caves, however, rely on the measurement of physical auditory effects within the space of the cave. In opposition, the site of Ostia is only preserved to a limited height and there are few enclosed spaces, which can be physically measured. The thesis here diverges from these previous studies in two primary and fundamental ways. First, an acoustic model is created to analyse incomplete and open spaces. The levels of preservation and reconstruction of the site of Ostia limit the rooms and spaces that can be physically measured for acoustic properties, unlike prehistoric caves, which present an enclosed and measureable space. Second, and related, the reliance on modelling requires a further level of interpretation of the space beyond the numerical values. In the case of prehistoric caves, the ability to physically measure the acoustics enables the analysis of specific auditory effects; however the specificity is at the expense of local and regional variations. That is to say,

[15] See Griffiths and von Lünen 2016; Creekmore and Fisher 2014.

[16] Senses, Day 2013; Butler and Purves 2013; Toner 2014; Haug and Kreuz 2016; Squire 2016; Betts 2017; smell, Lilja 1972; Potter 1999; Bartosiewicz 2003; Bradley 2015; cf. Veitch 2017b; prehistoric archaeology, Hamilton and Whitehouse 2006; Skeates 2010; Hamilakis 2014.

[17] Butler forthcoming; cf. Veitch 2017a, b.

[18] See Veitch 2017a.

[19] Skeates 2010; Hamilakis 2013; Eneix 2014; 'Songs of the caves' project (https://songsofthecaves.wordpress.com).

the focus on a single space hides the complex and hierarchical differentiation of spaces within a wider neighbourhood, locale or region.

This thesis draws on two particular fields, sound studies and movement studies, which have rarely been brought together.[20] Noise serves a dual purpose, as both a critical tool and object of study. As a critical tool, acoustic measurements display the interactions between sounds and spaces. At the centre of spatial theoretical discussions in ancient history and classical archaeology is the work of Henri Lefebvre, which has references to sensory perceptions and urbanism. These references have not been discussed in any detail and much of Lefebvre's approach to sensory perception is minimally understood. The acoustic measurements and standard units are part of the field of physics, which primarily works with an abstract notion of space. In terms of Lefebvre's conception, abstract space is geometric, ordered and static, which is at odds with other conceptions of space, especially those of geography, as will be discussed below. In the following discussion, Lefebvre's spatial theory forms the starting point for understanding a relational conception of space founded on sensory perceptions. Sound studies, as a field separate from physics, has had limited interaction with the field of historical geography.[21] In bringing together sound, movement and urban space, a new methodology was necessary and is introduced in chapter three of this thesis. Using the work of sound design and acoustic engineering, connections are made between spatial practices, activities set in time-space, and physical settings, the space in which these practices take place. The physical spaces of Ostia, their dimensions, decorations and construction materials, created an auditory field, or sound field, which was connected with the activities carried out in the space. Therefore, the measurement of acoustic properties which framed the auditory field, offer a critical perspective on the potential uses of urban space and their social production.

Noise, as an object of study, in comparison, relates to the characteristics of certain social activities and the social or cultural judgements made about such social interactions. This is a more relational approach to noise, as sounds and perceptions are socially constructed. Social activities, in any form, make different noises and relate back to the activity. The spatial practices commonly noted in studies of Roman everyday life, from walking and riding, building to conversing, dining and bathing, all make noise. Sound is both producer and product of its spatial setting.[22] Chapter two focuses on noise

[20] Notable exception for ancient history, Betts 2011; Hartnett 2016, 2017.

[21] See Bull and Black 2003, 2016.

[22] On production of space, Lefebvre 1991, 2003, 2013, 2014a, 2014b, 2016a; Soja 1989, 1996, 2000; see bibliography in Shields 1999; Soja 1996: 39-40.

as an object of study within the literary sources, while in chapter three, noise is used as a tool in interpreting the spatial arrangement of Ostian spaces. Therefore the interconnection between noise and urban space offers a new approach to the study of Roman urbanism.

The theoretical approaches to urban space behind this thesis centre on a spatial imaginary understood through noise.[23] Unlike previous approaches, which often present space in abstract and static terms, sound enables urban space to be conceived of in relational terms, as dynamic, open to contestation, and always in the process of moving or becoming. Drawing on the work of Henri Lefebvre, a key figure in the development of spatial theories and critical approaches to everyday life, urban space is considered as a product of the particular society and culture under analysis.[24] A critical rereading of Lefebvre serves to highlight the importance of conceiving a relational space, which form a foundation for understanding noise and urban space.[25] By conceiving space in relational terms, the physical nature of sound as a moving waveform, carrying geographical and material information, forms a central element in the experience of space-time. Knowledge of the urban environment is produced through movement, which is guided by perceptions of sounds. In measuring the acoustics, space is conceived of as constantly moving, forming an embodied knowledge, based reflexively on movement and constant interaction. This cycle of experience is aided by noise, as the human body processes and interprets what is around it.

1.4.1 Slices through time

Temporality has been the main emphasis in much of social theory, which has constrained approaches to space. Space and time have been viewed in opposition to each other, and as a result space has been 'treated as the dead, the fixed, the undialectical, the immobile. Time, on the contrary, was richness, fecundity, life, dialectic', as Foucault stated.[26] Sound renders this opposition problematic, as sound functions in space and time simultaneously, as well as offering metaphors for the relational processes of space, such as echo, resonance and reverberation. Here, I argue that space and time are not in opposition to each other, but are implicated within each other, and

[23] Lefebvre 1991, 1996, 2003, 2014b, 2016c; Harvey 1988, 1989, 2001, 2006; Massey 1994, 1995, 2005; Soja 1979, 1989, 1996, 2000; Thrift 1996, 2008; Amin and Thrift 2002; Urry 1995; Ingold 2000.

[24] See Lefebvre 1991, 2014a, 2014b, 2016a; although all of Lefebvre's writings from 1965-1974 develop his spatial theory, which culminates with *The Production of Space* [1974]; Stanek 2011.

[25] See Newsome's suggestion of 'thinking with Lefebvre against Lefebvre', Newsome 2009: 35.

[26] Foucault 2007: 177.

sound is the primary example of this phenomenon. Sound does not happen in space and time as separate entities, but happens in space-time. That is to say, sound is a phenomenon of both space and time, in the physical sense that sound moves in space and time simultaneously, as well as the metaphorical sense that auditory metaphors, such as resonance, reverberation, or echo, highlight the interconnection between space and time. I will take up the simultaneity of sound in space-time before turning to the politics of auditory metaphors in conceptualising social activity.

Reference to Martin Heidegger's phenomenology will elaborate the distinctive argument that temporality needs to be rethought in relationship to and with spatiality. Heidegger places temporality at the centre of experience, although the importance of space and spatiality emerge later in his career.[27] Merleau-Ponty, likewise, emphasises the temporality of subjectivity, rather than its spatiality.[28] As Elden argues, Heidegger, at several points in *Sein und Zeit*, downplays the importance of space and place, emphasising the existential and temporal character of *Dasein*.[29] Preference is given to time and temporality, although Heidegger later grounds being in dwelling.[30] Late in his career, Heidegger reprioritised space, in a non-Cartesian manner, where 'things in themselves are places, and not only occupy places'.[31] This was part of Heidegger's 'turn', which, Elden argues, had a second move in which Heidegger first opposed space and place, before reconceptualising space as place.[32] This prioritisation of temporality has implications for spatiality, as the argument here will show.

For Heidegger, experience is not one of geometric ordering or measurable distance.[33] Extension and geometric ordering were equated with Cartesian notions of space, which led to the rejection of space. In his early work, space was a sphere of geometric ordering and extension, which was opposed to place. This equation of space with extension required a rejection of space. Instead of measured distance, experience is in terms of common-sense notions of closeness or nearness [*Nähe*], distancing [*Ent-fernung*] or directionality [*Ausrichtung*].[34] In his later works, Heidegger reconceptualises space as place, which makes it more difficult to imagine space as relational and open or

[27] See Elden 2001.

[28] Merleau-Ponty 1962: 442.

[29] Heidegger 1962: 79-80 (discussing 'being-in'), 94-5 (discussing 'environment' [*Umwelt*]) and 418-9; Elden 2001: 16.

[30] See Heidegger 1975.

[31] Heidegger 2002: 207; translation, Elden 2001: 90.

[32] Elden 2001: 4-5.

[33] Heidegger 1962: 98, 141

[34] Heidegger 1962: 135-8; Elden 2001: 17.

porous, as argued by Massey.[35] Placing this in the context of this thesis, the experience of room acoustics is not an experience of the decibels (the measured intensity of a sound) nor the frequency or reverberation time in themselves, but an experience of the relationship between social forms and, I would argue, spatial forms. The experience of room acoustics is simultaneously the product of social relationships, cultural values and the physical properties of the space. The measurement of such acoustic variables is necessary for the analysis presented here and the emphasis on the spatial character of such sounds is in contrast to Heidegger's clear de-spatialising of his own philosophical terms, such as being-in [*in-Sein*] and environment [*Umwelt*].[36]

Sound is a product of the implication of space and time, as it refers to the sensation perceived by the vibration, a temporal process, of air or of a medium, both of which are spatial processes.[37] As will be shown in chapter three, the measurements of acoustic properties, as well as the modelling of such properties, are dependent on the recognition of space-time, as sound dissipates over geographic space and, simultaneously, time. This physical feature, however, is not limited to sound, and Massey has argued for a conception of space itself as a product of simultaneous spatiality and temporality, which is discussed below. To show the limitations imposed in prioritising temporality over spatiality, I next draw on the concept of nostalgia, which has been used in critiques of early sound studies and the often-used term soundscape.

The prioritisation of time and temporality over spatiality has implications for the way space is conceived. The notion of nostalgia brings the problematic aspect of time over space to light. Nostalgia can be interpreted as a temporal disjuncture at a specific location, a reverting 'back' to the past, in a present location.[38] The subjective judgement, whether nostalgia is good or bad, can be placed to the side, as either position can be invoked. What is important is that it is a temporal disjuncture which fosters feelings of nostalgia, and this disjuncture is always the past being brought into the present. Thus, the past time is spatialised in the present through feelings of nostalgia. In this process, the simultaneity of different times is brought together within a specific place, which, according to Lefebvre, through monumentality creates a form of violence. For Lefebvre, monumentality takes on an a-temporal quality that violently interrupts the everyday, which is the space of revolution in his thinking.[39] The experience of spaces, through

[35] Massey 2005: 201 n. 17.

[36] Heidegger 1962: 63-66.

[37] Everest and Pohlmann 2009: 1-17; see also Idhe 2007: 3-5; Ingold 2000: 243-287.

[38] Massey 2005: 124.

[39] Lefebvre 1991: 220-3; 2014b: 17-21; on everyday as the site of revolution, Lefebvre 2003; 2015; 2014a.

spatial practices, further emphasises feelings of monumentality in architecture. Monumental architecture has acoustic properties, which help to measure space. Silence, even, has a role in making buildings more immediate.[40] From the social side, the monument subdues the violence and conflict of society through a consensus in ritual actions, monumental space, and social participation. There is a dual violence: one that is subdued by the monument and another that the monument produces.

A common critique of the anthropological studies of soundscapes is its reliance on nostalgic conceptions of lost sounds.[41] Soundscapes, the sum total of sounds heard within a geographical area, have been studied in various locations; however an implicit emphasis is on the 'sounds of nature', and always with a strong notion that these sounds are being lost.[42] Soundscapes are, according to Schafer and his followers, perceived and conceived as natural, as though they are mirrors reflecting the way the world is.[43] There is an unreflective character to this interpretation of the environment, which Smith argued was part of the social production of space in any society.[44] A dichotomy is set up between the 'natural' world and urban space, in which urban space consumes the 'sounds of nature'. In fact, sounds are embedded in the social interactions between people, spaces, and the material world. By granting sounds produced in nature a privileged position, over urban or mechanical sounds, a static notion of an unchanging natural landscape is reinforced. The natural, just as the urban, landscape is rather a 'dynamic simultaneous multiplicity' of processes, a phrase Massey uses to describe the production of space.[45] Sounds are not unchanging, but, instead, reflect movements over space and time simultaneously, whether migratory patterns, seismic activities, or the slow decay of forestland. It does not matter, for the discussion here, if no one hears the tree falling in the forest, only it is recognised that the event reshapes the space of the forest in the production of a sound.[46]

The street is the prime example of dynamic simultaneous multiplicities of space-time. The street offers a space where a diversity of social activities and trajectories can

[40] Pallasmaa 2012: 55-8; Lefebvre 1991: 225.

[41] Ingold 2000; Chion 2016: 138-9; critiquing Schafer 1977; Corbin 1998; Truax 2001; much of this thought is derived from Theodore Adorno's classification of musical listening and his idea of the 'regression of listening', Adorno 1985; Jütte 2005.

[42] Schafer 1977; Corbin 1998.

[43] Schafer 1977; cf. Betts 2011.

[44] Smith 2010.

[45] Massey 2005: 61.

[46] Saying comes from a thought experiment in George Berkeley's *Treatise Concerning the Principles of Human Knowledge* (1710).

interact.[47] Noise can control the street space, despite its intended use, through appropriation, although this is always limited. In the case of a street, the space of movement is appropriated for talk, being used for the exchange of words and signs as much as the exchange of things.[48] Boudin has pursued this idea with regard to nineteenth-century Paris. Street hawkers utilised a variety of resources, including the architecture along streets, for the sale and exchange of goods.[49] In this case, the loud cries and noise of the streets, which represented both tradition and economic prosperity, were in contrast to the developing bourgeois demand for quiet.[50] The control of street noise developed out of an increasing social desire for quiet, rather than official noise regulation.

Social theory has begun to account for the importance of sound in conceptions of space through auditory metaphors. According to Smith, the spatial turn saw a development of the understanding of space in two independent trajectories: material space and metaphorical space.[51] Smith and Katz have shown the way spatial metaphors are deployed with 'uncritical political awareness'.[52] The conception of abstract space is related to the unreflective usage of metaphors and, again, their associations with particular implicit understandings of space. Visual metaphors have a tradition within approaches to the city, which take for granted certain aspects of the social production of space, especially problematic for archaeologists and ancient historians. First, the visual metaphors rely on distant, static or global views, which are part of an abstract conception of space.[53] The distance that these metaphorical images imply is from a perspective never experienced in the ancient world. The Roman town or city, however, was never experienced in its totality, from above, and to conceive of space in such a way implies a conception of the totality of city space, rather than the experiential portions, fragments, and parts, which are pieced together through movement.[54]

Part of the critique of such metaphorical conceptions is the reduction of complex social processes to simple dichotomies of A/Not-A types.[55] In this way, vision and

[47] Lefebvre 2003: 18-9.

[48] Lefebvre 2003: 19.

[49] Boutin 2015.

[50] Boutin 2015: 88-9.

[51] Smith 2010: 220.

[52] Smith and Katz 1993.

[53] De Certeau illustrates this in his opposition of strategies, relating to the view from the World Trade Centre towers, to tactics, those of the person walking on the street below, 1984: 91-2.

[54] Favro 1996; cf. Ingold 2000: 235.

[55] Massey 1993: 145-6.

cognitive understanding are equated in opposition to hearing, touching, smelling and non-recognition. In terms of space and time, Massey argues that time is given the position of A, and correspondingly associated with history, progress, civilisation, science, politics and reason, while space, not-A in the dichotomy, is associated with 'stasis, ('simple') reproduction, nostalgia, emotion, aesthetics, the body'.[56] We have already discussed the problems inherent in conceiving space in such terms, as well as the spatial-temporal disjuncture of nostalgia.

Nietzsche was one of the first to draw attention to the predominance of visual metaphors for abstract thought.[57] The historical development of connecting vision with abstract thought relegated the other senses to subordinate positions.[58] For Lefebvre, metaphors are part of the transposition of actions, associated with the body, the senses, emotions and life, to abstractions, those of signs and words, which are part of 'spaces of representation'.[59] Vision is given a sense of power in this translation of material to metaphorical space; Foucault's use of panopticon to represent power relations in the contemporary society is a fitting example, published the year after *The Production of Space*.[60] Foucault notes his own 'obsession' with spatial metaphors, although Foucault's own reliance on spatial metaphors elide the agency through which social space is produced.[61] The 'space' between material and metaphorical space is denied in Foucault, subsuming actual space with the metaphorical space of 'fields', 'domains', 'territories' and 'regions'.[62] Behind Foucault's spatial metaphors, as well as many other contemporary social theorists, is a naturalised abstract conception of space that is a particular form of space, growing out of capitalism.[63] Current approaches to cities have used the same visual metaphors, such as 'urban image' or simply 'image', to describe the way the city presents itself to inhabitants.[64] Overlooking the multitude of stimuli that make up embodied experience, these visual metaphors reduce knowledge of cities to the naturalised concept of abstract space, which is often a common-sense understanding of

[56] Massey 1993: 146.

[57] Lefebvre 1991: 139, although Lefebvre does not reference where this comes from in Nietzsche, but see Nietzsche 2009: 144-153; 2009: 149-151.

[58] This is main argument in Serres 2016.

[59] Lefebvre 1991: 139-40, 203.

[60] Lefebvre 1991: 140; see Foucault 1991; cf. Bull and Back, who note that Bentham's prison was not limited to sight, but had tubes through which the inmates could be heard at all times, 2016: 3.

[61] Foucault 2007: 176-7; Smith and Katz 1993: 72.

[62] Smith and Katz 1993: 72.

[63] Smith 2010: 220-5.

[64] Lynch 1960; for uses in ancient history and archaeology, Favro 1996; Zanker 2000.

space. Founded on a visual conception of space and abstract thought, the hierarchy of the senses is reinforced through these metaphorical descriptions of cities and space, giving way to the historical preference for vision in understanding social life.[65] In contrast, everyday life is experienced as dynamic space, what Lefebvre at points refers to as sensory space, a space connected with the body and rhythms, not vision.[66]

Auditory metaphors further imply a certain methodological practice, namely reflection. That is to say, the metaphors are grounded in the auditory experience of space and time. The interactions between people and space are reflexive and shape one another simultaneously, an aspect experienced in hearing an echo or resonant note. The physical measurements of such auditory experiences are discussed in chapter three. However, in terms of auditory metaphors, it is worth remembering the earlier argument that space should be conceived in terms of relational dynamics of spatiality and temporality, which are part of sound's very definition. Thus, auditory metaphors serve to reinforce a reflexive space-time that is open to contestations, whether in time like nostalgia or in space, such as spatial strategies or tactics.

1.4.2 Noise as movement

The formation of a relational space based on sound requires a reconceptualisation of relationship between sight and sound, seeing and hearing. The ephemeral character of sound is an experience of movement, an experience of sound passing one by. This experience, which is at the core of auditory perception, also enables auditory metaphors to express relational space, levels of mobility, and cultural changes through movement. I argue that the implicit movement, which is heard in sounds, is a central part of an embodied knowledge based on movement. Knowledge is not tied to vision and static inspection within the mind, but is experienced through movement and the continual construction of increasing experienced movements.[67]

The formation of an embodied knowledge of movement is in contrast to the association of vision with objective knowledge. Ingold has argued that it was in the specific project of modern objectification that vision was reduced to a faculty of 'pure, disinterested reflection, whose role is merely to deliver up 'things' to a transcendent consciousness'.[68] Recent arguments for the reassertion of hearing in the hierarchy of the senses have, as Ingold notes, reproduced this form of visualism, and with it a narrow and

[65] Jütte 2005: 54-71; cf. Ingold 2000: 281-5.

[66] Lefebvre 1991: 41-50; 210-2, 363.

[67] Ingold 2000: 228-231.

[68] Ingold 2000: 253.

limited notion of knowledge.[69] In these cases, sight and sound are in opposition, while the associated dichotomy of objective knowledge versus emotion and feeling, which maps onto sight and sound respectively, is not critically questioned. For Ingold, movement is the central experience of the world; an experience, which entails the intertwining of practical sensory perception with discourse and thought on sensory perception.[70] Noise, again, is at a basic level movement in space and time, as argued above. In this case, the perception of noise is a perception of movements; what one hears is the vibration of particles, at the basic level, or the particular movements of specific things. Silence is experienced as stillness, as made apparent in the discussion of Latin terms for noise and silence in chapter two. The acoustic analyses in chapter three are measurements of movements in spatial settings. However, these measurements also indicate the influence of the space, its shape, volume, and experience, on social activity. Noises are the movements in spaces and movements of spaces, as noise exerts a form of social agency. I refer to the movement of spaces, and the resulting influence on social activity, as architectural agency. I argue that the abstraction of social interactions to non-spatialised networks or lines of communication divorced from geographical reality has reduced our understanding of architecture to a passive role in the production of society. Instead, I suggest that the acoustics of a space, whether enclosed or open, influences the possible social interactions within that space, as well as generate forms of social interaction.

In auditory terms, the layout, structure and arrangement of the physical building provide insight to the building's agency in generating social interaction through acoustics and sound.[71] Physical dimensions and arrangement enable certain social interactions, which are embodied in spatial practices, while at the same time producing an acoustic field dependent on those interactions.[72] Blesser and Salter suggest thinking of the occupants as 'aural architects' rather than passive users.[73] Thus, social interaction in space shapes the acoustic field of the space, engendering ownership and social norms in the process.[74] The acoustic field is a measure of the sociality of space, providing quantitative measures of the reaction of buildings to sounds. Agency is not simply the people within a space; space is an agent in social production and reproduction of society.

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[69] Ingold 2000: 253; arguing against, Stoller 1989; Howes 1991; Classen 1993, 1997.

[70] Ingold 2000: 286.

[71] Cf. Laurence 2016.

[72] Blesser and Salter 2007: 35.

[73] Blesser and Salter 2007: 5.

[74] Blesser and Salter 2007: 26, 34.

Sounds are stimuli that require action, whether simple recognition or conscious movement. Here, the distinction between noise and sound is fundamental. Noise can be categorised into four forms of sound, although only one category needs to be mentioned here: noise as unrealised or unknown sounds.[75] In this way, the judgement of sound as noise, a judgement of recognition, indicates a sound beyond the perceiver's horizon of knowledge. Noise as unknown or not fully realised sounds underpins much of the acoustic analysis in this thesis and is one of the most difficult perceptual forms of evidence to assess in the ancient world, due to the types of ancient evidence that remain.

Finally, agency is subject specific, while reflecting the social and cultural norms. This process of education is often discussed in terms of 'reading' a socially specific system of signs, clothes, manners, gestures, hairstyles, etc., which often goes unreflected upon.[76] However, the openness of space to dynamic simultaneous multiplicities argues against a straightforward application of textual reading to social activities and space-time.[77] Instead, movement is the primary engagement with the world, and social activities reflect this engagement, which is interpreted through the body, not the mind.[78] In this way, agency has a learned aspect, which relates to the relationships and movements between people, spaces and noises. Adaptation is key to the repetition of social activities, as in each case the variables are slightly different.

1.4.3 From spatial practices to mobilities

Noise encapsulates the experience of space-time through architectural agency and the production of specific auditory rhythms and practices. These practices have specific geographical locations, hence, they are spatial. At the same time, these spatial practices are dependent on movement and should be conceptualised as in motion. The importance of movement is reflected both in the physical movement of sound in space-time, as well as in the auditory metaphors for social life. Spatial practices, just like space and knowledge, are mobile practices, experienced and analysed through sounds. Thus, auditory experience of movement and its embodied knowledge are part of the production of particular spatial practices, which are in constant motion and produce daily rhythms, or what Lefebvre refers to as 'everyday life' [*la vie quotidienne*].[79]

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[75] See 42-44; Truax 2001: 96-7.

[76] Bourdieu 1990: 69; Lefebvre 2014a: 605; cf. Laurence 2016: 28.

[77] See discussion in Massey 2005: 50-4.

[78] De Certeau follows this progression, but overemphasises textual interpretation of spatial practices, 1984.

[79] See Lefebvre 2013; 2014a; 2016a.

Most theoretical and methodological approaches in sensory archaeologies have developed within the field of prehistoric archaeology, beginning with Christopher Tilley's *A Phenomenology of Landscape*.[80] Tilley's concern was with the perception of landscape and centres on individual experiences of space and place. This thesis takes a different, although parallel and overlapping, approach, beginning with the physical space of architecture and the materiality of urban space, before moving into human perception. Materiality and physiological responses to materiality are at the core of the thesis, rather than subjective experience of space and place. This generalisation should not be reduced to a subjective-objective dichotomy; instead the physical and social world along with human perceptions, are constructed in the experience of space and place. In his critique of phenomenology, Lefebvre notes the prioritisation of the experience of space, over the representational aspects.[81] However, this experience is constructed out of engagement with materials; in this case, the interaction between sound and physical structures, which defines acoustics, and immaterial sensations.

This approach extends previous phenomenological approaches by incorporating notions of embodiment in the production of knowledge; in what is now being referred to as embodied knowledge.[82] It should be noted that this thesis does not take a specifically phenomenological approach, but begins with the architecture and urban spaces that are external to individual experience, before returning to the subjective experience of inhabitants. In this respect, the everyday rhythms of inhabitants are the product of multiplicities of subjective experiences that form routines, rhythms, or patterns at a higher scale than the individual.

A useful way of understanding the interconnection of time-space is the idea of everyday rhythms, which relate to the body's experience and measurement. For Lefebvre, everyday life was multisensory, and the end result was that the senses were more highly educated and their theoretical abilities increased to the point of being 'theoreticians'.[83] For Lefebvre, the analysis of everyday life is based on temporal and rhythmical features embodied in the senses, not visual features.[84] Rhythms are temporally and spatially defined routines, whether cyclical or linear in time.[85] Lefebvre

[80] Tilley 1994.

[81] Lefebvre 2014a: 264.

[82] Massey 2005: 17-59; Thrift 2008; see also Betts 2017 for its application to Roman material culture.

[83] Lefebvre 1991: 399-400; 2014a: 774.

[84] Lefebvre 2013: 41.

[85] On cyclical and linear time, Lefebvre 2013; cf. Lefebvre 1991: 405; 2003: 166-213; 2014a: 341-5.

suggested *rhythmanalysis* as the study of the time scales of everyday life.[86] For Lefebvre, rhythms are understood through their corresponding sounds. For example, the traffic light only makes sense within the noise of cars on the green and on the red, feet and words of pedestrians, as well as the idle hum of cars.[87] In contrast to the observer in the window, the pedestrian on the street is immersed in the multiplicity of noises and rhythms. From the window, 'noises distinguish themselves, the flows separate out, rhythms respond to one another.'[88] It is through listening that one is able to make out the various rhythms of the street, being either cyclical, of longer interval, or linear, short intervals.[89]

For Lefebvre, the body and its convergence of active and passive bodily action in space is at the centre of rhythmanalysis.[90] Windows, doors, streets and façades are measured in proportion to human scale.[91] Senses and labour are the passive and active actions of the body, which bridge the philosophical concepts of subject and object in the space of the body.[92] As Thrift notes, the body is always in motion, always tracing paths that connect with others in time-space, whether those others are animals, trees, dwellings, and so on.[93] Embodiment forms its own spatiality and temporality, which Merleau-Ponty notes unites past, present and future, creating time, rather than submitting to it.[94] The movement of the body actively measures space-time, rather than passively submitting to it.[95] Social relations, cultural norms, and spatial practices are structured into the body through rhythms.[96] The distinction between sound and noise is a distinction between judgements the body makes about the setting of sounds, in time and space simultaneously. Around the body, social and cultural levels of interaction structure interaction, within space and time.[97] Zones of interaction form microgeographies around the bodies, which reflect subject specific time-space

[86] Lefebvre 1991: 405; 1996: 219-40; 2013; 2014a: 526.

[87] Lefebvre 2013: 38.

[88] Lefebvre 2013: 38.

[89] Lefebvre 2013: 40.

[90] Lefebvre 1991: 405; cf. Hall 1990.

[91] Lefebvre 2013: 43.

[92] Lefebvre 1991: 407; 1996: 227; 2013: 45-6.

[93] Thrift 1996: 8.

[94] Merleau-Ponty 1962: 239-40; cf. Giddens 1984.

[95] Merleau-Ponty 1962: 100-2.

[96] Soja 1989: 151.

[97] What is refered to as 'proxemics', Hall 1990; Soja 1971; Wheatley 2014.

interaction.[98] The recognition of forms of experience emphasises the body's role in generating an embodied knowledge.

Spatial practices encompass the majority of everyday actions (talking, reading, walking, shopping, cooking, etc.) that take place in time-space. Many of these practices have an appropriated nature, partially taking over someone else's space for a given time.[99] The street is the prime example of the negotiation of space, as a diversity of people, goods, and movements intermingle in time and space. The street is a reflection of the things it links together, constantly changing and endlessly repeating, despite the unceasing shifts of times of day, people, and objects.[100] It is the appropriation of space that is at the centre of spatial practices.[101] In de Certeau's terms, these spatial practices are tactics, seizing opportunities in time, rather than starting from a place of power.[102] The various life paths of individuals can interact, due to proximity in space and time, but whether they will interact is dependent on patterns of locales and the patterns of production.[103] Sounds, above all, exist simultaneously in time and space, creating and influencing our perception of time, as noted in relation to nostalgia.[104] It is through attention, specifically listening, for Lefebvre in 'mentally prolonged spaces', that the multiplicity of rhythms enables the wider city to be known.[105]

This is a dynamic understanding of movement in space, not only physical movement, but also imaginary. The experience of sounds in space and time provides a flexible and open awareness that can be adapted to the situation.[106] Here the time-space rhythms and architectural agency are in dialogue with individual subjects through spatial practices. Sounds, in this way, serve to guide spatial practices, often unconsciously. Spatial practices offer insight into the relationship between sounds and urban space, although this is a relationship not governed by sight. In other words, by listening to noise, a person generates spatial knowledge about the world and its uneven development, which guides everyday activities.[107] Sound is able to permeate space in non-visual manner. The ability to overhear someone in the next room is a prime

[98] Soja 1989: 151; cf. Hall 1990; Soja 1971.

[99] de Certeau 1984: xix.

[100] Lefebvre 2014a: 604

[101] Lefebvre 1991: 31.

[102] de Certeau 1984: xix.

[103] Thrift 1996: 81.

[104] Truax 2001: 73.

[105] Lefebvre 2013: 42.

[106] Thrift 1996: 37.

[107] On uneven development see Smith 2010; Harvey 2006: 71-116.

example; many things are heard before they are seen. It is this basic attribute of sound, its incompatibility with physical boundaries that provides a different perspective on practice theories. The ability of sounds to transfer through materials acoustically links visually distinct spaces. Hearing acts a mediator between the body, located in space, and other bodies outside it.[108] The human processes of hearing and acoustic methods bridge the divide between architectural forms and social interactions in separated space. The acoustics of space offers indications of social interactions that are spatially distinct, although linked within the auditory field.[109] Sensory experience influences the spatial practices and conceptions of urban space. The analysis of sensory experience is not the analysis of thought, but the analysis of productive activity.[110] Misunderstandings prompt listening and expectancy, with other senses being brought in as well.[111]

It was through the emphasis on vision that architectural experience was set at a distance, making it passive, reducing the social existence to abstract space.[112] For Lefebvre, however, everyday life does not simply modify the senses, the senses actively fashion the object of perception.[113] Again, the object of perception is a product of creative activity, both sensory and social.[114] Human beings, in this manner, are sensuous objects, which through more or less rich complex social relations exercise their subjective powers – activity, reflection, and desire.[115] Thus, the senses are developed and refined through spatial practices.[116]

The emphasis here on the central importance of movement in the production of senses and social space requires what John Urry calls a 'mobilities theory'.[117] Mobilities refer to a broad movement-based conceptualisation of economic, political and social relations.[118] Viewing the objects, buildings, texts, and other sources as mobile, on a spectrum from fixed in place (buildings, roads) to codes (maps, texts, inscriptions), requires space to be seen as equally mobile, or what Thrift refers to as 'movement-

[108] Lefebvre 1991: 200.

[109] Rasmussen 1962: 224-37; Pallasmaa 2012: 53-4.

[110] Lefebvre 1968: 121; cf. Pallasmaa 2012.

[111] Lefebvre 1991: 212.

[112] Pallasmaa 2012: 19; Harvey 1990: 327; cf. Lefebvre 1991: 286; Rasmussen 1962.

[113] Lefebvre 1968: 33.

[114] Lefebvre 1968: 33.

[115] Lefebvre 1968: 39.

[116] Lefebvre retains the Marxist term *praxis*, rather than spatial practices, Lefebvre 1968: 41.

[117] Urry 2012: 44.

[118] Urry 2012: 43.

spaces'.[119] Sound is a primary experience, which opens up such movement-spaces. To a certain extent, much of the perception of sound involves the same unconscious frameworks of mobility and movement. This reframes the discussion of space around what Urry calls a 'mobility system'.[120] For Urry, mobility presupposes a system, in fact many systems, which allow for predictable and relatively risk-free repetition of movements.[121] Mobility systems offer a theoretically informed means of interpreting and conceptualising space in the ancient world. Sounds, and sensory phenomena in general, are part of the interpretative process, which happens through movement. The mobility system of Rome and Ostia shaped the perception and conception of space, which I argue needs to analysed through a relational spatial imaginary. Movement made noise, but it also drew out responses. By focusing on mobility, the perception of urban space makes sense.

The dynamic openness of space-time argues against a simple mapping of sounds in Ostia. Instead, these spatial practices form a relational map, a geographic network, of sounds and movements within the town. The ancient world was mobile, full of noise, and socially complex; all three elements fed into one another and created the urban space of Ostia.

1.5 Background to Ostia

In this section a review of previous work on Ostia provides the background for the case studies in the later chapters. Key to this discussion is the architectural interventions that result from rebuilding practices in Rome, as well as the geographical connections, which brought goods and material resources into Ostia. These wider networks were at the centre of the development of Ostia in the second century CE. The fire in Rome of 64 CE is commonly remarked as a turning point in the development of Roman architecture.[122] Suetonius and Tacitus refer to the architectural changes that were enacted following the fire as Rome was rebuilt.[123] While the literary sources may exaggerate the destruction, the fire still burnt through a large area of the city, potentially ten of 14 regions, according to Tacitus.[124] In an effort to make Rome less prone to fire,

[119] Thrift 2004: 583; Urry 2012: 45.

[120] Urry 2012: 12-3.

[121] Urry 2012: 12-3.

[122] MacDonald 1982: 92; Ward-Perkins 1994; Wilson Jones 2000: 96; Ball 2003; cf. Quenemoen 2014: 63.

[123] Suet. *Ner.* 38; Tac. *Ann*. 15.38.

[124] Tac. *Ann*. 15.40; Newbold 1974: 858.

Nero enacted several building codes on the streets and structures of the city.[125] The streets were to be wider and straighter, with porticoes and arcades in front of buildings; common walls and the use of timber within structures were banned; a height limit was imposed, and the use of fire resistant stone stipulated.[126] These building codes also had acoustic effects following their implementation, which are evident in the physical remains of Ostia.[127] The limitations on party walls, building heights and materials used all have direct influences on the acoustic properties of the buildings, as will be shown in chapter three. The widening of streets, along with the addition of porticoes and arcades, all of which altered the sounds of Ostia. Sounds transmit through building materials, and reflect off walls, ceilings and floors by analysing the acoustics of particular spaces, both internal and external, the relationship between individual inhabitants and these specific places becomes more porous and open.

These architectural changes would have also dramatically altered the social perception of movement along the streets. Newbold is right to argue that the economic and political implication of these enactments would have caused an increase in density within apartment buildings due to limitations on horizontal expansion, as well as an increase in rents to cover the costs of construction.[128] However, the social implication of the building codes has yet to be accounted for. The post-fire rebuilding changed the acoustic interactions of neighbouring buildings, which suggest a politics and economics of sound at work in Rome. The ban on common (or party) walls is evident in some Ostian buildings, where each property has its own walls.[129] The space between neighbouring buildings would serve as a sound barrier, although it would not isolate noises completely.[130] Sound barriers would change the power relations between neighbours, as would the increase in urban density. However, social relations between internal and external spaces, such as apartments and streets, would also change as the streets were widened, allowing more potential users. What has been overlooked is the change in social and sensory relations, which form part of the politics and economics of cities. This hints at an implicit shift in the geographical location of sounds, a shift away from sounds passing through neighbouring buildings, due to the ban on party walls, and toward sounds produced in the street with the potential of higher numbers of users.

[125] Tac. *Ann*. 15.43; Suet. *Ner.* 16.1; Hermansen 1982a: 217-223.

[126] See Pavolini 2010: 204-5.

[127] Pavolini mentions a fire, in 115 CE, found in the *Fasti Ostienses* in discussion with the Neronian building codes, Pavolini 2010: 205.

[128] Newbold 1974: 859.

[129] Hermansen 1982a: 212; cf. DeLaine 2002: 44-8; 2004: 169.

[130] See section 3.2.

These architectural changes and regulations were intertwined with the sensations of the city, changing the ways inhabitants interacted with the built environment. The widening of streets enabled more people and animals to use the space; porticoes and colonnades, as will be discussed, mediated the auditory field of the street and shops, as well as separating different forms of movement; and the height and construction materials were the foundation for the acoustic properties of streets. The building regulations, in this way, were as much auditory measures as they were fire prevention measures. More than simply changes in the style of Rome, the acoustic effects point to the relational aspects of city space, which have only recently begun to be explored. In this section, an overview of previous approaches to the development of Ostia highlights the ways in which space is equated with static, unreflexive, and abstract imaginations. Sound offers a way of approaching a dynamic and open conception of space, which brings together sound, architecture and urban space in the development of Ostia. A dynamic and open relational conception of space, through study of sounds and noises, I argue, generates a more nuanced understanding of the town, than previous abstract conceptions of urban space, which rely on architecture as representing social upheaval or urban decline beginning in the second century CE.

In previous city-scale studies of Ostia, an abstract conception of space has been employed to understand observable differences, such as the topography of the town, distribution of building types, or placement of religious sites.[131] Recent debates in the study of cities have argued for relational understandings of space, being constructed out of sensory perceptions, movements, and unstable identities.[132] While abstract conceptions and approaches are necessary and lay the foundations for much of the discussion here, a relational understanding of space, as open, dynamic, and constantly in the process of becoming, has the potential to enlighten our understanding of the town's more prosaic rhythms.

An overview of the process of procurement and the transport of materials will enable the specific building design and architectural choices to be contextualised within the wider region, which will enable an understanding of the acoustic variations and their social implications within the town of Ostia. The procurement and geological location of materials are part of the production of space, which includes perceptions of what is traditionally described as the city and country divide, urban-rural divide, or the integration of the urban hinterland.[133] Traditionally, discussion of such issues has been

[131] Steuernagel 2001; Heinzelmann 2002; Gering 2004; Stöger 2011a and b.

[132] See Amin and Thrift 2002; Massey 2005; Urry 2007; Laurence 2015.

[133] See most recently, Zuiderhoek 2016: 37-55.

limited to economics, stemming from the 'consumer city' model of Finley.[134] What has been overlooked is the role of sensory and social processes in the movement of goods, waste and materials into and out of urban centres. The movement of all such materials is part of the relational approach to space, highlighting the continual changes throughout the day, week, month, etc. that occur in a given geographical location. An overview of the regional character of the topography and geography surrounding Ostia is therefore key to the concept of relational space, as the social processes of sound are integrated into urban and regional movements.

The main topographical feature of Ostia is the river Tiber, which ran parallel to the east Decumanus past the current bend in the river, a 1557 flood altered the course to its current location. The Tiber separated the main town of Ostia from the Isola Sacra and Portus, the Claudian harbour built to the north. It was originally thought that the Tiber served as the northern boundary of the city; however excavations in 1957 discovered a warehouse on the opposite side of the river.[135] The earliest buildings on the northern side date to the first half of the first century CE and appear commercial in nature.[136] A Tiberian boundary stone (*cippus*) was found on the north bank of the Tiber, in the ancient bend of the river.[137] In early excavation photos, the river is shown washing away the edges of the northern buildings.[138] Meiggs mentions that visible traces of an embankment were seen on both sides of the Tiber between the Forum and Tor Boacciana.[139] Recent geophysical work has located a variety of other structures, including a northern section of the city wall.[140] Warehouses and large commercial structures have also been located along the northern bank. Floods are recorded in the Roman period, although much of the evidence relates to Rome.[141] Ostia would have suffered from similar inundations, and Tacitus makes reference to the deposition of debris from the 64 CE fire in the marsh around Ostia.[142] In the first century CE channels

[134] Finley 1973; cf. Rich and Wallace-Hadrill 1991; Cornell and Lomas 1995; Parkins 1997; Wilson and Flohr 2016; Zuiderhoek 2016.

[135] Bertacchi 1960.

[136] DeLaine 2016: 423.

[137] Pellegrino, Olivanti, and Panariti 1995; flooding, Aldrete 2007: 242-3.

[138] The river went up to 1.7.1-2 and the end of the Via dei Misuratori del Grano.

[139] Meiggs 1973: 303; citing Carcopino 1945: 510; Le Gall 2005: 335, 491; italised *forum* refers to Latin term, non-italised forum refers to general space, and capitalised Forum refers to the specific space in Ostia.

[140] Earl 2014.

[141] See Aldrete 2007: 15, tab. 1.1.

[142] Tac. *Ann*. 15.443.

at the northern end of the Isola Sacra were cut to provide flood relief.[143] Literary sources note the inadequacy of the Tiber mouth as a harbour, due to silting.[144] It is from this context of concern for moving goods along the river that the reclamation stones on the north side should be read.[145] While the changing landscape of the surrounding area requires further study, it is clear that Ostia extended north of the river and that the river itself should be thought of as part of the town's seasonal and yearly cycle. Dredging and clearance of the river would have been part of this cycle, as would transitions in the movement of goods from seaborne vessels to river barges.

Therefore, movement was primarily through Ostia and into Rome via the Via Ostiensis, until Portus gained the necessary infrastructure following the Claudian and Trajanic developments.[146] Studies of the role of Ostia in movements to Rome have focused primarily on the grain and marble trades.[147] Other construction materials were required for the rebuilding of Ostia in the second century CE. Necessary materials of pozzolana, tufa, basalt, clay and lime are unevenly distributed around Rome and its surrounding area.[148] This uneven distribution of natural materials created distinctive uneven social networks for the exploitation of such materials.[149] The social and natural networks were in reciprocal relation with one another, providing a clear example of relational spatial production.

Quarries for pozzolana, selce and tufa were located around Rome, although in an uneven distribution. Volcanic rock deposits are located in the Monti Sabatini and Colli Albani regions, north and south of Rome, while limestones are located to the east of Rome, in the Monti Sabini and Monti Lepini areas.[150] Around Rome, quarries of pozzolana, selce and tufa were located south of the city, along the left bank.[151] Recent work on the origins of selce paving stones indicates that lava rock was quarried west of the city, in areas not shown on older geological maps.[152] These locations suggest the

[143] Keay, Millet, Paroli, and Strutt 2005: 272.

[144] Suet. *Claud*. 20; Strabo 5.3.5; Dion. Hal. *Ant. Rom*. 3.44.

[145] DeLaine 2016: 423.

[146] See Keay, et al 2005; Keay and Paroli 2011; Keay 2012.

[147] Grain: Rickman 1971, 1980; Sirks 1991; Heinzelmann 2010; Keay 2010; marble: Baccini Leotardi 1979; 1980; Pensabene 1998; 2004; 2007.

[148] See DeLaine 1995b.

[149] On the social network, Graham 2006.

[150] DeLaine 1995b: 556, fig. 1.

[151] DeLaine 1995b: 557, fig. 2.

[152] Worthing et al 2017.

potential for using the Tiber to transport paving stones to Rome or Ostia, rather than relying solely on road transport.

The Anio and Tiber, as well as smaller tributaries, provided natural cuts for quarry exploitation and it is apparent that the geography of materials was important in the decision process for transportation.[153] Clay deposits for brick production were in close proximity to Rome, as well as further afield. The major clay deposits in the vicinity of Rome are located across the river, northwest of the city.[154] The geological resources furthest from Rome were in the area of Orte or Narni. The fuel needed to fire bricks was widely available in the Sabine region, helped these regions develop as the emperors took over large portions of brick production. In overall terms, only seven limekilns of 60 cu. m capacity would be needed each year for twenty years to produce the lime for the entire Hadrianic rebuilding of Ostia.[155] A surprisingly small industry of lime producers could adequately serve Rome and its ports.[156]

Again, extraction and exploitation of natural resources would alter the environment, playing a key role in the relational character of interactions between inhabitants and the landscape. That is to say, through resource extraction and infrastructural building, Roman workers reshaped the landscape in order for Ostia to develop its particular urban layout based on the street network. Use of the Tiber and roads had obvious sensory and social implications, and attempts at the regulation of such implications will be discussed in chapter two. Ox-carts (*plaustra*) were used for large blocks of stone, while pack animals and smaller carts could be used for other materials.[157] Patterns of movement between large or small carts would alter the perception of sounds associated with different geographical areas. Differences in types of transport, such as water or road transport, would further differentiate sensory perceptions. Such a reflexive approach to the building process highlights the social production of the town, as well as offering an analogy for more ephemeral prosperities, such as the sensory stimuli, in that same social production.

The connection between Ostia and Portus is evident in the social and commercial development of both sites.[158] It needs to be remembered that it is only at the end of the third century CE that Portus overtakes Ostia, in terms of size and imperial

[153] DeLaine 1995b: 557.

[154] DeLaine 1995b: 559, fig. 4.

[155] DeLaine 1995b: 560.

[156] DeLaine 1995b: 560.

[157] DeLaine 1995b: 558.

[158] Social connections, Cebeillac-Gervasoni et al 1996; Salomies 2002; Keay 2010; *collegia*, Sirks 1991; *CIL* 14.4648; Keay 2012: 3.

importance.[159] Portus was only separated from Ostia at the start of the fourth century CE when Constantine gave Portus its own status independent of Ostia.[160] Road connections between Ostia, Portus, and Rome developed over an extended period. The Via Ostiensis, connecting Ostia and Rome, was established in the fourth century BCE, and remained an important route throughout the imperial period.[161] The only connection by road from Rome to Portus, prior to the Claudian harbour, is the Via Campana, a Republican road leading to the salt beds at the river mouth, which was later replaced by the Via Portuense.[162] The north-south roads, Via Flavia and Via Severiana, developed later. The Via Flavia was a late first century CE establishment that connected Portus to Ostia, crossing the Isola Sacra.[163] The Via Severiana, a later second century CE development, connected Ostia to Laurentum and Antium in the south.[164]

Geographically, the progression runs roughly counter clockwise, beginning by connecting to Rome, then north as Portus develops, and finally extending south along the coast. The chronology hints at a social hierarchy, which reinforces the continuing importance of Rome, and connections to it, in Ostia's development. These land transport connections further emphasise the importance of interrelationship between Ostia and its surrounding area in the town's development into the second century CE. Set at a distance of 20 km from Rome, just over the average distance of 13 km between towns in central Italy, Ostia was within a day's travel from Rome.[165] The distance from Rome is a kilometre above the average distance from towns for rural populations in central Italy (between nine and 19 km).[166] These figures suggest that Ostia should be considered to be within the direct hinterland of Rome, whilst retaining its own administrative character. Ostia, with the expansion of Portus under Trajan, then gains the infrastructure to support Rome as the imperial capital.[167] In terms of a relational conception, these infrastructures were the fixed geographical locations for sensory and social movements. More than being simply locations of capital investment, roads had ideological importance in the Roman conception of space.[168] It is in this context that the

[159] DeLaine 2016: 422.

[160] Thylander B336.

[161] Keay 2012: 49; *LTUR* V 1999: 143; cf. Quilici 1990: 41-2.

[162] Keay, et al 2005: 279.

[163] Germoni, Millett and Keay 2011.

[164] Fogagnolo and Valenti 2005: 7-24.

[165] Average distance between towns, Bekker-Nielsen 1989: 28.

[166] Bekker-Nielsen 1989: 29.

[167] Keay 2012: 3.

[168] Laurence 1999: 192-5.

development of Ostia, and in particular the formation of an Ostia specific identity, takes shape.

Land reclamation for agricultural cultivation is evident in the first half of the first century CE.[169] RAF aerial photography displays the land division to the south of Ostia and the geological formations on which Ostia, Isola Sacra and Portus are constructed with evidence for the centuration of land in the area of the Pianabella.[170] A series of five roads cut Pianabella into strips down to the Canale dello Stagno with five roads running North-West/South-East cutting the region into parcels.[171] The Via Severiana was the westernmost street along the coast to a bridge over the Canale dello Stagno.[172] The area around the town shows fewer signs of formal land divisions then in Pianabella. While these studies indicate the wider connections between Ostia and its surrounding hinterland, the nature of the relationship between these areas requires further study.[173]

The central area of Ostia has been studied in terms of the development of a grid plan, the early site defined by the *castrum*, an organised rectangle with two perpendicular streets at the centre.[174] The overemphasis on grid planning, linked to modern colonial purposes and values, to describe the development of Roman towns has recently been questioned.[175] Roman literary sources describe Ostia as a fortified settlement, *castrum,* with a harbour built by Rome's fourth king, Ancus Marcius, but it seems that by the third century BCE, Ostia had already expanded beyond the *castrum* walls on at least three sides.[176]The mythic foundation was preserved on a later inscription pulled from a drain in the Via dei Molini area, while the Late Antique authors retained this chronology of the city's founding.[177] The phrase *ab urbe condita* appears in a series of inscriptions from Ostia and the surrounding area, which has no parallel

[169] Heinzelmann 1998: 176-82.

[170] Bradford 1957: 242-56; Heinzelmann dates the land division to the Augustan period, Heinzelmann 1998: 184.

[171] Heinzelmann 1998: 182-5.

[172] *CIL* 14.126; *AE* 1909, 67; Heinzelmann 1998: 221-4.

[173] Much is based on the geophysical survey of Heinzelmann, which still awaits publication.

[174] Calza 1953: 63-77; Meiggs 1973: 22-3; Boin 2013: 17-8.

[175] Laurence 1997; 2007: 12-19. Laurence, Esmonde Cleary and Sears 2011; Wallace-Hadrill 2013; *contra* Haverfield 1913.

[176] Literary sources, Enn. *Ann*. 2, fr. 22; Cic. *Rep*. 2.3.5, 2.18.33; Livy 1.33.9; Dion. Hal. *Ant. Rom*. 3.44.3; Strabo 5.3.5; Festus 214; Plin. *NH* 3.56, 31.89; Polybius attributes the foundation to Numa Pompilius; recent dating, DeLaine 2016: 420.

[177] *CIL* 14.4338 (=*AE* 2000: 266); Zevi 2000; on Late Antique authors' reception of Ostia, Boin 2013: 19-20

elsewhere.[178] The retelling of the foundation and monumental dating based on the founding of Rome connect the social importance of historical memory with the physical buildings of the town.[179] Geographically, the attestations link the development of Rome with the local area of Ostia. Temporal distance, in this case, draws attention to the antiquity of the Ostia's connection with Rome.

The epigraphic and infrastructural links between Ostia and its surrounding area, including Rome, display a constant negotiation that was part of the social production of space. The second century CE was a time of increased urbanisation and expansion at Ostia, considered to date only in terms of abstract notions of space.[180] For some, the continuation of the earlier street plan represents a 'failed' opportunity by Ostia to reorganise according to a grid plan.[181] Ostia's irregular plan remained due to private ownership and lack of public incentive.[182] The reduction of urban processes to simple economic, or social conflicts, such as public/private, free/freed or elite/non-elite, fails to realise the complexity of urban space.[183] Such dichotomies are a failure to recognise the complex processes that intermingle social, economic, political and natural elements in the creation of built environment. The physical topography of Ostia is limited by the river and coastline, both of which saw later development.[184] The environment served to set rough limits on the urban layout and influenced the everyday routines of inhabitants. Ostia expanded to the sea, as is evident in the highly urbanised area of the Porta Marina. There are some indications that certain later streets conform to early paths leading to sea.[185] The continued usage, even in the case of repaving and rising of the street levels, indicates a negotiation with the past, siding with the continuation of such features, rather than creating new routes. As will be discussed in chapter three, the realignment of the north Cardo Maximus is a clear indication that new routes were at times necessary. In that case, however, it was more than a simple functional choice, as the

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[178] *CIL* 14.4338 (=*AE* 2000: 266); 14.472; *NSc* 1953: 248, n. 16; *AE* 1977: 153; *AE* 1998: 278a; Bruun 2009: 127.

[179] See Bruun 2009: 126-7.

[180] Heinzelmann 2002.

[181] Heinzelmann 2002: 108; cf. Wallace-Hadrill's critique of grid planning as 'the essence of Roman town-planning', Wallace-Hadrill 2013: 75.

[182] Heinzelmann 2002: 108.

[183] See section 1.4; Lefebvre 2014b: 89.

[184] The coastline, tower at Tor Boacciana and harbour serve as Mar's three landmarks of the street network, however the DAI/AAR project further emphasises the area at the end of the Via della Foce (tower, harbour basin, etc.). Mar's second landmark, the harbour, corresponds to the area north of the *castrum* along the Tiber, Mar 1991: 86, fig. 2; cf. Stöger 2011a: 15.

[185] Mar 1991: 87-8.

redevelopment of the street went hand-in-hand with the building of shops and porticoes along both sides for the entire length.

As recent geophysical results indicate, the Tiber was not as hard a boundary to northern urban expansion.[186] The outline of the inner harbour can be seen in the ground depression on the south shore, roughly 200 metres wide and 100 metres deep. The current Tor Boacciana marked the western side, while a *navalia* complex was set on the eastern side of the harbour.[187] As Portus began to develop, the Ostian harbour received a new platform, containing a series of ship sheds.[188] A marble clad temple surrounded by a portico, possibly dedicated to Castor and Pollux, whose temple is known from inscriptions but has not been identified, marked the platform.[189] The earliest river installations can be dated to the Tiberian-Claudian period, making it one of the largest structures built in the first century CE. Along with the theatre, an aqueduct and the extension of the Forum square Ostia received what has been called a *façade maritime*.[190] The continued development of the harbour facilities, especially at Portus, marked the continued importance of moving goods through the region.[191]

The building of the second century CE in Ostia has been referred to as a 'boomtown' [*Bauboom*] model of expansion.[192] According to this interpretation, Ostia underwent large-scale rebuilding, as well as new construction using the distinctive technique of brick-faced concrete or brick and reticulate at the level of private individuals, not civic administration.[193] For Heinzelmann, the social organisation of the town is reflected in the layout; however he lacks the theoretical background to answer questions relating to the spatial arrangement of social relations.[194] Relying on a simplified and literal reading of the epigraphic evidence, Heinzelmann sees the replacement of first century CE monuments by later funerary structures as part of a social upheaval as a new class of traders takes over at the end of the first century CE.[195] When turning to the physical structures of the town, the lack of 'civic' buildings is

[186] See Earl 2014.

[187] Heinzelmann 2001; 2002.

[188] Heinzelmann and Martin 2002.

[189] *CIL* 14.1; Amm. Marc. 19.10.4; Heinzelmann and Martin 2002: 17.

[190] Heinzelmann and Martin 2002: 19; DeLaine 2016: 423; 'façade maritime' comes from Purcell 1996: 272-3.

[191] Continued building and rebuilding of Portus, Keay, Millet, Paroli, and Strutt 2005: 271-90, 297-305.

[192] Heinzelmann 2002.

[193] Heinzelmann 2002.

[194] Heinzelmann 2002: 103; cf. critique by Mouritsen 2004; Stöger 2011a: 8.

[195] Heinzelmann 2001: 273-84; cf. Mouritsen 2004: 287

interpreted in the same manner. An absolute space concept of building types, in this case either civic or private, is applied to a relational concept of social hierarchy. Rather than look for the relational character of the space in the forms of construction, Heinzelmann follows previous scholarship and attaches an absolute concept of social hierarchy to the building typology of civic/private.

The social upheaval Heinzelmann sees in the sources is an interpretation made without reference to any theoretical approach, whether social, cultural or spatial. The 'social revolution' seen by previous scholarship, where older aristocratic families were driven out of the *ordo* by freedmen, needs to be contextualised within the theoretical and methodological presumptions assumed.[196] Thus, Heinzelmann concludes that Ostia, over the second century, remains a town of urban deficits and contradictions with minimal new public buildings and a majority of private buildings for economic exploitation.[197] Key to this conclusion is the social make-up of the population, being a primarily commercially driven newcomer unconcerned with civic development.[198] As will be shown, the commercial aspects of Ostia do play a key factor in the soundscape of the town; however this is not in direct competition with traditional elite. In fact, the available evidence shows a diversity of social appropriations of the auditory space of Ostia. Appropriations of space reflect the dual contrasts with dominated space (politically controlled) and private ownership.[199] Ostia was appropriated by various groups for the diversity of needs in second century CE, a dynamic mixture of social, economic, religious, and political groups, although none of these can be separated.

With direct connections to Rome, Ostia experienced a higher urban density than other towns, such as Pompeii.[200] Free movement of goods and people through Ostia to Rome were part of the economic and social importance of its location.[201] The movement of goods and people through Ostia also included more permanent migrations and increased numbers of people stopping for extended periods. Part of the relational conception of space argued here are the interactions of inhabitants in the auditory landscape and built environment. Much of the discussion of acoustic properties is dependent on numbers of people and levels of usage. The commonly assumed population of Rome in the late Republic/early Principate of one million inhabitants is

[196] 'Social revolution', Wilson 1935; Meiggs 1973: 196-211; D'Arms 1976; Pavolini 2010: 386-411; Heinzelmann 2000; critique of 'social revolution', Mouritsen 1998; 2001; 2004.

[197] Heinzelmann 2002: 119.

[198] Heinzelmann 2002: 119.

[199] Lefebvre 2014b: 93-4.

[200] Trade connections, Zevi 2001; building industry, DeLaine 1996; living conditions, Gering 2002.

[201] On migration and the economy in the city of Rome, Holleran 2011b.

based on grain distribution figures, literary references to the amount of grain consumed, extent of built up space in the city, or numbers accommodated by the Regionary Catalogues, which puts the movement of both goods and people into perspective.[202] Recent geophysical work has expanded the known size of Ostia and needs to be factored into the population figures. The early population figures of Calza, at 100,000 people, and Meiggs, 50,000-60,000 people, seem to be better suited to the town's size than the recent estimations around 30,000.[203] Morley ranks Ostia and Puteoli as second level urban centres, under Rome itself, with around 30,000 inhabitants. This figure approaches Packer's estimation of 27,000, but is in sharp contrast to Meiggs' estimation of 50,000.[204] Storey estimated the population of Ostia, based on numbers of properties and a range of 3-5 or 6 for apartment dwellings and 13-17 for private houses, with a 20-25% variation of the expected numbers based on dwelling size.[205] In Storey's calculations, Ostia produced a population of 21, 874 with a density of 31, 700 persons per sq km.[206] This density figure for Ostia is well within the population density for pre-industrial cities, although at the high end.[207] The noise levels within the town of Ostia would reflect the total population numbers, although the noise levels would fluctuate seasonally, based on the flow of people and goods through the town and work cycles.

The common construction materials for the variety of building projects in the period have implications for the acoustics, as will be discussed more in chapter three. Here it is worth briefly setting out some of the basic assumptions that will be taken up in the later chapters. The interaction of sounds with the built environment is key to human perception of sound. The wave motion of sound means that sound is able to travel through solids, liquids and gasses; in fact, only in a vacuum, such as outer space, is sound not conducted. This means that all construction materials, as well as natural materials available to the Romans would conduct sound.[208]

Acoustic measures convert the physical building materials of brick, wood, glass and stone into quantifiable figures and acoustic properties, as shown in chapter three. These analyses, which will be discussed further in the following chapters, are connected

[202] Holleran 2011b: 156-7; 1 million, Jongman 2003, Lo Cascio 2000; Noy 2000; Packer 1967; Stambaugh 1988; Yavetz 1958; 870,000-970,000, Morley 1996.

[203] Calza and Lugli1941; Meiggs 1973: 534; 30,000 inhabitants see Morley 1996; cf. Scheidel 2004; Lo Cascio 2009.

[204] Packer 1971: 70; Meiggs 1973: 532-4.

[205] Storey 1997: 973.

[206] Storey 1997: 973.

[207] Storey 1997: 976.

[208] Veitch 2017a.

to the physical spaces of everyday life, the shops, bars, baths, warehouses and accommodation of second century CE Ostia. Roman construction methods and techniques show no sign of being able to soundproof buildings or isolating sounds as a designed capability. This does not mean that all spaces sounded the same or that noise was heard everywhere; however, the ability of all materials used by the Romans to conduct sounds, together with a minimal awareness of the technical requirements for the isolation and minimisation of sound levels, means that Roman architecture played an important role in the perception of sounds and spaces.

The development of concrete construction by the Romans led to new structural properties, like expansive interior vaults and non-congruent multistory floor plans. By the second century CE, the Romans had been using concrete for nearly three centuries; however, the innovations in construction and materials enabled architects to distribute loads in new ways.[209] The result was more complex interior spaces that had open expansive interiors or multi-storey structures with non-congruent plans.[210] The acoustics of these spaces also changed, as the larger vaulted structures, especially baths and temples, could accommodate more people and created volumes of interior space that reflected interior noises. The change in size, decoration and dimensions between the Sarno Baths in Pompeii and the Baths of Caracalla in Rome are an indication of the potential scale in building following innovations in concrete.[211] It is worth noting that concrete was an acoustically reflective material, similar to brick. The use of concrete and brick provided reflective surfaces for sounds to bounce off, creating spatially specific soundscapes.[212]

In order to understand better the acoustic properties of particular spaces, a brief discussion of the physics of sound and its relation to building materials is necessary. The absolute space of buildings, the physical structure of the walls, ceiling and floor, in which sound is produced influences the way sound is *perceived*.[213] The perceived acoustic properties of the space, based on the experienced material and absolute space, is referred to as the *aural architecture*.[214] The sound of a large church basilica, like St Paul's in London, will be perceived differently aurally from the subterranean catacombs of Rome, such as the Catacombs of St Callixtus. The differences in acoustics of the space tell

[209] Lancaster 2005: 3-5; Quenemoen 2014: 71.

[210] Quenemoen 2014: 71.

[211] See Lancaster 2005; 2015.

[212] See section 3.1.

[213] *Italicised* words are found in the Glossary.

[214] Blesser and Salter 2007.

the perceiver about the material space itself. We hear the changes in volume between St Paul's Cathedral and St Callixtus, as well as perceiving other locational information. An example will demonstrate the information derived from acoustics and sounds. If you clap loudly in any room, you will hear the initial sound of the clap followed by an echo as the sound rebounds off the surfaces of the room. The distance from the wall to where the clap is produced will determine the delay between initial sound and echo. The area of the wall from which the sound rebounds will determine the intensity of the echo, and the material of the wall determines the frequencies perceived in the echo. Thus, the physical features of the wall, its distance, size and materials, can be interpreted through the sounds perceived within the space.[215] In dealing with ancient walls, the ability to measure the clap and its resulting echoes is generally impossible. Gaps in the physical remains of the material space prevent such recording and measuring based on actual sounds. In this case predicative measures, based on the mathematical equations and dimensions of the space, are used to indicate acoustic characteristics of the material space.

In terms of timeframe for building, the *Digest* gives a hypothetical construction of an *insula* as two years, which corresponds with the Caseggiato del Serapide (3.10.3) and the Caseggiato di Bacco e Arianna/Serapeo (3.17.4-5) dedicated in January 127 CE with brickstamps dated to 123-126 CE.[216] In the *Digest*, the hypothetical timeframe is part of a verbal contract, which is not broken until the end of the time period, even if the building is not complete and there is insufficient time to complete it.[217] The building projects across Ostia include planned or organised building groups, such as the Terme di Nettuno and associated *insulae*, or the Case a Giardino, as well as individual buildings that collectively reshaped the urban space in the second century CE, as in the case of the Capitolium and buildings along the north Cardo Maximus.[218] Several of these buildings will be analysed for their acoustic properties in the following chapters but, broadly speaking, these groups form the main large-scale building projects although not all display signs of singular design and planning as a unified project. Variable construction techniques and details indicate that certain groups of buildings were developed over time and under different architects, suppliers and/or workmen.[219]

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[215] Veitch 2017a.

[216] *Dig*. 45.1.124; DeLaine 2000: 126; Insula of Serapis, Bloch 1959: 231-4.

[217] *Dig*. 45.1.124.

[218] For discussion of these different buildings as 'events' in construction history of Ostia, DeLaine 2002.

[219] DeLaine 2002.

Several building groups indicate a planned construction during this period.[220] The Terme di Nettuno (2.4.2), an imperial initiative at least in part, included shops, accommodation and a portico façade along the Decumanus.[221] The complex was in close proximity to the Caserma dei Vigili (2.5.1-2), which housed the *vigiles*, 'night watch' or city fire brigade. West of the Capitolium and Forum portico, *insula* 1.9 displays this variety in materials and techniques. The earliest structure is the so-called Curia (1.9.4), usually dated to around 100 CE.[222] The remaining three structures span the years 114-118 CE and based on evidence from the construction sequence and brickstamps can be further divided into 1.9.2 in 114-115 CE, 1.9.3 in 115-116 CE and finally 1.9.1 in 117-118 CE.[223] North of the Forum, the Portico di Pio IX and surrounding buildings were first thought to be another planned construction project. The brickstamp dates offer a different picture and display a continued restructuring of the area between 117-120 CE. The end result of this period of construction was the construction of the Capitolium and realignment of the Forum, blocking the earlier Cardo Maximus.

The labour process of Roman concrete was fairly straightforward, consisting of brick facing with a core of layers of mortar and rubble. Better walls were formed of alternating layers of rubble and a stiff mortar, such as the exposed layers in the Baths of Caracalla, while poorer quality walls had rubble thrown in more irregularly.[224] Differences in the size of aggregate pieces will change the labour time, less than 300 cm^3 and under 100 cm^3 mark dramatic increases in time taken, which lead to a standardisation of fist-sized, 300-500 cm^3, aggregate pieces in Ostia during the imperial period.[225] Facing and wall thickness have similar standardisations at Ostia and show a range of 0.66-0.81 days/m^3 for standard brick work; 0.79-0.86 days/m^3 for brick with some finish; and 1.0-1.2 days/m^3 for reticulate over 0.45-1.2 m walls.[226] Thus, a uniform construction rate across various brick and reticulate regimes could be deliberately chosen to mark space, as with the Piccolo Mercato (1.8.1) facework in public areas of the building.[227] As we will see, the standarisation of construction processes created certain uniformities in the acoustic properties of different buildings. Construction practices

[220] See DeLaine 2002.

[221] Pavolini 2010: 212-8; Veitch 2017a.

[222] Calza 1953: 123; Blake and Bishop 1973: 144.

[223] DeLaine 2002: 43.

[224] DeLaine 2000: 234.

[225] DeLaine 2000: 239.

[226] DeLaine 2000: 239.

[227] DeLaine 2000: 239.

were part of the developing standards in urban experience of second century CE Roman cities.

Chapter Two
Literary Noise and the Urban Image

"For twenty-five centuries Western knowledge has tried to look upon the world. It has failed to understand that the world is not for beholding. It is for hearing … Now we must learn to judge a society by its noise."
J. Attali, *Noise*, 3.

"We might try to dominate space with sound, as with the church bell or minaret amplifier, but once it has left its source it leaves our control (except in the special case of the acoustic design of concert halls)."
P. Rodaway, *Sensuous Geographies*, 92.

Cur saepe sicci parva rura Nomenti
laremque villae sordidum petam, quaeris?
nec cogatandi, Sparse, nec quiescendi
in urbe locus est pauperi.
Martial, *Epigrams*, 12.57

Today, city noises are managed through spatial strategies of building codes and traffic regulations.[1] Spatial strategies control noises through the regulation of *sound pressure levels* (SPL) and acoustic building materials, which isolate noise. Similar spatial strategies were not enforced in the Roman imperial period, despite the regular discussions of urban noises. The lack of sound measurement and legal regulation based on such measurements however, did not prevent Roman literary authors from constructing social stigmas and moral judgements about the noises in their city. The acoustic analysis of chapter three will provide a comparable auditory geography, which reinforces the distinctive types of spaces each source creates.[2]

Noise, therefore, offers insight into the social and spatial image of Roman urban space. This urban image of noise that is presented in the Latin literary sources has been uncritically and anecdotally used to describe Rome as noisy and crowed, comparable to modern metropolitan cities. Literary depictions were both the product of experience and imagination. In this chapter, a complete database of literary references to noise and

[1] See CEC vol 5 Noise 1992.

[2] See section 1.4.

silence is analysed to understand the ways in which noise was linked to certain urban spaces and particular urban practices.

Publications on Roman social history have, to date, assumed that noise pervaded the city of Rome. Ramage conflates the subjective judgements of the literary sources with sociological work of the time on urban problems, leading to the judgement that 'a noise pollution that must have reached levels at least as high as those in some of our noisier cities today' pervaded in the centre of Rome.[3] However, the anecdotal use of literary sources, especially Martial, Juvenal and Seneca, overlook the urban image produced by such authors. The literary sources are not, in fact, registering the intensity of noise, but produce an urban image of Rome as a city full of sounds. Thus, the literary descriptions cannot be used as indications of sound intensity levels, but do indicate judgements on the spatial locations and social status of noisemakers.

In this chapter, the literary topography of noise will be discussed in relation to changes in Rome during the period from the second century BCE to late antiquity, including population increases, devastating fires, and urban dislocation.[4] At the centre of this chapter is a database of the literary references to noise and silence within the Packard Humanities Institute Latin library (PHI). This database allows for the urban spaces associated with noise and silence terms to be analysed in a more systematic way, going beyond the usual anecdotal references. In particular, text-mining and network visualisations were used to compile and display the literary references and associated spaces. Increased references to noise in the urban space of Rome in the Latin literary sources show anxiety towards cultural changes in the period between the first century BCE and the second century CE, which are implicitly in the legal codes compiled in the *Digest of Justinian* (simply, *Digest*).[5] Noise provides an outlet through which Roman authors comment on, and socially construct, the urban environment around them. Noises are associated with particular movements and social interactions. Similar movements and interactions were evident in Ostia and the literary imagination provides a different perspective to view the acoustic and architectural changes that shaped second century CE Ostia. Aspects of social status, wealth and gender are always part of the literary image, and influence the interpretation of literary production, providing insights into the social character of noise in the city of Rome. Social control, through power/knowledge, is exercised via noise complaint, which distinguishes elite and non-

[3] Ramage 1984: 69; Jenkyns 2013: 38; Ramage takes a similar approach to Scobie 1986, although Scobie is concerned with sanitation, not noise; cf. Laurence 1997; Morley 2015.

[4] Urry 2012: 43; cf. Laurence 2015.

[5] The majority of the *Digest* is from the mid-first to early third century CE, Johnston 1999: 15.

elite forms of urbanism.[6] Direct spatial control of noise is missing in the legislation, which emphasises the conceptual and perceptual understanding of urban space in the literary sources.[7]

First (2.1), the literary definition of noise is assessed, drawing on the database of references to seven terms (see Appendix 3). This group of terms covers noise and silence. Using the typology of noise developed by Truax, the terms are linked to functional understandings of noise as a negative response, an obstruction to auditory clarity, or unknown sound. The opposition between noise and silence reveals the importance of movement as a concept of noise. The second section looks at the temporal distribution of these terms, highlighting the peak period between 100 BCE and 200 CE. This temporal distribution is evenly distributed across different writing styles, and corresponds with the peak periods for literary sources. It is in this period that a distinctive image of Rome develops based on noise and movement.

Section 2.3 considers the links between noise terms and particular urban spaces. Cicero, Livy and Justinian provide the most references to public space, and each represents a different approach to the city. The three authors provide insights into the personal, historical and judicial images of Rome. These images of Rome are followed by explorations of specific spaces within the city and the associated noises. First, the enclosed space of the theatre and courtroom are explored to understand the negotiation between individuals and audiences within confined spaces. Second, the open area of the forum is analysed. This is a space of both movement and stopping. Noise in this space is transitional, based on the activities of those listening. Finally, the street space is analysed to assess the role movement as a defining feature of noise.

Section 2.4 addresses the link between noise and movement. Movement was defined as noise, encompassing the various social interactions that took place in the city. In the literary sources, noise and movement were central to the image of Rome and were brought together in the discussion of rumours in the city. In the late Republic, a concern over the movement of rumours developed in response to non-elite communication networks. These communication networks functioned outside of the elite networks and were subject to social and moral judgements by the literary elite. In this way, attempts were made to control the noise of rumours.

Section 2.5 explores attempts to control noise through legal regulation and social judgements, to understand the perception of noise and its influence on social

[6] Crampton and Elden 2007: 177.

[7] Laurence 2015: 176, 1997; Edwards 1996; Larmour and Spencer 2007; cf. Lefebvre 1991: 38-41; Soja 1996: 66-7.

interactions. Control was exercised in various ways, but did not lead to any regulatory spatial strategies of noise control. Instead, social control was exercised through moral topographies of the city. Looking specifically at the *Digest*, property regulations and administrative duties would influence noises in certain spaces. The influence was on the conceptual understanding of noise and movement. Taking the public space of the forum, two particular social groups, *praecones* and *circulatores*, were targets of social controls to regulate noise and movement within that space. The social stigmatisation of these two groups was an attempt to suppress potential non-elite subversion of communication networks. The adoption of *praecones* into imperial administration ensured the loyalty of the group.[8] *Circulatores* were not adopted into elite networks, and remained socially stigmatised. A final way of controlling noise was to leave the city. This way of dealing with noise played off a series of dichotomies, such as city and country, business and pleasure, and noise and rest. These dichotomies were at the centre of the image of Rome as full of noise, which could only be overcome by retiring to the countryside.

The digital methods utilised within this chapter enable the analysis of a larger corpus of Latin sources than has been achieved previously. In particular, text-mining has enabled the compilation of the database in Appendix 3, and its analysis within the given time for producing a thesis. The advantage of such tools is the ability to analyse a larger set of sources that provides a more systematic picture of the literary conception of noise. In depth studies of all the references are not possible within this thesis, but the overall trends are indicative of a more complete picture than previous references to limited sources.[9]

The emerging picture is one of the Roman literary productions of new concepts of space that are associated with noise.[10] The urban image of noise is based on the link between movement and noise. Physical structures, such as buildings and public spaces, were socially produced by sounds and noises, animating the space, while literary descriptions form part of the internalised spatial image of the city of Rome. The legal discussions of cities and civic communities (*civitates*) define their sociality, as the Romans conceptualised it.[11] This sociality was the product of publicly owned buildings, rules enacted by the people, and private social bonds formed in community.[12] The same

[8] See Bond 2016.

[9] The database is not complete, as it is dependent on the texts available in the PHI, however currently no Latin database is complete.

[10] See Laurence 2015: 175.

[11] Ando 2011: 45-6.

[12] Ando 2011: 45.

social elements, public ownership, communal rules, and private social bonds, were part of the discussion surrounding noise, which were an attempt to control noise through a social image of the city. In auditory terms, the social, political, and economic relations of the imperial period amplified city noise.

2.1 References to 'Noise'

Within the corpus of Latin texts in The Packard Humanities Institute (PHI) Classical Latin Library there are 5,099 references to 'noise' and 'silence' (Appendix 3).[13] The PHI contains essentially all Latin texts from before 200 CE, as well as a series of texts from late antiquity, including Justinian's *Digest*. This database of Latin texts includes the majority of texts prior to and during the time of development at Ostia, providing insights into the perceived urban image of the literary elite in Rome in the previous and contemporary periods. Chapters three and four will look at the particularities of Ostia in terms of streets, buildings and movement, to critically question the relationship between the literary conception of urban noise and the materials remains of Ostia. In this section, an overview of the Latin terms for noise and their associations with urban spaces are discussed at the level of general trends evident in the statistical analyses of the database of sources. Included in the list of terms are *sono*, *clamo*, *strepo*, *fremo*, *murmur*, *sileo* and *taceo*, which make up the most frequently used terms and their references (Appendix 3). The role of noise, as well as sound in general, within urban space can be analysed through the digital humanities tools of network graphing, text-mining, and statistical analyses.

Network visualisations and statistical analyses help to display the links between noises and spaces within the literary urban image. Here, urban image functions as shorthand for the literary depiction of the city of Rome, whether real or imagined. The digital approaches of text-mining and network graphing allow for the general trends within Latin literature to be visualised, as well as enabling statistical analysis of particular words across the entire Latin corpus. The total of references display trends in word choice and associated spaces for different periods, which can then be further analysed from within those confined data sets. At this initial level, the visualisation of total references and other statistical calculations are important in setting the context for particular passages or texts. These dual functions, of general trends and particular usage, are instrumental in charting the connections between sounds and spaces, while

[13] http://latin.packhum.org. Accessed: 2 June 2016.

also allowing for traditional readings to draw out the social-historical aspects of specific associations.

2.1.1 Defining 'noise' in Latin literature

Noise can refer to various phenomena and it is worth setting out some of the key elements that will be taken up in this chapter, as well as the rest of this thesis. Truax provides a functional typology of noise based on auditory communication.[14] Noise has three primary functions, for Truax, which hinder auditory communication. Noise can function as a negative response, an obstacle to clarity, or as unknown or new information perceived.[15] Each of these functions depends on the perceiver and are therefore internal judgements made about a sound. The fluidity between sound and noise is then in the perceptions of the one hearing; one person's noise is another's sound. Truax's typology of noise is useful in categorising the various words commonly defined as noise and his typology is refashioned here around words indicating production of noise and words denoting the character of noise. The final function of noise in Truax is noise in a non-pejorative sense, meaning sounds that could be *potentially* meaningful, but are unknown at first. This function of noise, although the most useful, is the most subject specific and is hardest to infer from the literary sources. Noise in this sense lacks the social and behavioural reactions learned through repetition. It is worth noting that this sense of noise cannot overlap with noise in a pejorative sense, as negative judgements are part of the social and cultural conditioning of the individual. In chapter five, noise, in this sense, as unknown or yet to be understood sounds will be discussed in terms of the formation of urban knowledge. In the literary sources, however, noise is rarely unknown, which provides a valuable insight into the social capital of the literary sources. Moral and social judgements about sounds as noise indicate aspects of the auditory imagination of the Roman literary elite; although it does little to alleviate the actual sound, it allows the authors to marginalise the associated activities and people. Appendix 3 contains several word roots that are defined as 'noise' and it is worth discussing their etymological associations, as those indicate certain perceptions of urban noise.

[14] Truax 2001: 96-7.

[15] Truax 2001: 96.

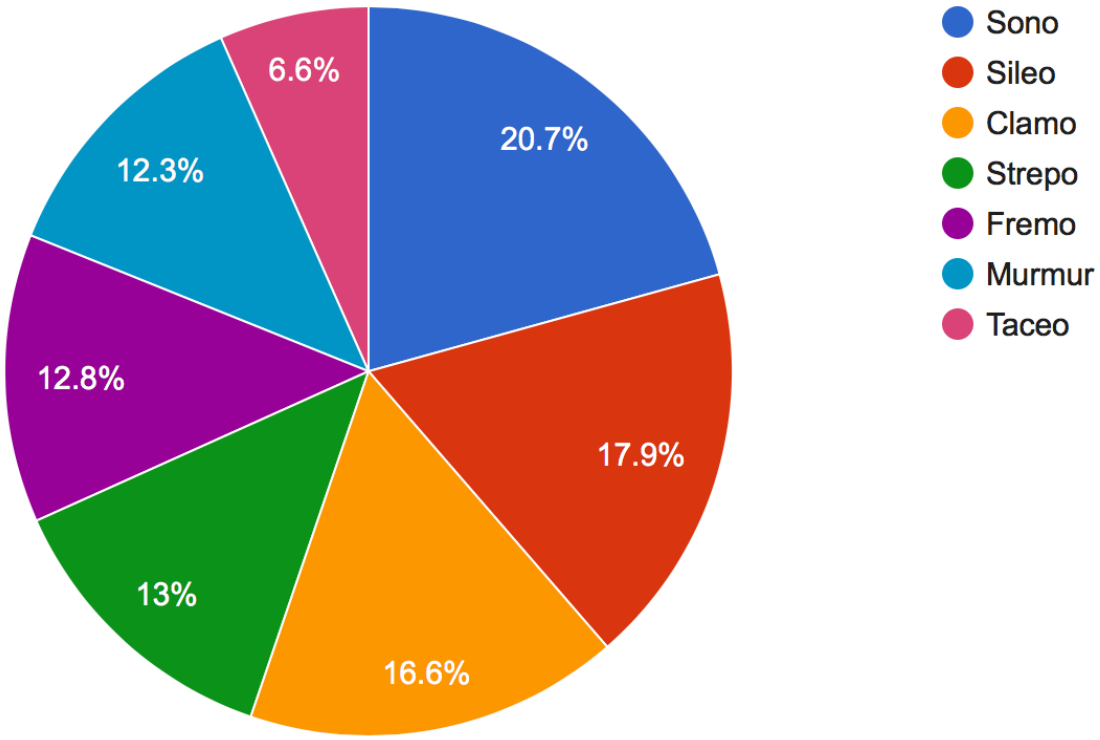

Figure 2.1 Noise and silence terms from Appendix 3 database. (Author)

First, there are words that indicate the production of noise. *Clamo* and *sono*, as well as their associated words, are the most specific form of noise, indicating to shout, call out, or to make a sound. These terms indicate the production of sound and the action of noisemaking and make 37.3% of references (see Fig. 2.1) As Figure 2.1 indicates *sono* accounts for 20.7% and *clamo* 16.6% of the references in Appendix 3. In Truax's functions of noise, *clamo* and *sono* relate to the first function, as a negative response by the listener.[16] In the adjectival form, *clamosus*, it indicates loud resounding or full of noise, suggesting undifferentiated sounds. The emphasis of *sono* and *clamo* is on who or what makes a noise in comparison to the other three noise terms.

Second are terms that indicate the character of the noise, rather than indicating who or what created the noise. *Strepo* (confused noise, din, or clash), *fremo* (rushing or resounding loud noise), and *murmur* (roaring, growling, or humming), relate to Truax's second function of noise, as an obstruction to auditory clarity.[17] The individual percentage for each term is lower than those of *clamo* and *sono* (13% for *strepo*, 12.8% for *fremo*, and 12.3% for *murmur*), although the three terms make up the largest combined percentage at 38.1% (Fig. 2.1). Thus, although the particular word choice is

[16] Truax 2001: 96.

[17] *OLD* '*strepo*' '*fremo*', and *'murmur'*; Truax 2001: 96-7.

relatively even, between 12.3 and 13 %, the preference for description of the character of noise is telling. In these cases, the particularities of the sound are kept at the general level of animal like sounds. Without a quantifiable measure of sound intensity of noise, the literary authors resort to language of *strepitus* or *fremitus*, which were both associated with animal sounds, roars or buzzes, and busy activity. *Strepitus* and *fremitus* characterise this function of noise in their association with roaring, buzzing, and natural sounds, such as rumbling, rattling, or creaking, which provide insights into the mental image of the noise and associated space. *Murmur* as well carries associations with the noise of animals, like roaring of lions or humming of bees.[18] This function of noise is the basis for changes in social practice, which are not always consciously perceived.[19]

These terms display non-verbal forms of communication in their connection with animal and natural sounds. Several categories of non-verbal communication are auditory, relying on hearing for comprehension. These sounds range from grunts and groans to feet or shoes on pavement, to silence. Tacitus, who has 207 references to noise/silence terms (4.1%), uses non-verbal communication regularly in the *Annals* and *Histories*. In Tacitus, 65 out of 471 nonverbal gestures or utterances (13.8%) are auditory sounds.[20] These sounds are often categorised as noise using the associations of the Latin terms with animal sounds. In contrast, the previous group of terms relating to the production of noise are associated with particular or specific actions.

Alongside these social dynamics implicit in the terms, noise also marked non-Roman identity based on foreign noises. Noise, in this case, becomes a defining feature of non-Roman culture and, therefore, a target for xenophobic ridicule. Juvenal is the most telling example of the image of foreign noises invading Rome and causing disease.[21] Juvenal describes foreign cults that come to Italy in terms of non-Roman noises. Four out of the six types of 'sewage' the Syrian Orontes drains into the Tiber are auditory perceptions, while, in his sixth satire, Juvenal uses the sounds of foreign cults and witches to describe women's talk at dinner.[22] This image of noise as 'foreign' was part of the relational negotiation of Roman identity and was framed by the definitional associations of the Latin terms.

The definitions and associations of the Latin noise words with forms of movement further nuance the conception of literary spaces. Certain words are connected with

[18] *OLD 'murmur'*.

[19] Truax 2001: 96.

[20] Newbold 1974: 193.

[21] Juv. 3.62-5, 234-6; see also Liv. 39.8.

[22] Juv. 3.62-65; 6.434-443; Hartnett 2016: 166.

movement, which indicates a conceptual link between noise and movement in the Roman imagination. For example, *strepitus* carries the connotation of busy or stressful activity. In contrast *sileo*, silence, is connected with non-movement, or stillness, which emphasises the combination of sound and movement in urban space. Through both etymology and associations, noise words are connected with movement; to move is to make sound.[23]

The social distinctions between elite and non-elite are mapped onto topographies of noisy and calm spaces. In Rome, social interactions defined places as people moved through, stopped or chatted.[24] These locations were associated with particular literary designations, such as *locus celeberrimus*.[25] It is important to stress the dichotomy of noisy and calm, not loud and quiet. The association of silence with stillness emphasises the role of movement in defining noise. *Fama*, either rumour or fame, is constantly on the move, restless and unstable.[26] The spatial boundaries of *fama*, therefore, constantly shift, or more precisely never stop long enough to be spatially fixed.[27] Speed is part of the moral topography of movement, as O'Sullivan has shown.[28] Running is characteristic of slaves and effeminate action, an association also connected to movement of *fama*.[29] Movement, in these instances, creates sound; either the movement of information, even if partial, associates speech with travel, or the lack of movement, produces silence.[30] The speed at which this travel happens reflects the growing anxieties, as well as distinguishing identities.[31] Discussions of sounds, especially noise, are not indications of high sound intensities within the built environment, as will be shown in chapter three and four, but are reactions to social differences in the use of space. In this context, moral, social, and political topographies of noise in Rome, work alongside the regulatory mechanisms of the jurists to create a cultural apparatus (*dispositif*).[32] The apparatus functions at an abstract level, but is reinforced by the social practices and urban image of Rome.

[23] Newsome 2011b: 41.

[24] Laurence 2015: 181.

[25] See Newsome 2011b.

[26] Hardie 2012: 3-11; 248.

[27] Laurence 2015: 181.

[28] O'Sullivan 2011.

[29] Corbeill 2004: 107-139; O'Sullivan 2011: 11-33; Hardie 2012: 357-360; 387-391.

[30] On physical aspects of movement sound, 163-71.

[31] O'Sullivan 2011: 11-33; Spencer 2011: 62; cf. speed of *fama* amongst the Gauls, Caes. *BGal*. 7.3.2-3.

[32] Crampton and Elden 2007: 194.

2.2 Temporal Distribution of Noise References

Looking at the overall timeframe of the literary sources use of noise terms, there is marked emphasis on sources in the first century CE and late Republican period (Fig. 2.2). The PHI does not contain all Latin authors, and its bias is towards the period before the second century CE. However, the PHI database does include the *Digest*, along with assorted later Latin authors. The PHI categorises the *Digest* under a single author, Justinian, which places the start and end dates at the time of its compilation (see Appendix 3 'Iustinian'). As will be discussed in a later section, the *Digest* includes various juristic writings that cover several centuries, but the PHI website does not allow for the further breakdown of the individual authors within the *Digest*. For that reason,

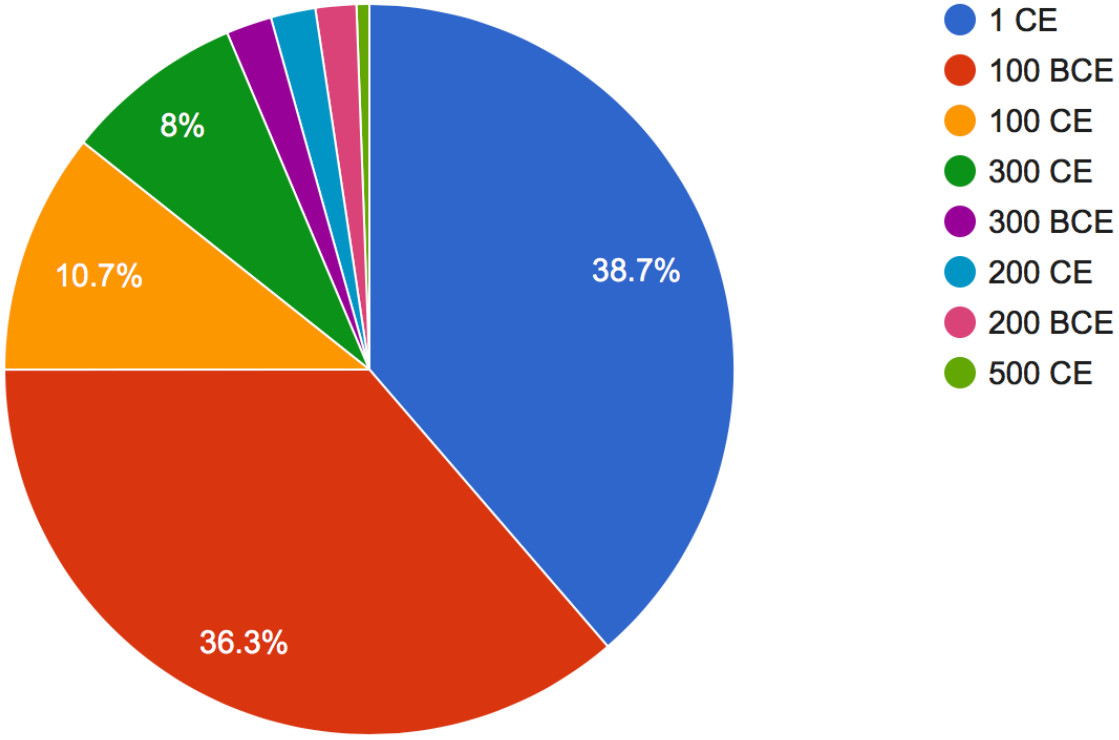

Figure 2.2 Latin authors in Appendix 3 database by starting date. (Author)

'Justinian' refers to the *Digest*, which is the only text within the PHI listed under Justinian.[33] In a later section, the breakdown of jurists found within the *Digest* is given in order to contextualise the formation of potential regulatory image of the city (see Tab. 2.2).

The PHI does not have a listed chronology of Latin authors so, the chronological conventions for the Loeb Classical Library (LCL) was used (see Fig. 2.2, and Appendix

[33] See PHI list of authors, http://latin.packhum.org/author/2806.

3).[34] The dates for Latin authors in the LCL are divided into centuries and were the author spans a threshold between two centuries both are tagged on the LCL site. Therefore, the date ranges in Appendix 3 sometimes span two centuries, which skews the figures for particular date ranges. This bias extends the outer range of dates, therefore creating increased numbers in the peripheral periods. Instead of listing each century individually, which would lead to double counting of the middle date, only the outer dates are listed in Appendix 3. Figures 2.2 gives the starting dates for the source listed in Appendix 3. As seen, 1 CE and 100 BCE are the top two starting categories with

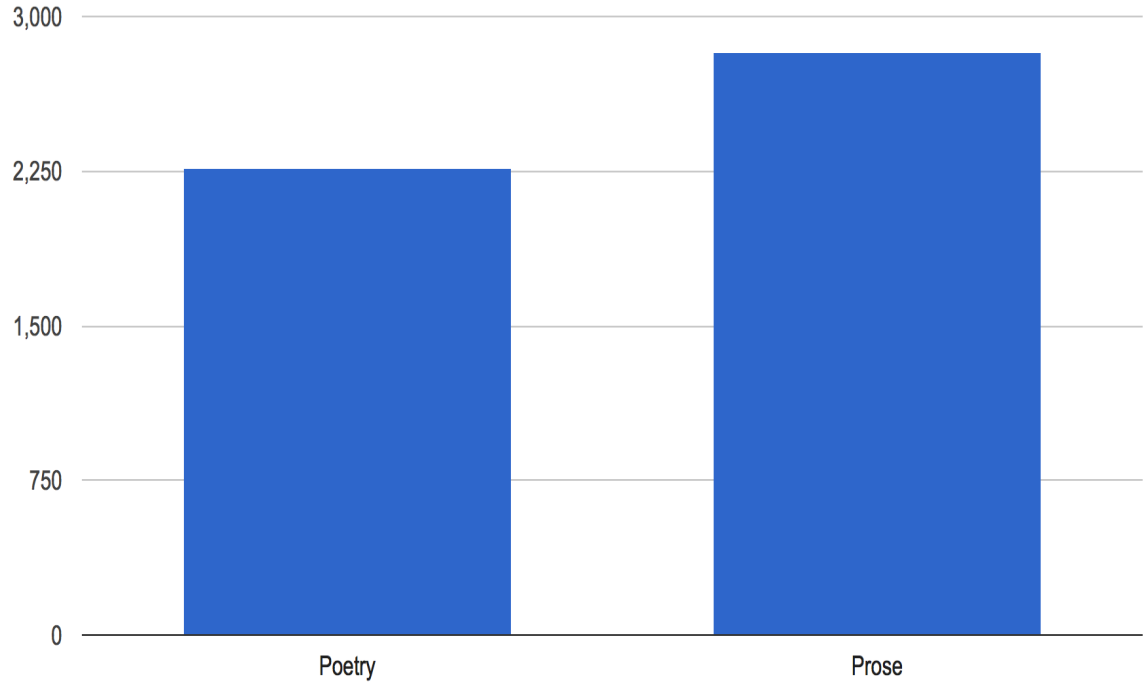

Figure 2.3 Style of writing and total count of noise and silence terms in Appendix 3. (Author)

38.7% and 36.3% respectively. Thus, the peak periods for references to noise and silence are the first century BCE and the first century CE.

The various authors can also be divided based on the writing style used in their texts, whether poetry or prose (Appendix 3 'Style'). This basic division indicates whether the writing is in verse or not and indicates that the writing style did not effect

[34] http://www.hup.harvard.edu/features/loeb/timeline.html. Accessed 24 May 2016.

the overall choice of describing noise within certain writing styles; that is to say, Appendix 3 does not emphasise one or the other writing style (Fig. 2.3).

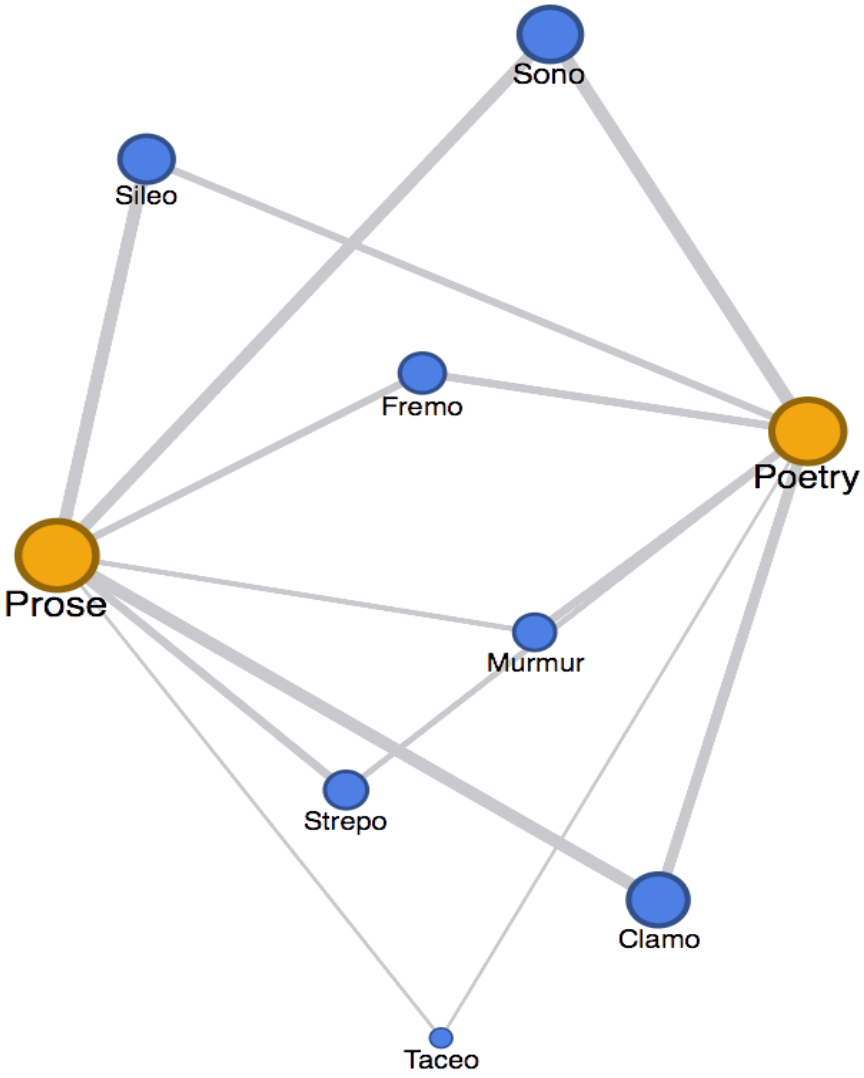

Figure 2.4 Network graph of noise and silence terms in relation to writing style. The graph is weighted by total count of the given term. Heavier lines indicate more total references. (Author)

Within those broad categories particular word choices are evident (Fig. 2.4). In general, *clamo*, *sileo*, and *sono* are the predominant references in both prose and poetry. When graphed together, *clamo* and *sileo* display more references in prose writing, while *sono* is evenly distributed between both poetry and prose (Fig. 2.4). Although not in the top three, *strepo* also shows an increase in prose references; *fremo* and *taceo* show a relatively even total number of references between the two styles. Overall the

distinction between prose and poetry writing styles does not seem to influence the choice of referring to noises or the general choice of words. The network graph reflects the same ranking of noise and silence terms seen in figure 2.1 above, however in the case of figure 2.3, the references to *sileo* are more often found in prose writing. Nuances such as this should be kept in mind, as particular authors and passages are discussed in relation to the spatial setting for noise.

2.3 Associated Public Spaces with Urban Noise

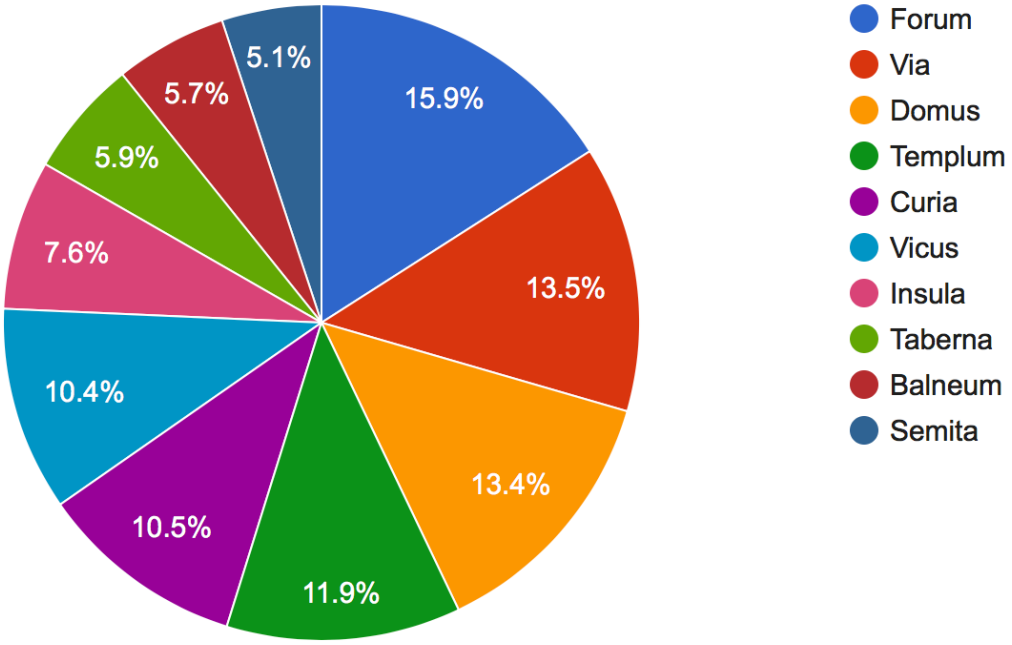

Figure 2.5 Top 10 spaces referenced in the PHI. (Author)

Noise in spatial contexts provides insights into the literary production of urban space. As figure 2.5 shows, the forum is the most referenced space in the city, followed by *via* and *domus* (15.9, 13.5, and 13.4% respectively). When the references to urban spaces are paired with references to noise and silence terms *domus* remains the third

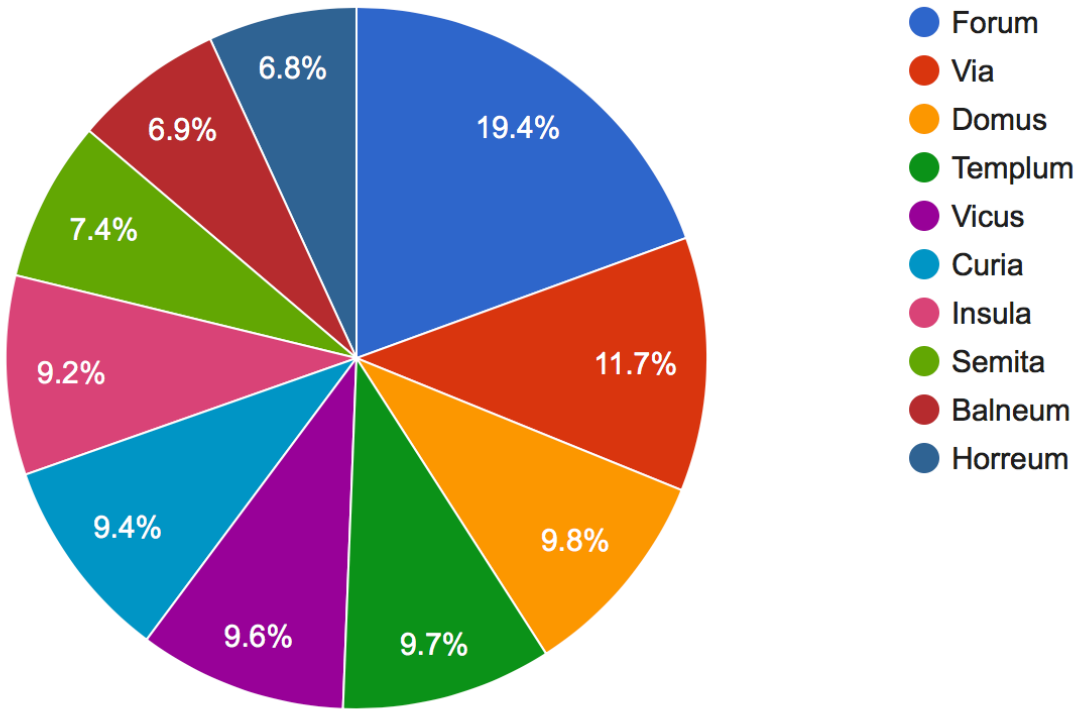

Figure 2.6 Urban spaces ranked by references to noise/silence terms. (Author)

most cited, but drops to below 10% (9.8%), suggesting an emphasis of noise and silence on streets and public space (see Fig. 2.6).

What makes these spaces important is their openness to a variety of people. In streets, *sileo* and *sono* are the most often referenced noise/silence terms, although *clamo* is not far behind (16.9, 16.8, and 16.2% respectively). As noted above, *sono* and *clamo* indicate different types of noise, which also relate to different spatial practices. *Sono* and *sileo* in this space indicate the extremes of auditory practices and should not be taken as reality; the space was not in constant flux between silence and shouting. Instead, the literary descriptions use the extremes to indicate the certain socio-political conceptions of the space. At times of crisis, silence or commotion registered the general feeling of the people. Noise or silence in these cases indicate not individual actions or responses, but a communal feelings.

Overall, Cicero, Livy and Justinian (*Digest*) provide the most references to public spaces and properties (Fig. 2.7). These three authors represent different approaches to the urban image of Rome, although they are not the usual 'everyday' authors normally cited (Martial, Juvenal and Seneca). All three authors are categorised as prose authors in

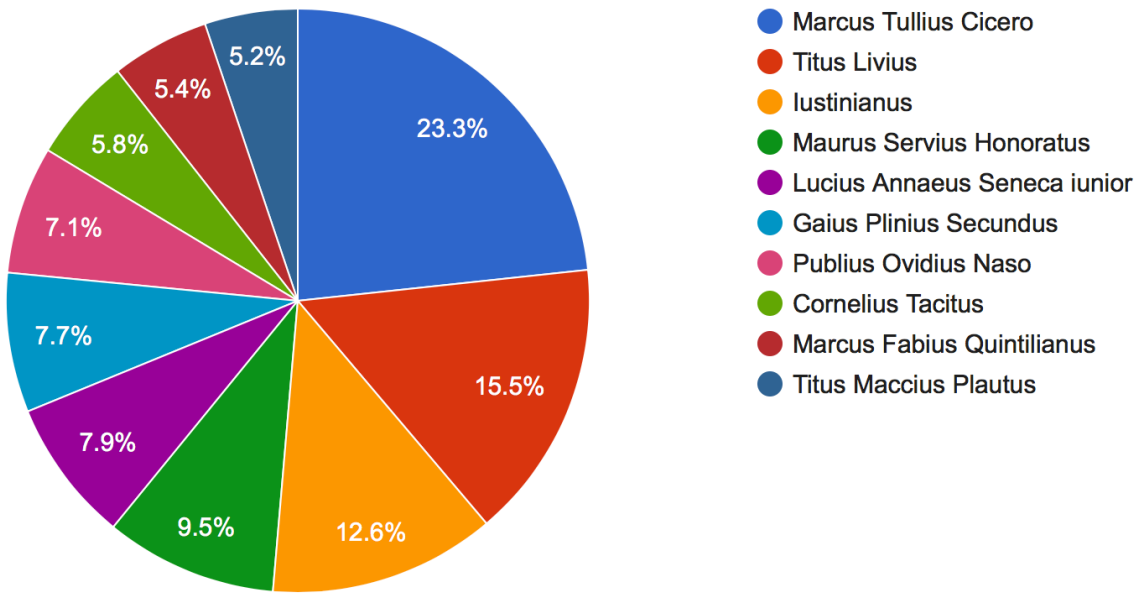

Figure 2.7 Top 10 authors in PHI Latin library ranked by references to urban spaces. (Author)

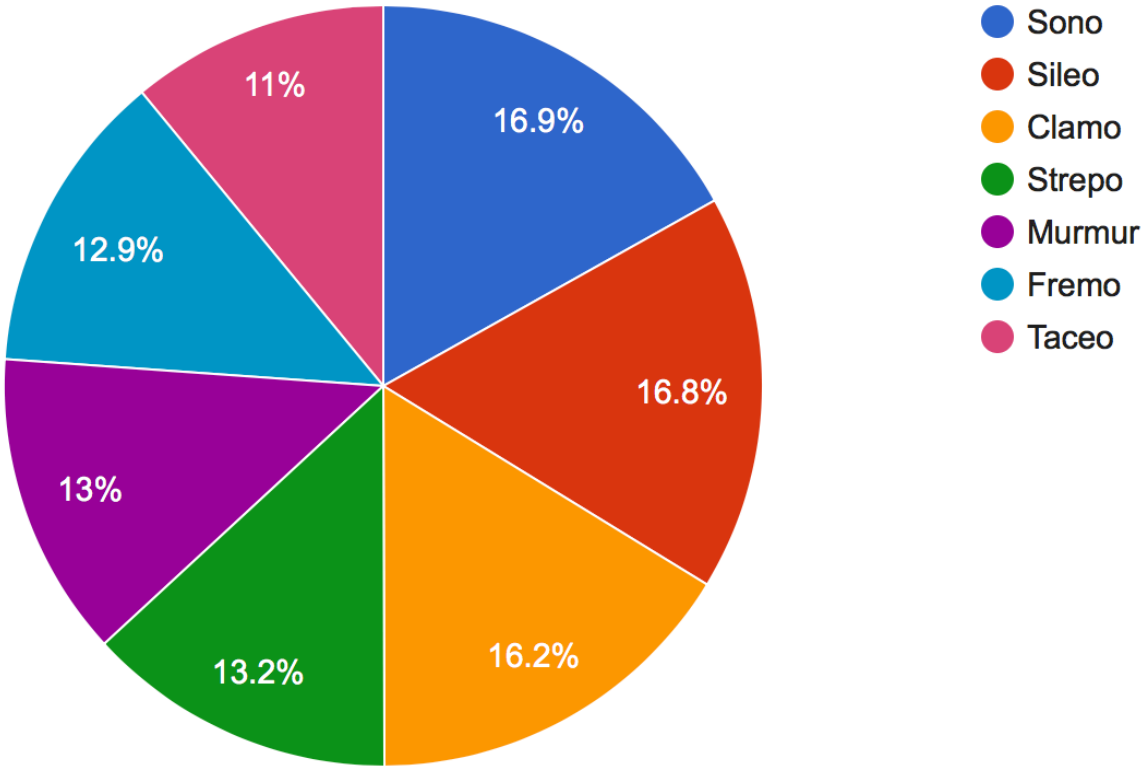

Figure 2.8 Noise/silence words ranked by total references to streets and public spaces. (Author)

Appendix 3, however they represent personal, historical and judicial approaches, respectively, to the city. These different aspects of the city worked together to create an image of Rome, although the authors span different time periods and also represent changes to the urban image they produce. In relation to noise, the way in which each author associates certain frequently mentioned spaces with particular noises provides insights into the mental perception of urban space in Rome. Streets and public spaces were marked by particular sounds, some of which defined the character of those spaces (Fig. 2.6).

The three authors who refer to public space the most: Cicero, Livy and Justinian, relate to the activities and noise of the city in different ways, each drawing a different image of the city based on their authorial context. In terms of noises and silence, Livy uses *clamo* (276 references) and *sileo* (141 references) more than *sono* (38 references), whereas Cicero uses *clamo* (120 references) and *sono* (95 references), more than *sileo* (73 references). Justinian has the least noise references with *sileo* (12 references), *clamo* (7 references), and *sono* (2 references) in that order. The choice of terms, again, reflects the style of writing and the author's own image of the city. The prominence of *clamo* in Livy and Cicero reflects an image of Rome as full of noise and activity, while *sono* in Cicero is connected with the frequent references to specific activities associated with the forum (377 references to forum in Cicero). The emphasis in the *Digest* on *sileo* is part of the process of formation implicit in the jurists. As discussed below, the juridical writings are not pre-emptive legal regulations, but in fact reflect prior social interactions between individuals, which cannot be worked out without recourse to law. Here, it is worth pointing out the limited references in total to noise or silence in the *Digest* (22 references), which highlights the minimal legal regulations of noise. This is in contrast to contemporary regulation of noise, which develops in the modern period.[35] The topic of noise regulation will be addressed further below, as well as the social relationships implicit in the *Digest* and their relation to spatial practices.

2.3.1 Noise in the Theatre and Courtroom: enclosed space

Noise can function as a means of power or control over public space. As Attali has argued, in contemporary society the prohibitions against noise have been melded with surveillance and social control.[36] While this process of surveillance and noise prohibition is distinctively modern, social control and noise have been in tension in

[35] Thompson 2002.

[36] Attali 2014: 122.

previous eras.[37] In particular, the spaces associated with noise in ancient Rome are spaces of communal expression. Public gatherings of various sorts were key places for community responses, as well as being spaces of uneven power dynamics, especially in terms of the literary elite. Noises associated with specific public spaces could be an attribute of right behaviour, or when unexpected, as an indication of abnormal practices within public spaces that were defined by specific ritual practices. Here, it is worth drawing out some of the literary negotiations that shaped the image of urban noise in relationship to different city spaces.

The status dynamics between elites and non-elites cannot be removed from the public noise made by crowds. Noise made in public space by crowds asserts control over that space for the length of the noise. Crowds, therefore, can spatially control an area through noise making, which is an aspect of the second function of noise. Applause, hissing, booing or catcalling were auditory responses of the people within certain spaces, like the theatre, amphitheatre, courtroom or forum, which was based on the negotiation of power between an individual and audience. The circus and theatre were not simply reflections of the Roman social order, seen in the seating arrangements, but enacted that social order through the reaction of the audience, whether approving or disapproving.[38] Noise in this space was central to the social production of Roman social hierarchies. Cicero described the reaction of the crowd in the theatre as blows from a sword (*conscissi*), clearly demonstrating the centrality of public reception in the civic space of the theatre.[39] The physical space of the theatre was filled with noise, which mirrored the public reception of crowds in a *contio*. What was different in the noise of the theatre was the instigation of the reaction. In a *contio* an auditory response was elicited by spoken word, while the reactions in the theatre were the product of seeing the particular person. It was the act of entering and being visibly seen, not speaking that elicited reactions. Applause (*plausus*) was not just a reaffirmation of elite status, but was central to non-elite assertions of power and uneven social dynamics.[40] Non-elites held the power in the situation, asserting themselves in the social space of the theatre to vocalise feelings of approval or disapproval through noise making.

Noise itself marked the approval of an elite by others in the community. A cheering crowd was an end in itself for a member of the Roman elite with high

[37] On the rise of noise control in modernity, Thompson 2002; Attali 2014.

[38] Parker 1999: 163.

[39] *Ep ad Att.* 2.19.3.

[40] Parker 1999: 176.

ambitions.[41] The crowds of the theatre could show their support or their disproval of other literary elite besides politicians. Poets included the reception of theatre crowds as the highest honour.[42] Being applauded by the theatre crowd was compared with the triumph as the archetype of the highest form of achievement.[43]

The assertion of space through noise is also evident in the case of court activities, although the descriptions differ from the sound of the theatre. In these instances, cultural norms based on routine practices are evident in the choice of noise terms associated with the space. The law courts display the variation in sensory distances, which were reinforced by the activities within the courtrooms. Unlike the theatre, courtrooms were enclosed architectural spaces. The 'audiocentrism', as de Angelis calls it, of legal trials is visually manifest by the *corona circumstantium*, the ancient definition given to the audience.[44] However, the engagement was not limited to those who were directly involved with the law courts. The audience in the law courts were drawn from a variety of social groups who did assert their presence through noise making, particularly *clamor*.[45] The courtroom, therefore, differed from the theatre in auditory terms; the theatre was marked by *plaudire*, applause, while the courtroom was marked by verbal explications, *laudare*, *clamare* or *clamor*.[46] The power was, literally, in the hands of non-elite in the theatre, and in their throats in the courtroom. Hands and voices create particular noises in relation to the acoustics of the space. These differences in spatial practices both point to the importance of auditory responses, while simultaneously highlighting the importance of location in producing particular noises. Thus, the noise made in public, in response to members of the elite defined the space through the type of noise, applause in the theatre and vocal exclamations in the courtroom.

Differentiations in time were marked by when law courts could meet, not the architectural definitions of spaces of justice.[47] A charter from the *Lex Coloniae Genetivae*, issued in 44 BCE, provides a temporal framework for the administration of law courts by the *duovir*. The remaining tablets are Flavian, suggesting a continued utility into the

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[41] Bell 2004: 7.

[42] Hor. *Cam*. 1.20, 2.17; *Odes* 1.1.1-8; Vir. *Gorg*. 2.508-10; Tac. *Dial*. 13.3.

[43] Luc. 7.712; Plut. *Pomp.* 68.2; Prop. 3.18.18; Parker 1999: 170.

[44] de Angelis 2010: 11; *TLL* 4.986.20-56.

[45] Quint. *Inst*. 4.2.37, 12.8.3; Mart. 1.95; Bablitz 2007: 134.

[46] *Laudare*, Sen. *Cont*. 9.pr.2; Quint. *Inst*. 4.2.127, 6.4.6, 10.2.27, 11.3.131; Mart. 6.38; Plin. *Ep*. 2.14.8, 4.19.3, 9.23.1; *clamore* or *clamor*, Quint. *Inst*. 4.2.37, 12.8.3; Mart. 1.95; Bablitz 2007: 134.

[47] de Angelis 2010: 10.

imperial period.[48] The *Lex Coloniae Genetivae* indicates that lawyers were given fixed amounts of time for their case, six hours for the prosecuting party and twelve for the defence.[49] The chief prosecutor was allowed four hours, and an assistant, two hours; however, the prosecutors could transfer allotted time between each other as long as they remained within the six-hour time limit.[50] *Lex Coloniae Genetivae* specifies that the trial should take more than one day, as the trial should not start before the first hour or continue after the eleventh hour.[51] In acoustic and spatial terms, this presents a fairly continuous level of speech in a fixed location throughout the day. Seasonality would alter the length of hours, as the Romans divided the days into twelve segments of daylight and twelve segments of night.[52] Thus, days varied in length from the longest day, 15 hours (04:30 to 19:30, in modern 60 minute hours), to the shortest day, of nine hours.[53] These variations in the length of the day would create seasonal changes in the rhythm of noise in the courts and forum.

Noise had their own moral character, which was used to define social groups, relationships, and spaces. The performative aspect of rhetoric was judged by the voice and gestures.[54] Within the urban space of the second century CE, the voice was a competitive marker between elite.[55] Social status, in this case, was worked out through the cultivation of an 'ideal' male voice; a gendered debate held within an entirely masculine context.[56] The sound of the voice reinforced the otherwise arbitrary status differences between elite and non-elite, in the same way as gait and deportment.[57] The social 'ideal' within the literary sources shaped the embodied practices of speech and walking, reinforcing particular behaviours. Distinctions are drawn by the sound of the voice or other audible noises, like snorting. Dio Chrysostom critiques the people of Tarsus for their habit of nasal snorting.[58] For Chrysostom, the nasal snorting is worse than men speaking with women's voices, due to the noise's association with

[48] Crawford 1996: 395.

[49] Crawford 1996: 409, Tablet c, Col. IV, ln. 23-36.

[50] Hannah 2009: 104.

[51] Crawford 1996: 409, Tablet c, Col. IV, ln. 24.

[52] Laurence 2007: 156.

[53] Balsdon 1969: 18.

[54] Gleason 1995: 159.

[55] Gleason 1995: 164.

[56] Gleason 1995: 101-2, 160-1.

[57] Gait, O'Sullivan 2011: 16-31; deportment, Gleason 1995: 21-81.

[58] Dio Chrys. *Or*. 33.

indeterminate gender (*androgynoi*).[59] The voice is an indicator for distinguishing sex, similar to gait and gestures, as well as indicating the blurred boundaries of gender identity, or signifying the insider/outsider status of a group.[60] The voice, specifically its pitch, was associated with courage, low-pitch, or cowardice, high-pitch.[61] As will be discussed in chapters three and four, the acoustic properties of certain spaces would amplify high or low frequencies within that space, emphasising certain pitch frequencies. The moral judgements of the phyiogomists can serve as social guides to the importance and dynamics at work within these spaces.

Noise and activity was also noted through the opposite of stillness and silence. The interventions of the judge, bemoaned by Maternus, is reversed in Quintilian, who comments that the hardest part of the transition out of the rhetorical schools is that the judge sits silently (*iudex tacet*).[62] However, the agency implicit in the different terms for silence is important. *Silentium*, as noted above, implies silence and stillness, while *taceo* is limited to the voice.[63] Thus, for Maternus, the judge imposes stillness and silence, in contrast to Quintilian's quiet judge, a point further emphasised by Quintilian's discussion of reading the judges' facial expressions.[64] Quintilian, along with other first-century sources, also requires physical stamina and a powerful voice to speak of the simultaneous activities of the forum, either over the open air, or to be heard in the resonant basilica.[65]

In his discussion of the building's surrounding the forum, namely treasury (*aerarium*), prison (*carcer*), and senate-house (*curia*), Vitruvius specifically comments on the decoration of the interior of the *curia* to enable speech intelligibility.[66] Vitruvius advises that the *curia* is covered in stucco half way up the interior walls. His reasoning is that the stucco delays the voice before it rises into the air and is scattered.[67] Vitruvius equates the reflection of sound off the walls with an architectural delay induced by the

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[59] Dio Chrys. *Or*. 33.38; Gleason 1995: 82.

[60] Gleason 1995: 83.

[61] [Arist.] [*Phgn*.] 806b; Gleason 1995: 83.

[62] Quin. *Inst*. 12.6.5; cf. Frier 2010: 77-8.

[63] *OLD* '*taceo*'.

[64] Quin. *Inst*. 6.2.7, 6.4.19, 12.10.56.

[65] Cic. *Brut*. 317; Sen. *Constant*. 9 pr.4-5; Quint. *Inst*. 6.4.9-11, 10.3.30, 12.5.5-6, Plin. *Ep*. 2.14.10; Crook 1995: 135-6.

[66] Vitr. *De arch*. 5.2.2.

[67] Vitr. *De arch*. 5.2.2, *quae si non erunt, vox ibi disputantium elata in altitudinem intellectui non potererit esse audientibus. cum autem coronis praecincti parietes erunt, vox ab imis morata priusquam in aera elata dissipabitur, auribus erit intellecta*.

cornices and stucco. What is informative here is the experience of the space in Vitruvius' decorative account. The spaces are experienced as being enclosed through the addition of cornices and stucco half way up the walls. In the passage before, Vitruvius lays out the dimensions of the *curia*: if it is square, the height should be one and a half times the width; if it is rectangular, the height should be half the length plus the breadth.[68] In effect, the dimensions of the *curia* space emphasise verticality, creating a grand effect, while the acoustic experience needs to maintain speech intelligibility. For Vitruvius, the decoration provides a means of creating the appropriate balance.

The theatre and courtroom emphasise the importance of crowd noise. Audiences, in both cases, tailor their responses to the space. In these cases, the space is architecturally enclosed in some way. For the theatre, applause was the image of acceptance or disapproval. The urban image of entering the theatre was one of community recognition and honour. Noise could be the sign of approval, rather than a negative response. In the courtroom, verbal noise marked the space. This was an area of further enclosure than the theatre, which restricted the number of people and centred on a few particular people. The decoration of the space was seen to emphasise the importance of vocal clarity, as Vitruvius makes clear. However, this vocal clarity could be reversed as audiences used the same acoustic characteristics to subvert the speaker. Negotiations were therefore central to the politics of the space, as individuals and audiences engaged each other. This contestation, however, was not limited to enclosed spaces. Public spaces and streets display similar negotiations within an open space. In these spaces, attention was not focused on specific activities.

2.3.2 Noise in the Forum: open space

The distinctions between particular spaces and types of noise, indicated above, was also present in the image of Rome's streets and public space. In the city of Rome, literary descriptions of noise relate primarily to the forum in general (19.4%, see Fig. 2.6) and the Forum Romanum in particular. The forum is usefully understood as a space of interaction: a continuum of social interactions and encounters with varying degrees of formality, with islands where these relationships were formalised and more clearly defined, legally, politically or economically.[69] Unlike the theatre or courtroom, what set the forum apart was its open space and lack of enclosure or separation from its surrounding streets. Laurence points out the contrast between the space of the forum

[68] Vitr. *De arch*. 5.2.1.

[69] de Angelis 2010: 10.

and that of the theatre. The theatre was constructed with audibility in mind, even if one could not hear the actors. The forum, on the other hand, was a place of hearing and partial hearing, a space marked by the choice of where to stop and experience the activities taking place.[70] Thus, within the forum, hierarchies and overlapping political, social, and economic relationships were negotiated in everyday practices and the literary image of the space.

The Forum Romanum was the centre of political knowledge and information, which was verbally conveyed to the urban population through a series of official actions.[71] The movement of information is key to understanding the role of noise within the Republican city. As noted at the start, one way of conceiving noise is as an auditory obstruction, which lessens auditory clarity. That is to say, auditory communication was central to negotiating political and social control from the Forum Romanum, which could be either interrupted by noise or transmitted beyond the Forum Romanum, with varying levels of reliability, through social relationships. In this case, noise serves both to interrupt the content of auditory communication and to reconfigure the social relationships assumed within the literary elite image of Rome.

Crowds in the forum have been emphasised, but without the direct connection to the acoustics and auditory communication.[72] Formal gatherings of people for political purposes were either for voting assemblies (*comitia*) or mass meetings of the people called by a magistrate (*contiones*).[73] Speaking to the people was a constituent element of the power of magistrates and was a privilege of the social elite.[74] By calling *contiones*, social elites were able to control effectively a majority of political information transmitted to the community.[75] In this case, the ability to formally call the *contio*, which was limited to certain magistrates, was key to the control auditory communication to the people; however, calling a *contio* required the use of a *praeco*, a public crier, to announce and disseminate information.[76] In the late Republic, *praecones* served both civic and private parties as auctioneers and announcers for games, religious festivals, and funerals.[77] As will be discussed below, control over this group was exercised through social status designations and bans in the late Republic, but by the empire their

[70] Laurence 2011b: 395-6; Betts 2011: 126-9; cf. Trifilò 2011: 315-7.

[71] See especially Betts 2011.

[72] The exception is Betts 2011; see Hölkeskamp 1995: 38, 2013; Mouritsen 2001: 13-14; Russell 2016: 46.

[73] Ziołkowski 2013: 391.

[74] Piña Polo 2011: 301.

[75] Piña Polo 2011: 301.

[76] Var. *Ling. Lat.* 6.9; Liv. 33.28.4; Luc. *De Rer. Nat.* 4.563-7.

[77] Bond 2016: 31-6.

adoption into Roman administrative retinues legitimised their status as the audible symbol of authority.[78]

Within the social context of the literary elite urban image, there is also a shift in the conception of noise from the Republic to the mid-Empire. The *contiones* of the Late Republic were highly formalised and addressed to the entire Roman people, no matter how many were actually present.[79] *Contiones* were important venues for information of official business, public debate, and discussion of acts that affected the communal life of the people.[80] In the Republican era, the public had three market days (i.e., at least two weeks) to debate issues posed in the context of *contiones*, creating a particular temporal soundscape on these occasions.[81] Republican concerns centred on the movement of auditory information through unofficial small groups, *circuli*, which will be analysed in section 2.4.1. In opposition to the unofficial *circuli*, the *contiones* were officially called gatherings. In short, these groups were seen as the place of rumour and resistance, which functioned outside standard social relationships of patronage. Noise, in this sense, moved through Rome in an uncontrolled fashion, outside official networks of information exchange, such as the *contiones*. As the forms of auditory communication channels changed, the literary soundscape shifted.

The negotiation and contestation of space within the forum was further reflected in the choice of speaking platform, from which to address the people.[82] In the Forum Romanum, the rostrum was set in the northwest corner, in front of the Curia.[83] Speakers faced the Curia, not the open space of the forum, which had an area of 2,650 m^2.[84] This was a space bordered by the façade of the Curia, acting as a sounding board for the speaker. In the mid-Republic, speakers turned to address the open area that was previously behind them, facing out into the central open space with their backs to the Curia. Auditory clarity and audience size were in tension, as the open space of the central forum dissipated the sound of an individual speaker. Within this space a crowd of 10,600 to 19,000 could potentially stand in the 2,300 m^2 area, although only 9,200

[78] Bond 2016: 45.

[79] Hölkeskamp 1995: 38; Mouritsen 2001: 13; Russell 2016: 48.

[80] Piña Polo 2011: 287.

[81] Piña Polo 2011: 287; cf. Betts 2011: 126-9.

[82] A German project, 'Analogspeicher II - Auralisierung archäologischer Räume' (Humboldt-Universität zu Berlin), has been reconstructing the auditory field for the speaker's locations within the Forum Romanum utilising the 'Digitales Forum Romanum' model (http://www.digitales-forum-romanum.de).

[83] Rostra, *LTUR IV* 1999: 212-4.

[84] The dimensions of the Forum Romanum are from the 'Digitales Forum Romanun', see n. 81.

people would be within the audible area (up to 35 m from the speaker).[85] This was a symbolic move, addressing a wider area and, therefore, potentially larger audience, that was not practically confirmed by the acoustics of the space. Open air and lack of architectural boundaries allow for greater levels of sound dissipation with the speaker in this location.[86] It was with the relocation of the rostrum to the western side, being backed by the Aedes Concordia, that potential reflected sound would boost auditory clarity across the forum area.[87] In comparison, addressing the audience from the Temple of Castor increased the available space to 2,950 m^2 (11,800 to 23,000 people), although the area of audible communication remained at a threshold of 35 m from the speaker. Thus, the location of address, as well as the architectural frame, influenced the need for lines of communication to relay speech content beyond the audible boundaries.

Under the Principate, the *contiones* did not disappear, but were less frequent and continued to be public notices of official news and information.[88] Importantly, the imperial *contiones* were presided over by the emperor, who is generally the only person to speak.[89] Reasons for calling *contiones* in the imperial period usually relate to imperial funerals or the introduction of new consuls each year. New consuls would swear an oath to obey the laws, and the outgoing consuls would swear that they had upheld the laws during their term of office.[90] This ritual also marked the beginning of a new year, making *contiones* ceremonial in nature particularly during the Principate.[91] *Praecones* also transitioned into representitives of symbolic authority by the Principate, representing the emperor or provincial governor through their announcement of edicts and laws. The result of this change for the everyday rhythm of the forum is that the conflict between orators, with active participation of the crowd, emblematic of the late Republic becomes more passive and controlled, although the forum remains the centre of popular disturbances.[92] Thus, official information was audibly passed to the people through the political process of *contiones*, which was in contrast to other auditory communication methods. Noise in the forum is part of the negotiation of control between official and unofficial forms of auditory communication.

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[85] Based on 4 people per sq metre used by Analogspeicher II project.

[86] Sebastian Schwesinger pers. comm.

[87] Aedes Concordia, *LTUR I* 1993: 316-20.

[88] Piña Polo 2011: 294.

[89] Piña Polo 2011: 295.

[90] Piña Polo 2011: 295.

[91] Hannah 2013: 91-4.

[92] Ziołkowski 2013: 405.

2.3.3 Noise in the Streets: moving space

In distinctively different manner from the enclosed space of the theatre and courtroom or the bounded open space of the streets and forum were the sites of two interconnected aspects of literary noise, namely, social mixing and spatial movement. Changes in technologies of transport are evident in the descriptions of street noise. At the lowest level, the paving of space set in motion the shift in mobility that would take centuries to realise.[93] The association of streets with certain noise terms reflects the perception of noise as involving movement. On the one hand, the street was a space of movement, on the other, that movement made noise, which is exaggerated in the literary image of Rome. However, the exaggeration of street noise should not be cast

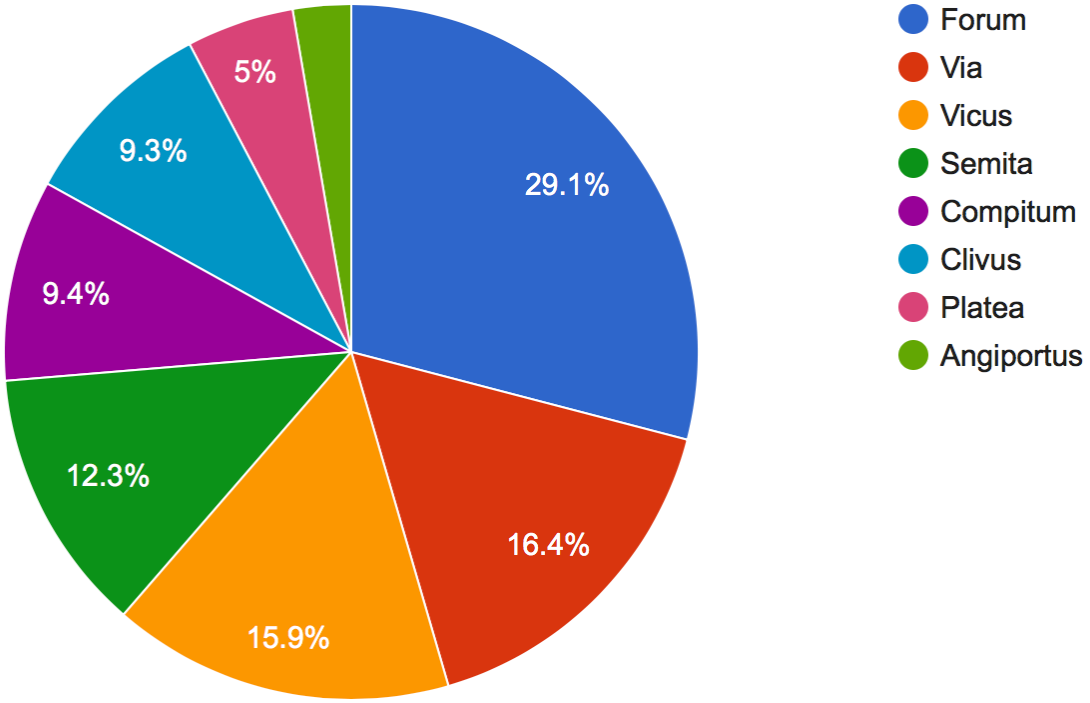

Figure 2.9 Street terms ranked by references to noise and silence terms in Appendix 3. (Author)

aside as simply literary disgust. Implicit in the exaggeration are a more nuanced reaction to cultural developments and changes to behavioural patterns. Street noise, in this sense, is indicative of the changes to movement within the street and, at a more general level, changes within the broadly defined urban form.[94] Before turning to the role of

[93] Laurence 2015: 182-4.

[94] 'Urban form' is used here as shorthand for three interconnected elements that make up a city: 1) a spatial object; 2) a space of mediation between state and local scales; 3) a work formed by a group. Urban form, in

movement in descriptions of street and urban noise, a brief discussion of street terms will contextualise the conceived character of urban streets.

The naming of streets, either *via*, *vicus* or *semita*, categorises the 'common-sense' understanding of streets (see Tab. 2.1).[95] These categories of streets indicate aspects of street width and functional usage. Thus, the *Digest* defined public streets, *viae publica*, as streets open to use by all, although *via* could be a *semita*, path or road, *iter*, way, or *actus*, track.[96] A variety of terms were used to indicate streets of varying width or certain features, the most common being the triplet of *via*, *iter*, and *actus* (Tab. 2.3).[97] *Via*, *iter*, *actus* originally formed the basis for the rustic servitude for right of way, differentiating the manner in which way is given; *iter* is the right to go on foot, *actus* is the right to drive animals or vehicles, and *via* is both.[98] Already the Roman legal definition of 'street' is complicated by the variety of terms. The broad definition of *viae publica*, however, had certain characteristic limitations, such as the prohibition of funerary monuments on public roads.[99] The Twelve Tables are cited as giving *via* a width of eight Roman feet, which is to be used if no other width is indicated.[100] Festus gives the same width as standard for both public and private streets, although there are no strict dimensions for public streets.[101] In discussion of rural servitudes, a *via* could be wider or narrower than eight feet; however, it must permit the passage of a vehicle to be considered a *via*.[102] *Via*, therefore, carries the legal width of eight Roman feet within urban space and the ability to handle vehicles, animals and pedestrian movement if it deviated from eight Roman feet. The roads radiating out of Rome were named *via*, such as the Via Appia, Via

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this sense, encompasses these three characteristics, the social, economic, and political relationships that centre in the city. See Lefebvre 2003: 194.

[95] See Harvey 1990: 211-225, on 'common-sense' understandings of space-time. Further study of the relationship between named streets and particular experiential qualities of the street is needed, see Trifilò 2013.

[96] *Dig*. 43.7.1; 43.8.2.23, 24; 43.20.4.pr; *Dig*. 50.16.157, *Item 'via' est, siue semita siue iter est*.

[97] *Dig*. 8.1.13; 8.3.1; 8.3.7; 8.3.12; 8.4.15; 18.1.66; 20.1.12; 33.2.1; 39.3.17; 43.7.1; 43.8.2.23-5; 43.19.1.7; 45.1.72.

[98] *Dig*. 8.3.1 pr.

[99] *Dig*. 43.7.2.

[100] *Dig*. 8.3.8; 8.3.13.2; see also van Tilburg 2007: 27.

[101] Festus 371M.

[102] *Dig*. 8.3.23 pr.

Ostiensis and Via Tiburtina.[103] The Via Ostiensis, connecting Rome and Ostia, was 4.5 m wide with sidewalks of 1.8 m and 1.1 m.[104] The Via Severiana, connecting Ostia and

Latin Terms	Features	Occurrences
Viae, via	Roads radiating out from gates;	148
Vici, vicus	Within the city, flat street; neighbourhood	82
Semita	Path, narrow street, sidewalk	40
Angiportus	Alleyway	13
Clivus	Sloping	23
Compitum	Crossroads	29
Iter	Foot path	147
Actus	Animal driven path	64
Platea	Street, square (later)	18

Table 2.1 Latin terms in reference to streets and occurrences. (Author)

Terracina along the shore was 4.1 m wide. These 'highways' had narrower widths than the average, 4.74 m or 16 Roman feet, for main roadways outside Rome, but are still within the normal range.[105] *Actus* and *iter* were given narrower widths of four and two feet respectively by Festus, although these widths are not indicated in the *Digest*.[106] Other terms for streets are used infrequently, such as *clivus* or *semita* (Tab. 2.3). *Semita* indicates a narrow road, or path, more like an *iter* or *actus*.[107] Varro traces the etymology of *semita* back to *semiter*, half-street, indicating the narrowness of the street

[103] Via Appia, Quilici 1990: 49; *LTUR V* 1999: 130-33; Via Ostiensis, Quilici 1990: 42; *LTUR V* 1999: 143; Via Tiburtina, *LTUR* V 1999: 146-7; Bjur and Frizell 2009.

[104] Quilici 1990: 42.

[105] Macaulay-Lewis 2011: 267.

[106] Festus 17M; *Dig*. 8.3.13.2.

[107] Varro *Ling*. 5.35.

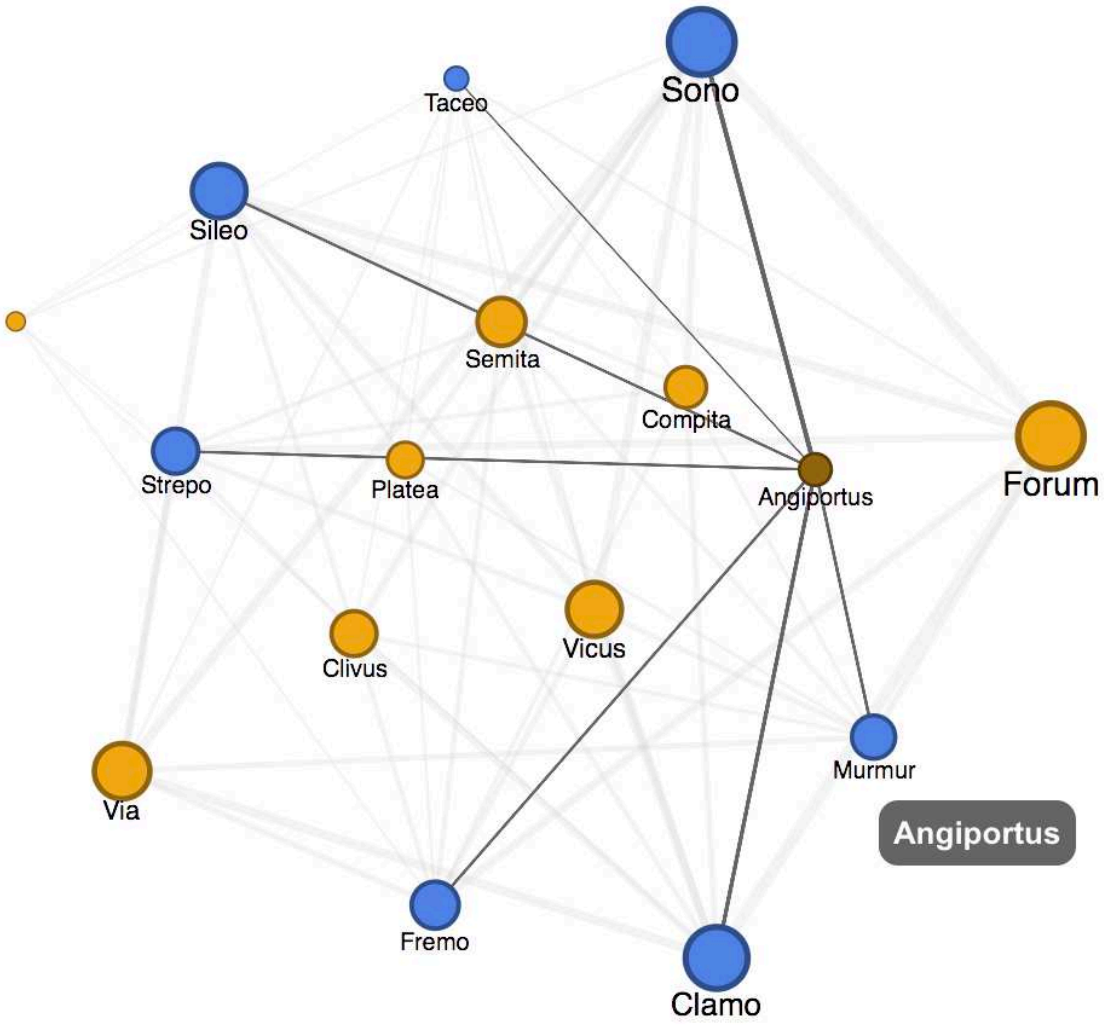

Figure 2.10 Network graph of associated noise/silence terms associated with v*ia*. Dataset derived from Appendix 3. (Author)

in comparison with *via*.[108] *Semita* also refers to sidewalks, commonly known from the streets of Pompeii.[109] In relation to public spaces, *via* is used to describe streets leading to *foro* and city gates, while *semita* is used in relation to shops and commercial transactions.[110] Other streets have similar associations that help frame the literary image of the space. *Angiportus* is associated with pleasure in *lupanar* (brothels) and dark

[108] Varro *Ling*. 5.15; See also Servius, *Verg. A.* 4.405.

[109] Plaut. *Curc*. 287; on Pompeii, Hartnett 2003; 2008.

[110] *Via* in connection with *foro*, Apul. *Met*. 2.27, 3.2; Suet. *Vit*. 17.1; Livy, 5.41.5; 9.24.12; Ov. *Fast*. 6.395-408; Ser. *Verg*. *A*. 1.422; Ter. *Ad*. 570-582; *via* with gates, Cic. *Cat*. 2.273; Caes. *BCiv*. 1.27; *Semita*, Plaut. *Cruc*. 287; *Dig*. 9.2.52.1.

places that 'fear the *aedile'*, according to Seneca (cf. Fig. 2.9).[111] The association is not one related to the auditory nature, but does indicate a moral topography that relates to the social control of space. In auditory terms, *angiportus* is ranked eighth in terms of references to noise and silence terms (see above Fig. 2.9) and the references are divided between all the noise and silence terms, although *sono*, *clamo*, *strepo*, and *sileo* are top (in that order; Fig. 2.10). The moral topography of the urban image, in terms of *angiportus*, is implicit in the low total count of noise references and the relative even distribution of terms. The image of *angiportus* as morally suspect is in part the product of limited references to the space, its lack of particular noise associations, and its non-auditory connection with spaces beyond civic administration. These elements create a space on the boundary of public space, but susceptible to literary control through the deployment of 'common-sense' negative clichés. 'Common-sense' definitions of functional usage, such as this, are also implicit in the associated descriptive noise and silence terms for *via* (see Fig. 2.11).

None of the associated noise terms are directly correlated to the legal width of eight Roman feet, but the passage of vehicles and animals can be assumed based on the noise terms (*clamo* and *strepo*). In the case of *via*, noises associated in the Latin sources are *clamo*, *sono*, *sileo*, and *strepo* (Fig. 2.11). The network graph visualises the total counts for each term in the width of the dot, while the width of the line indicates the total count of both terms. In Virgil, Aeneas marvels at the gate, din, and paved roads of Carthage (*miratur portas strepitumque et strata viarum*).[112] In Petronius, the slave Corax continually stops to complain, lifting his leg and farting, filling the street with noise (*strepitus*) and odour, while Giton matches every fart with the noise (*clamo*) of

[111] Sen. *Vit*. 7.3; Wallace-Hadrill 1995: 54.

[112] Verg. *Aen*. 1.422.

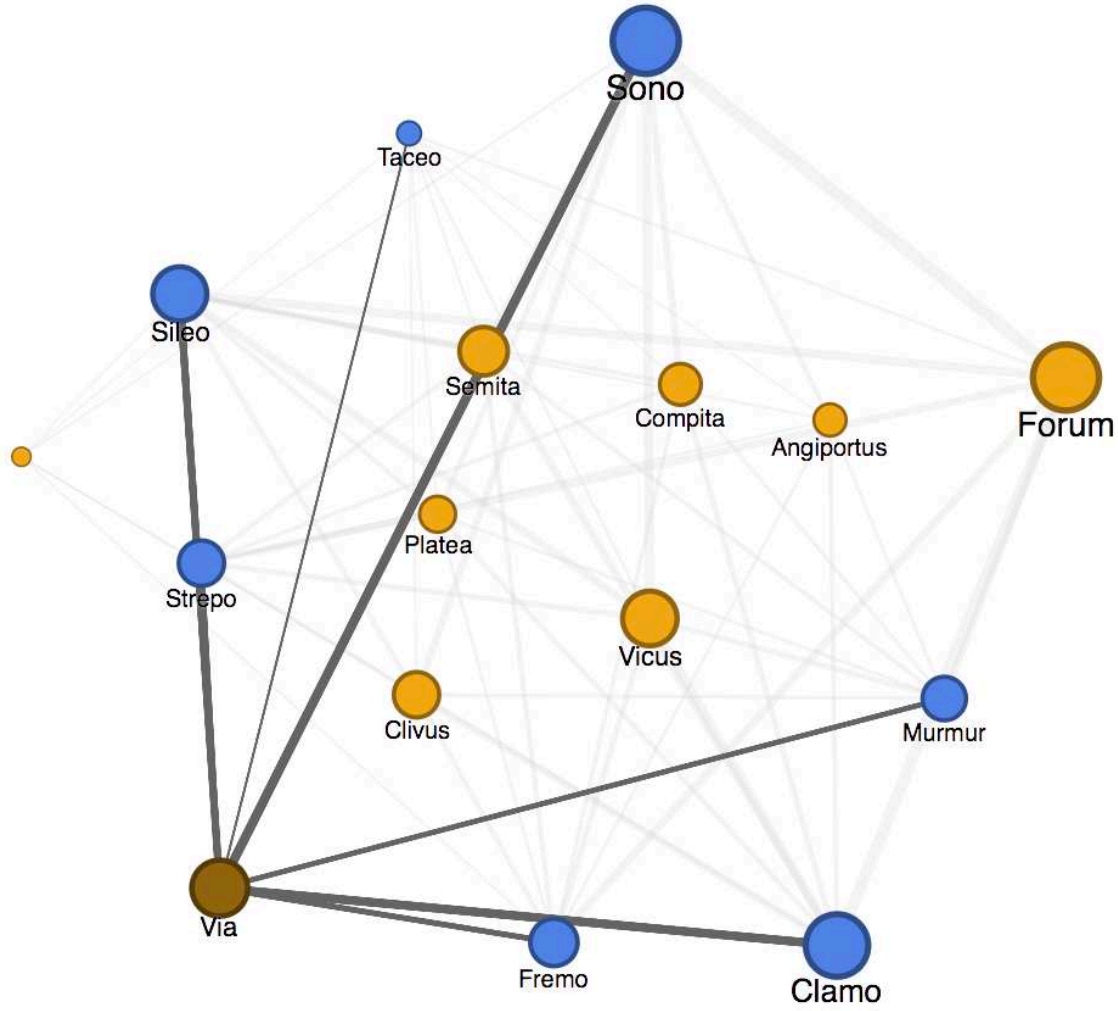

Figure 2.11 Network graph of associated noise/silence terms associated with v*ia*. Dataset derived from Appendix 3. (Author)

laughter.[113] *Clamo* carries less difference in definition and Livy has the most references to *clamo* and *via* (11 instances). It is worth noting that in many cases there is a spatial aspect in *clamo*, particularly the fact that it 'fills' space.[114] In terms of *clamo*, the spatial character of the noise as filling the street emphasises the total volume of the street space over the intensity of the noise. The physical measurements of street volume will be discussed in chapter three, but it is worth pointing out here that intensity of sound and volume of space are both measurable influences on the auditory field of the street. The literary descriptions however do not relate to the physical measurements in a direct

[113] Petron. *Sat.* 117.

[114] See 97-100.

manner, but are mediated by the social and cultural perceptions of noise, space, and time.

Administration and control of streets were primarily directed towards maintenance, repair, and cleanliness for pedestrian movement.[115] The ease of movement takes precedence over the control of noise in this case. The importance of walkable streets and porticoes had direct implications for the sounds of movement. The *Tabula Heracleensis*, which derives from the first century BCE rulings for Rome, indicates that the aediles, both curule and plebeian, within five days of entering office divide the city geographically, and each should repair and maintain the roads in that section.[116] The magistrates are given the duty of maintaining and repairing the public streets and contracting the work for public spaces; however owners are to maintain the street in front of their property. If they fail to do so, the aedile can contract the work at the owner's expense.[117] *Quattuorviri* were charged with cleaning the streets within the city, while *duoviri* were responsible for the streets a mile from the city.[118] Included in the repairs of streets, in the *Digest*, is cleaning, which is defined simply as clearing everything on top of the street, reducing it to its proper level.[119] Clean streets would have been louder streets, as will be discussed in chapter five. The build-up of mud, dirt, hay and street waste would dampen the noise of cartwheels.[120] In the legal codes, the trade-off between efficient movement and street noise was on the side of movement, although the actuality of efficient movement was likely minimal.[121] The *aediles* were also charged with ensuring that porticoes were open for pedestrian use.[122] The *aediles* were given the power to destroy, or have demolished, things that blocked the road or were left out in the streets.[123]

In several places, ease of vehicular movement is the motivation for keeping streets clean.[124] The overflow of shops onto the street is a specific issue taken up in the *Digest*.[125] Associated with shops spilling into the street are the dirt and grime of the

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[115] Laurence 2015: 183.

[116] *Tab*. *Her*. 20-23; Crawford 1996: 358-362.

[117] *Tab*. *Her*. 32-45.

[118] *Tab*. *Her*. 50-2.

[119] *Dig*. 43.11.1.1.

[120] Mart. 5.22; 7.61; cf. London in the 17th century, Smith 1999: 59-60.

[121] Street encumbrances to traffic, Hartnett 2011: 137-43; see also Newsome 2009.

[122] *Tab*. *Her*. 68-72.

[123] *Dig*. 18.6.13 (12).

[124] *Dig*. 43.10.1.3, 4; 43.8.2.25; 43.8.2.32.

[125] *Dig*. 9.3.6; 43.8.2.25; 43.8.2.32; 43.10.1.3.

moral topography.[126] Noise was implicit in this moral topography and cleanliness produced a contradiction of louder streets. Each person was to keep the public street frontage in good repair and clean out the gutters to allow passage.[127] If the property was rented, and the owner failed to undertake the work, the occupiers were responsible and could deduct the expenses from rent.[128] Exceptions were given for fullers to dry clothes and carpenters to leave wheels outside their shops, although these must not block people or vehicles from passing. Martial's *Epigram* 7.61, along with the legal codes, brings together the moral and social importance of street cleanliness; however, the emphasis on ease of movement contradicts elite complaints of cart noise. The tension, between clean streets and noisy streets, is never adequately resolved.

The opening up of Roman space through the paving of streets and roadways is mirrored by an increase in references to carts (Fig. 2.12 and 2.13). Again, peak start dates are 100 BCE and 1 CE, while the end dates pick-up at 1 CE, peak at 100 CE and continue into 200 CE. The range for most references to carts centre between 100 BCE and 100 CE (Fig. 2.12 and 2.13). In the sources, despite genre of writing, movement by cart is grounded in a differing conception of mobility that begins to take place during

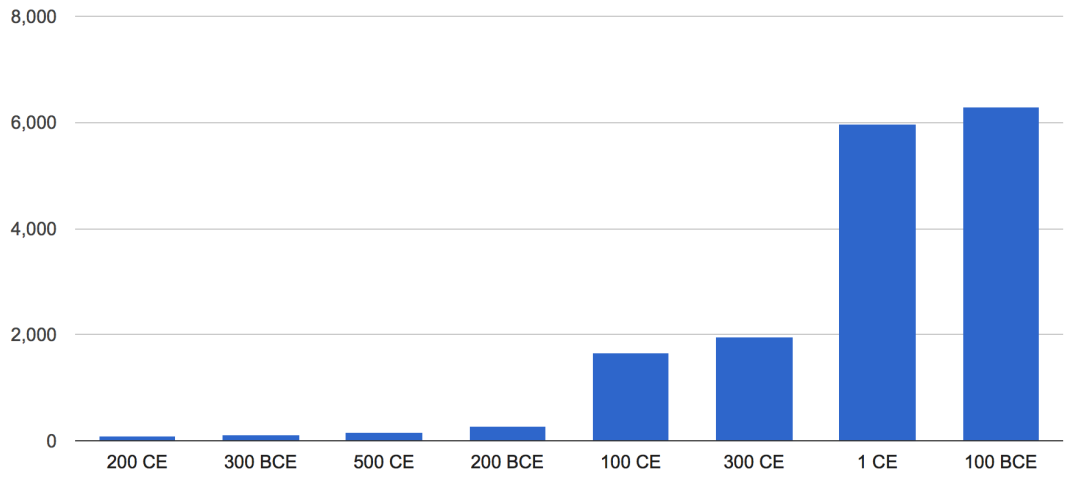

Figure 2.12 References to carts in the PHI Latin library ranked by starting date. Starting dates based on that of Appendix 3. (Author)

[126] Mart. 5.22.

[127] *Dig*. 43.10.1.3.

[128] *Dig*. 43.10.1.3.

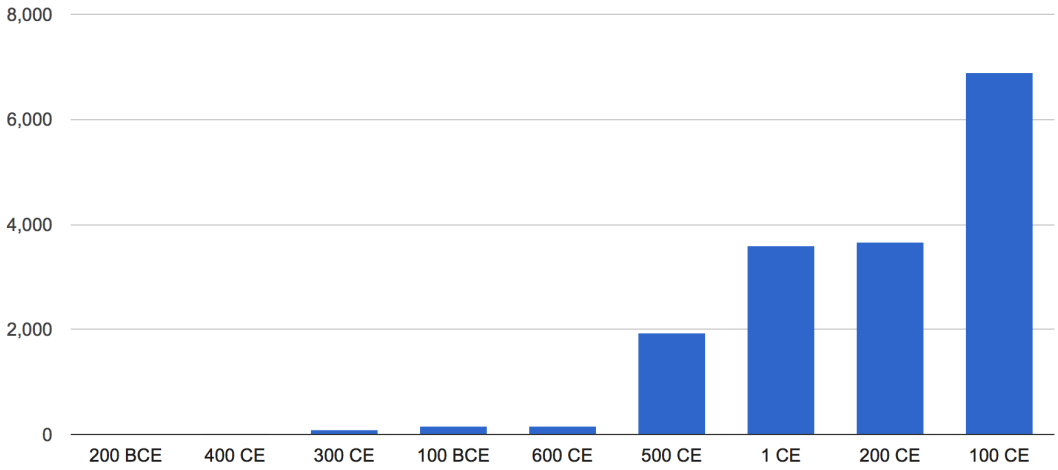

Figure 2.13 References to carts in the PHI Latin library ranked by end date. Starting dates based on that of Appendix 3. (Author)

this period.[129] The paving of streets was the beginning of a shift in the perceived nature of movement, such as the distance covered in a day, or speed of travel.[130] Within the context of peak writings, the increase in references to carts shows changes to the

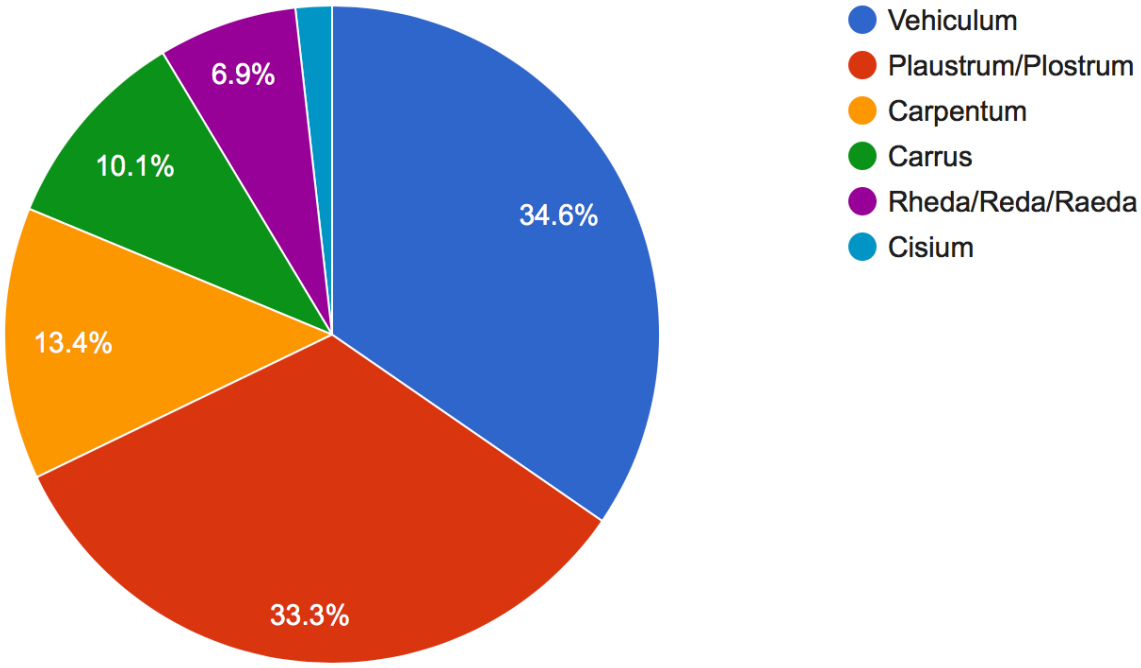

Figure 2.14 References to cart terms in the PHI Latin library. (Author)

[129] Urry 2012: 66-77 for similar development in early modern Europe.

[130] Laurence 2015: 182.

cultural and behavioural understanding of movement. In particular, *vehiculum* and *plaustrum* make up the majority of terms used for carts (67.9% Fig. 2.15).

The *Digest* differentiates types of carts, especially in relation to transportation of goods. Two normative forms of contractual arrangement can be reconstructed from the jurists' discussion; either a carrier was hired to complete the entire job, or one could oversee the hiring of the various necessary components. The jurists use distinctively urban settings in several of the examples, such as two carts (*plostra*) being driven up the Capitoline Hill or the hiring of a *cisium*.[131] Other examples indicate the movement of goods, such as wine or quarried materials, into the city of Rome.[132] Further, the *Digest* refers to the rental of vehicles and animals to transport goods or people.[133] Cattle were predominantly used for traction and associated with larger vehicles, such as the *plaustrum*, while the *cisium* was a lighter, passenger carriage. Similar to the jurists' approach to tenancy and landlords, the legal impact on contractual hiring of transportation was for those with wealth and resources to access the legal system.[134] Thus, utilisation of land transport, in terms of legal recourse, was limited to wealthier individuals, although not strictly the elite.

In the context of the literary image of Rome, the correspondence of increased references to carts and the widespread paving of streets developed into a conception of the street as full of activity, and in particular, noisy activity of moving goods and construction materials. As noted at the start, the Latin definitions of 'noise' are associated with movement. The linking of movement and noise is a central part of the literary image of Rome as city of noise. The cultural perception is also an auditory shift, as movement becomes indistinguishable from noise.

2.4 Movement as Noise

Sound, therefore, is part of the social and cultural production of Rome's developing urban image, in its broadest sense. As shown in section 2.3, noise was associated with different spaces of the city, as well as with different social interactions and relationships. However, noise, and sound in general, is not static or stationary, but moves, filling, reflecting and resonating in space. The interdependence of noise and

[131] *Dig*. 9.2.25.2; 19.2.13.pr.

[132] *Dig*. 19.2.11.3; 19.2.25.7.

[133] *Dig*. 13.6.5.15; 17.2.25.15; 19.2.60.8.

[134] Tenancy, Frier 1980.

movement in Latin, discussed above, is part of what Urry calls a 'mobility system'.[135] A mobility system encompasses the embodied practices of movement, as well as the conceived image of movement and the perceived social aspects attached to movement and stillness. Included in a mobility system are the movement of people, vehicles, and things, as well as movements of information, infrastructural flows, and social mobility, which are described in relation to auditory perceptions of Rome in Latin literature. The city of Rome developed a 'mobility system' through new forms of space, such as *vici*, paving of streets, spatial concepts, such as *platea*, new urban genres, new flows of traffic, and new hierarchies of space.[136] When approached from the field of physics, noise is the movement of particles, as will be discussed in the following chapter. This conception of noise, as particles moving through space-time, helps to bridge the discussion of the ways in which the Roman literary sources conceive noise with the development of mobility in Rome. Noise is the result of things moving, while at the same time a product of movement. The image of Rome as a noisy provides insights into the social-cultural contestations between different city users in the literary sources. These images of the city reflect the mobility system, highlighting one aspect of the movement of people, goods, and animals, as well as the infrastructural elements that enable such movements: the auditory perception of movements.

This aspect of noise, its moving character, also had a moral quality, just as movement, in general, had a moral, as well as a social, aspect.[137] The written sources used to define Rome's cosmopolitan standing were attempts to police, limit and control the movement of people and social groups on which the city depended.[138] Attempts were made to limit the movement of rumours and information, which involved urban space, social groups, and noise, in the late Republic. These attempts highlight the social production of noise and movement control, which were outside the legal and regulatory controls.

2.4.1 Movement of Rumours

The social image of Rome, evident in the noise of cart movement, road paving and crowds also appears in relation to the movement of rumours. Horace brings together movement and rumours in the description of the city in *Satires* 2.6 when he asks if rumours run from the *rostra* to the *compita* (*frigidus a rostris manat per compita rumor*).

[135] Urry 2012; cf. Laurence 2015.

[136] Laurence 2015: 175.

[137] Corbeill 2004: 117-123; O'Sullivan 2011; Jenkyns 2013: 143-191.

[138] Edwards and Woolf 2003: 9.

This question begins a section where Horace describes the various questions he receives in connection with his patron Maecenas (2.6.50-8). In spatio-auditory terms, the *forum*, *via*, and *vicus* are the urban spaces most referenced by the Latin authors (see above Fig. 2.5). Combining the references to public spaces and Latin noise and silence terms, certain public spaces are emphasised. In particular, *vicus* is sixth (10.4%) in total references to urban space and third (15.9%) when ranked by references to noise and silence terms (see above Fig. 2.5 and 2.9). The development of *vici*, from the Republic to the Augustan reformations, highlights the socio-spatial clustering of activity in locales.[139] *Vici*, by the late Republic, acquire 'revolutionary' associations with groups of urban plebs.[140] The reform of the *vici* by Clodius exemplifies the concern over the movement of information, as Clodius enabled direct communication to local levels through the *magistri vici*.[141] In contrast to elite patron-client relations, political knowledge, in the form of rumours, moved spatially through the city of Rome from the Forum Romanum to the *compita* shrines.[142] Pliny the Elder defined Rome by regions and *compita* shrines, 265 *lares campitales*, while Martial imagines his *Epigrams* being read at dinners, in the forum, in houses, in the porticoes, in the shops, and at the crossroads.[143] In both instances, the spatial understanding of Rome was movement through *compita*, a movement, which was founded on walking in Pliny's description, and recitation or speaking in Martial's *Epigrams*.[144]

The use of the terms *rumor* and *fama* also shift the ordering of public spaces (Fig. 2.14). Each public space or street term is weighted by the number of references to *rumor* and *fama* so, the higher the number of references the larger the dot; the same is applied to the Latin authors and the lines connecting the dots indicate the words used by that author. As visualised, *vicus* and *via* are referenced the most, while Cicero, Ovid, Livy make the most references (Fig. 2.14). Hardie argues for the importance of *fama*, defined

[139] Wallace-Hadrill 2003b: 13; 2008: 266-8; Laurence 2015: 184.

[140] Wallace-Hadrill 2008: 267.

[141] Laurence 1994: 68-9.

[142] Hor. *Sat*. 2.6.50; Laurence 1994: 63, 2011b: 388.

[143] Plin. *NH* 3.66; Mart. *Ep*. 7.997.

[144] Laurence 2011a: 98.

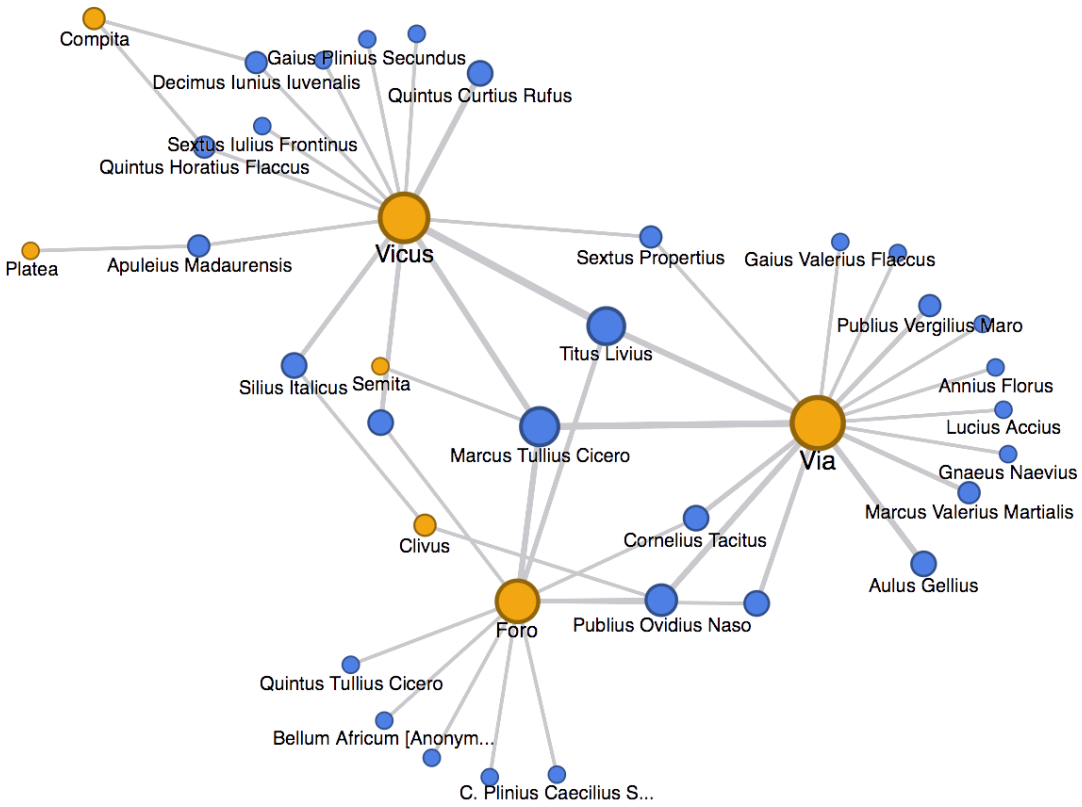

Figure 2.15 Public space, street terms, and Latin authors (weighted by references to rumour terms). (Author)

as both 'fame' and 'rumour'.[145] Cicero's *Pro Caelio* is a struggle to discredit the rumours and gossip about Caelius, while validating the rumours about Clodia. The speech exploits the moral contrast between actions commonly associated with *fama*-as-rumour and those deeds celebrated as *fama*-as-fame.[146] The increased use of the terms by authors of the Republican period is well known.[147] If, however, the use of rumour terms is cross-referenced with public space and street terms, the results indicate an increase in references to *vicus* over *forum* (Fig. 2.14). In terms of spatial references, *via* and *forum* are the most common public space terms used by Latin authors, with *vicus* being a distant sixth (see above Fig. 2.5). Gladhill brings out the connection between *fama* and *forum*, in his discussion of Ovid's description of the house of Fama.[148] Throughout the *Metamorphoses*, *fama* is articulated as a Republican force through the language of the

[145] Hardie 2012.

[146] Hardie 2012: 242.

[147] See Laurence 1994; Hardie 2012.

[148] Gladhill 2013.

forum.[149] Gladhill argues that the shift from *fama forensis* to *libera fama* is modelled on the Augustan reorganisation of the Forum Romanum.[150] While the Principate could control the speech of elite, the chatter of the *vulgi* in the forum is beyond the authority of the *princeps*; however, Ovid's poetry works to control the seditious noise of the *domus* of Fama.[151] The seditious rumours, as well as free talk, are spatially located in the Forum Romanum, an alternative centre of power to the Palatine.[152]

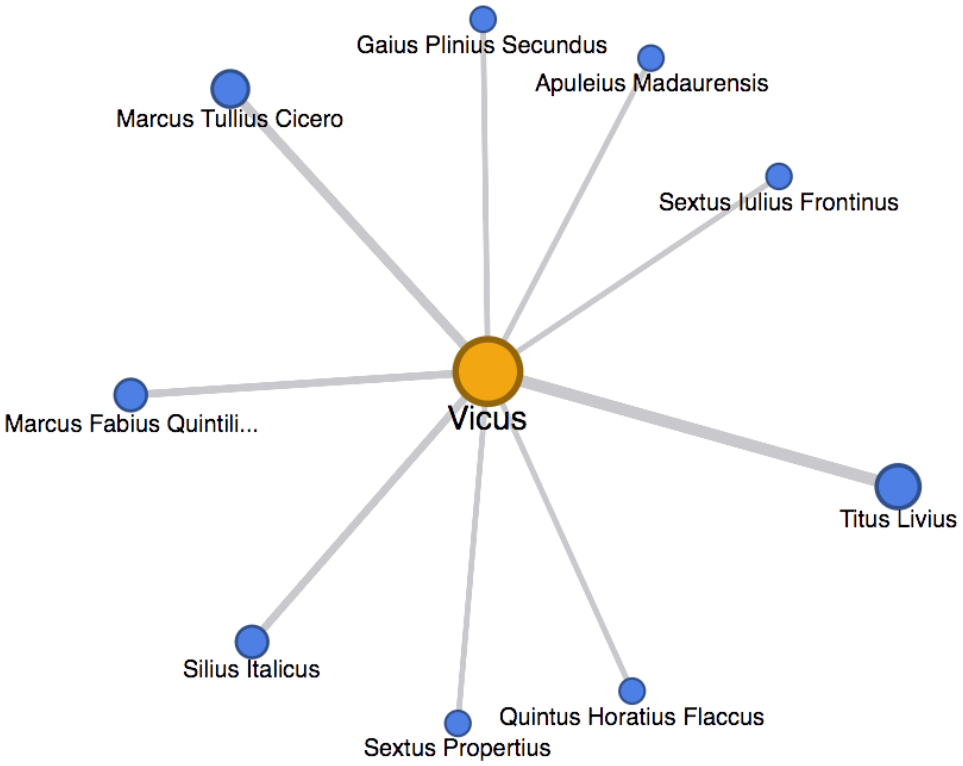

Figure 2.16 Latin authors referencing *vicus* and rumour terms. (Author)

The addition of rumour terms clearly moves *vicus* closer to *via* and above *forum*, suggesting a conceptual link between the *vici*, *fora* and *via* in terms of informal

[149] Gladhill 2013: 316.

[150] Gladhill 2013: 317-8; see also Newsome 2011b.

[151] Ov. *Met.* 15.878-9; Gladhill 2013: 317.

[152] Gladhill 2013: 305.

communication in the city (Fig. 2.16). Cicero, Tacitus and Quintilian have the highest reference count for *rumor* in relation to *vici*, as well as to *forum* and *via* (Fig. 2.17). The network graph in figure 2.17 is a concentrated graph of that in figure 2.14, focused on the term *vicus*. The correlation suggests that the *vicus*, along with the *forum* and *via*, was conceived as a space of informal communication. As Laurence argues, implicit in the movement of rumours from the forum to crossroads are social networks outside patron-client relations.[153] Where traditional elite patronage clustered around elite houses and kinship relations, the *vici*, at least in the Republic, served as a 'grass roots' political organisation of city space.[154] The movement of sound, by means of rumours, was a spatial, as well as social movement, which took on new meaning in the late Republic. Spatially, central areas of the city shifted, based on the social groups and forms of social relationships related to those spaces. The movement of rumours was seen as subversive to elite social control strategies in the official political information systems, like the *contio* discussed above. Noise, as the medium through which rumours moved, was politically charged in the late Republic and set the background for the later attempts to control social groups or movements associated with noise, rather than the direct regulation of noise based on intensity level.

2.5 Controlling Noise

In this section, streets and public spaces are discussed in relation to administrative control, taken from the *Digest*, and the literary image that shaped the literary conception of urban noise. The political tensions, seen in the discussion of rumours, did not lead to direct regulation against social groups, movement or noise, but did bring to light the social relationships that tied noises and street spaces together within the literary image of Rome. The legal codes outline certain administrative measures that would affect noises in streets and public space, yet no direct noise control was legislated. Control, therefore, was based on the framework of regulative practices, implicit in the jurist's writings, and power relationships between literary authors and other city inhabitants.

The largest portion of sources from the *Digest* comes from the second and third centuries CE; Ulpian and Paulus make up the vast majority of cited material (Tab. 2.2).[155] Appendix 3 does not have the individual jurists, who make up the *Digest* and are listed in

[153] Laurence 2011b: 388.

[154] Wallace-Hadrill 2008: 268-9.

[155] Ulpian making up around 40% and Paulus some 17% of the material, see Tab. 2.1.

table 2.2, broken down into their individual writing centuries, as the PHI categorises the *Digest* as a single text under Justinian ('Iustinian' in Appendix 3). In the late Republic, Roman civil law had become a quasi-academic discipline whereby Roman jurists conceived of the legal corpus as a cognitive field that could be studied, organised and further developed.[156] There was resistance to the jurists, the *advocati*, trained in Greek rhetorical technique, who dealt with much of the procedure in private lawsuits.[157] By the second century CE, jurisdiction was spread between the emperor, consuls, and magistrates, with various means of controlling the political and civil organisation of Rome, and by extension other urban centres. Justinian, in sixth century CE, compiled and codified Roman law up to that point making the *Digest* a compilation of earlier juridical writing, which had been regarded as authoritative. Thus, the attribution of the *Digest* to the sixth century within the PHI overlooks the specific dates of individual authors contained in table 2.2.

The legal texts formed a balance between the competing interests of individuals within wider society, on the various topics discussed.[158] Frier is right to stress the elite nature of the legal texts; however, as Crook points out, non-elite interests play a role in the legal texts, as well.[159] For example, a funerary monument of Ostia depicts a woman, Iunia Libertas, giving the usufruct of garden, buildings, and shops to her freedmen and

Source	**Date**	**Books**[160]
Alfenus	1st c. BCE	1
Gallus Aquilius	1st c. BCE	1
Quintus Mucius Scaevola	Late-1st c. BCE	1
Labeo	Augustan	2
Masurius Sabinus	Early-1st c. CE	1
Proculus	Mid-1st c. CE	1
Neratius	Late-1st c. CE	3
Javolenus	Late-1st c. CE	3
Celsus	Early-2nd c. CE	1 (144)
Terentius Clemens	2nd c. CE	1

[156] Frier 1985, 2010: 67-8.

[157] Frier 2010: 68-9.

[158] Frier 1980: 191; Bannon 2009: 125.

[159] Crook 1983: 214.

[160] Numbers in parentheses are excerpts or percentage of the *Digest*.

Pomponius	2nd c. CE	9
Valens	2nd c. CE	1
Gaius	2nd c. CE	13
Julianus	2nd c. CE	4
Maecian	Mid-2nd c. CE	2
Africanus	Mid-2nd c. CE	1 (121)
Marcellus	Mid-2nd c. CE	3 (120)
Quintus Cervidius Scaevola	**Late-2nd c. CE**	**6 (300+)**
Mauricianus	Late-2nd c. CE	1
Venuleius	Late-2nd c. CE	6
Taruttienus Paternus	Late-2nd c. CE	1
Papinianus	Severan (193-211 CE)	6
Paulus	**Severan (193-211 CE)**	**71 (17%)**
Tryphoninus	Severan (193-211 CE)	1
Callistratus	Severan (193-211 CE)	5 (100)
Menander	Severan (193-211 CE)	1
Marcian	Early-3rd c. CE	6 (280)
Furius Anthianus	Early-3rd c. CE	1
Modestinus	**Early-3rd c. CE**	**15 (300+)**
Tertullianus	c.160 -c.240 CE	2
Macer	3rd c. CE	5
Rufinus	3rd c. CE	1
Domitius Ulpian	**3rd c. CE (dies 228 CE)**	**23 (40%)**
Arcadius	Diocletian (284-305 CE)	3 (6)
Hermogenian	Late 3rd-early 4th c. CE	1
Florentinus	4th c. CE	1

Table 2.2 Jurists in the *Digest of Justinian.* (Author)

freedwoman and their descendants for her funerary rights and her remembrance.[161] If the *familia* did not continue, the city of Ostia was charged with performing the commemorative rights on the appointed days. The inscription clearly indicates that the freedmen and freedwomen were given usufruct of the property and did not inherit

[161] Calza 1939: 160; Meiggs 1973: 224; social setting, Dixon 1992.

ownership, which would go to someone else.[162] This inscription displays the complex social relations implicit within the household, and the legal options available to various members. These complex social relations are the basis for social practices implicit in the legal sources. Regulation and administration were only part of the social relationships that were negotiated through the legal texts. In this context, noise was only minimally restricted and resolution of tensions between individuals was left to other social interactions outside of courts.

Noise was not seen as harmful or damaging, unlike in modern sound regulations.[163] In a well-known text, discussion of the suffering of upstairs neighbours due to a foul smelling smoked cheese is given as an example of limits of individuals rights within their own property.[164] A neighbour produces a foul smelling cheese that is accompanied by smoke. It should be emphasised that the smell does not prove to be the point of contention, but the smoke. Aristo (1st c. CE) states that the emission of smoke, like the emission of water, from the cheese factory was unlawful, since someone is only allowed to carry out operations within their own property. Had the smell been unaccompanied there would not have been recourse to the interdict. In another passage, Nerva (1st c. CE) is cited by Ulpian (3rd c. CE) as saying that a public place or way made unhealthy by smell, does not justify recourse to the interdict for preventing something to be done in a public place or way.[165] The intrusion of smells, therefore, has to be accompanied by other intrusions, such as smoke, for recourse to legal remedies. Spatial control over smells has no legal standing, which is supported by the lack of evidence for zoning or planning controls.[166] This basic functional definition of damage, requiring a visible change or alteration, meant that noise, like smells, did not qualify as damage in a material manner. Noise control had to be maintained through other social relationships, although the legal definitions provide a framework for negotiating those relations.

Residential space was a particular area of potential noise control. The Roman jurists do not seem to legislate noise control in or around residential spaces. Focusing on particular forms of urban property, the legal codes in the *Digest* reflect wider property discussions in Latin literature (Tab. 2.3). The jurists are concerned with the institutions of property rental and inheritance that pertain to specific property types. Movement of

[162] Dixon 1992: 168.

[163] Any sound above 85 dB(A) can induce immediate hearing damage, see National Institute on Deafness and Other Communication Disorders (https://www.nidcd.nih.gov/health/noise-induced-hearing-loss).

[164] *Dig*. 8.5.8.5.

[165] *Dig*. 43.8.2.29.

[166] Laurence 2007: 78; Droß-Krüpe 2016; Goodman 2016; Wilson and Flohr 2016: 13.

people, whether short term migration or permanent relocation, required accommodation of varying longevity. Ostia has long been the case in point *par excellence* of the development of migration in urban density.[167] As Frier shows, a majority of references in the *Digest* are to the rental of apartments (22),[168] then house rentals (15)[169] and only select references to rental of apartments within houses (six).[170] Frier begins with a discussion of Ostian apartments, and their relation to housing in Rome,

Term	Total Citations	Sources	Date range
Domus	89	Alf. (1); Cels. (1); Iav. (1); Marcell. (1); Mod. (1); Ner. (1); Gai. (3); Lab. (4); Marcian. (4); Pomp. (7); Scaev. (9); Pap. (10); Paul. (15); Ulp. (31)	1st c. BCE - 3rd c. CE
Cenaculum	6	Ulp. (5); Scaev. (1)	Late-2nd c. CE - 3rd c. CE
Pergula	1	Ulp.	3rd c. CE
Taberna, *-ae*	28	Ulp. (12); Paul. (5); Scaev. (5); Iul. (1); Marcell. (1); Ner. (1); Pap. (1); Pomp. (1)	Late-1st c. CE - 3rd c. CE
Insula, *-ae*	71	Maec. (1); Men. (1); Papir. (1); Pap. (1); Gai (2); Iav. (2); Proc. (2); Scaev. (2); Tryph. (2); Alf. (3); Afr. (5); Marcian. (5); Lab. (7); Pomp. (9); Ulp. (24)	1st c. BCE - 3rd c. CE

Table 2.3 House terms used in the *Digest*. (Author)

[167] Meiggs 1973: 70-1; see discussion of P. Aufidius Fortis, Broekaert 2016: 228-9

[168] *Dig*. 1.15.3.4; 9.2.27.11; 9.3.1.7; 9.3.1.10; 9.3.1.7; 9.3.1.10; 9.3.5 pr.; 9.3.5.2; 9.3.5.4; 9.3.5.9; 13.7.11.5; 19.1.53.2; 19.2.13.7; 19.2.19.6; 19.2.25.2; 19.2.27 pr.; 19.2.30 pr.; 33.9.7; 39.2.29; 39.2.43.1; 44.7.5.5; C. 4.65.3; *Cod*. *Theod*. 11.20.3.4.

[169] *Dig*. 19.2.9 pr; 19.2.9.6; 19.2.11.4-12; 19.2.19.4-5; 19.2.24.2; 19.2.25.1; 19.2.28.2; 19.2.45 pr.; 19.2.60 pr.; 29.2.20.1; 31.88.15; 39.2.13.6; 41.2.37; *C*. 4.65.5; *Cod*. *Theod*. 11.20.3.4.

[170] Frier 1980: 46; *Dig*. 7.8.2.1; 7.8.4; 8.2.41 pr.; 19.2.28 pr.; 19.2.60 pr.; 43.17.3.7; see also 7.1.13.8.

connecting the legal sources with Ostia's housing.[171] The widespread use of Ulpian throughout the *Digest* is noted in references to rental properties (20 of 43 references). References to rental apartments have a higher proportion than rental houses, suggesting the importance of apartments in property rental discussed in the *Digest.* The emphasis in the *Digest* reflects the importance of rental property in legal definitions of property, ownership, and lease.

Urban property was utilised for a variety of purposes, including commercial, rental or residential, which are suggested in the terms used, such as *tabernae*, *insulae*, *domus*, and *cenacula* (see Tab. 2.3). In comparison with Latin literature in general, a clear bias appears in the *Digest* for multifunctional spaces, which suggests the need to formalise legal management of these spaces. The emphasis on *via* and *insulae* in the *Digest* further reinforces Wallace-Hadrill's point that *insulae* were the quintessential Roman structure, a multifunctional block, rented out for profit.[172] This was a shared space, open to a variety of tenants and mixed use, as well as being a space of multiple forms of noise. In contrast, *domus* served as a conceptual term, indicating a luxurious space to live or rent, rather than a space with certain architectural features. What made a Roman *domus* Roman was the perception of spaces, and its utility in providing for Roman public and private life.[173] As Bourdieu made clear, social distinctions of status motivate discussions of particular spaces, in this case political and elite residential space.[174] Latin authors in general speak of the *forum* and *domus* before *insulae*, reflecting the status and wealth inherent in the perception of the literary sources.

The most direct form of noise would be through the walls of the building, which is an aspect of property regulations.[175] In particular, common walls were seen by the jurists to be a distinctly urban characteristic.[176] Paulus (Severan) makes reference to the distinction between rural lands, for which there is an action for regulating boundaries, and urban lands, which are spoken of as 'neighbours'.[177] Citing Pomponius (2nd c. CE), a common wall is a wall built on behalf of the builder and neighbour with the intention of recovering a proportion of expense from the neighbour, or as a gift.[178] This definition comes at the end of the discussion of actions for dividing common property. Since the

[171] Frier 1980: 3-20.

[172] Wallace-Hadrill 2015: 185; cf. 2003b: 13-4

[173] Wallace-Hadrill 2015: 184.

[174] Bourdieu 1979.

[175] See 88-91.

[176] *Dig*. 10.1.4.10.

[177] *Dig*. 10.1.4.10 (Paul.) *sed magis vicini dicuntur et ea communibus parietibus plerumque disterminantur.*

[178] *Dig*. 10.3.22.

wall is common property neither has the right to demolish or rebuild without the neighbour's consent.[179] Social interaction is required for the altering of the common wall, as well as in the resolution of damages to the wall. The concern with common walls in the *Digest* is in the definition of ownership for liabilities. Damage to common walls was the shared expense of the owners and, like single-owner walls, was only identified by visible marks. Noise falls outside of damages, as noted above, due to its lack of visible alteration and an inability to quantify the liability incurred between the two neighbours.

The lack of visible damage caused by noise makes noise control a problem for social and behavioural regulations. Liability, however, can be determined for the producer of noise. Liability for making a noise shifts the social control away from a general sense of noise, such as *background noise*, to the particularities of the content of noise and the social position of the noisemaker. Here, status distinctions, most often expressed in moral judgements, are central to the relationships of power and control. In the next section, regulation through social power and control are addressed in terms of specific careers and communal consent.

2.5.1 Noise Control in (Public) Space

Control of noise was attempted at times through social and moral judgements, rather than direct noise legislation. Non-elite spatial behaviour, evident in the case of rumours (2.4.1), was at the centre of literary concerns over movement within the city. Direct control over urban space was only possible through urban cohorts in the imperial period.[180] Prior to this period, contestation of space was a regular occurrence, producing a relational space negotiated between literary images, behavioural practices and architecture. In this sense, control over the spaces of elite power, especially the forum, was exercised through spatial strategies, which fixed public response in time-space through calling public assemblies. Elite concern is also evident in the sources of noise in the *fora*, as well as sounds outside the narrowly defined 'official' political space.[181] However, the forum itself was not static, in terms of sound, but in fact a dynamic auditory space.[182] Different forms of auditory communication were part of the rhythm of the forum and relational contestation was slowly worked out through different social channels.

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[179] *Dig*. 8.2.8.

[180] See Robinson 1992: 181-8.

[181] O'Neill 2003: 137.

[182] Betts 2011: 124-9.

Control over the auditory space of the forum was not through noise regulation, but part of the conceived use of the space, as well as the architectural arrangement.[183] Political leadership constituted an experienced leadership; Roman civic leaders required audiences to reinforce their standing within the social hierarchy. Certain citizens were seen to stand apart from the rest through the performance of ritualised roles, simultaneously religious and civic in nature.[184] More than simply being seen to perform the right activities, elites required sounds to mark the affirmation of their deeds by non-elites. The perceived nature of the Forum Romanum, as a shortcut on longer routes, reflects the movement through the space, as well as the networks of communication embedded within the space, which produced certain spatial practices.[185]

Two particular terms illustrate the growing concern with elite literature towards noises, specifically announcements by *praecones*, and the gatherings of *circuli*. *Praecones* and *circulatores* are connected with similar forms of activity, namely disseminating political news, such as consular edicts.[186] O'Neill differentiates the two by reference to official and unofficial speech.[187] Unofficial speech, for O'Neill, is cause for elite suspicion and concern, however, as Bond has shown, *praecones* are also targets of elite social stigmatism, which ultimately resulted in legal banishment from serving on city councils in the *Lex Iulia Municipalis*.[188] This argues for a different form of differentiation between *circulatores* and *praecones*, as both were socially stigmatised in elite literature. Rather than official or unofficial lines of communication, it is the moral topography of the city, which further nuances the target of social stigmatism. These two examples address two sides of anxiety, namely concerns relating to a specific job, which was dependent on noise, and concerns relating to spatial practices that utilised noise outside of elite social networks. These two aspects of noise, its relation to specific jobs and its relation to characterizations of groups, were dealt with in different ways. The eventual incorporation of *praecones* into the imperial bureaucracy allowed control to be exercised through relationships of power. In contrast, *circuli* were more difficult to control through incorporation into imperial administration, although the Augustan reformation of the *vici* could be interpreted in such a way.[189] Instead, *circuli* were

[183] On the importance of architectural control, over regulation in the forum, Newsome 2011b: 293.

[184] Bell 2004: 7.

[185] Newsome 2011b: 295.

[186] scholion on Persius 1.134; O'Neill 2003: 151-2.

[187] O'Neill 2003: 152.

[188] O'Neill 2003: 152; Bond 2016: 45.

[189] See Lott 2004.

socially stigmatised in an attempt to undermine the status of such informal groups, while allowing the term, *circuli*, to be associated with moral suspect characterisations.

Praecones were criers or auctioneers, who plied their trade privately or publicly, as part of a retinue of a magistrate. The division between public and private capacities is not fixed, especially in the late Republic. However, there is a distinct difference in which type of event the *praecones* presided over. Private events can be classified as those put on by individuals or *collegia*, in which the *praecones* would moderate and announce the events time, place, and gather participants. *Praecones* were hired for games, funerals, auctions and served as mediators in contracting actors, gladiators or musicians.[190] Public duties would involve state events, although similar type events, such as games, funerals and announcements. Bond is right to note that in public events the *praecones* represented the state as a proxy and were charged with maintaining order in markets, courts, public assemblies and auctions, as well as relaying messages to lictors.[191] These duties reinforce the general similarity in private and public duties of mediation between parties through control, information dissemination and contracting. As discussed above, *praecones* were employed to call *contiones*, mediating between the state and people on such occasions. While Bond keeps the two forms of *praecones* separate, there is little evidence that public and private distinction were strictly maintained and it must be assumed that *praecones* could go between both forms of work depending on needs.

Social stigma and legal regulations were the means by which social and political control was exercised over *praecones* in the late Republic. The distinction between public and private roles, although problematic, indicates the social group symbolically represented by the *praeco*, whether a magistrate, civic authority, or individual. These distinctions were reinforced by the legal regulation of *praeco* by *the Lex Iulia Municipalis* of 45 BCE, which barred them from municipal offices.[192] However, from the *lex Iulia* on, trends in legislating order and control over expanding sociality in Rome are evident in Augustan and the later imperial decrees.[193] The Augustan one percent tax on auctions and its continuation cited by Tacitus indicate the state's response to wealth gained through auctions by private *praecones*.[194] Administrative *praecones* are listed, as *apparitores*, in the charter from Urso (c. 44 BCE), as well as being listed as *immunes* in

[190] Bond 2016: 32-3.

[191] Bond 2016: 37.

[192] *Tab, Her*. 24.94-6; Cic. *Fam*. 6.18.1; Bond 2016: 24, 42.

[193] See Woolf 1996. In Bond 2016: 232, n. 103.

[194] Tac. *Ann*. 1.78.

the military community by Paternus (2nd c. CE) in the *Digest*.[195] The continued appointment to administrative retinues was part of the growing awareness of their role in mediating communication between the state and people of the empire. The developing mobility system in Rome functioned from on a mobile centre, the emperor, and a reliable communication network of military and administrative *praecones*.[196]

Circuli and *circulatores* provoked anxiety about the unauthorised nature of these forms of gatherings, and the people associated with them.[197] O'Neill notes the development and metaphorical usage of *circuli* as appearing in the late Republic/early Principate.[198] The appearance of *circuli* in the late Republic fits with the wider argument of this thesis of a developing experience of mobility and noise that covered movements of people, goods, information, as well as changing conceptions of space. In the case of *circuli*, as O'Neill points out, it is used seven times in Livy, who appears to be using a 'fashionable' term in his own recent period and retrojecting it back onto the early and middle Republic.[199]

In opposition to the *contio* were the *circuli*, a small group of unofficial character, who were an accepted social phenomenon.[200] The spatial setting, in public, is also important to understanding the potential danger posed by these small groups.[201] *Circuli* are associated with noise, which point to their social meaning. Livy, in two instances, uses the verb *fremere* to describe the talk of the *circuli*.[202] The references in Livy provide a rough outline of the potential dangers of *circuli*; they could meet at night, often at times of crisis; they might involve great emotion and/or anger; they tended to be associated with the non-elites; they could invoke popular actions; and they could influence the ruling class to take unusual action.[203] The use of *fremere* to describe the talk of *circuli* equated the speech with the irrational and inarticulate noise of roaring animals.[204] Unlike the *contiones*, *circuli* were not defined spatially, or ritually governed.[205]

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[195] *CIL* 2.5439; *Dig*. 50.6.7; Bond 2016: 50-1.

[196] Bond 2016: 51.

[197] O'Neill 2003: 135.

[198] 2003: 137 n. 6.

[199] O'Neill 2003: 138 n. 7.

[200] O'Neill 2003: 137.

[201] On writing in public space, Corbier 2013; on non-official writing in public space, Newsome 2013.

[202] Livy 7.12.14.2, 34.37.1.1; O'Neill 2003: 141.

[203] O'Neill 2003: 143.

[204] O'Neill 2003: 159.

[205] O'Neill 2003: 145.

The *Digest* refers to street traders as *institores*, legally appointed representatives.[206] Ulpian notes that *institores* were commonly known as *circitores*.[207] Although anyone could be *institores*, the legal sources suggest that the name was primarily given to slaves.[208] The technical sense of the term within the legal sources implies a level of organisation within these forms of street trade, also indicated in the use of *institores* for business managers.[209] The *Digest* refers to *institores* who were sent out by tailors to sell clothes, as well as food.[210] The relation of *semita* with commercial activities is part of the structure of streets. As discussed, there were a variety of terms for particular streets, many of which overlapped in meaning. The connection of *semita* with sidewalks, a meaning absent from *via*, draws on the location of shop fronts and the sale of goods at the entrances, a characteristic still visible in many warmer climates (e.g. Islamic souks).[211]

Tacitus draws together several of the ideas surrounding the anxiety over noise, movement and *circuli*.[212] After Agricola's death, the people came together in the forum and *circuli* to express their grief (*per fora et circulos illocuti sunt*). Tacitus uses *agens* to describe the activity and business of the people, along with the verb *ventito*, signifying multiplicity of movement.[213] However, it is not only the people that move, as a c*onstans rumor* of Agricola being poisoned moved through various areas of the city, *fora* and *circulos*. *Circulatores* were pedlars or itinerant hawkers, which implies movement in the use of *circulus*.[214] The connection of *circuli* and *circulatores* with *fora* is also seen in other contexts. In a note on Horace *Sat.* 1.6.114, Porphyrio describes the fortune-tellers that Horace stands by as *circulatores*, and the groups as *circuli*.

Information moved from the forum to other communication nodes within the city, such as *vici*, and then into individual dwellings.[215] Both *circulatores* and *praecones* are associated with social activities in the forum. Quintilian places *circuli* in the *fora* and *aggeres* of Servius Tullius (*Inst*. 12.10.74). Varro connects the calling of a *contio* with

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[206] *Dig*. 14.3.

[207] *volgo circitores appellamus*, *Dig*. 14.3.5.4.

[208] *Dig*. 14.3.7.1; 14.3.8; assumed slaves, *Dig*. 4.4.4; 7.8.20; 26.7.37.1; 33.7.7; 12.1.29; 14.5.8; 15.1.47 pr; 33.7.13; 33.7.17.2.

[209] Holleran 2012: 198.

[210] *Dig*. 14.3.5.4; 14.3.5.9.

[211] See Kostof 1992.

[212] Tac. *Agr*. 43.

[213] Jenkyns 2013: 189.

[214] Jenkyns 2013: 190.

[215] Laurence 1994: 63.

auspices and ordering a *praeco* to call the citizens (*LL* 6.9).[216] Social stigma, in Seneca and other sources, is directed at the play of elite status by *circulatores*, such as idleness (Sen. *De Prov*. 1.5.4) and lacking 'proper' elite qualities such as philosophy (Sen. *Ep*. 29.7), education (Per. *Sat*. 68), and the wider concern with inferior speech (Sen. *Ep*. 40.3; Livy 7.12.14; 34.37.1). Social concerns over private *praecones* are directed at the profiteering from mediating transactions for the elite, beginning in early Republic.[217]

The spatial and social location of activity in the forum can be explored through the social distance between people during encounters.[218] In this process of information dissemination, rumour and gossip played a role in reliability of transmitted information.[219] Social and political control was applied through stigma and legal regulations, which are evident in the *Lex Iulia Municipalis*, as well as satirical sources.[220] While social stigma could be applied preemptively, legal regulations were reactionary, and followed from experiences of distrust and malpractice.[221]

Of importance here is the centrality of the voice in marking these distances. Political speeches, both in the law courts and *contiones*, were also crucial to the spread of information throughout the city. In particular, the speeches of Cicero refute rumours of violence, bribery, seduction, adultery, extravagance and debt, in short things under the category of immorality (Cic. *Flac*. 6; *Cael*. 29-30).[222] The movement of information and sound was the opposite of its movement in the streets: rumours came from outside into the forum in their refutation by Cicero.

Social control of the movement of information was part of the politics of speeches. The reliability of such claims should be criticised, as Cicero accuses Piso of the same immoralities levelled at him: Cicero's servile background (*Sull*. 22), physical appearance (Macr. 2.3.5), and immorality (Psu-Sall *in Cic*. 5).[223] Correcting the mistaken rumours, whether true or not, would seem to be part of the politics of speeches. Nisbet emphasises the literary convention of such invective, and here the importance should be placed on the repetition of such claims as part of the construction of moral topographies.[224] That these invectives were entirely fictitious should not argue against

[216] Bond 2016: 36.

[217] Bond 2016: 45.

[218] Referred to as proxemics, Hall 1990; cf. Soja 1971.

[219] Laurence 1994: 63.

[220] Hor. *Sat*. 1.6.86; Juv. *Sat*. 3.34-7; 3.155-9.

[221] Bond 2016: 26.

[222] Laurence 1994: 64.

[223] Nisbet 1961: 192-7.

[224] Nisbet 1961: 192; Edwards 1993: 10-11.

the power that the accusation could have on other people. It is precisely this aspect that seems to raise concern.

Here, again, the noise itself marks the social standing of the individual within the community, as well as simultaneously defining the social relationship between the community and the space. As Hartnett points out, if someone of lower standing felt they had been wronged by a more powerful individual there was recourse for auditory protest, namely *convicium* or *occentare*.[225] *Convicium* could be prosecuted, if the shouting ran contrary to the community's morals (*Ait praetor: qui adversus bonos mores convicium cui fecisse cuiusve opera fact else dictum, quo adversus bonos mores convicium fieret, in eum iudicium dabo.*).[226] Here, the community (*civitatis*) legally defined whether the noise was *convicum* based on the combination of noises produced by an individual or crowd and the status of the recipient.[227] However, the shouting does have to be targeted at a particular person; if no one is specified there is no legal consequence.[228] Hartnett rightly emphasises the social quality of such noise making, that it targeted the personal reputation and good name of the socially more powerful in their specific neighbourhood.[229] Thus, noise morally, as well as socially, was used to control other people's behaviour, particularly if they failed their legal duties.[230]

2.5.2 Leaving the City as Noise Control

Movement appears as a way to control noise, although through leaving the area. In chapters four and five, the role of movement in the town of Ostia is discussed to draw out the implications of movement as a form of noise control. Cicero, Horace, and Pliny the Younger all locate *strepitus* in the city and retire to the countryside to get away.[231]Pliny, in his description of his villa, states that it is at the furthest end of the villa that he has a suite, which feels as though he has left his house.[232] It is the distance, which enables him to work during the Saturnalia merrymaking (*clamoribus*).[233] Riggsby argues for the qualitative difference between rooms in Pliny's description, noting that Pliny takes 'differences in degree between different rooms and schematizes them into a

[225] Hartnett 2016: 169.

[226] *Dig*. 47.10.15.2.

[227] *Dig*. 47.10.15.6.

[228] *Dig*. 47.10.15.9.

[229] Hartnett 2016: 171.

[230] See XII Tab. 2.3, 8.1; Hartnett 2016: 171.

[231] Cic. *Arch*. 12; Hor. *Carm*. 3.29.12, *Ep*. 2.2.79-80; Plin. *Ep*. 1.9.7.

[232] Plin. *Ep*. 2.17.24; Platts forthcoming.

233 Platts forthcoming.

difference of kind.'[234] The isolation of the room is part of the effect, supported by the fact that only *cubicula* are praised for isolation from noise and activity.[235] Thus, Pliny displays the reflexive character of social and cultural production of space. It is in the midst of defining luxury through qualitative differences in rooms that quantitative distance is brought to differentiate Pliny from his slaves on the occasion of their festival celebrations.[236]

As with Pliny's villa, distance served as the primary way elites could control noise. The advice to leave the city to be away from the noise was a common remedy.[237] In *Satires* 2.6, Horace compares the city and country, creating a dichotomy of the city as busy, crowded, filled with rumours, while the country is full of idle hours, books, and forgetfulness of life's cares.[238] Horace, like Lucretius and Virgil, idealises the country, making it morally superior to the city.[239] The connection between perceived business and constant rumours is telling. Movement of noise was a particular feature of the image of the city in literary sources. Here, the distinction between city and country is created through the triptych of a day filled with rumours, carried by people hindering movement, between side panels of a morning and evening of peace in the country.[240] Juvenal, as well, through Umbricius speaks of leaving as the main means of controlling sound. Juvenal's *Satire* 3 creates an image of Rome of personal expectations and imaginations, a soft city of illusions, myths, aspirations and nightmares.[241] Juvenal sets up a series of contrasts between city and county, which culminates in Umbricius' dichotomy between rich and poor in the second part of the satire (190-308).[242] The contrast in Juvenal, like Horace, are ideologically loaded, but at line 232 Umbricius relates insomnia to the lack of wealth.[235] Physical distance, in this case being at the back of a town house, creates separation from the noise of the street for the rich man, while the poor man has a room overlooking the street. Ease of movement makes up the next dichotomy, as the rich man is carried in a litter, protected by a retinue, and the poor man

[234] Riggsby 2003: 172.

[235] Plin. *Ep*. 2.17.22, 24; 5.6.21; Riggsby 2003: 172.

[236] The role of distance in acoustics will be discussed in apartments and *domus*-type houses, 142-61.

[237] See previous note; Juv. 3.

[238] Hor. *Sat*. 2.6.23-63; Braund 1989: 39-40; Harrison 2007:

[239] Hor. *Ep*. 2, Luc. 2.20-36; Verg. *G*.; Sen. *Ep*. 87.41; Livy pr. 11-2; cf. Tac. *Ann*. 3.55; Plin. *Ep*. 1.14.6; Braund 1989: 41.

[240] Fairclough 1929: 208; Braund 1989: 40-1.

[241] Laurence 1997: 15 citing Raban 1974: 10.

[242] Braund 1989: 32.

struggles on foot.[243] As Braund notes, the poem compresses the horrors of the city into a single, chronologically structured, day.[244] Both Horace and Juvenal set movement out of Rome as the means by which the noise of the city can be controlled. One must leave the city to attain peace, if you were poor, or you must have a large enough property to distance yourself from the noise.

2.6 Conclusion

The argument of this chapter can be summarised in three main points: 1) a literary image of Rome was created around noise in the city; 2) the urban image of noise was linked to movement; and 3) the control of noise was through social stigma and moral judgements, not legal regulation. Overall, these points indicate the importance of noise in the conception and perception of Rome, and draw attention to non-regulatory manners of social control. Each of the three points will be discussed briefly, with connections made to the arguments developed in the later chapters.

The literary sources create a specific image of Rome as full of noise and activity. This image has been used in previous studies, such as Ramage, to indicate high levels of sound intensity and urban malaise.[245] What these studies have failed to address are the various definitions of noise, which do not always indicate negative responses. Noise offered Latin authors the ability to comment on social and cultural interactions beyond simple noise making. In this way, noise was a stand-in for cultural changes that were not always fully realised. Negative conceptions of urban space were created through descriptions of space, using specific noise terms. This chapter has shown that this was only a small part of the urban image of noise, which included everyday routines, as well as exceptional narratives. The urban image of noise is an image of diversity and complexity, not simply a city full of sound.

The link between noise and movement in the literary sources was part of a wider development of movement, beginning in the second century BCE. The link between noise and movement was a practical matter; movement entailed noise. This basic fact was reshaped through the cultural and social changes prior to the second century CE. Mass movement of people, urban dislocation, and disasters created new urban forms, and reshaped the architecture of Rome. The literary sources reflect these changes

[243] Juv. 3.239-48; cf. Miller 2007: 139-40.

[244] Braund 1989: 34; Miller rightly emphasises a distinctive difference between Juvenal and Ovid, thus between elegy and satire, where 'Ovid longs to return from his exile, Umbricius cannot wait to leave Rome', Miller 2007: 141-2.

[245] Ramage 1984; followed by Scobie 1986; see the introduction to this chapter.

through a distinctive image of Rome as constantly moving and full of noise. The real and imagined urban space was marked by noise, especially the sounds of movement. Acoustics offers an insight into the emerging urban image discussed in this chapter. The acoustics of spaces display several ways of dealing with noise. The legal sources did not provide a legal definition of noise, and the social control exercised in the literary sources was filled with tension between ease of movement and levels of noise. Architecture provides another avenue to assess the control of noise. To that end, chapter three will introduce a methodology for the analysis of acoustics, and set out the basic framework of street acoustics.

This chapter has demonstrated that the social control of noise was part of the negotiation of different forms of urbanism. The movements of noise were a central element in the perception and conception of urban space in Rome. The urban image expressed in the literary sources of noise and movement has a bearing on the spatial control exercised in the *Digest*. The legal sources indicates that neighbours were expected to have a certain level of knowledge about the neighbouring buildings and owners or tenants, as well as willingness to negotiate with neighbours prior to legal recourse. Noise control was not legally defined in the *Digest*, as shown in this chapter, but social perceptions of noise are part of the literary image of Rome, developing between the late Republic and second century CE. The literary concerns did not extend to the formation of regulations; rather they remained at the level of social stigma and moral judgements. The concern over *circuli* represents an elite concern regarding the use of space in the forum. The movement of rumours, as argued in this chapter, was key to non-elite communication networks. The connection between rumours and street space highlight the importance of these spaces to non-elite forms of urbanism. In contrast, the placements of official responses by the people were set in the forum or theatre. Crowd responses, whether good or bad, were located in structured and controlled spaces. Here, again, the temporal shift from Republic to Empire changed the manner in which structure and control of space was exercised. By placing the shifting conception of noise within its spatial and temporal location, a nuanced picture of urban space emerges. Streets have distinctly different social possibilities for different social groups. The administrative control of street space emphasised ease of movement, which created a space of fluidity and continual negotiation. Thus, the street space is a dynamic space of contestation, even within the literary topography. Turning to Ostia, the acoustics of dynamic street spaces are analysed to assess the extent to which social control of noise was the only form of regulation or if architectural practices had a role in isolating noise.

Chapter Three
Constructing Aural Architecture

"Every city has its echo which depends on the pattern and scale of its streets and the prevailing architectural styles and materials. The echo of a Renaissance city differs from a Baroque city. But our cities have lost their echo altogether."
J. Pallasmaa, *The Eyes of the Skin: Architecture and the Senses*, 55

"Monumental qualities are not solely plastic, not to be apprehended solely through looking. Monuments are also liable to possess acoustic properties, and when they do not this detracts from their monumentality. Silence itself, in a place of worship, has its music."
H. Lefebvre, *The Production of Space*, 225.

"But sensing spatial attributes does not require special skills — all human beings do it: a rudimentary spatial ability is a hardwired part of our genetic inheritance."
B. Blesser and L-R. Salter, *Spaces Speak, Are You Listening?* 1.

Second century CE Ostia has been described as a period of 'architectural revolution' in the Roman Empire.[1] The development of certain construction techniques and materials enabled the Romans to build in new ways. The revolutionary nature of the architectural changes, most notably the expanding use of concrete in monumental works, has been questioned in recent years.[2] However, the period was dynamic, as architects and builders systematised existing practices, allowing for innovations.[3] The constant destruction by fires, both large and small, meant that structures were rebuilt, using increasingly advanced technologies.[4] For example, bath complexes, prone to fires and requiring large, covered spaces, presented challenges.[5] As noted in chapter one (1.3), the rebuilding of Rome following the fire of 64 CE is seen as a turning point in Roman urbanism, as the street infrastructure was altered. According to Tacitus, the alterations to streets were an experienced change as light and heat increased within the street space.[6] These architectural developments, however, have not been studied in terms of the experience of urban space.

[1] Meiggs 1973: 133-46.

[2] Lancaster 2005; Ulrich 2007.

[3] Quenemoen 2014: 64.

[4] Lancaster 2005: 168.

[5] Lancaster 2005: 169.

[6] Tac. *Ann*. 15.43.

It is worth noting briefly the chronology of porticoes outside of Ostia. 79 CE Pompeii does not have any porticoes along its streets. Rome, on the other hand, sees two distinctive groupings of portico construction, namely the late Republican/Augustan period and the Flavian period.[7] However, these porticoes were a distinct architectural form, one that does not continue after the Flavian period in Rome.[8] Street porticoes have a more widespread adoption, although similarities in chronology are evident. After the fire in Rome of 64 CE, Nero sought to improve Rome's fire prevention, appearance and communication: he ordered the widening of streets and the lining them with arcades and porticoes (*porticus*); banned the use of common walls and timber within structures; and placed a height limit and required fire-resistant stone to be used.[9] In Suetonius' description, Nero himself devises and pays for the new form of street front, a raised porch (*porticus*) from which fires could be fought and the regulation of street porticoes is prescribed.[10] While the literary sources from the second century CE (Tacitus and Suetonius), set the motivation for porticoes in the need to control and prevent fires, it is worth noting that it is in the same time period as the last series of portico structures in Rome. Here, the distinction between experience in the streets of the second century CE, and narrative reflection, instigated in the first century CE, is evident.[11] In Lefebvrean terms, the unlimited everyday experience of the architectural effects of porticoes in the second century CE was set within the literary and historical narrative of an earlier period to attach a particular message to that experience.[12] In this case, the experience precedes the ability to define the architectural message, which cannot enter into the production process, but relates to spaces already produced.[13] Returning to Ostia, it is not during the Flavian period that porticoes begin to appear but rather at the start of the second century CE. That is to say, the porticoed street was a feature in Rome that appeared between Pompeii's destruction and the start of Ostia's large-scale rebuilding.

The combination of widening and straightening streets, additions of porticoes, and the increase in expansive dimensions of interior space, created a new urban experience; an experience that can be quantified through acoustic analysis and measurement. The construction and innovation of this period can also be examined in terms of acoustic properties that reflect the changes in building techniques, as well as socio-cultural transition towards an emerging

[7] Macaulay-Lewis 2011: 274.

[8] Macaulay-Lewis 2011: 274-5.

[9] Tac. *Ann*. 15.43; Suet. *Ner.* 16; Newbold 1974: 859.

[10] Tac. *Ann*. 15.43.1-2; Suet. *Ner.* 16.

[11] See Lefebvre 2014b: 122.

[12] Lefebvre 2014b: 124.

[13] Lefebvre 1991: 160.

mobilities system, as discussed in chapter one (1.4.3). The construction techniques and building materials used in the second century CE were the foundation of the acoustic properties at work in buildings in Ostia, and reflect the lived experience of everyday life.

In this chapter, a new methodology for the modelling of acoustic properties is explained and set out within the context of second century CE Ostia. The first section provides an overview of the basic mathematical model, which is derived from the physics of sound, used in the acoustic analysis. Three basic measurements are explained: absorption coefficient, reverberation time and transmission loss, and their relation to acoustic properties detailed (3.2.1-3.2.3). These mathematical measures are then tested, in the second section, against the reconstructed remains of the Mercati di Traiano in Rome. Testing the mathematical model of the shops in the Mercati di Traiano shows several key points of contact between contemporary sound design and ancient building materials. The strong correspondence between the mathematical and physically measured acoustic properties proves the validity of the mathematical model to predict acoustic properties and allows for the model to be used on incomplete structures, such as those found in Ostia (3.2.4). In section 3.3, attention is turned to street canyons, which are open spaces, not enclosed spaces. The shift from enclosed to open spaces reflects a shift in the complexity of the model, which guides the discussion in the chapter. Two streets are analysed, to illustrate the transitions at work within the second century CE (3.4-3.5). These two streets were chosen as they represent the early and late second century CE development of Ostia. One street displays the initial phase of redevelopment, which is likely to have been initiated by the town, while the other street represents individual small-scale developments that reshaped a street at the end of the second century CE. The North Cardo Maximus (3.4) was the focal point for entry into the town from the river. Built in 116-117 CE, the shops and porticoes that lined the street gave the space a uniform feel. In contrast, the Via degli Augustali (3.5) underwent a transformation at the end of the second century CE with the building of the *fabri tignuarii* temple on the Decumanus. These two streets are emblematic of the multifunctional and dynamic spatial transformations at work, which were experienced through the acoustic properties of the streets. What results from their analysis are two distinctive acoustic fields that suggest a local awareness of noise in the everyday choices to deal with such auditory intrusions.

3.1 Physics of Sound

The physics of sound is best thought of in terms of territory.[14] Territory, in this sense, signifies the bounded geographical expanse of noise: sound, functioning as a wave motion, has a relative speed of 1,235 km/hr; the sound *frequency* (f) is the number of cycles per second measured in *hertz* (Hz).[15] These physical properties enable sound to travel at a relatively fast speed, although the speed of sound is dramatically slower than the speed of light, and it takes sound about 3 seconds to travel a kilometre. Thus, the movement of sound is constrained by the physical properties of its speed, creating a territory of noise, or a space in which the sound could be heard. This physical speed serves as a starting point for the mapping the territory of noises, as the geographical spread of a sound extends in all directions from the starting point. The negotiations of social judgement about the sound and its territory of noise create politics of sound. That is, the speed of sound helps to understand the politics of sound through the social control of space. Lefebvre's point that the senses mediate the appropriation and domination of space helps to interpret the forms of spatial control.[16] Noise, at certain levels, can fill a space and, simultaneously, elicit bodily responses, disabling others from using a space. Loud sounds can cover a geographical space at a relatively quick speed, as well as generating bodily responses, such as pain, nausea or fatigue. Architecture and spatial works are located between the sensory perception of noise and the metaphysical possibilities of noise.[17] In this way, the physics of sound can be a guide to ephemeral forms of spaces, creating possibilities for appropriation and control.[18] However, the physics of sound are based primarily on geometrical and an abstract understanding of space. As noted in the introduction (1.4), such an abstract notion of space has its limitations, and a basic understanding of the physical properties is necessary before turning to the social implications, which require a more political conception of space, as dynamic and in constant production.

Taking away the physical encumbrances of buildings, people and materials, one is left with a *free field*, an abstract and theoretical space where sound travels unimpeded and free of any physical influences.[19] In a free field, sound travels out from a particular source, referred to as a *point-source*, spherically, and the sound is of uniform intensity in all directions. As the sound travels outwards, at a speed of 1,235 km/hr, in all directions at the same sound power

[14] On the development and history of the concept of territory, Elden 2013.

[15] Everest and Pohlmann 2009: 5-6, 119; Veitch 2017a.

[16] Lefebvre 2014b: 95.

[17] Lefebvre 2014b: 95.

[18] Lefebvre 1991: 164-8.

[19] Everest and Pohlmann 2009: 33.

level, the sound is spread over an increasingly greater area as the radius increases, resulting in a decrease in the sound energy.[20] Simply put, the sound energy decreases the further away it travels. The relationship between *sound pressure level* (SPL), which is the common measure of intensity for sounds, and the sound energy level as it expands over distance, is inversely proportional to the square of the distance from the source (the *inverse square law*). Thus, as one doubles the distance from the sound point-source, the SPL is reduced by a factor of four, or decreases by 6 *decibels* (dB).[21] The inverse square law will not provide the actual SPL of sounds in the space, only a theoretical estimation of the level from a certain point-source at a given unmediated distance. In order to attain actual measurements of the SPL, calculation of the absorption coefficient and transmission loss for materials must be added together, as well as the distance from the point-source measured according to the inverse square law, and these two calculations subtracted from the SPL at the point-source. This complex calculation will be explained below and examples given in the preceding chapter.

Not all sounds emanate from a single source, or point-source, as will be discussed in the following chapters.[22] Ancient examples of multi-source sounds include processions, the triumph being the largest, and possibly the loudest.[23] In this case, the sound functions as a *line-source*, or many point-sources acting in line. Sound spreads from the line cylindrically, resulting in a reduction by a half, or 3 dB, when distance is doubled.[24] With a line-source the sounds and movement work together and the acoustic quality of the action changes; but the way a person interprets the action also varies. Other factors affecting the utility of the inverse square law are the reflection of the earth's surface outdoors. In this case the reflection from the earth's surface will make the SPL somewhat less than that indicated by the 6 dB free field approximation. In outdoor situations the 6 dB approximation is usually closer to a decrease by 4 or 5 dB with the doubling of distance.[25] Thus, quantifying distances with measured sound pressure levels offers only half the auditory picture. The location and temporality of the production of sounds also needs to be considered in order to understand the spatial quality of sounds. Moving to the level of place requires that attention shift to the locations of sounds and the influence of architecture on those sounds.

[20] Everest and Pohlmann 2009: 34.

[21] Everest and Pohlmann 2009: 36.

[22] See section 5.2.1.

[23] Favro 1996; Brilliant 1999; Beard 2007; Östenberg, Malmberg, and Bjørnebye 2015; Littlechilds and Veitch forthcoming.

[24] Everest and Pohlmann 2009: 36.

[25] Everest and Pohlmann 2009: 38.

The interpretation of sound directions and distances is part of the perception of sound, which is an aspect of psychoacoustics. Psychoacoustics is the study of psychological and physiological responses to sounds.[26] The process of hearing is complex, involving the sounds, ears, motor skills and brain working almost instantaneously to interpret the sounds heard. The process happens quickly, with almost no thought to its various processes. We hear and interpret the sounds without telling ourselves to do it; we cannot turn off our ears. The specific structure of the human ear shapes the way humans hear and perceive sounds; and the audible spectrum of frequencies for humans is between 20 Hz and 20,000 Hz.[27] The human ear can detect about 280 discernible steps in intensity and some 1,400 discernible steps in pitch.[28] These physical properties of the human ear will vary from person to person, but the variations will happen within a given range. That is, people can hear different frequency ranges within 20-20,000 Hz, but will not hear sounds above or below the outer limits of the range.

The perception of sounds by the human ear is not based on arithmetic differences between frequencies but frequency ratios, perceived logarithmically. This means that the interval between 100 Hz and 200 Hz is perceived as being larger than the interval from 200 Hz to 300 Hz. Frequency is related to pitch, the perceived tone, but not in a linear fashion. Pitch is a subjective unit, whereas frequency is a physical unit. This means that a soft 1k Hz signal will remain 1k Hz even if its sound pressure level (SPL) is increased. Here we encounter the subjective phenomena of sound; the sounds we hear elicit unconscious thoughts or emotions, as well as being measurable and quantifiable. Low frequency noise, between 20-160 Hz, has been connected with health issues, such as depression and loss of sleep, while high frequency noises, between 10-20k Hz, are associated with auditory discomfort, tinnitus, balance disturbance, persistent headaches, fatigue, malaise, and even nausea.[29] Gender and age differences will affect hearing and perception, but again, these differences fall within the bounds of the auditory range. These subjective responses to sounds will vary from individual to individual; however, basic trends are evident in much of the unconscious responses to such noises.

The *intensity* of sound, calculated as the sound power per unit of area in decibels (dB), is not the same as the *loudness* of a sound.[30] Loudness is another subjective term that is used to

[26] Truax 2001: 59-60.

[27] Everest and Pohlmann 2009: 14.

[28] Everest and Pohlmann 2009: 54.

[29] See Low Frequency Noise, University of Salford (http://www.salford.ac.uk/computing-science-engineering/research/acoustics/psychoacoustics/low-frequency-noise) 8 July 2015.

[30] Everest and Pohlmann 2009: 1.

describe the perceived magnitude of the sound. In terms of sound pressure levels, the minimum change in level the human ear can detect is 2 dB in the important mid-frequency range, the speech range.[31] Short sound pulses are perceived differently. A short sound, three milliseconds, must have an SPL 15 dB higher than a 0.5 second sound to be perceived at the same loudness.[32] Random noises and tones function in similar manner, in terms of perceived loudness. The nature of the human ear and the process of hearing are tailored to the frequencies of speech and attune humans to easily hear and interpret these mid-range frequencies.[33]

The ear and brain together take the combined sound waves and separate out particular sounds, such as specific instruments in a symphony orchestra, or a certain conversation in a crowded room, referred to as the 'cocktail party' effect.[34] What is often overlooked in the 'cocktail party' effect is the concentration and focus required to pick out a conversation within the wider background noise.[35] In particular, far more energy is used to focus hearing on particular sounds, tiring the auditory system and body, than eyesight, although eye fatigue is also common under certain circumstances. Physical strain and fatigue, therefore, are products of intense auditory focus, and will affect the body. This highlights the role of the body as a single organism, which uses all its resources in hearing.[36]

However, hearing also includes other bodily functions and responses beyond the ears and brain. The body 'hears' low frequency noise more through the feeling of vibration, than through ears, in part a product of the greater wavelength of the cycles. Such perceptions relate to both the physical structure of the human body, as well as cultural conditioning and social learning.[37] The human response is the product of physiology, while the descriptions of such experiences are dependent on social and cultural norms and habits. Sight and hearing are connected in the bodily perception of noise. We often unconsciously turn towards the direction of a sound, in expectation of where the sound should come from. The SPL of sounds when picked up by the ear also transmits information about the distance of the sound. The repetition of such auditory and spatial events creates an unconscious link between the sound and its place. Because the ears are located on the side of the head, slight changes in hearing time enable the

[31] Everest and Pohlmann 2009: 54.

[32] Everest and Pohlmann 2009: 53.

[33] Veitch 2017a.

[34] Everest and Pohlmann 2009: 63.

[35] Chion 2016: 25.

[36] This is a central point in Ingold's arguments about wayfinding, navigation, human movement, as well as vision and hearing, Ingold 2000.

[37] See Lefebvre 1991: 399-400; Serres 2016.

brain to triangulate the source of the sound. In this process, directional data is transmitted with the sound signal and interpreted by the brain. These processes are fundamental in the human interpretation of place, navigation, and wayfinding, although these are distinctively different processes.[38] In his discussion of wayfinding, Ingold usefully differentiates these processes and argues that human experience is one of continual movement, which the senses take in simultaneously, while navigation is based on a singular vision devoid of such movement.[39] Again, the relative speed of sound means that humans perceive the distance over which sound travels, unlike perception of light. Along with this locational data, the sounds and noise also elicit reactions from those who hear them. In terms of ancient evidence, the literary descriptions offer insights into psychoacoustics responses to sounds and noises (2.1). This is a perception of movement, either the movement of the sound, its physical property, or the movement of perceiver, the human physiology, which Ingold extrapolates out to the perception of the 'texture of the environment'.[40] This forms a different, although equally mappable, type of sound source evidence, as the literary descriptions are often coloured by the author's own interpretation and judgment of the sound.[41] The importance of movement will be considered in the third section of this chapter (3.3). Before that, with the body's auditory system in mind, the mathematical modelling of acoustic properties needs to be explained.

3.2 Mathematical Model: Enclosed Space

Following the work of sound and architectural designers, the predictive measures of auditory space can be analysed to show the potential acoustic properties of spaces. These predictive measures have been correlated with actual building acoustics, which provide the measures with a reasonable level of certainty in describing the acoustic character of incomplete structures or architectural designs.[42] The acoustic measures can, therefore, be worked out based on the physical remains and evidence for incomplete buildings, as in the case of historical sites. The use of acoustic measures in understanding the past environment is still developing

[38] See Ingold 2000: 219-242.

[39] Ingold 2000: 242.

[40] Ingold 2000: 242.

[41] See example of 'streets', 55-68. The mapping of such psycho-sensory affects in Rome would be produce a distinctive form of the city, unlike its visual counterpart.

[42] On the historical development of acoustic measures, Thompson 2002.

and prior to this thesis has not been used to describe incomplete structures.[43] Previous studies focus on a complete structure, such as a prehistoric cave or early medieval church, and single buildings devoid of their spatial context.[44] In this chapter, three main measures, absorption coefficient, reverberation time, and transmission loss, will be used to describe the acoustic properties of spaces, and contemporary acoustic measurements tested against the ancient materials. This will verify the method's ability to predict acoustic properties of ancient spaces, as well as incomplete spaces. This is the first thesis to test an acoustic model in the fields of classical archaeology and architecture. Other studies have used acoustic models to analyse particular spaces, but none have compared the predicted measurements to physical measurements taken within an ancient space. As tested in my fieldwork, Roman baked brick displays a high correspondence with modern acoustic measurements of baked brick therefore allowing for the prediction of acoustic properties. Before turning to the testing of ancient and modern correspondence, an overview of the mathematical measures, the basic model found in the appendices, and the relationship between the physics of sound and architecture is in order.

3.2.1 Absorption Coefficient (α)

All materials absorb or reflect energy when struck by sounds.[45] As noted above, a free field is an abstract space of mathematical production, while daily activities take place within architecturally defined spaces with walls, ceilings, floors, as well as other furnishings and materials. The *absorption coefficient (AC)* is a measure of materials' sound energy absorption, or how much sound energy is reflected back into the room after the sound waves strike the materials' surface.[46] This measure, therefore, quantifies the amount of energy absorbed by the physical structures of the absolute and material space. Absorption coefficients can be measured for the walls, ceilings and floors, as well as furniture and people in the space (Tab. 3.1). This basic property of all materials can therefore be quantified and compared to show the different influences the materials have on sounds. The measurement of the absorption or reflection of a material can be quantified as the absorption coefficient (designated $\propto$).[47] The absorption

[43] Most studies of ancient acoustics are undertaken in complete structures, usually a cave or other natural enclosed space, see Eniex 2014.

[44] Hal Saflieni Hypogeum, Eniex 2014; Haggia Sophia, Pentcheva 2017.

[45] Everest and Pohlmann 2009: 180.

[46] Everest and Pohlmann 2009: 180-1.

[47] Veitch 2017a.

coefficient is the ratio of absorbed energy to incident energy (∝= Ea/Ei).[48] The absorption coefficient varies based on the frequency of the sound and is usually given at six standard frequencies.[49]

Material	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz
Brick (natural)	0.03	0.03	0.03	0.04	0.05	0.07
Brick (painted)	0.01	0.01	0.02	0.02	0.02	0.03
Plaster (gypsum or lime, on masonry)	0.01	0.02	0.02	0.03	0.04	0.05
Concrete block (coarse)	0.36	0.44	0.31	0.29	0.39	0.25
Wood flooring	0.15	0.11	0.1	0.07	0.06	0.07
Doors (solid wood panels)	0.01	0.07	0.05	0.04	0.04	0.04
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02
Glass (small pane)	0.04	0.04	0.03	0.03	0.02	0.02
Benches – wooden (empty)	0.1	0.09	0.08	0.08	0.08	0.08
People – adults	0.25	0.35	0.42	0.46	0.5	0.5
Water or ice surface	0.008	0.008	0.013	0.015	0.02	0.025

Table 3.1 Absorption Coefficients for common building materials. (From Everest and Pohlmann 2009)

[48] Everest and Pohlmann 2009: 181.

[49] 125 Hz, 250 Hz, 500 Hz, 1k Hz (or 1,000 Hz), 2k Hz, 4k Hz; Everest and Pohlmann 2009: 181.

Appendix 1 provides the acoustic measurements of the various internal spaces analysed within this chapter and the next. At the core of each analysis, the absorption coefficients are given for all the materials within the room, including floor, walls, ceilings, and extras, such as doors or windows. In each case, the room is broken into six surfaces (four walls, plus a ceiling and floor) and the surface materials absorption coefficients given. The absorption coefficient for the material is listed at each of the six standard measurements, while in the majority of cases two extra frequencies are listed, one above and one below the standard six. These extra frequencies, 63 Hz and 8k Hz, indicate a wider range of responses that go above and below the standard range based on the human vocal range. That is, these extra frequencies can indicate the acoustic properties and auditory responses outside of human produced vocal noise; however just because the frequencies centre on the vocal range, this does not suggest that only noise within that range would be heard. Where peaks in the frequency response or reverberation time happen in these outer frequencies, it suggests auditory responses to other noises, beyond the human voice, would have a greater effect on the space.

Absorption coefficient measures range between 1.0, indicating perfect absorption, and 0, complete reflection, however in reality the measures can exceed 1 (Tab. 3.1). An open window serves as a perfect absorber as no sound returns into the room. The presence of windows and doors are indicated in the models in Appendix 1 and are give an absorption coefficient for either an open space (1 across all frequencies) or the AC for the material used to close the space (glass or wood). Although counterintuitive, defining absorption as the lack of reflected sound back into the room is helpful in gauging the potential for sound to filter into neighbouring spaces.[50] Perfect absorption, therefore, does not automatically indicate complete diffusion of sound, nor that the sound is no longer heard elsewhere. Since absorption coefficients vary across frequencies, the *noise reduction coefficient (NRC)*, a single-number rating based on the average of the mid range frequencies that pertain to speech, is often used for individual materials.[51]

The absorption coefficient for various modern construction materials has been formulated and provides a basic framework from which to analyse the ancient acoustics of the spaces. The exact measurement of ancient construction materials requires technical equipment often requiring small finely cut samples of the materials and is not easily attainable in the field. As will be discussed below, the modern values were used in a mathematical model, which was

[50] This poses a problem for certain spatial models, such as space syntax, due to the limitations of programming. Modelling the interaction between two distinct spaces, separated by a visual barrier, is inherently problematic, as programs tend towards analysis of a single space, see 133-48.

[51] Veitch 2017a.

tested against physical measurements of the same space. This high correspondence between modern measurements and ancient materials reflects consistency in basic types of materials.[52] In the context of Ostia, Roman baked brick shares a consistency in production and physical make-up with contemporary brick. Other materials, like stone or wood, have direct correspondence with contemporary materials, as the stone or wood goes through no changes to its physical form in the production process, only the shaping of its outer surface. Brick, on the other hand, changes with different forms of production. Mudbrick, or unbaked brick, tends to be considerably more porous, and therefore more absorptive, than baked brick. These contemporary measures are not the exact measures of ancient materials, however, changes over time have not significantly altered the acoustic properties of the individual materials. Despite the deterioration of the site over time, the individual materials remain consistent in their acoustic properties. In this way, the AC value will not change over time; only when the material is physically altered to an unrecognisable state will the AC change. A modern example is the use of basalt for acoustic insulation. The natural properties of basalt, its resistance to high temperatures, strength, durability, and its local supply in Italy made it a particularly good stone for paving. The stone was used in the paving of street surfaces in the Roman context from the second century BCE, which has a highly reflective AC measurement.[53] If the stone is melted and woven together, it can be formed into a basalt fibre, which is used for thermal and sound insulating panels.[54] The physical changing of the basalt from a hard stone to fibre is reflected in the acoustic properties changes, as well.

As the models in Appendix 1 show, the AC for an entire room can be calculated based on the spatial dimensions and known ACs for the materials. The sound absorption (A) provided by a given area of material is calculated by multiplying the material's absorption coefficient ($\propto$) by the surface area (S) of the material exposed to the sound, or $A = S\propto$. Therefore, the entire AC for the room is the sum of all materials multiplied by the materials' AC. The totals for the rooms are given below the individual wall charts in Appendix 1, and follow the same frequency values as the individual material AC values. Total AC ratings for the rooms give a summary of the rooms absorption, although experiential differences in absorption require drastic changes, such as the effect of an anechoic chamber, which absorbs all sound. Variations at the level of decimal points will produce different experiences, but other factors will have a great immediate effect. The

[52] Brick has a low absorption coefficient and has not dramatically changed over time, pers. comm. Gary Seiffert.

[53] On the chronology of basalt in paving Roman streets, Laurence 1999: 62-7.

[54] See Buratti et al 2015. The basalt panel had a similar AC trend to rock and wool panels, although the high density of the rock and wool panels gave them a 0.1-0.2 higher AC rating.

absorption units are calculated in Sabins, named after Wallace Sabine, an early pioneer in the modern field of acoustics.[55] A Sabin is an unrecognisable unit outside acoustic absorption measurements, and requires translation into other values before it can be expressed in relational terms. Thus, the individual mathematical models must be interpreted in order to draw conclusions about the significance of the numbers. Reference will be made to certain properties of particular materials, which stem from the AC ratings, such as high reflexivity or low absorption. These properties based on the mathematical measurement suggest certain auditory effects, even when the individual numbers are not referenced. It is worth noting that the numerical value, say between an AC of 0.1 and 0.2, indicates minimal experiential change. This is not to discourage the use of such measurements, but to advise caution when translating the numbers into social space. The experience of acoustics, it should be remembered, is not first and foremost the experience of numbers, even when the experience can be quantified through mathematical calculation.

3.2.2 Reverberation Time (RT60)

The Sabin units, derived from the AC, can be transferred into more useful values through calculating the reverberation time (RT60). The reverberation time gives a measure, in seconds, of the time for a sound to diminish to one tenth of its starting intensity, or to drop 60 dB. Two main calculations of RT60 are usually made: the Sabine or Eyring. These calculations, named after their discovers, are differentiated by the total absorption within the room. In cases where the total absorption is below 0.2 the Sabine formula is used, while the Eyring formula is used ion instances with a total absorption above 0.2. The RT60 is also an experienced occurrence within the space. Unlike the AC, the RT60 can be physically felt. Measurement in the space can also be performed in instances where a complete space is available, as will be discussed below. Again, the example of clapping in St. Paul's Cathedral would produce an initial sound and a reduced echo. The length of time for the initial sound to die down is the RT60, while the echo is the reflection of the sound back to the point where you are. In this case, the RT60 is experienced as a decay of sound, while the AC influences the intensity of the echo, but is not directly experienced in hearing the echo. However, not all spaces have such clear reverberations and, therefore, the mathematical calculation of the reverberation is helpful in quantifying the experience of the space, or predicting the acoustic character of an incomplete space, such as at Ostia.

[55] On Wallace Sabine, Thompson 2002.

The RT60 is measured based on two key elements, the AC of the various materials and the dimensions of the surface. The surface dimensions are measured for all six surfaces of the room and the volume of the room is multiplied by the total absorption of the room (or each individual surface). In Appendix 1, the dimensions are given at the top of the spreadsheet, as well as the volume of the space and total surface area. The RT60 will vary slightly with different frequencies, the same as the AC, although the RT60 usually remains more constant across all frequencies. Like the AC, the RT60 takes into account the physical size of the space, as well as the decoration within the room, as the RT60 is based on the AC ratings of the surface materials. Other furniture and physical structures also affect the RT60; however, in Ostia, these structures were for the most part cleared during the early excavations. The initial analysis does not take into account the number of people potentially using the space, nor potential furniture, to allow for comparisons across the site and between different functional rooms. In the few cases where items remain, such as bar counters or indications for dining couches, these elements can be added to the model for analysing the RT60. For the apartments discussed in the following chapter (4.4.1.3), the RT60 was measured for dining spaces with and without couches and people. Using the known dimensions of couches and textile coverings from Pompeii, and the standard dining arrangement of nine people, the RT60 was measured to see the influence such additional furniture and people would add to the space. People are the most influential element in analysing RT60, as the human body easily absorbs sound (Tab. 3.1). In certain rooms, like *triclinia*, the dining couches, which are often indicated by floor patterns or physically built into the structure, can be added to the space.[56] Comparisons can be drawn between the empty room and its furnished layout to assess the acoustic changes based on room usage.

It is worth pointing out that the RT60 is a measurement of the experience of the space from within the space. It does not indicate the influence of outside noise, nor the amount of noise heard outside the space. Therefore, the RT60 serves as a form of spatial monumentality and display, although in this case, a non-visual display. While much of acoustic analysis is based on RT60 measurement, as well as other internal measurements like frequency response, this thesis is concerned with the transfer of noise between spaces, especially internal noise being heard in the street and vice versa. In order to assess these properties another measurement is required.

[56] See Veitch forthcoming for acoustic analysis of the Mithraic cult spaces in Ostia, which have demarcated dining benches.

3.2.3 Transmission Loss (TL)

The primary means of quantifying the level of sound that passes through a material is through *transmission loss* (TL). The basic measurement is the decibel change between the external noise level and the internal noise level (Fig. 3.1, 3.2). The basic measurement:

External SPL (source side) — Internal SPL (receiver side) = TL.[57]

The measure of the TL of the material is, again, frequency dependent, and will vary based on the mass of the material. A material's calculated TL rating is effective only if there is no bypassing or

[REDACTED]

Figure 3.1 Wall weight (lb/sq ft. of wall surface) and transmission loss (TL) in dB. (From Everest and Pohlmann 2009)

flanking of the physical structure, i.e. sound going around the edge of the wall or over an opening at the top. TL is dependent on the weight of the wall (Fig. 3.1). Figure 3.1 shows the six standard frequencies and the TL based on wall weight (in lb/sq ft). If the wall weight is calculated, the frequency response can be indicated by the given trend line. 500 Hz is the marked in bold, as it is the common reference point for the overall TL of a given wall. Thus, heavier materials tend to be more effective sound insulating materials. In figure 3.2, the relation of the density of the wall to the TL is shown. Here, the mass is more important than the material, unlike the AC, which is material specific.

The thickness of the wall is not directly considered in calculating the TL, however, it does affect the weight of the wall.[58] Wall thickness has traditionally been used to predict the height of the building.[59] Storey by comparing evidence from Pompeii, Herculaneum, Ostia and Rome has shown this to be an unreliable predicative measure for the overall height of buildings.[60] Ostia has an average wall width of 56.6 cm, with only a 30 cm difference between one storey and two-four storey buildings.[61] Different construction methods also produce varying widths. TL will increase with an increase in wall mass, as well as with an increase in

[57] Everest and Pohlmann 2009: 291.

[58] Everest and Pohlmann 2009: 292.

[59] Meiggs 1973; Packer 1971; cf. Storey 2003.

[60] Storey 2003.

[61] Storey 2003: 26, Table 3.

[REDACTED]

Figure 3.2 Transmission Loss (TL) of the wall. Sound ray (S) striking a wall, resulting TL (D). AC is represented as curved lines (F and G). (From Everest and Pohlmann 2009)

frequency. For example, the *opus incertum* of the Casette Tipo (3.12, 3.13) is 0.50 m thick, producing a surface mass of 835.44 kg/m^2.[62] *Opus reticulatum* from the Insula dei Dipinti (1.4.4), on the other hand, is 0.60 m thick, with a surface area mass of 976.11 kg/m^2, and the brick-faced concrete of the Insula dei Dipinti (1.4.4) has a surface area mass of 1,028.54 kg/m^2. The differences in width and mass result in different sound propagation through the walls of the buildings, as do the differences in internal layout, decoration and wall material. The TL for a wall can be calculated as TL = 20 log (fm) — 47; where f = frequency of the sound, Hz, and m = surface mass of barrier, kg/m^2.[63] This gives the *opus incertum* a TL of 65.42 dB(A), *opus reticulatum* 66.77 dB(A), and brick-faced concrete 67.22 dB(A). Again, the human body will only hear differences above a certain threshold, about 2 dB. In the case of these different construction methods, the difference between *opus incertum* and *opus reticulatum* would be unnoticeable, while the difference between *opus incertum* and brick-faced concrete could be heard.

The differences between these forms of construction are further indications of the social and design side of construction. The acoustic properties of the different construction techniques indicate changes in the experience of the space. In particular, the Casette Tipo (3.12-13) apartments are the earliest form of the developed '*medianum*' type apartment and constructed in *opus incertum* around 100 CE.[64] The wall construction indicates an experienced damping of noise under the level of a conversation (c. 65 dB). Anything above that threshold could be heard in a neighbouring space, whether another room or outside space. Later variations on the apartment style, such as the Case a Giardino (3.9) complex dated by brickstamps to c. 125 CE, retain the same arrangement, but are constructed in brick-faced concrete.[65] Here, the increased TL of brick-faced concrete was an experienced form of increased auditory privacy, as the threshold for audible noise was raised enough for the human ear to detect a difference. The transition from *opus incertum* to *opus reticulatum* or brick-faced concrete was a transition in the level of sound isolation. DeLaine has shown the transition from *opus incertum* to *opus reticulatum* cannot be explained by labour-saving in the construction process alone. Social and

[62] Following DeLaine 1997, 2001a.

[63] Everest and Pohlmann 2009: 293.

[64] DeLaine 2012: 336.

[65] See DeLaine 2002: 54.

cultural perceptions of noise, such as those associated with TL and sound isolation would influence such economic strategies as well.[66] A potential chronology of auditory experiences can be constructed for shifts in construction techniques. Bridging the technological and experiential aspects of architecture, acoustic properties bring to light the influence of this broad definition of architecture. Alongside technological changes, the experience of urban space also transitioned, as further levels of sound isolation, although minimal, were attained.

TL measurements will vary over different frequencies, in casual estimates the transmission loss for 500 Hz is often cited.[67] Alongside the TL ratings for different construction techniques, the TL rating for wood and several other materials is given in Table 3.2. As with the AC ratings, natural materials, such as wood, stone or glass, have consistent TL ratings in comparison with modern examples. The thickness and weight for these contemporary measures of construction techniques are rarely as thick as the Ostia wall materials; however in certain cases, such as wood and glass, contemporary measures are closer.

[REDACTED]

Table 3.2 Transmission loss for contemporary materials. (Gonser 1970)

Higher frequencies show a higher transmission loss rating, indicating that low frequency noise will be the more noticeable difference when hearing outside noise from within a neighbouring space. The experience is common today, as well. Most often it is loud low frequency noise, such as trucks or subwoofers that are heard and felt through walls or doors. The material's weight also influences the TL, evident in the higher TL levels for Roman wall construction and plastered brick in Table 3.2.

It is of note that the TL ranges between 13 and 72 dB(A). The measures for the Roman wall structures fall within the upper region of this range. This constitutes a wide range in noise reduction, depending on the material, weight, and frequency. In the case of the *opus incertum* and *opus reticulatum*, the TL ratings are equal to average conversation noise, c. 65 dB. It is only with brick-faced concrete that the sound reduction surpasses the conversation threshold. In the case of other materials, like wood or glass, the TL rating is well below the conversation threshold indicating that internal conversation noise would be heard outside the windows and doors, whether closed or not. The politics of such experiences will be discussed further in the following chapter.

[66] DeLaine 2001: 239.

[67] Everest and Pohlmann 2009: 291.

3.2.4 Mercati di Traiano: Testing the models

In order to assess the validity of the mathematical models produced in Appendix 1, a test case was analysed to compare the model with physical measurements taken of the space. The so-called shops that form the first floor of the Mercati di Traiano were tested as the comparative space.[68] The Mercati provided space for the commercial premises demolished for the construction of the Forum and Basilica of Trajan.[69] The Mercati consist of five levels, reaching the height of 35 m above the Forum pavement.[70] The five levels can be split at the Via Biberatica, forming three divisions above and below the street.[71] The complexity of the layout has led to its association with a distinct urban unit. The shops and streets connected directly with one another, and the small interior spaces forced inhabitants into the streets for social interaction.[72]

Constructed between 107-110 CE and using similar brick-faced construction technique to that of Ostia, comparisons were ideal for testing the model. The shops along the first floor were physically measured for their acoustic properties, namely the RT60 and frequency response.[73] The reconstructed Mercati provide the opportunity to test the acoustics of the physical space, a possibility limited to specific spaces in Ostia.[74] By physically measuring the RT60 in the Mercati di Traiano, the acoustic model used in the Appendix 1 was calculated for the same space. The testing of the model provides a verification of both the predictive capabilities of the acoustic measures and the accuracy of contemporary material measures, like the AC values discussed above. This is the first verification, I am aware of, for using modern values to predict ancient acoustic properties. There are several auditory analysis software programs for purchase, but all rely on a series of standard measurements of contemporary materials for their analysis.[75] Thus, in order to verify the reliability of such an assumption the calculated measurement was tested again the physical measurement of the space.

The shops of the Mercati di Traiano are of similar construction to those in Ostia. Mercati di Traiano shops were on average 3.6 m deep and 5.5 m wide, with similar wooden shutter

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[68] On Mercati di Traiano, MacDonald 1982: 75-93; Lancaster 1998: 25-44.

[69] MacDonald 1982: 78; on the Forum and Basilica, Packer 1997.

[70] MacDonald 1982: 78.

[71] MacDonald 1982: 79-82.

[72] MacDonald 1982: 90.

[73] Bloch 1947: 49-57, 348; Lancaster 1998:39-40.

[74] There are a couple of single room shops reconstructed in Ostia, however the majority of reconstructed spaces are more complex, like the Caseggiato del Termopolio.

[75] Odeon is the most common and expensive, http://www.odeon.dk.

doors.[76] The ceilings are barrel vaulted, with no mezzanine levels. The shops were reconstructed under Mussolini, for display, and the floors are all reconstructed; however the analysis of the space and physical measures included the reconstructions in the analysis. These shops are shallower than those in Ostia, although the testing was between the mathematical model of the Mercati shop and the physical measurement of the same space, not between the two sites in Rome and Ostia. In this instance, the difference in physical dimensions between Ostian shops and those in the Mercati does not affect the testing of the model's predicative capability. Of central importance is the difference between the predicted model, derived from the mathematical calculations, and the physical measurement of the shop space. After that difference has been tested, the model can be scaled to analyse any space.

The eleven shops along the hemicycle on the first floor above ground were all measured using a frequency response program, ClapIR.[77] ClapIR is an iOS app that measures the reverberation time and frequency response of a handclap in the given room. Each of the eleven shops was tested, and the results averaged. The physically measured RT60 was 0.98 seconds, and had a frequency response from 22 Hz to 1900 Hz. Using the mathematical model for AC and RT60 discussed above, the physical measurement was compared with the calculated measures, which used modern AC values. The calculated RT60 from the model was 1.07 seconds, a difference of 0.09 seconds from physically measured RT60. This indicates a high level of accuracy between the calculated model and physically measured RT60. The close proximity suggests that certain features, evident in the physical measures, produce only minimal differences; differences that are undetectable to the human ear. Where the physical measure takes atmospheric pressure and weather conditions into account, the calculated model assumes a standard atmospheric condition at sea level. This difference between the RT60 for the model and the physical measurement indicate that the weather and atmosphere do effect the acoustics, however these changes need to related to a reference standard, which until now has not been devised. Even more informative is the lack of dramatic change due to the use of modern absorption coefficients. The close proximity of the measures indicates that the use of contemporary absorption coefficients will give highly accurate measures in comparison with the actual RT60 of the space. This provides a firm basis for the use of modern brick measurements in assessing the acoustic properties in Ostia. Further testing of ancient wall materials will develop analogous modern measurements for other construction techniques.

[76] MacDonald 1982: 203.

[77] https://itunes.apple.com/gb/app/clapir-acoustics-measurement/id521153051?mt=8

3.3 Mathematical Model: Street Acoustics

The transition from interior spaces to the exterior space of the street involves a parallel transition in the manner of discussion. The materiality of the façade, its parts, construction and material remains, provide the basic structure for analysing absorption and reflection. This is the same basic analysis as undertaken for internal spaces discussed above; however, in this case, the façade is only one aspect of the street canyon. The paving and lack of covering produce different acoustic effects in comparison to rooms constructed out of similar materials. The exterior space, in this case the street, presents itself as a continuous object through the connection of various outside boundaries, such as building façades.[78] Although it has been referred to by several different names, the concept of a continuous image of urban space is long standing.[79] However, the experience of the space is broken up by sensory boundaries and perceptions.[80] As noted in the introduction, the street experience is produced from the movement along it, rather than as predefined image. The acoustic properties and physics of sound mean that distance and time are fundamental to the perception of space by the ear.

The acoustic analyses of the street are divided into the particular architectural features that make up the street canyon. Basic elements, including paving, façades and building heights, are the foundational elements of the acoustic analyses. These features enable general acoustic properties to be measured, which will be nuanced further by the other elements. As will be seen in the discussion of movement, additional features of sidewalks, benches, fountains and shrines, will affect the aspects of movement and, importantly, the shape of the soundscape at those places. The developments of porticoes and monumental features along streets in Ostia provide an experiential hierarchy and chronology that spans the second century CE. These elements are deployed in a variety of manners in the streets of Ostia and highlight the role auditory experience in the development of Ostian streets. Each general grouping of elements will be discussed before turning to the social context for two streets that form spatially and auditorially distinct spaces at either end of the second century CE.

3.3.1 Paving

The basic structures of street layout and arrangement in Ostia have several common features. The most visible is the widespread use of paving on streets. The carriageway, or central section of the street, is almost exclusively paved in lava rock, *selce* (*silex*) on the vast

[78] Hillier and Hanson 1984: 144.

[79] See Raper 1977; 1979; MacDonald 1986; Kostof 1991; 1992; Favro 1996.

[80] See Hall 1990.

majority of streets. Pliny mentions the high quality of black stone, *silex*, from central Italy, and its importance for paving.[81] Several forms of *silex* are evident in the paving of roads in Italy.[82] The distinctive petrology of *selce* can be visually distinguished, especially when cut to produce a smooth surface.[83] A marked preference for *silex* from the middle Tiber valley, in the area of Monte Aguzzo and Monte Maggiore, alongside *silex* from the quarries associated with the Alban hills, closer to Rome, is evident at Ostia.[84] The mixture of *selce* used in paving the streets of Ostia covered a wide geographical area, as noted in the introduction, and suggests a mixture in transportation costs, which argues against the economic determination of closer quarries.[85] From the second century CE onwards, a *procurator* of *selce* at Rome organised the supply of stones. *Selce* blocks required 4.41 man-days per m^3 for the quarrying, which was predominately undertaken by unskilled labour.[86] The larger scale of resources needed for the repaving of roads by Nerva and Trajan, as well as the rise in street level in Ostia, meant a more complex use and exploitation of *selce* in the second century CE around Rome and Ostia. The *procurator* in Rome would therefore manage the supply of stones for various paving projects, and enable Rome and Ostia to draw from a wider source of stones beyond the local quarries.[87]

The *selce* from central Italy also had a characteristic sound. Harder forms of *selce*, used in the later paving, provided a smoother surface area for wheeled movement, and may have grown in preference due to this characteristic. Although streets do not produce sound in their own right, certain activities or natural phenomena would. Rain would produce a seasonal noise,

[81] Pliny *NH* 36.135, 167-8.

[82] See Laurence 1999: 62-77; 2004.

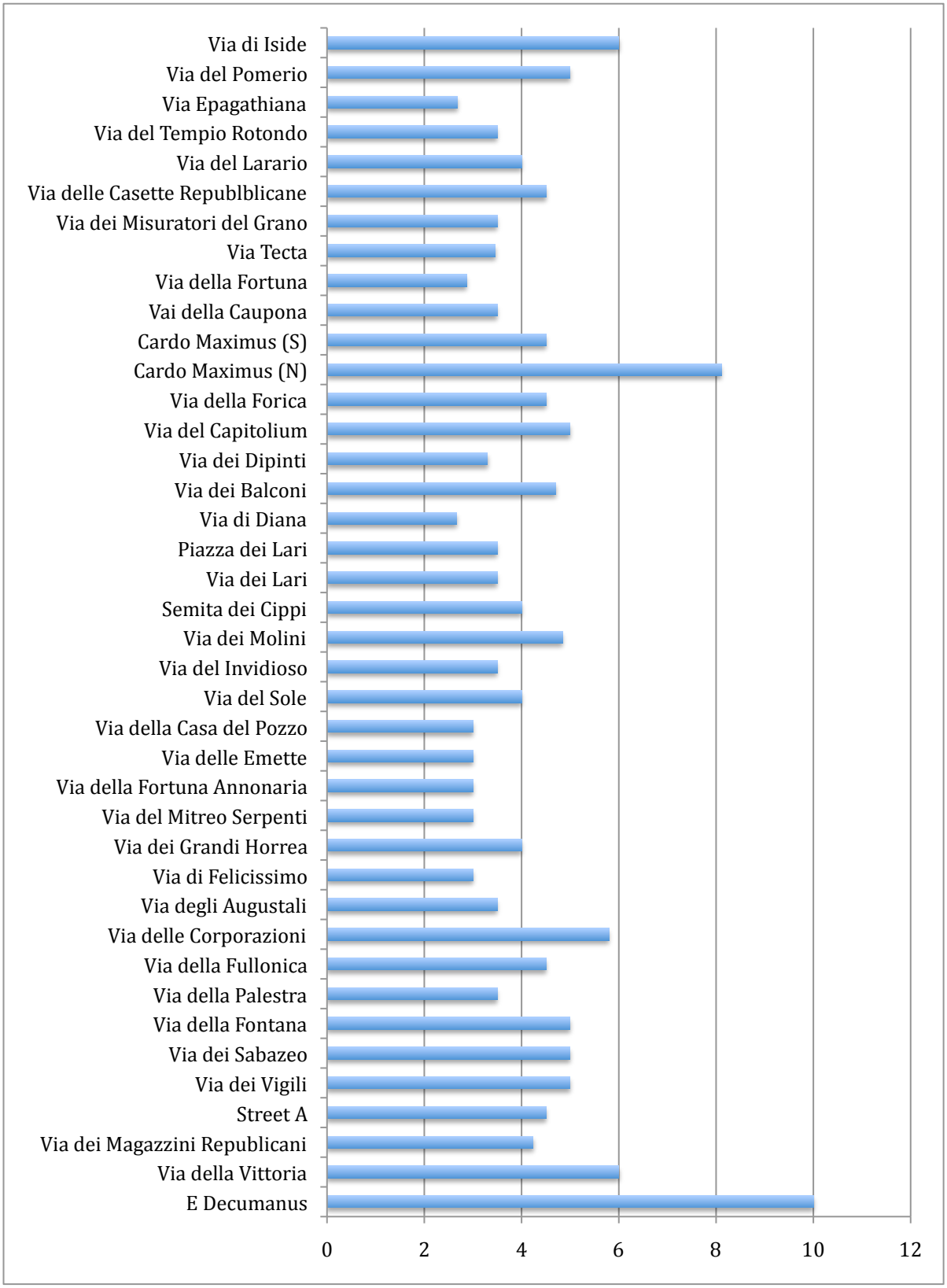
[83] Laurence 2004: 286.

[84] Laurence 2004: 292.

[85] Laurence 2004: 292.

[86] DeLaine 1997: 109-111.

[87] Laurence 2004: 293.


Via di Iside
Via del Pomerio
Via Epagathiana
Via del Tempio Rotondo
Via del Larario
Via delle Casette Republblicane
Via dei Misuratori del Grano
Via Tecta
Via della Fortuna
Vai della Caupona
Cardo Maximus (S)
Cardo Maximus (N)
Via della Forica
Via del Capitolium
Via dei Dipinti
Via dei Balconi
Via di Diana
Piazza dei Lari
Via dei Lari
Semita dei Cippi
Via dei Molini
Via del Invidioso
Via del Sole
Via della Casa del Pozzo
Via delle Emette
Via della Fortuna Annonaria
Via del Mitreo Serpenti
Via dei Grandi Horrea
Via di Felicissimo
Via degli Augustali
Via delle Corporazioni
Via della Fullonica
Via della Palestra
Via della Fontana
Via dei Sabazeo
Via dei Vigili
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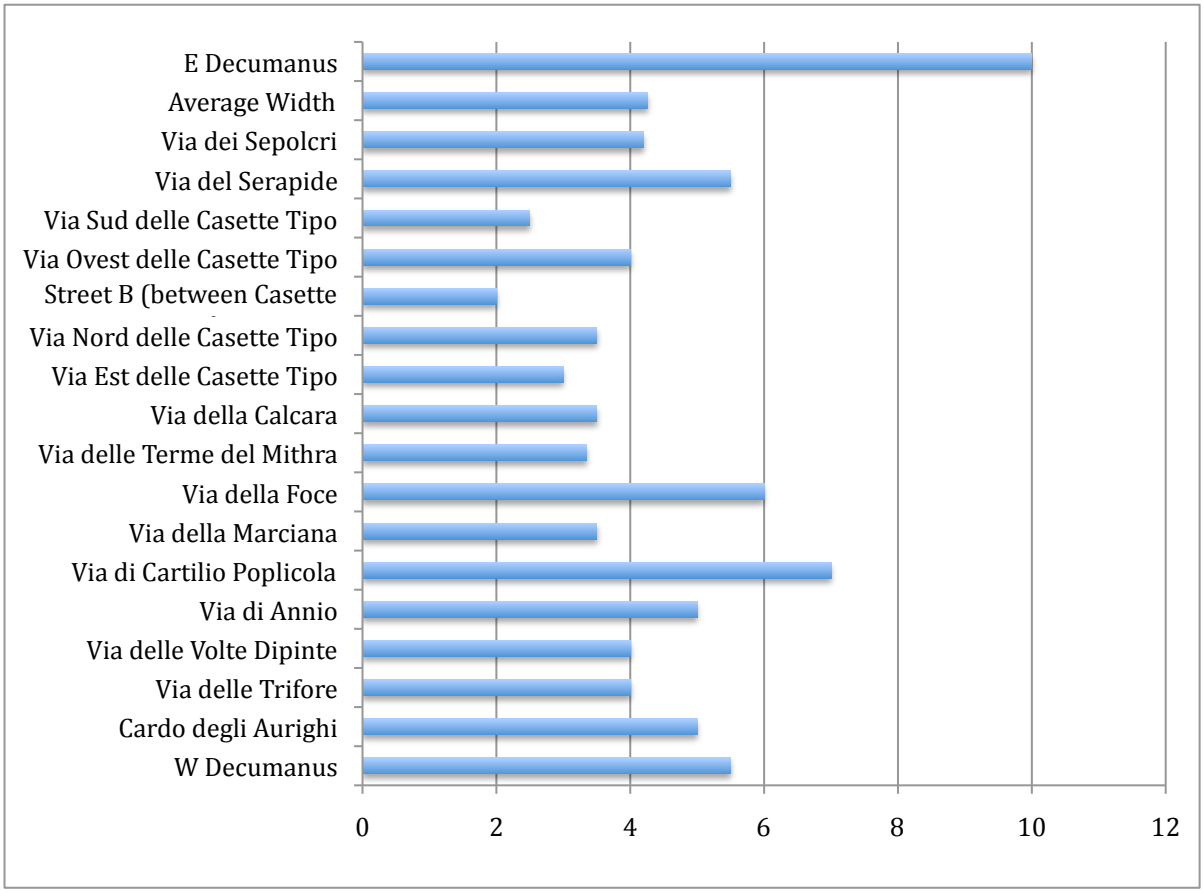

Figure 3.3 Width of streets in Ostia. (Author)

as average rainfall rises above 60 mm between September and April, while July is the driest month.[88] Measures of rain noise where taken at the corner of Via di Diana and Via dei Dipinti during a heavy rain storm, 30mm/h < *I* > 60mm/h, producing a median level of 52.1 dB(A).[89] Weather, especially rain, is an important part of the auditory perception of space for the blind. Rain produces a geographically continuous sound across the landscape, in what Hull describes as throwing a 'coloured blanket over previously invisible things'.[90] Rain, according to Hull, is perceived not as coming from a particular place, but from all quarters in equal measure, enabling the blind perceiver to hear the surfaces struck by rain all around them. In the context of the street, the ubiquity of basalt would create an even sound across the town, while differences would be heard in relation to the surfaces surrounding the street. The sound of rain would create a background noise around 10-15 dB below the conversation threshold across the lava stone paving of the streets during imclemet weather.

[88] Data from Climate-Data.org, https://en.climate-data.org/location/1185/ Accessed 21 June 2017.

[89] On site measure, 3 Oct. 2015.

[90] Hull writes about his own experience of going blind as an adult, Hull 2001; see discussion in Ingold 2000: 271.

In terms of wear and tear on the paving stones, differences in the geological characteristics of the stones means the stones have different patterns of erosion, making certain forms of wear more or less visible. This led to certain stones being used more regularly, such as the absence of *occhio di pesce* at Ostia, and a preference for smoother stones in the second century CE.[91] In terms of width, the streets of Ostia have relatively standard measurements (Fig. 3.3). All of the streets in Ostia are listed in figure 3.3 and where street names were not given in *Scavi di Ostia* I, general designations were assigned. The average width is 4.38 m, which includes the Via Flavia and Decumanus, the two widest streets. Excluding the two streets of 10 m or wider, the average drops to 4.17 m, or 14.18 Roman feet.[92] This is considerably over the 8 Roman feet minimum for *via*, which doubled to 16 Roman feet around corners.[93] In fact, all of the streets in Ostia are at least the minimum 2.35 m required by the legal codes.[94] The majority fall within the range of three to five metres, with only five streets less than three metres and nine over five metres. The consistency of widths across Ostia indicates that many of the differences in acoustic properties between streets are due to the ratio of height-to-width, rather than the single measure of width, or height. At the same time, it suggests that the acoustic measures will reflect a similar narrow range of properties for the majority of streets. There will be marked differences, especially in terms of the widest streets, like the Decumanus and Cardo Maximus.

[91] Laurence 2004: 292-3.

[92] Using 0.294 m per Roman foot, as is indicated by several Severan constructions, DeLaine 1997: 49, n. 10.

[93] Varro *Ling*. 7.15; see 60-1.

[94] See section 2.3.2.

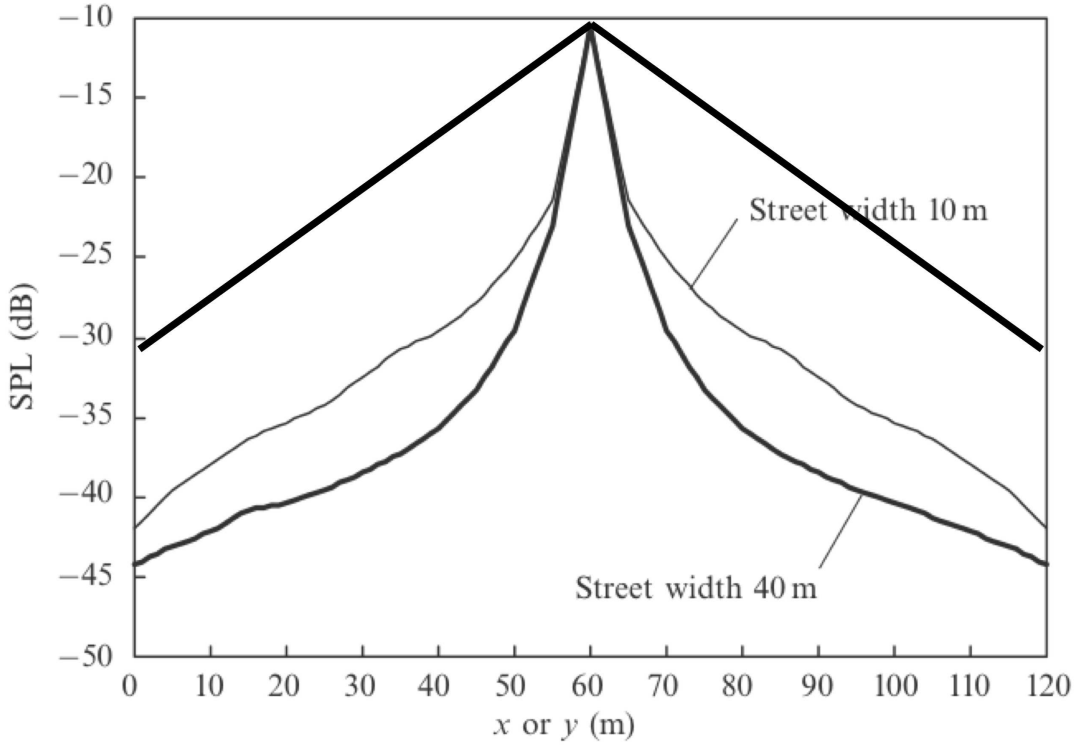

Figure 3.4 Sound dissipation at 10 m and 40 m street widths. (Based on Lee and Kang 2015)

The Decumanus can be analysed to provide the potentially widest possible *sound dissipation*, the drop in SPL over the distance of the street (Fig. 3.4). Figure 3.4 displays the sound dissipation at two fixed street widths, 10 m and 40 m. A hypothetical sound is produced at the mid-point, 60 m on the X or Y axis and the decay of the sound is charted based on the width of the street. Both lines indicate that as one moves either direction from the mid-point of the street the sound will decrease. In the case of a 40 m wide street, the decay will be quite sharp up to 15 m from the mid-point, at which the sound will decrease by 33-4 dB (indicated as either the x or y plane from the mid-point). Beyond the 15 m threshold, the decay continues to fall, but at a gentler slope decreasing to 44 dB at 60 m from the mid-point. In the 10 m wide street, which is equivalent to the Decumanus, the steep decline only happens within the first 5 m from the mid-point where the SPL drops by 22-23 dB before a more gradual decline to 42-3 dB at around 60 m from the mid-point. The difference in decay rate over the length of the street indicates the general influence street width has on sound dissipation. The narrower street the shorter the steep initial drop in sound level. This suggests that narrower streets will have less sound dissipation in proximity to the point-source of a sound. However, there will always be a

decay of at least 6 dB as the distance is doubled from the source, as the inverse square law indicates. In this way, the inverse square law forms a straight line of sound dissipation from the mid-point to -36 dB at 60 m from that point (at the edges of the graph). The sound dissipation curves of a street will never be a straight line like the inverse square law, but can approach the line. The hierarchy of street widths, therefore, serves as a range of sound dissipation levels, which will fall between inverse square law and the 10 m wide sound dissipation curve, although as will be shown below, additional features, like porticoes, will alter the curves and increase the dissipation, dropping below the 10 m width curve.

3.3.2 Building Height

The layout of the façades and street, often referred to as the street canyon, has direct implications for the sound field of the street. In enclosed spaces like shops, apartments or houses, if the height and width increase, the level of lateral reflection, reflection off the parallel sidewalls, will decrease relative to the direct sound.[95] In contrast, smaller distances between the reflecting sidewalls produce stronger lateral reflections. In the case of the street canyon, the same basic principle stands, as the building façades are reflective surfaces and the height of the façades will impact lateral reflection, which can be interpreted by the RT60 and SPL measures.[96] Lee and Kang tested the RT60 and SPL for street canyons with fixed height-to-width ratios (width: 6 m, 13 m, 20 m, and 27 m; height: between 3 m-36 m for narrow streets and 3 m-162 m for wide streets).[97] They found that the various elements of the street canyon had different influences based on the height-to-width ratio, meaning that no simple formulation could predicate all possible outcomes. In terms of SPL in the streets, the building height did not contribute to the SPL of streets with large widths.[98] In Ostia, however, the upper limit on street widths does not reach the 'wide street' designation of Lee and Kang, at 27 m. As Appendix 2.1 shows, the overall widths of Ostian streets fall between the lower two widths of 6 m and 13 m. The RT30, which is the reverberation time for sound to drop by 30 dB, results show a range from 2.0 seconds (at 6 m) up to 7.0 seconds (27 m).[99] The range is a product of the differences in the overall volume of the street canyon. With a fixed height-to-width ratio, the reverberation times of the wider streets are longer due to the increase in the total volume of the street.

[95] Lee and Kang 2015: 74.

[96] Lee and Kang 2015: 74.

[97] Lee and Kang 2015.

[98] Lee and Kang 2015: 77.

[99] Lee and Kang 2015: 77; RT30 is the same measurement as RT60, but for a drop of 30 dB.

The overall height of buildings in Ostia has sparked debate and has implications for the dissipation of sound in streets. Literary evidence emphasises the concern of several emperors with safety and the height of buildings. Strabo reports Augustus' limitation of buildings to 70 Roman feet (around 20 m), while Tacitus documents Nero's reduction of building heights following the fire in Rome in 64 CE.[100] Pseudo-Aurelius Victor reports Trajan's further reduction of building heights to 60 Roman feet (about 17 m). With an average floor height in Ostia of 3.5m, the limitation to 70 and then 60 Roman feet would be a limitation to five or six floors.[101] There are no references to a specific number of floors for the buildings under the legislation and, in fact, the sources do not mention any buildings of five or six stories, a common height in scholarship.[102] Packer was one of the first to offer calculated heights for a majority of buildings, between 3-6 floors, in Ostia.[103] Packer, with Hermansen following suit, used the thickness of walls to estimate the height of buildings.[104] Storey tested Hermansen's rule of thumb against 1,273 wall thickness measurements in 308 buildings from Rome, Ostia, Pompeii and Herculaneum. No evidence beyond a fourth floor remains in Ostia.[105] Both Boersma and DeLaine reconstruct buildings to a third or fourth floor and the evidence from Rome of higher buildings are from instances that took advantage of the topography, being built against hills, to support such heights.[106] While Storey's testing did, in fact, display a correlation between thicker walls and higher building height, it did not prove to be a reliable predictive feature in the data set (59% classification errors). The miscalculation rates for the individual sites were lower, for Rome 52%, Ostia 22%, Pompeii 37% and 36% for Herculaneum. In Pompeii and Ostia, it seems that there was a certain level of standardised wall thickness, with only a centimetre or two differences between buildings with two, three or four floors. The reliance on standard measures for wall thickness can also be seen in the standardisation of building forms post-64 CE.

The conclusion that a majority of buildings were of three to four storeys at most can be tested against the known horizontal dimensions of the street. The findings will certainly vary from street to street, but a general range will provide the limits for sound propagation in the streets of Ostia. Street widths and heights were tested for SPL and RT30 measures (Appendix 2). The figures in Appendix 2.2 are based on a street canyon model developed by the University of

[100] Strabo 5.3.7; Tac. *Ann*. 15.43.

[101] Storey 2003: 8.

[102] Storey 2003: 8; five to six storey references, Carcopino 1945: 26; Claridge 2010: 58.

[103] Packer 1971.

[104] Hermansen summarises Packer's calculations forming a 'rule of thumb', Hermansen 1982a: 51, n. 27.

[105] Storey 2003: 13.

[106] Boersma et al. 1985; DeLaine 1995a; Rome, Storey 2003: 9-11.

Sheffield Acoustics Group.[107] One problem with the street canyon model is the misnaming of the axes, as the street length should be the Y-axis and street width the X-axis. Another issue is that the scale will change relative to the street being modelled so, that in this case where a large number of streets are modelled the scales will differ between the streets. These issues are part of the scripting of the application and could not be changed. However, keeping them in mind, the results are still useful in interpreting the changes to the street auditory field at various building heights.

Using the widths of 2 m, 3 m, 5 m, and 10 m and heights of one to four storeys the analysis was run with a 100 dB(A) sound 1 m x 1 m in the street (roughly the bottom left corner of the SPL and RT30 graphs). The top graph in Appendix 2.2 shows the SPL decay from the point-source in the bottom left corner. Despite the changing scales, the colours indicate 5 dB ranges, which form bands of various widths moving away from the point-source. In the narrowest streets, 2m in width, the bands form straight lines, as the sound will not reduce to the next 5 dB band before reflecting off the opposing wall. In these instances, it is moving down the street that the next reduction band will be crossed. The number of rectangular squares in each band correspond with the sound dissipation curves from figure 3.4 and if the graph where drawn in two-dimension would make sound dissipation curves from the point-source across the coloured graph. Thus, as the reduction bands of 5 dB get wider, they indicate gentler slopes in the sound dissipation curves.

The overall intensity of the sound, 100 dB(A), and the close proximity of the building façades in the 2 m wide graphs suggest that such high intensity sound will fill the lateral space of the street and the reflections off the facades will offset the sound dissipation curve. Sound intensity levels were not common in the streets, but enable certain interactions between the architecture and sound to be incorporated into the model, such as façade reflection. At 10 m widths, the opposite end of the street from the sound point-source has the greatest decay. Even at the same end of the street as the sound point-source, a decay of 20 dB(A) occurs by the middle of the street (5 m away). At the intensity level of 100 dB(A), the reduction in sound intensity to 80 dB(A), while being noticeable, is still not a significant drop. This shows the dissipation of sound in all directions from the point-source. At the narrower street widths, the reflection off the building façade effected the dissipation across the width of the street, as noted. In wider streets, this effect was not as prominent and sound dissipation would function in line with the sound dissipations curves in figure 3.4.

[107] See http://www.acoustics.group.shef.ac.uk Accessed 21 June 2017.

Individual buildings are not part of the model, as the height is fixed at the given floor level. In acoustic analysis, particularities are often reduced to general characteristics, as modelling all possible variations is too complex for the model. In this case, the floor levels function as averages heights, therefore creating graphs of trends in auditory fields as the building height increases. When looking at specific streets within Ostia, the street width will match a set of graphs from which different building heights can be selected. In this way, Appendix 2.2 serves as a comparative framework for the range of possible auditory properties within the specific context under discussion. This is in contrast to the mathematical model, which described the auditory field of specific spaces and only through comparison with all other models in Appendix 1 could potential trends be developed.

Another feature of the height-to-width measures is the extension of RT30 measures. These characteristics are modelled in the bottom graphs in Appendix 2.2 and have the same issues of misnamed axes, although in this case the scale is standardised. The point-source for the sound remains 1 m x 1 m from the bottom left corner of the graph. Again, at 2 m widths, there is a relative uniformity of low RT30 times, between 0-0.6 seconds. In contrast, at 10 m widths, the RT30 measures increase to 2.1 seconds. However across the various building heights the RT30 graphs remain the same, indicating that the changes are evident as the street widens, but not as it vertically expands. The difference in RT30 measures is a result therefore of the basic width of the street. The sound is produced at one corner of the street canyon, and direct sound will reflect off the opposite façade, as well as the façade behind the sound producer. The low level of absorption from the façade and ground will increase the RT30 when the sound is able to fill the street canyon. That is as the street widens the sound will fill the space with more pronounced reflections, which are evident in the increased RT30 values in the top left and along the right side (in yellow) of the 10 m wide graphs. These indicate instances were the reflected sound is more prominent than direct sound. This is a feature of wide streets, such as the Decumanus and N. Cardo Maximus, although it appears in a more limited fashion at the widths of 3 m and 5 m. This feature of increased reflected sound produces a different, although analogous hierarchy of streets, where narrow streets are differentiated from mid-size widths and wide streets. Again, this feature is separate from the sound dissipation, which is dependent on a height-to-width ratio, while RT30 values did not correspond to changes in height.

The importance of intersections, as nodal points in the street network, has already been noted in several street studies.[108] The correspondence between intersections, fountains, shrines, food counters, and benches all highlight the central role of intersections as gathering spaces in the Roman city. In acoustics, intersections create a complex sound field between the façades, height and width of streets and sound source locations. In a parametric study of intersection acoustics, Kang showed that multiple sources, or a source moving along a main street, had an average SPL drop of 9 dB in side streets.[109] Reflected energy from the side streets to the main street is negligible; however, reverberation in the main street is typically between 1-3 seconds, suggesting its importance when considering sound in the streets.[110] Changes to the height to width ratio, from 0.5 to 3, resulted in an average SPL variation of 3-8 dB.[111] In the case of Ostia, the 9 dB drop would correspond to particular intersections, those where streets met perpendicularly, namely Semita dei Cippi/Via dei Molini and the east Decumanus, intersections along the Via della Fortuna Annonaria (Regio 5), and the intersections north of the Forum. In cases where the streets are staggered, a further attenuation of 5-15 dB could be achieved.[112] These findings indicate the complexity of the sound field at intersections, especially where streets do not directly connect on either side of the intersection. All the intersections along the Via della Foce and west Decumanus are at angles to those main streets, producing more complex reflection patterns. However, in certain instances streets will connect across a main street, which will produce a decibel drop around 9 dB. The particularities of each intersection must be accounted for in order to adequately describe the acoustic properties and the decibel level drops will vary based on those particulars.

3.3.3 Entrances

The analysis of street acoustics requires an understanding of the façades and frontages that formed the walls of the street canyon, as well as the physical height of the buildings and façades. As discussed above, the paving served to reflect and absorb some of the noise caused by moving along the street. The façades and frontages acted as walls, influencing the reflection and direction of sounds. A total of 1,263 entrances and doorways are marked on the 1953 plan. Laurence calculated the number of streets with doorway occurrences in metres, comparing

[108] Cf. Laurence 2007; Ellis 2004; Stöger 2011b.

[109] Kang 2001: 292.

[110] Kang 2001: 292.

[111] Kang 2001: 293.

[112] Kang 2001: 293.

Pompeii with Rome and Ostia.[113] While not discussing the location of the streets, the calculations indicate a higher density of street front utilisation at Ostia than at Rome, and nearly double that of Pompeii.[114] The median occurrence of doorways in Ostia was every 3.2 m in comparison with Pompeii's median of every 7.3 m.[115] Laurence notes the particularities of the excavations at Ostia, which centre on the east and west Decumanus and Via della Foce.

The overall number of entrances can be divided further based on the type of threshold.[116] Packer divided thresholds into two categories: wide openings, usually closed with shutters and giving entrance to shops, and all other narrower doorways.[117] Shop entrances have wide, direct entrances to the street and passing traffic, in contrast to the narrow domestic doorway.[118] The shop doors averaged 3 m in width, 5 m being the widest (3.17.5), and had heights between 2.9 m and 3.5 m.[119] A 'night door', a single door set on one end, predominately on the right side (when facing the door from the street), allowed access when the shutters were in place.[120] The wide, direct opening of shop doorways led into the main room, sometimes with mezzanine rooms or back rooms. Sounds produced within the space thus interacted mainly with the central shop room. Shop doors all had travertine thresholds with grooves for wooden shutters. Ellis argues that the late first century CE saw a reorganisation and standardisation of the streetscape, following the 64 CE fire and Neronian building codes.[121] This standardisation of street fronts included widening of streets and building of porticoes, as well as the preference for right side entrances into shops. The preference for right side openings would indicate that furniture, such as a counter, would be set on the left side. This was in contrast to Pompeii, which displays a more even placement of counters, although often guided by visual preferences and attraction.[122] The changes in preference from Pompeii to Ostia, Ellis argues, was part of a developing 'cult of the right', or superstitious preference for the right.[123] The regularity of wooden shutters, and their systematised layout, suggests that the acoustics characteristics of

[113] Laurence 2008: 104, fig. 12.

[114] Laurence 2008: 95-6.

[115] Laurence 2007: 107.

[116] Shops, Hermansen 1982a: 125-83; Ellis 2011; apartments, Packer 1971: 21-31.

[117] Packer 1971: 21.

[118] Wallace-Hadrill 1994: 118; MacMahon 2003: 58-9; Proudfoot 2013: 96-7; cf. Ellis 2011.

[119] Packer 1971: 21.

[120] On 'night-door', Packer 1971: 21; 502 on the right, 37 on the left giving 93% of the total, Ellis 2011: 165.

[121] Ellis 2011: 169-171.

[122] Ellis 2011: 164.

[123] Ellis 2011:171.

shop doors would vary little from shop to shop. Instead, it was the presence of other architectural features, such as porticoes, or the dimensions of the street that differentiated the auditory experience, discussed below (3.3.6).

The narrower doorways led to more complex structures, such as apartments, upper stories, houses or warehouses. The narrower doorways are on average just over 1 m wide by 3 m high.[124] These doorways tend to be slightly wider than internal doorways, which average 1 m in width.[125] Proudfoot categorises the doorways in Pompeii into four types: 1) direct entrances, 2) entrance vestibules, 3) entrance vestibules with side rooms or side passages, and 4) entrance passages with or without side rooms.[126] Only direct entrances had a single door marking the threshold. Types 2-4 all have double doors, one at the entrance from the street and another at the inner threshold to the interior space. Locks and security measures are more evident on the outer doors, closer to the street, while the inner doors rarely have security devices.[127] The majority of doorways in Ostia are direct entrances (type 1) with a selection of entrance passages (type 4), although they tend to be shared entrance passageways. The emphasis, therefore, is on segregation, despite a limited amount of shared space. The shared entrances all display thresholds with locking abilities. Most common are hinged doors opening inward, which could be secured with a cross board or, in rare cases, a vertical bar.

In terms of wide entrances in Ostia, the main thorough routes have the largest number of wide entrances (Fig. 3.5). Of note in figure 3.5 is that streets ranked 6-10 are all north-south

[124] Packer 1971: 22.

[125] Packer 1971: 22.

[126] Proudfoot 2013: 95.

[127] Proudfoot 2013: 103.

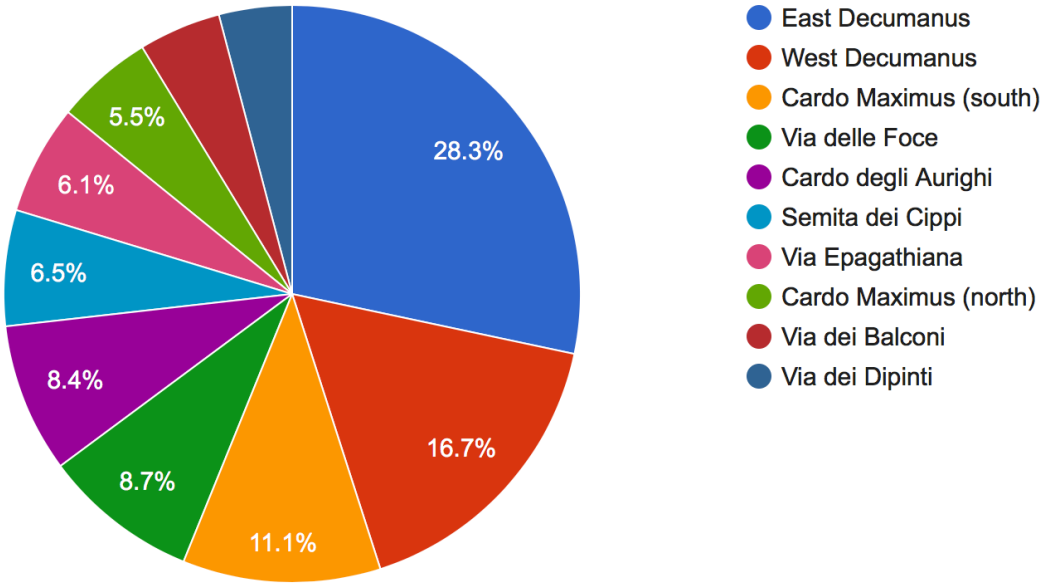

Figure 3.5 Top 10 streets with highest total of wide entrances. (Author)

in movement direction, while only the Semita dei Cippi is south of the Decumanus. As noted in relation to the specific heights of buildings, the acoustic modelling of the streets are more reliant on general trends in material usage, than with specific instances of every form. In only two cases, the Via dei Balconi and Via dei Dipinti, do the streets lack porticoes for some portion of the street. The importance of porticoes for the separation of noises here indicates a connection between shops and portico façades. In this case, the predominance of wide doors shut with wooden shutters will influence the acoustics more, than if there was a predominance of narrow doors.

Frontages and thresholds are usually studied for their architectural and social connotations.[128] While visual studies focus on the monumentality of frontages, here the differentiations in entrances are analysed in terms of acoustics. The connection between street front and interior was a liminal space, which had its own superstitions and rituals.[129] The threshold of sound is similarly liminal, as sounds regularly bleed through visual boundaries and change over distance. Thus, frontages and thresholds serve as one part of the mediation between the street and interior spaces.

[128] Stöger 2007; Lauritsen 2011.

[129] See Ellis 2011.

It is now common for ancient historians and archaeologists to assume that doors were left open and that the alignment of artistic works corresponds to sight lines from outside the structure. However, this idea is based on the common *atrium*-peristyle layout of Pompeii. In Ostia, the layout of various structures had different formal features. These narrow doorways were fitted with two wooden leaves, as opposed to shutters placed in shop entrances.[130] The thresholds usually have two pivot holes on which the leaves turned and opened inward, evident by the raised outer edge of the threshold. Shared entrances in Ostia, usually open into a small, shared space, from which one has to turn 90 degrees to enter individual apartments. The perpendicular setting of the individual entrances argues against direct visibility into the apartment space. As will be argued in the next chapter, the lack of visibility was off set by an auditory openness of the windows and façades.

The experience of noise around bars would be a mixture of noise from the streets, bar and anything else in the area, creating typical background noise. In several articles, Ellis has explored the relationship of frontages and streets through the analysis of bars and food selling shops in Pompeii.[131] The bars were at locations on main routes and intersections.[132] As noted above, intersections were places of complex auditory fields that mixed direct sounds from the various streets, with reflected sounds in the others. In contrast to the decibel level drop around corners, in the range of 5-15 dB, the presence of bar noise will mask the effect. Only eight of the thirty-two bars were located at intersections, while only two counters were located on the right side of the threshold.[133] The noise of the bar, if it reached the background noise threshold, would cover the particular sounds emanating from the streets off the intersection. A significant number in Ostia are found along the west Decumanus between the Porta Marina and intersection of the Via della Foce and east Decumanus.[134] Bar noises, along those streets, would break up the continuous nature of the streets. Placement at intersections and on main routes would mask certain auditory effects, alongside dividing the street space into smaller sections.

3.3.4 Windows

In a similar fashion to entrance doors, windows differentiated the acoustic properties of façades. Wooden window treatments had similar acoustic properties to shutters and doors,

[130] Lauritsen 2011; Proudfoot 2013.

[131] Ellis 2004; 2011.

[132] Ellis 2004: 378-9; similar finding at Ostia, Hermansen 1982a: 185.

[133] Ellis 2011: 164

[134] 11 along the street (28%), 3 around the Porta Marina, Hermansen 1982a: 185.

whilst the use of glass in windows gave them a distinctive acoustic character. There were three forms of window treatments with acoustic effects: open windows, shutters and glass panes. Open windows were uncovered, open to air and elements, and have a standard RT60 rating of 1. All sound through an open window would dissipate into the surrounding area, and none would be reflected back into the room. Window shutters were usually made of wood, and had similar acoustic effects to doors, as wooden shutters were constructed in an identical fashion to doors.[135] Two preserved shutters were discovered between 1929-1931 when Lake Nemi was partially drained to recover two barges constructed in the time of Caligula (37-41 CE).[136] The better preserved shutter measured 1.3 m x 0.45 m and would fit a window of 1.3 m x 0.90 m, which fits the average window measurements from Ostia.[137] A similar pair of hinged window shutters can be seen at Herculaneum from the north side of the Decumanus.[138]

Ancient glass is composed of similar materials to modern forms, and it is the thickness of the panes that influences the auditory properties the most. Early Roman windowpanes were usually cast on a flat stone or roller-moulded, which would be around 30 by 60 cm, 5 mm thick on the edges and 2 mm in the centre.[139] As with other materials, the acoustic effects of glass will not diminish over time and its acoustic properties remain intact as long as the glass itself is preserved.

Glass windowpanes were made of glass and reflected some of the sound back into the room, while also absorbing the remaining sound energy (see Tab. 3.1). The low absorption coefficient measures for glass, in comparison to brick, concrete or wood, means that glass will absorb less of the sound energy than the other materials. It is worth noting that glass does show a distinctly different frequency response, a relatively stable decrease in absorption, with an increase in frequency. As the frequency gets higher, corresponding to a higher pitch, glass will absorb less, reflecting more high frequency noise back into the space. This is in contrast to the general trend of curved frequency responses of other materials were the high and low frequencies are both reflected back into the space. In experiential terms, noise in the speech frequency range and higher will be reflected off the glass, creating a high frequency ring. The effect can quite noticeable, commonly called 'slap-back'.[140] Another interesting effect of glass is

[135] Ulrich 2007: 191-2.

[136] Ulrich 2007: 192, fig. 9.14.

[137] Ulrich 2007: 192.

[138] Ulrich 2007: 194, fig. 9.15.

[139] See Pavolini 2010: 68, fig. 22, 71 for an example from Ostia; Foy and Fontaine 2008.

[140] Everest and Pohlmann 2009: 493.

the product of what is called a *resonant frequency*, which indicates a frequency at which the material resonates at the same cycle as the sound frequency. Thus, the sound frequency and glass resonate, or vibrate, at the same frequency reducing the AC of the glass. The effect is that sound at that frequency will pass through the glass without being diminished by the AC. Other materials will create the same effect, but with glass the frequencies tend to be at common high frequencies enabling the effect to happen more regularly. Further discussion of the effect will be covered in the following chapter in the context of apartment receptions rooms, which had significant portions of walls covered in glass.

3.3.5 Balconies

Another feature of façades found, in limited quantities, in Ostia are balconies. The evidence suggests that there were several forms of balconies that extended into the street in Ostia. The three types are differentiated by the supports and form of vaults.[141] The most basic consisted of wooden beam supports that did not have vaults, but instead supported flat wood flooring. Two examples of this type are visible (Tab. 3.3): one, which gave the Caseggiato del

Façade	Type
1.2.5	Barrel vaults, travertine corbels
1.2.6	Wood beam supports
1.3.3-4	Groin vaults
1.6.2	Barrel vaults, travertine corbels
1.7.1	Barrel vaults, travertine corbels
1.8.3	Groin vaults (unpreserved)
1.9.3	Wood beam supports
1.9.3	Groin vaults (unpreserved)
3.14.4	Groin vaults
3.10.1	Groin vaults

Table 3.3 Location and type of balconies in Ostia. (Author)

Balcone Ligneo (1.2.6) its name, and the other from the Caseggiato del Larario (1.9.3).

[141] *NSc* 1914: 588-9; 1923: 16-8.

The second type consists of a balcony supported by a row of barrel vaults with travertine corbels. Three of these types are evident in Ostia, and they differ in their construction despite a similar appearance. One is located on the Via della Fortuna, and wraps around the west and south façades. This balcony is integrated into the building structure, with the barrel vaults in the shops continuing out past the façade to support the balcony. The travertine corbels do not support the balcony, and instead serve a decorative purpose.[142] The twentieth century restorers put in place the current pier supporting the first corbel on the west façade.[143] The pier originally belonged to an arch that spanned the Via della Fortuna, dated to the Antonine period.[144] In the case of the Caseggiato del Termopolio (1.7.2), the balcony was a later addition added onto the façade.[145]

The third category, balconies supported by groin vaults, is the most common of the preserved balcony types. Of the five known cases, two were not reconstructed due to the state of the buildings at their excavation. Along the south and west façade of the Caseggiato di Diana (1.3.3-4), and the east side of the Via Epagathiana, run continuous balconies of the same type, wrapping the two façades in a continuous visual image. Meiggs saw these as 'not true balconies' due to their narrow width, lack of correspondence with floor levels and inaccessibility from inside the building.[146] However, in acoustic terms, the balconies produced more complex surfaces for noise reflection. The extension of the balcony into the street, at any distance, broke up the surface area of the façade, altering the acoustic character.

The combination of façade materials, doors, windows and balconies make up the principal elements of building façades. The analysis of these elements provides a basic understanding of the sound field in front of buildings; however, as indicated, the overall dimensions of the façade are of equal importance to the sound field. The main acoustic influence of balconies is similar to that of porticoes or arcades. The architectural features form a 'pseudo' covering, enclosing the space under the balcony. The partial enclosure of the space will therefore reflect noise within the area under the balcony. In contemporary auditoria, balconies were experienced as 'inferior' acoustic positions within the room. The acoustic experience under balconies is a 'dull sound at low frequencies, [which] make the listener feel as though the sound is coming through a

[142] Packer 1971: 34.

[143] Packer 1971: 34; see images in Calza 1914: 566, fig. 10.

[144] Packer 1971: 34.

[145] The images in *NSc* 559-60, fig. 8; 1915: 325, fig. 1; Packer 1971: pl. 6, fig. 12 show the unrestored building, which clearly indicates that the surface behind the balcony was already brick faced and complete before the balcony was constructed, Packer 1971: 34 n. 87.

[146] Meiggs 1973: 240.

window'.[147] This acoustic experience is due to the diminished direct and reflected sound of the balcony opening, and the limited acoustical space under the balcony.[148] The 'through a window' effect of the heard sound is illustrative of the disconnection between visual cues and sonic experiences. The heard noise creates an experienced space that at times does not relate to the physical shape of the space the sound is heard in. This mental disconnection is also experienced in highly reverberant spaces, like cathedrals, where the long reverberation time gives a feeling of expanding space in comparison to the minimal reverberation heard in outdoor settings, with the highest levels of expansive space. The effect is a product of reverberation, which requires enclosed space. Here, again, the body serves as a measure of the acoustic experience, and is limited by the range of frequencies and the ability to differentiate time scales. In an outdoor setting, with a short overhang of a balcony, these effects would have been significantly reduced. In the open air, there will already be a lack of reflected sounds, reducing the effect in the under balcony space. The short depth of the balcony will further reduce the acoustic isolation, which corresponds with the 'through the window' acoustic effect. The result, therefore, is a minimal effect on sounds produced outside of the space under the balcony, with a slight damping experienced as a dull sound at lower frequencies.

Where the noise was produced in the space under the balcony, the effect would be more noticeable. In this case, the balcony would serve as a reverberant material reflecting the noise back into the space under the balcony. This effect is balanced by the open space around the area under the balcony, in which noise would dissipate. The reflections off the façade and bottom of the balcony will be more noticeable at lower frequencies, and in close proximity to the façade. Depending on the intensity of the sound, as well as the frequency response, certain noise will feel more confined within the area under the balcony, as the reflected noise is more audible. For example, a fight or argument would fill the space under the balcony, and the reflecting noise would increase the overall sound level in the surrounding areas. This psychoacoustic characteristic is dependent on the level of background noise, which can ultimately drown out the nuanced effect of the balcony if loud enough.[149] Conversations, at certain times, will create an intimate feeling, which is dependent on low background noise and perceived isolation caused by the overhang of the balcony. While moral judgements explored in chapter two were the basis for the literary urban image, the effect, in this case, would potentially produce ephemeral divisions of space. Low background noise will occur at times when low numbers of people are

[147] Watanabe and Ikeda 2011: 1.

[148] Watanabe and Ikeda 2011: 1.

[149] See, for example, Sen. *Ep*. 56.

present in the area. The effects are therefore cyclical; the isolated experience of conversation outside under the balcony is dependent on the physical isolation of the participants from other noises, while the physical isolation creates a feeling of sound isolation experienced. The distribution of balconies indicates that this would only be likely to occur in particular places, such as the Via della Fortuna, where a portico lines one side of the street and balconies overhang the shops on the other. In this case, the narrow width of the street and wide coverage by the portico and balconies would create an enclosed auditory space. It was the combination of narrow width, portico frontage and balconies that would produce potential feelings of isolation, despite being one street over from the monumental north Cardo Maximus.

The discussion here has focused on the auditory effect created under the balcony, but the balcony itself was the place for social interaction. Cowan emphasises the role of balconies in the formation of urban gossip in early modern Venice.[150] He notes that it was not sight, but sound, or one of the other senses, that drew people to the balcony for social interaction; whether in order to see what caused an unexpected sound, or at the calling of an acquaintance.[151] In the context of Ostia, balconies were part of the auditory field of the street, and had a direct connection with that field. Sounds in the street would be heard on the balcony, and balconies served as points of contact with the street below. Physical distance from the street was bridged through the interjection of sound. Boudin, discussing street hawkers in nineteenth-century Paris, notes that the cries of hawkers were directed at balconies and open windows. Such social interaction over the physical separation between street and first, or higher, floors was mediated precisely by sound, as it carried over the distance.

3.3.6 Porticoes and Arcades

The separation of movement was done simply, with sidewalks, but also in a more monumental form, with porticoes or arcades. The vaulted structures with columns or piers along the street provided shade and moved the pedestrian traffic closer to the shops that lined the streets. Porticoes appear in Ostia, although in an uneven geographical distribution across the town. Beginning in the early second century CE, several large-scale building projects, with associated porticoes, began to reshape the town's urban experience.[152] Unlike benches, fountains or shrines, porticoes create a *space* of experience defined by the architecture. The

[150] Cowan 2013.

[151] Cowan 2013: 243.

[152] See DeLaine 2002 for discussion of large-scale building at this time.

semi-enclosed area was experienced as acoustically separated space from the roadway beyond, even as sounds will pass between the two auditory fields. In this way, the two auditory fields influence each other. Sounds from one bleed into the other.

The placement and arrangement of shops in Ostia were part of the emerging urban experience of street space following the rebuilding of Rome in the second half of the first century CE. In the literary sources, the rebuilding following the fire of 64 CE created wider streets with porticoes, which resulted in more direct sunlight into the previously narrow streets of Rome according to Tacitus.[153] While not described as an auditory experience, the increase in width and new frontages were part of new form of street experiences that were reshaped the embodied knowledge of Roman streets. At Ostia the process begins in around 116 CE, with the reconfiguration of the north Cardo Maximus and area north of the Forum. It is interesting to note that it is not the east Decumanus that leads the way, as the monumental portico there was part of the later (127-130 CE) Terme di Nettuno project. The importance of the Decumanus has been noted for some time; however, the north Cardo Maximus as the monumental entrance to the town has received much less attention. The monumentality was not limited to its visual aesthetics, but included its auditory experience as well.

Hermansen counts twenty-nine *insulae* in Ostia with porticoes surrounding them, and calculates the height by assessing the load bearing elements and the width of the portico.[154] Packer notes the high frequency of porticoes, and their ability to support upper levels.[155] Out of the forty-seven structures along the east Decumanus, fourteen have porticoes, with four

Frontage	Street	Description
1.1.4	Via dei Molini	
1.5.2	Cardo Maximus (north)	Loggia
1.6.1	Cardo Maximus (north)	Loggia
1.7.1	Via d. Fortuna	
1.8.1	Via d. Misuratori	
1.12.7	Semita dei Cippi	
1.12.10	Cardo Maximus (south)	
1.14.2	Via della Foce/Via Epagathiana	

[153] Tac. *Ann*. 15.43.

[154] Hermansen 1982a: 222.

[155] Packer 1971: 31.

1.20.1	Cardo degli Aurighi	
2.2.6	Decumanus (east)	
2.3.1	Decumanus (east)	
2.4.1	Decumanus (east)	
2.8.1	Decumanus (east)	
2.9.5	Via dei Molini	
2.9.6	--	
3.2.3	Decumanus (west)	
3.9.24-6	Cardo degli Aurighi	
3.10.1	Cardo degli Aurighi	
3.16.6	Via della Foce	
3.17.5	Via della Foce	
4.2.2, 3	Cardo Maximus (south)	Travertine blocks
4.5.1	Decumanus (west)/Via del Pomerio dei Iside	
4.7.2	Decumanus (west)	Raised above street
4.8.5	Via d. Cartilio Poplicola	
4.9.1	Decumanus (west)/ Via d. Cartilio Poplicola	Loggia
5.5.1, 2	Semita dei Cippi	
5.11.4, 7	Decumanus (east)	Raised above street
5.12.1	Decumanus (east)	
Unidentified building	Decumanus (east) (northeast of Porta Romana)	

Table 3.4 Arcades and porticoes in Ostia. (Based on Packer 1971)

being on a relatively large scale (Tab. 3.4).[156] Other streets with porticoes include the north Cardo Maximus, Semita dei Cippi, Via della Foce and the Cardo degli Aurighi (Tab. 3.5).

Beyond separating movement, porticoes affected the acoustic character of the street and shop spaces. The permeable yet covered space of the portico acoustically separated the space to a certain degree. The architectural form and setting of porticoes and arcades would have had implications for movement, alongside the experiential difference evident in the acoustics. Colonnaded walkways were common and enclosed porticoes were also destinations for the

[156] Large porticoes: 2.2.6; 2.3.1; 2.4.1; 4.7.2, Packer 1971: 32.

inhabitants of Rome.[157] As Kostof pointed out, the arcade and portico were a means of negotiating the unavoidable tension between public and private spaces along the street.[158] The space of the portico served as an extension of the shop space into the street, without blocking movement in the carriageway. The overflow of goods from shops onto the street was a constant issue.[159] Porticoes provided a partially enclosed space that brought street traders, walkers and shop owners together.

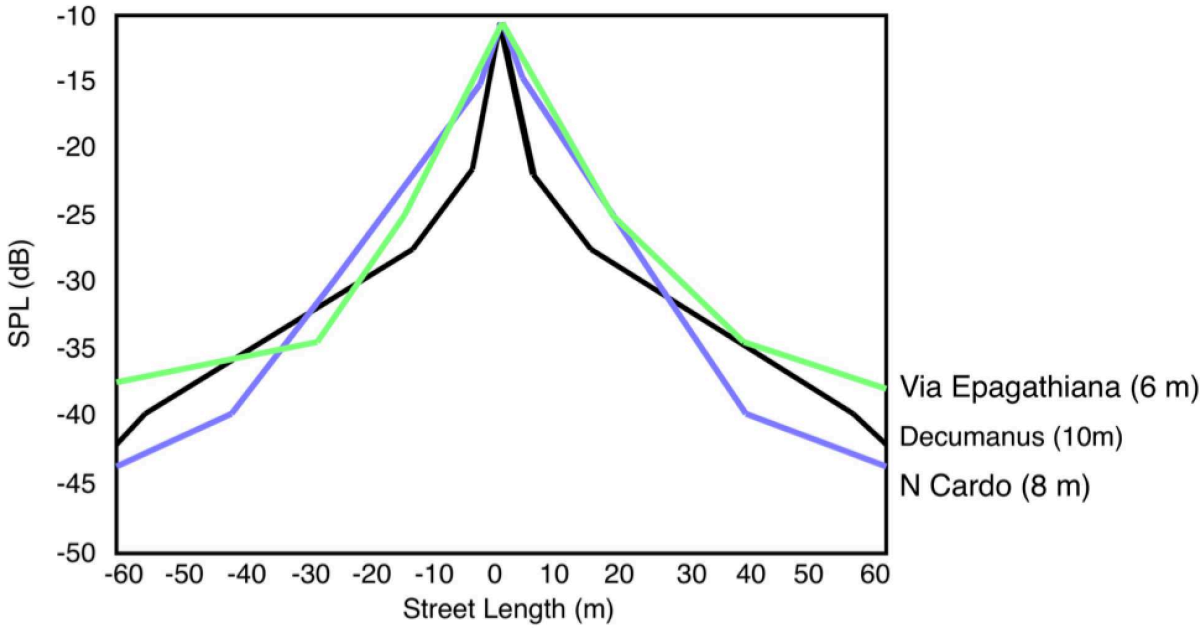

Figure 3.6 Sound dissipation on three portico streets: Via Epagathiana (green), Decumanus (black) and N. Cardo Maximus (blue). (Author)

The acoustic properties of street canyons, for the Via Epagathiana, east Decumanus and north Cardo Maximus, were modelled based on the materials and dimensions of the street in figure 3.6. The sound dissipation on three streets, all with porticoes along some part, is included in the model. Again, a hypothetical noise is placed at the mid-point (0 on the x-axis) in all three streets and each graph is aligned to the same mid-point. The sound dissipation curve for the Decumanus resembles the curve in figure 3.4 for the 10 m wide street. The Decumanus is the widest (10 m), while the north Cardo is the only street with porticoes on both sides for the whole length (130 m). What the graph indicates is a steep dissipation of sound in the Decumanus, within the first 10 m from the point-source; while north Cardo mimics this

[157] Macaulay-Lewis 2011: 275.

[158] Kostof 1992: 216.

[159] See section 2.3.3.

experience due to the addition of porticoes, its dissipation curve is less steep, but drops below the Decumanus at around 30 m from the sound. The porticoes, thus, produce an even dissipation decline along the street up to a point, around 40 m from the point-source, at which the dissipation curve mellows. In the case of the Via Epagathiana, with a portico on one side and for a limited length, the dissipation is skewed on the left side of the graph dropping below the Decumanus curve at around 25 m from the point-source, while to the right the dissipation has a more steady curve, never dropping below the Decumanus dissipation curve. The comparison with the Decumanus is insightful, as it displays the ways in which the presence of a portico will alter the experience of a street, as well as showing that the Decumanus, while being at the top of the hierarchy in terms of street width, is not an extreme within dissipation curves.

The experiences of sound in all three streets, however, show similar general trends. Sound dissipation will have a constant steep decrease to a certain point, based on the width of the street and any additional features, from which the dissipation drops at a more relaxed rate approaching the inverse square law line. These trends are in part the product of the physics of sound and its movement in space and time, however as shown here, architecture can influence the physical phenomena, producing particular experiential spaces.

To contextualise the methodology discussed in this section, two streets will be analysed to show the possibilities of the approach. The two streets, the north Cardo Maximus and Via degli Augustali, are different in several respects, as will be shown. Chronologically, the north Cardo is the earliest large-scale redevelopment with a portico as a defining feature in Ostia (116 CE). Porticoes are constructed along the neighbouring Via dei Misuratori del Grano and Via della Fortuna the next year (117-8 CE), while the forum to the south is completed in the 120s.[160] Towards the end of the second century CE, the Via degli Augustali underwent a series of

[160] See DeLaine 2002 for dates.

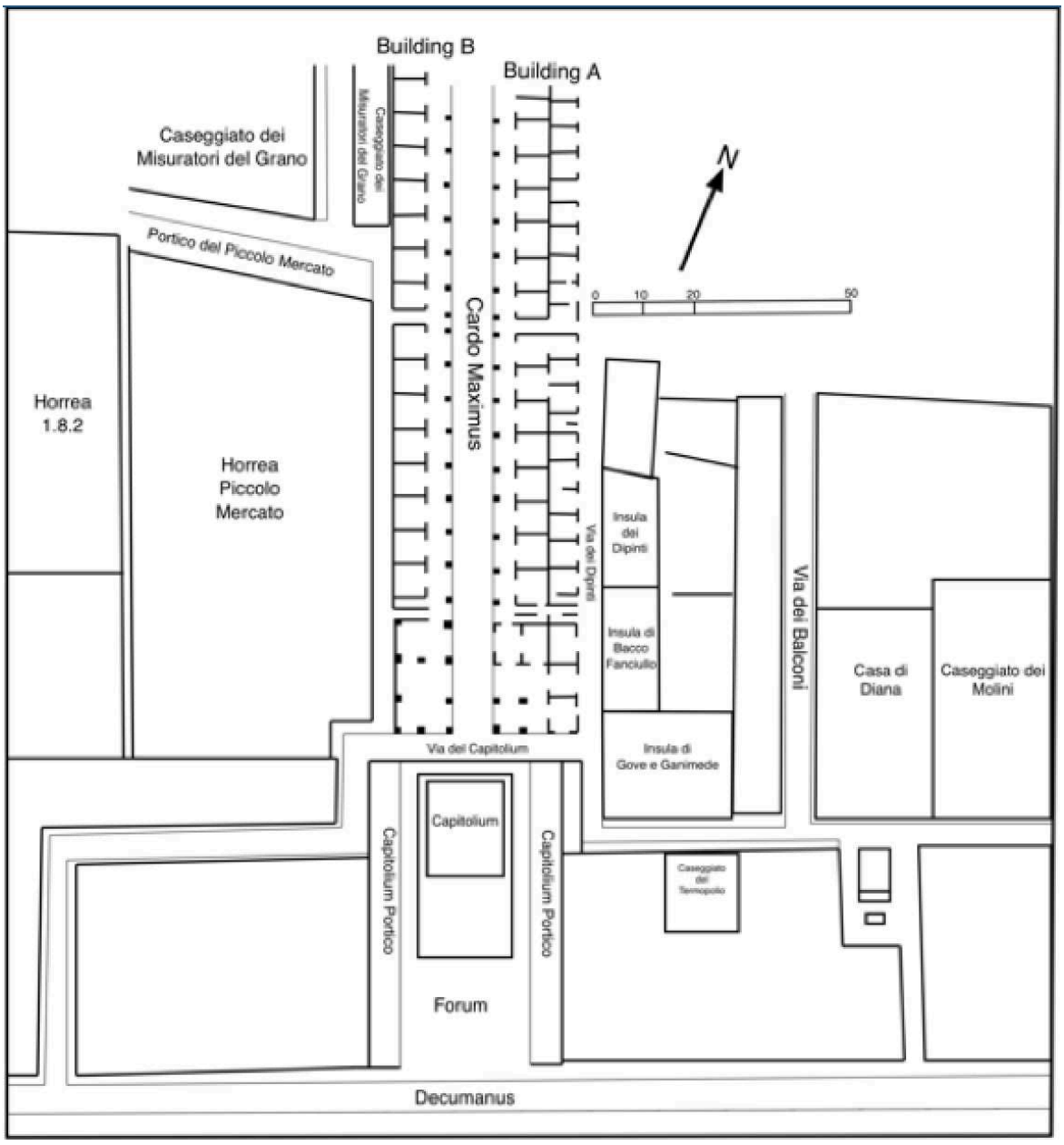

Figure 3.7 Portico di Pio IX and surrounding area. (Author)

independent alterations that transform the auditory experience of the street. These alterations were in sharp contrast to the unified porticoes and shops of north Cardo Maximus and comparisons between the two streets overlook the particularities of the spatial and temporal setting of each. In short, the north Cardo Maximus presents a monumental entry experience, fostering movement in the first third of the second century CE. In the final third of the same century, the Via degli Augustali was closed off from the Decumanus, creating a locally focused area. A simple trajectory from the north Cardo Maximus to the Via degli Augustali is not being

advanced. Instead, I argue, that the experience of monumental streets, like the north Cardo Maximus, opened up new forms of auditory street experiences and the Via degli Augustali displays one reaction to such experiences.

3.4 North Cardo Maximus

The building of the Portico di Pio IX changed the movement between the Forum and Tiber. The north section of the Cardo Maximus was exceptional in certain respects: at roughly 130 m in length it was the only street with porticoes fronting it on both sides for the majority of its length, and it was the second widest street in the city, at 8.11 m. Its building was the likely occasion for the realignment of the north Cardo, as the earlier first century BCE Forum temple respects the earlier Cardo location leading to the gate in the *castrum.*[161] The change also resulted in a considerable rise in ground level, from 1.40 m to around 2.40 m above sea level, which corresponds with a section of road under the east portico flanking the Capitolium.[162] The raised ground level suggests that the Cardo and the inner pomerial road, located under the Capitolium portico, originally intersected under the later Capitolium.[163] The Capitolium is not centred with the realigned north Cardo, suggesting a later building than the Portico di Pio IX.[164] As noted above, the Portico di Pio IX was the first large-scale building project of the second century and is dated by brick stamps to 116 CE.[165] Directly following the Portico di Pio IX, the Piccolo Mercato (1.8.1), Caseggiato del Balcone a mensole (1.6.2), and the Caseggiato dei Misuratori di Grano (1.7.1-2) were completed in 117-118 CE, and the Capitolium and flanking porticoes were later additions.[166] Thus, the realignment of the north Cardo linking the Tiber and Forum, and the building of the Portico di Pio IX, began a process of reorganisation that ended with the later Capitolium and extended the Forum porticoes.[167] The process of reorganisation was intertwined with the sounds of construction and the acoustics of the new street.

The noise of this area, however, began before the building was completed in the 120s CE. The construction of the Portico di Pio IX and its neighbouring buildings was on such a scale

[161] Calza 1953: 104, 130-2.

[162] DeLaine 2002: 96-7.

[163] DeLaine 2002: 97.

[164] DeLaine 2002: 99.

[165] DeLaine 2002: 64.

[166] DeLaine 2002: 64.

[167] See Lavan 2012.

[REDACTED]

Figure 3.8 North Cardo Maximus SPL and RT30 for conversation noise (65 dB(A)) in the centre of the street. (From Acoustics Group - University of Sheffield http://www.acoustics.group.shef.ac.uk/asalink.php)

that the movement of materials, goods, and workers would have started the monumental process. The individual suppliers of brick for each building argue against a single patron, such as an emperor, instead suggesting urban regeneration undertaken by different patrons.[168] That said, continual building between 116 into the 120s would mark out the region as it developed. Noise, in particular construction noise, would mark the transformation of the area from its previous form into the twin rows of shops, porticoes, and the neighbouring warehouses. As discussed in the introduction, construction materials were brought to the town from the surrounding region using both the Tiber and road networks. These materials required both technological and manual power, requiring a variety of resources beyond the basic construction materials.

Once constructed, the Portico di Pio IX noise would also shift from construction to functional usage noise. The sounds and levels of noise along the Cardo further quantify the social importance of the street. Noise along the street was primarily related to work, either retail or commercial noise. The distinction is clearly arbitrary as commerce and retail overlap in several key manners, however it does distinguish two primary purposes of the noise. Retail noise is the noise for the sale of goods and is mainly focused on the voice. Street hawkers, criers and peddlers use noise to sell their goods. Street traders and hawkers commonly used portico space for temporary stalls, as is displayed in a pair of reliefs from Rome depicting the sale of clothes.[169] Food stalls are depicted in a series of reliefs from Ostia, selling a variety of fruits, vegetables and slaughtered animals.[170] The more transient forms of commerce, street traders and hawkers, also utilised the porticoes and streets to sell goods, likely acquired from the docks or warehouses in the vicinity, so the street would be full of the cries of sellers.[171]

In the case of retail noise, the human voice limits the range and clarity of shouts. The competition for attention (something Seneca points out, *Ep*. 56.2) motivated sellers to cry out so

[168] DeLaine 2002: 70.

[169] Kampen 1981: 98; George 2006: 24.

[170] See Kampen 1981: 52-64.

[171] Holleran 2011a: 254-5.

that they might stop passersby. Haggling and bartering were commonly used in settling the prices for goods, and these interactions of buying also required sounds.[172] Whilst we may not be able to replicate these sounds perfectly, they can be approximated, and their impact on the aural architecture of the shops modelled using the AC and RT60 measurements outlined earlier. Normal conversation is in the range of 55–66 dB, whilst shouting tends to be between 72–80 dB, sometimes higher.[173] There is a noticeable shift in the frequency range for loud and shouted speech, especially in men. This means that at louder conversation levels sound energy is produced in high frequencies. The frequencies do not reach the levels at which absorption increases, as the highest energy is in the range of 1250–1600 Hz, meaning that although higher in perceived pitch, the shouts are not absorbed at higher levels by the buildings along the street. As seen in the sound dissipations curves (fig. 3.6 and fig 3.8), the north Cardo Maximus has distinctive acoustic properties associated with the presence of the porticoes. The street space has a rapid dissipation along the length. Shouts or other noises made at a fixed point, a point-source, would diminish considerably as one moved away from the source (evident in the transition to different colour bands in fig 3.8). This is a space open to various shouts and cries, as the invisible boundaries of the sound dissipation were closer in proximity to source. The high ratio of open to closed area of the street (55%) is important in the acoustic properties seen here.[174] In contrast, the Via della Fortuna, one street to the west, was a narrow street at 2.87 m and was lined with a portico on one side and a balcony overhang on the other. A shout in the street would fill the pseudo-enclosed space and the dissipation would have been prolonged in comparison to the north Cardo. Yet, these two streets were part of the redevelopment of the area. What the north Cardo allows for acoustically is a multiplicity of noises to fill the space, as the space itself creates a need for proximity to hear clearly.

The peaks in retail noises related to peaks in activity along the street during the day and into the night, whilst the types of sounds related to the tasks and duties being performed. At dawn the shops would open; the wooden shutters would be taken down and merchandise arranged at the front.[175] The noise of opening wooden shutters and moving various goods would dominate. By the second hour, the shops would have been open, and the law courts were in session from the third hour.[176] The thresholds between the brick piers alongside the Cardo

[172] Sen. *Ep*. 42.8, *Ben*. 6.17.1.

[173] Olsen 1998.

[174] Ratio, DeLaine 2005: 41, fig. 3.8.

[175] *Dig*. 43.10.1.3-5; see also Mart. *Ep*. 7.61.

[176] Suet. *Clau*. 34.2; Mart. *Ep*. 4.8; Laurence 2007: 159-60.

suggest that these spaces could have been closed off, possibly to protect goods after hours. Just around the corner from the Cardo was the Caseggiato del Termopolio (1.2.5), a large food vendor taking up three shops on the ground floor. Late in the day, the bar would be busy serving food to those in the area.

The rhythms of sounds that structured the street activity were also dependent on the number of people on the street. Packer suggests building A (1.5.1–2) of the Portico di Pio IX was four stories, with twenty-nine ground floor units, eighteen on the first floor and twenty units on the second and third floors.[177] This gives the building eighty-seven total units and a population of 348. Building B (1.6.1) had fifteen units on the ground floor, seven on the first, and nine on the second and third, making a total of 40 units and a population of 160.[178] In terms of the total population, the quasi-steady noise level is in the range of 104–107 dB, a loud noise level. The peaks could potentially hit 110 dB, which is comparable to noise levels at modern sporting events and rock shows. Compare this with the crowd noise predictive measurements for buildings A and B in the north Cardo. The relative noise levels are lower than the total population predictions, but still in the top 24% for average predictive measures in buildings (41 out of 171 units). The acoustics of the shops would filter out some of this 'crowd' noise, although the shops themselves could do little to block unwanted sounds, since the wooden shutters reflected minimal levels.

In contrast, commercial noise is the noise of production. Manufacturing noises, noise of moving goods or materials, and construction noise are examples of commercial noises. Porters (*saccarii*) loaded and unloaded ships, moving between the Tiber and warehouses in the area. Unloading of ships potentially made noise at the north end of the street, along the Tiber. Even if their ships were unloaded closer to the harbour basin, the movement of goods into and out of the warehouses would mark the day.

Spatially, the Portico di Pio IX was the western edge of an multifunctional area, bordered by three *horrea* to the west of the street, the Piccolo Mercato (1.8.1), Horrea Epagathiana (1.8.3), *horrea* (1.8.2) and the Grandi Horrea (2.9.7) to the west. The warehouses to the west of the Cardo would have been active with the noise of workers piling and storing goods, as well as potential retail noises of selling directly from the warehouse rooms. As noted, the Via della Fortuna, despite having similar architectural features, has a dramatically different acoustic character producing different potential usages for the street. The ephemeral auditory boundaries evident in the acoustic properties were part of the social practices that separated

[177] Packer 1971: 80.

[178] Packer 1971: 80.

retail and commercial activities. In this case, retail, and in particular auditory sales, was more suited to the acoustic space of the north Cardo Maximus, than the neighbouring Via della Fortuna. This was reinforced by the architectural connection between the neighbouring streets to the east of the Portico di Pio IX. On the other side, the Portico di Pio IX also faced onto the Via dei Dipinti, 4.7 m wide. This side of the Portico di Pio IX lacked porticoes and opened directly to the street. Acoustically, the street was wide enough that sounds would dissipate before reaching the other side, unlike the narrowest streets (see Appendix 2.2, 5 m width).

The north Cardo Maximus was at the transition between commercial and retail noises, as the street was predominantly shop, portico and open space that served social as well as economic functions. It is likely that day labourers would have loitered the north end of the street looking for work as porters or in unskilled construction, filling the portico and street side with conversation.[179] Migration from further afield is implicit in the unskilled labour market, as employment would demand resources, such as tools, space and knowledge, which were rare in the movement of people across long distances. Informal retail added to the noise of the street, as street hawking and trading were unskilled and required minimal upstart costs.[180] With the warehouses in close proximity, it is reasonable to assume unemployed unskilled labourers would congregate in spaces that were public and associated with commercial social networks, but not necessarily directly involved with commerce. Movement to and from the Forum, especially in association with the two *loggia* at the south ends of the Portico di Pio IX, had its own noise and likely added social value to the area for social interactions between different status groups. The area surrounding the Portico di Pio IX would therefore have been relatively active in the morning, especially with the movement of goods from the ships on the Tiber to the warehouses in the area.

3.5 Via degli Augustali

In a different spatial and temporal context, the Via degli Augustali presents another interaction between noise and street life. Located south of the Decumanus, the Via degli Augustali runs east of the so-called Sede degli Augustali (5.7.2), terminating at an intersection with the Via della Fortuna Annonaria. The area surrounding the Via degli Augustali went through an intense phase of building in the later third of the second century CE, with the

[179] Matt. 20: 1-16; Holleran 2011a: 253.

[180] Holleran 2012: 216.

rebuilding of the temple of Bona Dea complex, building of *collegia* temple, extension of the shops behind the temple and associated balcony, and the rebuilding of the *fullonica* across the street. The development of this street was achieved by multiple patrons, as previous buildings were destroyed, reused or extended to serve the needs of the various groups on the street. In contrast to the north Cardo Maximus, were a variety of projects that came together in the

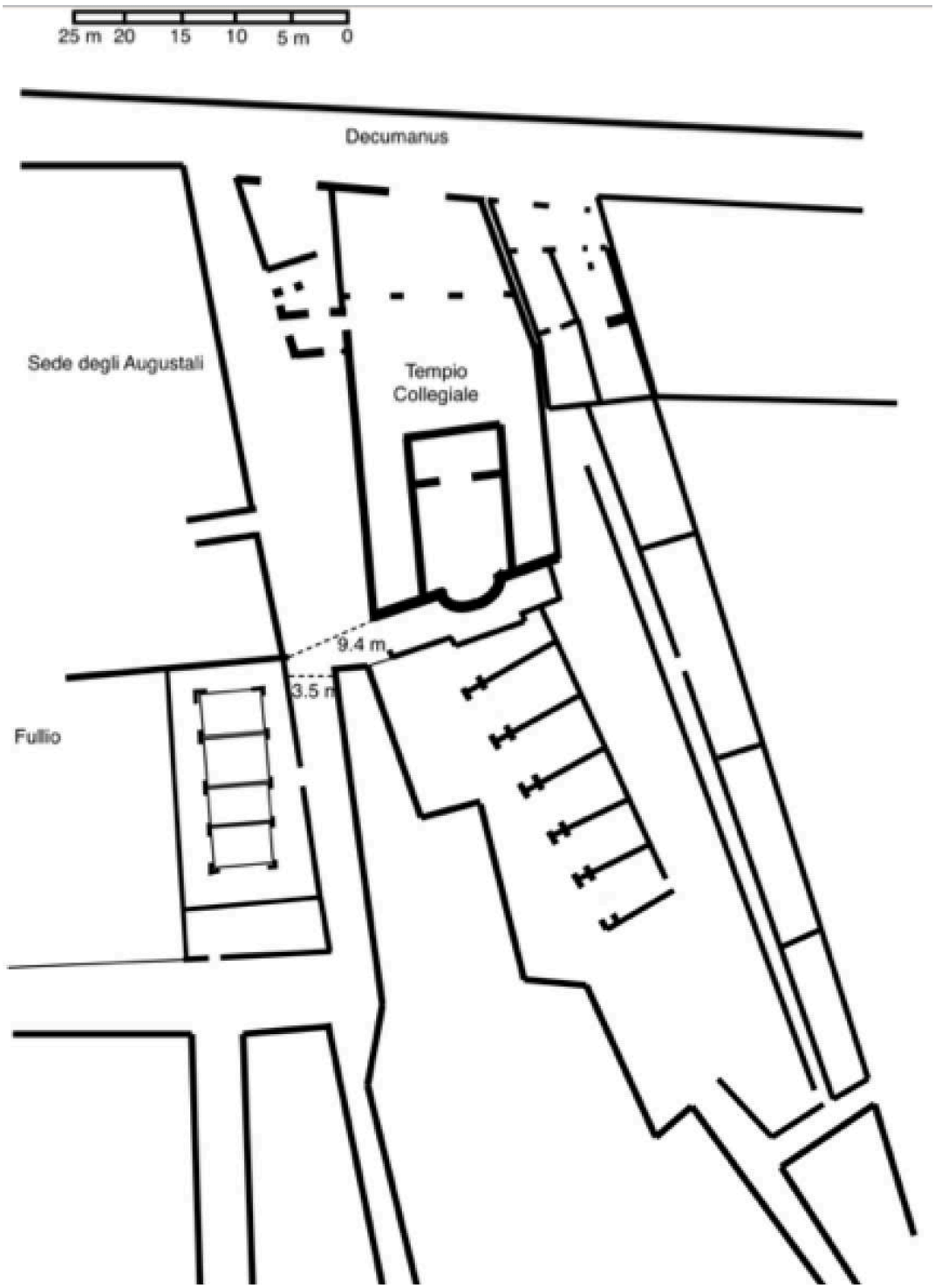

Figure 3.9 Via degli Augustali and surrounding area. (Author)

continual transformation of the street and its acoustic character. The variety of functional spaces on the street suggests an equally diverse social space, with domestic, commercial and religious activities all on the same street.

The street has the common lining of shops on the west side, which backed onto the east peristyle wall of the 'Sede degli Augustali'. The 'Sede degli Augustali', likely built in the second-half of the second century CE, was initially thought to be the meeting place of the Augustales, however Laird has shown this to be a mistaken identification.[181] In its final form, the 'Sede degli Augustali' was likely a *domus*, and the sculptures found there were either connected with a limekiln or were *domus* decorations in themselves.[182] On the east side of the street, the Tempio Collegiale (5.11.1) of the *fabri tignuarii* is located on the Decumanus. The temple was built at the end of the second century CE, dedicated in 194 CE to Pertinax, and offset the earlier shops along the Decumanus, still visible to the east of the temple.[183] Behind the temple is a complex earlier building, referred to as the Caseggiato del Temistocle (5.11.2), which is made up of apartments and shops lining a narrow open alley.[184] The Caseggiato del Temistocle does not follow the street, but is at an angle aligned with an earlier street, which Mar calls the Via del Temistocle.[185] After the temple was built, cutting off the original entrance to the Caseggiato del Temistocle, an addition to the shops along the street was made.[186] What had been a "y" shaped open space, where the Via del Temistocle and Via degli Augustali connected, was cut off by the temple, reducing the Via del Temistocle entrance to almost a doorway. A trapezoidal block split the Via del Temistocle and Via degli Augustali and was formed of four shops, with stairs to an upper level and a small converted shop space (5.10.1).[187] The southern two shops were converted into a house in the second century CE, by blocking the shop doorways and the alley behind the Tempio della Bona Dea (5.10.2). A later paving block records the gift of Octavia, wife of P. Lucilius Gamala, an active member of the elite in Ostia, who had the portico plastered, benches made and the kitchen roofed to the temple.[188] In the Augustan period, the temple was surrounded with a high wall enclosing the portico space. At the end of the second century CE, the temple and courtyard were rebuilt at a higher level (1.20 m). Across the street, south of the Sede degli Augustali is a large commercial *fullonica*. The *fullonica* is dated originally to the first

[181] Laird 2000; 2015.

[182] DeLaine 2012: 344.

[183] Inscription, *CIL* 14.4365+4382; *AE* 1971: 64.

[184] See Hermansen 1982a: 96-111; Mar 1996: 153-6.

[185] Mar 1996: 153.

[186] Hermansen 1982a: 103.

[187] Mar 1996: 154-5, fig. 22, 23.

[188] Brouwer 1989: 68-9, n. 63; cf. *CIL* 14.376.

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Figure 3.10 Via degli Augustali SPL and RT30 for conversation noise (65 dB (A)) in the centre. (From Acoustics Group - University of Sheffield http://www.acoustics.group.shef.ac.uk/asalink.php)

half of the second century CE, and rebuilt in the later third of the same century.[189] There are no visible windows along the street, and to the south of the central room are two storage rooms accessible from the street.[190] These various alterations and construction projects reshaped the acoustics of street throughout the second century CE.

In comparison with the north Cardo Maximus, the Via degli Augustali is a much narrower street, with its own distinctive acoustic properties (Fig. 3.10). The narrow width at the southern end indicates that noises would span the width without diminishing, as figure 3.10 shows. Sound dissipation was along the length, rather than the width, of the street, and in this instance the sound source is in the middle of the graph. The street paving runs all the way to the façades, and there are no differentiations in the carriageway. Lacking any porticoes or balconies along the street, it was only as the street opened up at the south-west corner of the Collegial Temple that sound would have dissipated into the open space. This open space on the street was set below the foundations of the Collegial Temple, creating a physical hierarchy between the temple and street. At certain times, this hierarchy would have been sensorially defined, as sounds and smells would descend into the street, while the temple's wall visually excluded the street from the activities within the temple. Sound dissipates in all directions, suggesting that the physical topography of the temple placed higher than the street would have auditory effects. In particular, the separation in height, along with the materials used to fill the temple foundations, would isolate some of the street noise from the inner temple courtyard. In the other direction, the sounds of the temple would not be isolated in the same way. This suggests that the activities of the temple would have been heard in the Via degli Augustali to a higher degree than the sounds of the Via degli Augustali would be heard within the temple courtyard. As will be discussed in chapter five, the connection of certain noises with temple practices extended beyond the physical bounds of the space, and included noises associated with processions and sacrifices.

[189] Pietrogrande 1976: 70; see also Flohr 2013.

[190] 'Storage' room is used as there is little evidence to show the exact function, and the rooms were blocked from the central hall.

The use of the temple would have contradicted the everyday use of the other significant building in the street, a *fullonica*, creating a variety in the temporal rhythm of noise in the street. As Flohr has discussed, the *fullonica* was not a habitable workspace with domestic and commercial spaces.[191] The workers likely came to/from accommodation elsewhere. Potentially, the surrounding shops were used for residence, as the late antique conversion of two shops into a small house makes evident. The shops attached to the 'Sede degli Augustali' lack evidence for mezzanines, while the shops on the ground floor of the Caseggiato del Temistocle are all interconnected, suggesting some formal relationship between individual users. It is likely that shops were used as residential spaces, and the first floor of the Horrea Epagathiana offers a possible indication of upper floor residential spaces (see section 5.1.3).[192] The individual rooms that surround the courtyard had their own entrances, and one threshold remains. As the Caseggiato del Temistocle had the later addition of an external balcony, access to the upper floor was directly from the street. In the context of noise, the various spaces within the street indicate structural divisions, as opposed to the acoustics of the north Cardo, which suggested ephemeral divisions. The closure of the space outside the Caseggiato del Temistocle, the narrow southern end of the Via degli Augustali, and the encroachment and placement of the Collegial Temple formed structural barriers to the movement of sound. In particular, the separation of the temple space, either by the raising of the ground level for the temple or the encroachment of the back wall of the temple into the shops of the Caseggiato del Temistocle, from the street physically isolated sound in a different manner to the way open space created isolated pockets within the street of the north Cardo Maximus. These two examples display different ways of dealing with street noise and can be seen as different points on the spectrum of material interventions to control noise.

3.6 Conclusion

The acoustic methodology set out in this chapter enables the analysis of particular spaces in Ostia and their placement on the spectrum of material interventions and control of sound. The measurement of acoustics in enclosed spaces was tested against the reconstructed shops in the Mercati di Traiano in Rome. The close correlation between the mathematically calculated and physically measured acoustic properties validates the mathematical model, as well as the use of modern material measurements for ancient equivalents. The acoustic measurements

[191] Flohr 2013: 208-11.

[192] See Packer 1971: 67; cf. Wallace-Hadrill's disccusion of the upper floors of the *insula* Ara Coeli and *insula* under SS. Giovanni e Paolo, 2003b: 14-5.

discussed here make up the main measures that form the work of Appendix 1. In the next chapter, the internal spaces are analysed to better nuance and interpret the acoustic properties measured in Appendix 1. In the final section of this chapter, the measurements were contextualised through their experience in the street space of the north Cardo Maximus and the Via degli Augustali. These streets are examples of two different ways in which acoustics and sound could be physically isolated, either through material interventions and built structures aimed at blocking sound, such as walls and raising of ground levels, or through the addition of spaces to the street, in this case the addition of porticoes. In both cases, noise and movement were part of the social context in which the development of the streets were negotiated.

The discussion of acoustics and the physics of sound can be summarised in a few key points:

0. All six surfaces in a room influence the acoustic character of the space.
1. Sound can travel through air, water and gas, as well as physical materials like concrete, wood and glass.
2. A point-source, like a single person, will function differently to a line-source, a procession of people.
3. In outside spaces as the distance doubles from a point-source, the SPL decreases by 6 dB or by 3 dB in the case of a line-source.
4. Humans perceive sound logarithmically, so different frequencies are perceived at different levels of loudness despite having the same intensity (SPL). Certain frequencies will be perceived as louder than others, whether they actually are or not.

The comparison of the north Cardo Maximus and Via degli Augustali offered a chance to contextualise the methodology in terms of interpreting the social relationships between noise and architecture. Three concluding points are worth stressing: first, time is always a factor in interpreting the social side of acoustics. Noise happens in space and time; one cannot be separated from the other (see 1.4.1). The rhythms of noise need to be thought through to assess the potential sounds throughout the day.[193] Second, there are always multiple agents at work in the auditory field. Buildings and people, as well as animals, as will be discussed further below (5.2.2, 5.2.3), all influence the noise of public space. Third, the auditory hierarchies are not just loud and silent places, although this is a part of the hierarchy. In the majority of urban spaces, the hierarchies are constructed from types of noises, as well as types of material interventions in the urban space. These hierarchies cannot be separated from the human perceiver and the

[193] Lefebvre 2013: 61-5.

social environment.[194] Sounds were everywhere in Ostia and the auditory hierarchies need to be contextualised within the construction chronologies, spatial differentiations, and social relationship of the different agents. Auditory hierarchies were part of the production of space in Ostia, creating spaces that influenced and created the moral judgements discussed in chapter one.

The next chapter presents an acoustic analysis of a variety of internal spaces that lined the streets of Ostia. The basic acoustic measurements discussed here serve as tools to understand the social control of space through other means than constructed boundaries. In chapters five, the analysis will turn to the streets, at a town-wide scale. Acoustic measures do not stand by themselves, but need to be related to social interactions in the street space. The interpretation of the data requires the application of other forms of evidence in order to understand the relevance of acoustic measurements. In the following chapters, various forms of evidence are applied to the acoustic spaces of Ostia to draw out the implications for social interaction and everyday rhythms.

[194] Lefebvre 1991: 196.

Chapter Four
Acoustics in Practice

"Injecting noise of whatever kind into an acoustic arena is nothing more than the exercise of sonic power: social or political, autocratic or democratic, supportive or destructive."
B. Blesser and L. Salter, *Spaces Speak, Are You Listening?* 31.

"We can tell whether we are happy by the sound of the wind. It warns the unhappy man of the fragility of his house, hounding him from shallow sleep and violent dreams. To the happy man it is the song of his protectedness: its furious howling concedes that it has power over him no longer."
T. Adorno, *Minima Moralia*, 49.

"The same is true for colors and sounds and their use as it is for being and nature, susceptible to an indefinite number of interpretations and perspectives. The immediacy of the continuum confers upon it a quality and properties: it becomes the spatial support of mediations, interpretations, perspectives."
H. Lefebvre, *Toward an Architecture of Enjoyment*, 114.

The acoustic properties of spaces offer insight into the influence of physical materials on the social interactions within the space. As will be shown, social activities within certain rooms are influenced by the acoustic properties of the space. Traditional, visually defined, boundaries are more porous when considered in terms of noise. Shops and apartments, as will be shown, were oriented towards the street, and the architecture did little to isolate street noise. An inability to soundproof internal rooms required other ways of negotiating the intrusion of outside noise in second century CE Ostia. However, noise intrusion goes both ways. High-status inhabitants could display their wealth through noise-making within their buildings, which filtered into the street. In this way, noise constantly crossed the visual boundaries of the street and served as form of social power, evident in the Blesser and Salter quote above. The power implicit in sound-making has received limited attention in Roman studies, and has not been discussed within Roman architectural studies. This chapter will explore the role of acoustics in negotiating auditory power and control in the internal spaces of shops, apartments and courtyards. As will be shown, choices of location and arrangement were the primary ways of mitigating, as well as exercising, auditory power. Thus, a rational space of noise

production and sound isolation is at work in the boundaries between internal space and the street.

In the first part of this chapter (4.1.1-2), the shop spaces along streets are analysed to assess their acoustic properties. The shops that lined the majority of streets in Ostia were the primary spaces of interaction just beyond the street (4.2). The close links between street and shop space are reinforced by the acoustic connection between them. In certain cases, as with the presence of porticoes, the boundary was mediated between the street and shop, creating a distinctive auditory field. In comparison, the so-called '*medianum*' apartments were also oriented towards the street, but have distinctively different acoustic properties (4.1.3). The hierarchy of rooms in these apartments, based on acoustic properties, reveals ways in which acoustics can differentiate spaces within an individual apartment. Chronologically, the apartments appear around the same time that certain porticoed streets are built. The relationships between different street experiences are explored further in the next chapter, while the focus here is that the development and design of apartments emphasised the social importance of external space surrounding the apartments. The production of sound within apartments could also extend to the surrounding spaces, thus audibly connecting visually separated spaces. As will be shown, the axiality and visual definition of space limits the available forms of interaction between the street and associated spaces. The apartments have clear auditory connections with street space, although in a different form from the shops. These different experiences, apartments and porticoes, reflect the growing experiential importance of streets in the production of space at Ostia. In the final section (4.1.6), courtyards are analysed to provide a third comparison. Courtyard spaces were part of domestic and commercial spaces. Acoustically, the houses have a different orientation to shops or apartments, which focus on the courtyard. The presence of courtyards provides a differentiated space from the street, which is not possible in the shops or apartments. The courtyards were not isolated from the street, and noise would still penetrate the space. Acoustically, the courtyard is connected to the street, although again, in a different manner than shops or apartments. The arrangement creates a different experience from the shops and apartments, highlighting the acoustic and architectural differentiation of the space.

This chapter argues that the spaces analysed indicate different auditory productions of space in Ostia. The acoustic hierarchies indicate that spaces could be differentiated, as well as the ability of sound in one space to bleed into surrounding spaces. Despite an inability to soundproof and isolate noise completely from other spaces, the acoustic architecture could still be used to control certain forms of sound, or

control surrounding spaces through auditory dominance. The auditory bleed-through is in this way a form of social control through sound, and could be used by either inhabitants or outsiders. The argument in chapter two, that literary control was exercised through social control rather than legal remedies, is challenged by the acoustics of internal spaces themselves, which display a different auditory power. This is not saying that the complaints of Latin authors were not based on the experience of auditory intrusions, but rather that the intrusions went the other way as well. As will be shown, the spectrum of mediations between internal space and streets was dependent on certain social and economic categories; however this spectrum of sound mediation retains a key element at all levels, which reinforces the social importance of the street. This chapter focuses on the internal acoustic properties, while the auditory experience of the street in relation to work noise is the focus of the next.

The building types analysed in this chapter provide three key points on the spectrum of architectural mediation of sound in Ostia. First, the most common and basic structure of a shop (*taberna*) in Ostia displays the lowest level of sound mediation between the street and internal space. In the majority of cases, the shops open directly onto the street and are linked to the street auditory field. In certain cases porticoes could mediate the interaction in front of shops, but these instances were limited to particular places within the street network. The case study presented here is the Portico di Pio IX (1.5-6), north of the Forum, on the north Cardo Maximus. These shops display common architectural features and can, therefore, serve as a baseline for the analysis of variations in shop architecture.[1] Chapter three discussed the north Cardo Maximus in relation to the street acoustic properties (3.4) and here, the internal acoustic properties are analysed (Appendix 1).

Following the analysis of shops, we turn to the acoustic organisation of '*medianum*' apartments, which are typically understood through the visual boundaries between the street and internal space (4.1.3). However, acoustically, the division of internal and external space is porous and the strict visual distinction is problematic. The apartment façades indicate a second point in sound mediation, as the walls and windows mediate direct noise intrusions. The '*medianum*' apartment refers to a particular apartment layout found in 40 out of 100 apartments in Ostia, with limited evidence for this apartment layout in Pompeii or Herculaneum.[2] These apartments are rare outside Ostia, and certain elements seem to develop in the late first century CE,

[1] See Veitch 2017a.

[2] Gering 2001: 202

towards the end of Pompeian housing development.[3] The basic layout comprises a central hall with two reception rooms at either end, and smaller single rooms opening on one side of the hall. The arrangement of the space indicates a close connection with street space, and the acoustics provide a means of measuring the intrusions inside and outside the apartments. Unlike the shops, which had direct interaction with the street auditory field, the apartments have simplified mediation of sound through the building façade and windows, in certain cases. This arrangement indicates a middle ground in terms of auditory mediation, as certain sound frequencies and SPL intensities would be heard outside the apartments. Building materials will affect the clarity of noise heard outside, but would not radically diminish the overall noise level above that of general conversation noise (c. 65 dB).

Section 4.1.4 analyses courtyard space in Ostia. The architecture and acoustics of courtyards present a further sound mediation by internal space. Internal courtyards differentiate the internal space from the outside noise, but there was not complete sound isolation, and noise would still be heard within the courtyard area, although the noise will be altered through the architectural mediation by the space. The internal courtyard organisation seems to be a product of the urban density at Ostia, and was less of a concern for Pompeii. The acoustic features of the space can be compared with previous spatial analyses that point to the importance of the courtyard for access and control to other spaces within the building.[4] The relationship between the courtyard and street indicates that these spaces were not separated or completely isolated from the street, although they formed a different relationship between street and internal space than shops or apartments. The spectrum of sound mediation is evident in these particular building types and ground floor arrangements. In chapter five, the specific sounds evident in the archaeology and material culture will be explored to contextualise the acoustic analyses of generic noise undertaken here. The architecture of sound mediation provides insights into the distinctive dynamics at work in Ostian architecture in comparison to the more commonly studied sites of Pompeii and Herculaneum.[5]

[3] Many of the windows seemed to have used glass, although there is little in any publication on glass windows and apartments, DeLaine 2012: 336.

[4] See Clarke 1991; 2014: 355; Calza 1941; Ulrich 2014.

[5] Sound studies in Pompeii and Herculaneum are still needed, see Hartnett 2016; for a modern sound study of the archaeological site, Brambilla et al 2007.

4.1 Aural Architecture of Ostia

As seen in the last chapter, the acoustic measures based on the archaeological remains provide quantifiable data that can be compared across the different architectural buildings and spaces in Ostia. The acoustic models presented in Appendix 1 are the basis for the comparative work analysed within this chapter, which, as noted, focuses on the spectrum of sound mediation between internal spaces and the street. By focusing on the internal and external division of space, which usually is thought of in terms of visibility, the permeability of the spaces to noise argues against defining control of space based on the presence of an agent within that space. Simply put, a person can exert a certain level of control through making noise, and that control filters into spaces where the noise-maker is not. In this sense, control, in the form of noise, extends beyond the physical location of the person. In fact, the spectrum of sound mediation creates a different conception of public and private, one that is not defined in visual or physical setting terms.

The work in Appendix 1 needs a brief introduction to understand the different elements within the acoustic models and their relation to sound mediation. As noted in the previous chapter, the AC and RT60 measurements form the main measurements within the acoustic analyses. These measurements both relate to the acoustic models presented in Appendix 1. Appendix 1 is organised in the numerical order of the building classifications of *regio*, *insula* and building numbers. In this chapter, the discussion is based on a typology of buildings and, therefore, the building identification numbers are listed to ease finding the appropriate model. It should be noted a representative sample of 26 buildings across Ostia were modelled, rather than all buildings. The basic structure of the model is broken into four main parts: the room dimensions are given at the top left; the surface area, materials, and absorption coefficients are listed for each side (walls in the cardinal directions, ceiling, floor, and room contents) under the dimensions; the calculated absorption in Sabins are listed for each surface material on the right; and at the bottom the total absorption and RT60 are listed for the Sabine and Erying formulas. Additional items, such as furnishings, are listed under 'Room contents' Other possible elements that could affect the acoustic properties, such as tapestries or other textiles, people or room furnishings, could be placed in this section. However, as this is the first application of such a model to any Roman site, the models are given in their most basic form from which further studies can nuance the specifics of individual rooms. This also enables the upper limits of AC and RT60 measurements to be classified, as any additional elements will reduce the AC and RT60, not increase them. The results

therefore indicate the highest possible RT60 measurement and the lowest possible AC for the space.

Looking at the city as a whole, the consistent use of brick and reticulate throughout various structures means that acoustic differentiation will mainly come from changes in size of spaces and decorative elements, like marble revetment or plaster and paint, or the use of vaulting. As discussed in the previous chapter, the differences between types of brick and concrete construction were at the scale of 2 dBs, which is at the bottom of the auditory spectrum. The presence of marble revetment will have the highest auditory effect, as the AC for marble is more reflective than brick, while the difference between plaster and brick is negligible.[6] These variables produce different acoustic experiences, despite the limited changes in other architectural elements. The aural architecture of the common shop will be experienced differently from the cold rooms of a bath complex, even though both spaces are constructed with similar materials. Internal acoustic properties will affect the total SPL within the space, which gives the highest level of sound that could be heard outside. With no electrical amplification, it was only the rooms acoustic properties that could produce any form of amplification, although this would vary based on frequencies. Simply put, without electric amplification, which would recreate the full frequency spectrum of the sound at a greater intensity, the room's acoustic properties, which have a particular frequency response, would amplify only certain frequencies, namely those related to peaks within the rooms frequency response. In order to understand the role of the street space in structuring social interaction, the acoustics of three internal spaces are analysed in order to differentiate three different points on the spectrum of sound mediation between the street and internal space.

4.1.1 Portico di Pio IX

The most common and basic form of architectural space in Ostia is the small one or two room commercial shop lining a majority of streets in Ostia. These common shops,

[6] Marble has an AC of 0.01 at 500 Hz, while both plaster and brick have ACs of 0.02 at 500 Hz. Differences are present between plaster and brick at higher frequencies were plaster absorbs 0.01, 0.02, and 0.03 Sabins more at 1k Hz, 2k Hz, and 4k Hz. These changes will not dramatically effect the overall RT60 times and will only minimally alter the frequency response of the room.

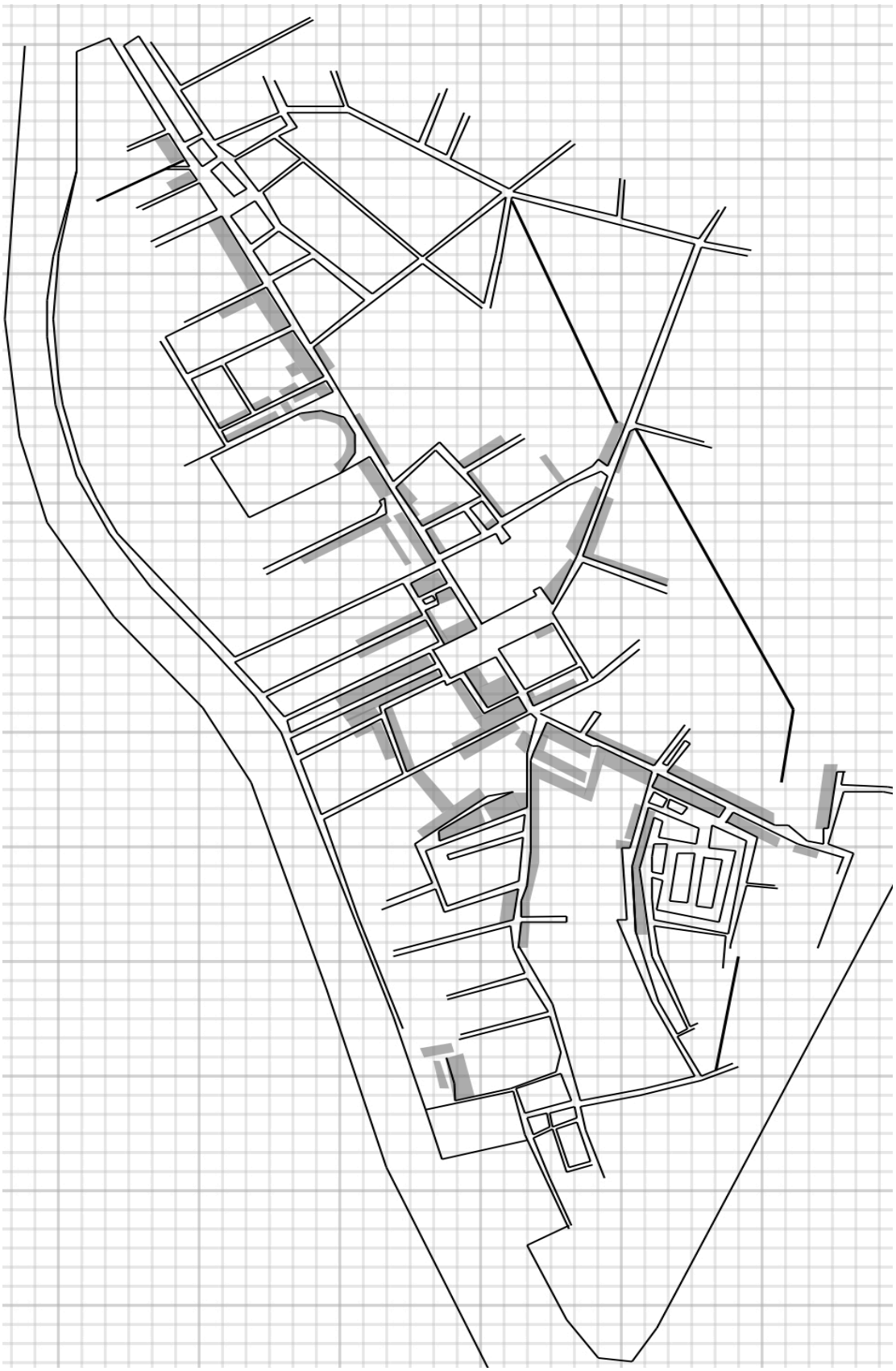

Figure 4.1 Shops (*tabernae*) in Ostia (second century CE). (Author)

tabernae, are found throughout the city, with over 806 in the excavated area (Fig. 4.1).[7] They also form the most direct form of sound mediation, as they open onto the street directly or onto a portico, which serves as a semi-enclosed, public space. Of the 806 total shops, 229 shops open onto portico along a street (just under 30%), not including shops opening onto an internal courtyard. The wide doorways and one or two room layout, could accommodate a variety of needs, in terms of the commercial manufacture of goods, services, and the residential needs of habitation. Backrooms and mezzanines could offer a differentiation between residential and commercial space, while in the most basic shop both needs would be fulfilled within the same room. The basic dimensions and physical structures provide the necessary data to analyse the acoustics of the space and its connection with the street, whether mediated by a portico or not. In this section, the acoustic analysis of the Portico di Pio IX on the north Cardo Maximus is discussed, before turning to the town distribution of different shops.

The Portico di Pio IX, made up of two buildings fronting the north Cardo Maximus leading from the Tiber to the Forum, is a prime example of the shop row building typical of DeLaine's first category of distribution (Fig. 4.2).[8] The Portico di Pio IX was part of several construction projects in the area, including the Piccolo Mercato (1.8.1), Caseggiato dei Misuratori di Grano (1.7), Caseggiato del Balcone a Mensole (1.6.2) and the *horrea* at 1.8.2, that reshaped the north Cardo Maximus and Forum from c. 116 CE. On both sides of the street, rows of eight shops take up the ground floor, with external stairways leading to the upper levels, to make up the Portico di Pio IX. The eastern building, Building A, has a row of shops that front onto the Via dei Dipinti, while the western building, Building B, is backed by the narrow Via Tecta. If the portico continued to the Tiber, which is likely, it would have taken up nearly 4,700 m^2.[9] Although all these were originally thought to be part of a single project, the brick stamp evidence indicates a more nuanced chronology of construction.[10] The Portico di Pio IX was completed before 116 CE, followed by the Piccolo Mercato, Caseggiato del Balcone a Mensole and the Caseggiato dei Misuratori di Grano in 117-118 CE, with the Capitolium and flanking porticoes possibly in the 120s CE.[11] The Piccolo Mercato and Caseggiato dei

[7] Girri lists 806 but recent excavations and geophysical survey have added to this number; Girri 1956: 36.

[8] DeLaine 2005: 33; Veitch 2017a.

[9] DeLaine 2002: 71.

[10] DeLaine 2002: 64.

[11] DeLaine 2002: 64.

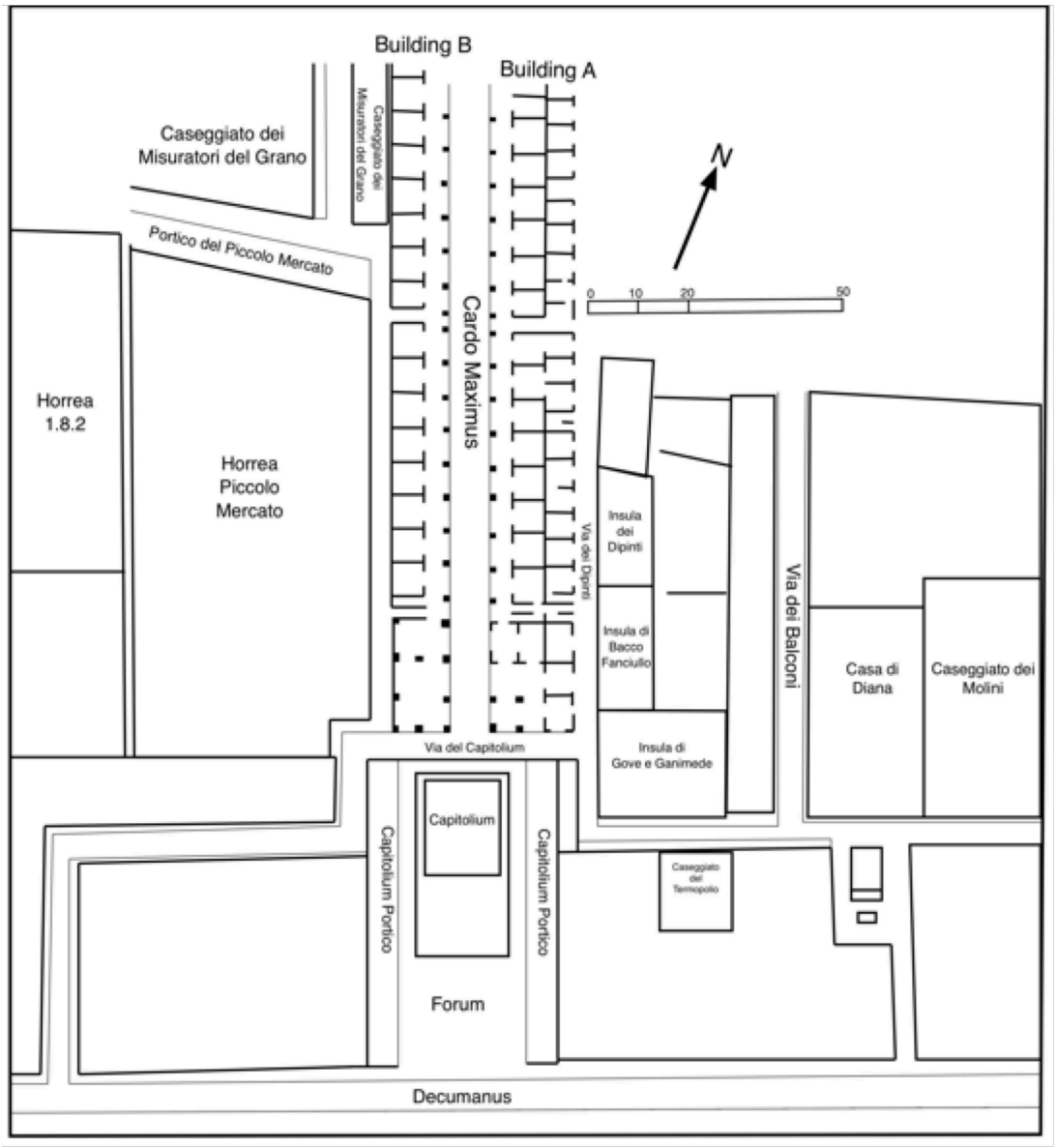

Figure 4.2 Portico di Pio IX and surrounding area. (Author)

Misuratori di Grano both have shop and portico structures along one façade, creating an experiential continuity between the various building projects.

In analysing the acoustics of the shop space, the primary materials for analysis are wood and brick, both of which are absorptive materials (Fig. 4.3, 4.4; Appendix 1, 1.5.2, 1.6.1). The shops of the Portico di Pio IX were constructed as single rooms, although cornices for mezzanine floors remain in a majority of the shops (Fig. 4.3). Each shop had a 3 m wide doorway that held wood panels (Fig. 4.4).[12] The ground floor spaces were lit through the main doorway, with windows only above the wide door, which gave light to the mezzanine level. Plaster, likely painted, is also evident in some of

[12] Average width of doors, Packer 1971: 21.

the shops, although, as noted above, the AC for plaster and brick are the same at the 500 Hz NCR frequency, with a minimal increase in absorption for plaster at the higher frequencies (1k, 2k, and 4k Hz). The absorption units can be calculated for the brick surfaces of the shops (see Appendix 1, 1.5.2, 1.6.1): the three walls have surface areas of 20.4 m^2 (east and west) and 18.7 m^2 (back), whilst the NRC for brick is 0.0375, giving the walls absorption units of 0.765 and 0.701 Sabins respectively. The shop spaces are

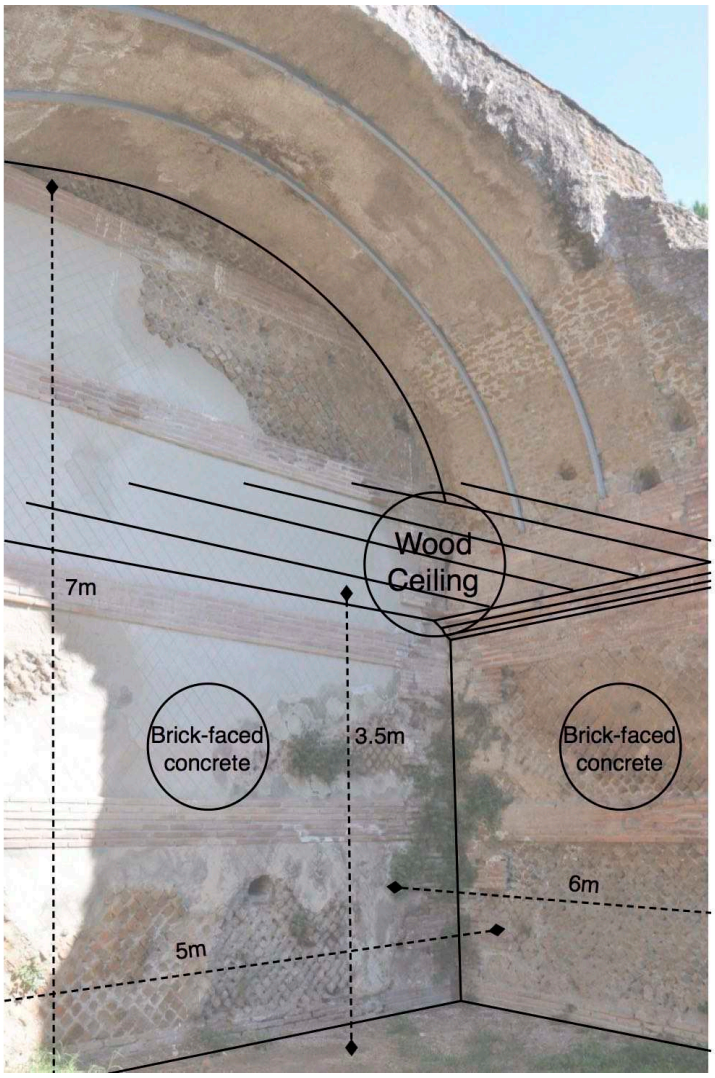

Figure 4.3 Reconstructed shop (Portico di Pio IX) with mezzanine elements. (Author)

all of the same style and dimensions, resulting in similar RT60 measures of 2.18 seconds at 1 kHz in each one.[13] This means that it would take a 1 kHz note 2.18 seconds to decrease one tenth below the original intensity of the sound. This effect is different to echo, as the reverberation is a continuous sound. Background noise will alter the perception of the RT60 within the space, as will be discussed in the following chapter.

[13] Veitch 2017a.

For now, it is important to note that the shops themselves do little to absorb noise within the space, evident in the RT60 measures.

Upper floors, most commonly mezzanine levels, are found in a variety of shops throughout the city (Appendix 1, 1.5.2, 1.6.1 Mezzanine). Referred to as *contignatii*, the upper floors would be constructed from a wooden base of beams and joists (Fig. 4.3).[14] Literary references to *contignatii* are associated with a variety of spaces, including galleries in houses and porticoes, floors and catwalks of military fortifications, as well as temples.[15] Although wooden flooring was used regularly by the early Imperial period it seems that wooden planks formed the support for a thick concrete subfloor for tile or mosaic.[16] Despite the standardised façades of the shops, mezzanine floors were supported in various manners, such as by corbels, cornices or simply using joists, and show no consensus in building.[17] The underside of the wooden flooring could be

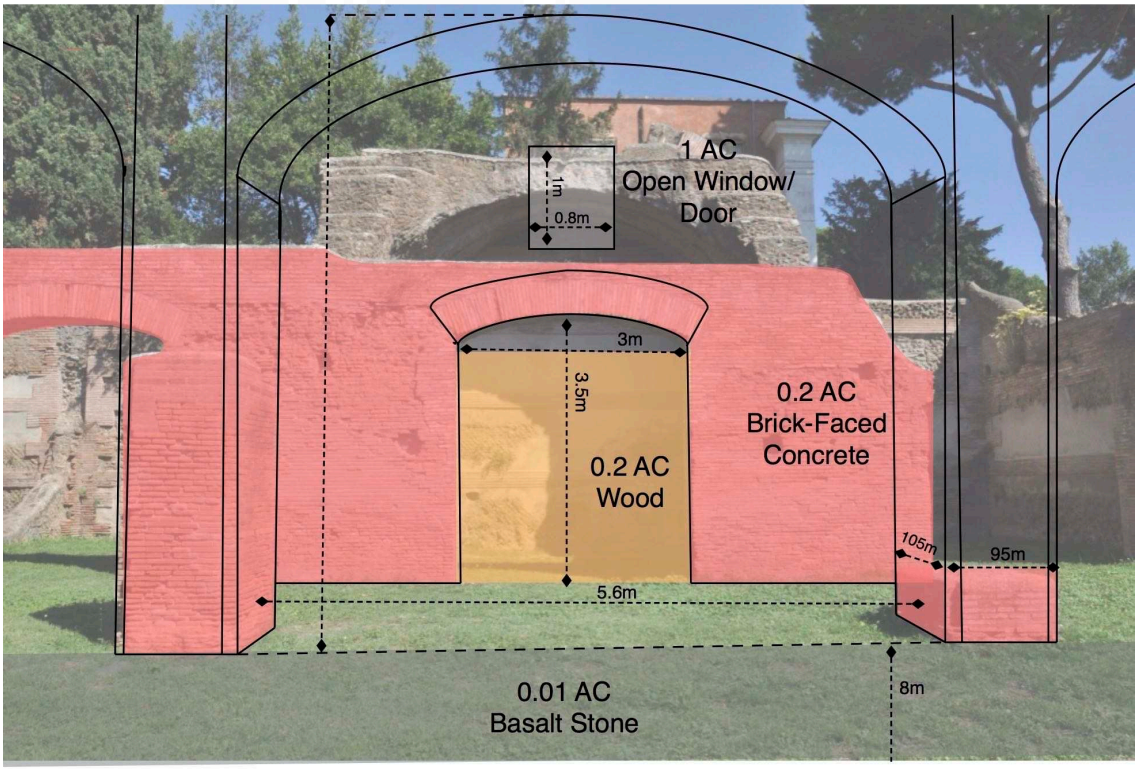

Figure 4.4 Portico di Pio IX façade with NCR ratings and measurements. (Author)

[14] Adam 1994: 196-200; Ulrich 1996: 137-8; Ulrich 2007: 112-122.

[15] Citing Vitruvius, Julius Caesar and Pliny, Ulrich 1996: 138.

[16] Ulrich 1996: 138.

[17] Ulrich 2007: 118.

exposed, covered with planks nailed into the joists, or incorporated into coffering.[18] The wooden planks could further be covered in plaster and paint depending on the expenditure of the owner.[19] The Portico di Pio IX had cornices of layered bricks that extended from the walls on three sides, with the mezzanine floor resting on top. Joists were also used, usually three or four, set into the walls. Again, in comparison to Pompeii, the Ostian joists tended to be set three to five times wider, with fewer joists. Ulrich takes this arrangement to indicate that second, lighter, joists and floorboards were set on top of these primary joists.[20] In any case, the wooden base layer was then covered with a mortar layer, between 15-30 cm thick, and finally a mosaic or *opus signinum* top layer.[21]

The wood flooring frequently supported a thick concrete subfloor, which held mosaic.[22] This heavyset concrete would greatly diminish the amount of sound that would absorb through the flooring, also potentially insulating the upper floors from smoke or other disturbances. In his discussion of upper floors, Vitruvius speaks of the insulation and protection from fire that these thick flooring conditions would provide.[23] In acoustic terms, the flooring served two simultaneous purposes of insulating noise between the ground floor and mezzanine level, evident in the TL rating, as well as reflecting sound energy back to either the ground floor or mezzanine space, indicated by the AC ratings. The AC measurements are given in the models in Appendix 1, but the TL ratings need to be calculated for the floor, in the same way as the calculations made for walls from the previous chapter. Ulrich has calculated the floor weight for three examples from Pompeii, with upper and lower figures (12 cm or 33 cm thick with light (700 kg/m^3) or heavy pumice aggregate (1,400 kg/m^3)).[24] For the Portico di Pio IX, the calculations in Ulrich's example two resemble the overall dimensions of the shop space and are scaled to the Ostian dimensions. Incorporated into the Ulrich's calculation was the empty space of the stairway, which was 0.80 m x 4.55 m.[25] In this case, the floor would have a total weight of 5,330 kg (W1), 7,791 (W2), 9,644 (W3), and 16,420 (W4). At 500 Hz, the TL would therefore be 99.13 dB (W1), 102.44 dB (W2), 104.30 dB (W3), and 108.93 dB (W4) due to the extreme weight of the floors. This is in contrast to the wall weights, which indicated TL ratings in the range of 65-67 dB. In this instance, noise

[18] Ulrich 1996: 138.

[19] Ulrich 1996: 138.

[20] Ulrich 1996: 146.

[21] Adam 1994: 198.

[22] Ulrich 1996: 138.

[23] Vitr. *De arch*. 7.1.5; Adam 1994: 199.

[24] Ulrich 1996: 149.

[25] Ulrich 1996: 150, example 2.

heard within the mezzanine space would likely derive from the street entering through the open window or stairway. This suggests a level of sound isolation in contrast to the ground floor space.

Within the mezzanine space, flooring of the upper rooms would react in a similar manner to the ground floor tile or mosaic. The materials would absorb a majority of the high frequency noise, although low frequencies would still be heard and felt. It seems that, in terms of acoustics, the design of upper floors followed the characteristics of ground floors. There does not seem to be any clear differentiation between the internal acoustic character of the ground floor spaces and those of the internal mezzanine space. What differentiated the two spaces was the insulation provided by the heavy-set subflooring for mosaic or tile when they were used.

The significantly lower volume of the mezzanine space offset the reverberant nature of vaulting. The Portico di Pio IX had barrel vaulting 7 m in height at the crown, giving the mezzanine space a height of 3.17-3.38 m, depending on the thickness of the floor.[26] The portico along the east side of the Caseggiato dei Misuratori del Grano has the same height of 7 m to the crown, which suggests that if the portico of the Portico di Pio IX was the same height, the opening for the portico space would include the shop door and mezzanine windows (see Fig.4.4). Acoustically, this would open the space within the portico to street noise and noise emanating from the shops. The portico would only serve to set the façade of the shops back, off the street. In this case, noises from any of the spaces, whether the ground floor shop, mezzanine, portico or street, would filter into the other spaces.

Windows above the doors of shops, which lit the mezzanine space, were commonly less than 1.0 m in height and between 0.60-0.80 m in width (Fig. 4.4).[27] However, in the case of the Caseggiato degli Aurighi (3.10.1), the mezzanine was amply lit, with open segmented arches (2.80 x 1.50 m) above the doors of shops 19 and 20.[28] The openings above the doors of shops 19 and 20 in the Caseggiato degli Aurighi are the largest in Ostia, in terms of shop windows, as well as being at the larger end of the scale for apartments and *domus* windows.[29] In acoustic terms, the large openings would reduce the RT60 measurements within the space, as well as increasing the SPL of noise heard outside. As just noted, windows and stairways enabled noise from neighbouring spaces into the mezzanine areas. The location of windows above the doors was a

[26] Using Ulrich's measurements of 0.12 m or 0.33 m, 1996: 140.

[27] Packer 1971: 25.

[28] The visible façade is the work of restoration, see Packer 1971: pl. LX fig. 166, 167, pl. LXI fig. 168.

[29] See 104-5.

product of the minimal depth of the shop space in the case of most shops. Without back rooms, the division of space was vertical, with mezzanine levels allowing a separation of space within a single room.

The differentiation of the acoustics of the space between the ground floor and mezzanine has social implications for the utility of the space. The ground floor shop spaces display a certain ability to perpetuate sounds, although it must be stressed that the space itself cannot be labelled as noisy. The RT60 for the ground floor spaces argue against the space serving to dissipate or dampen sounds, unlike the mezzanine spaces. The direct connections to the street or portico space through the front doorways and the shops' internal acoustics suggest that space alone would do little to dampen noise. In contrast, the subflooring for mosaic and tile on mezzanine levels or upper floors would isolate more noise, although open windows would offset this. While an acoustic hierarchy based on the reverberation time could be constructed with the ground floor at the top, it seems better to see the differences as implications for the social usage of the space. The difference was that mezzanine space served a smaller group of people, namely the inhabitants, whereas the ground floor space was focused on the street.

The difference in shutter position would alter the acoustic character of the shop, as well as indicate changes in potential noise produced in the space. Modern wood flooring is of a similar size to the wooden shutter boards used in ancient shops. The NRC rating for modern wood flooring (similar to wooden planks used on the shutters) is 0.085. In the shops of the Portico di Pio IX, this gives the closed wooden shutters an absorption unit of 0.8925 Sabins, although when open the space would completely absorb the sound.[30] The difference in absorption between open and closed doorways would alter the amount of noise, and the quality of the sounds, heard outside the shops. These differences have implications for the character of sounds heard in and around the shops.[31]

There is a correlation between shops and porticoes, as seen in the previous chapter. The acoustic character of the portico marked the space as transitional, heightening the sounds produced within the portico, while still being open to the street. The shops were spaces of minimal RT60s, which meant that sounds would dissipate quickly in the space. A majority of the shops have no indications of counters, bars or other furniture despite being part of typical shop depictions. Even in the cases where these elements remain, bars and counters function to further dampen sounds in the shops, although these items also indicate increased activity in those particular spaces.

[30] Veitch 2017a.

[31] See section 3.3.4.

4.1.2 Shops

Much of the evidence for specific shop activities was not documented in the excavations of Ostia and, therefore, commercial needs can be identified in only a limited number of shops. Hermansen catalogued thirty-eight bars within the excavated area, while Bakker and Flohr catalogued the bakeries (ten) and fulleries (six) respectively.[32] While the noises associated with specific productive processes, including bakeries and fulleries, will be discussed in the next chapter, not all of the sites of production had associated retail space. The distinction between production noise and retail noise reflects differences in the economy of urban spaces. Recently, Ellis has argued for a shift in the production and commerce of Pompeii in the Augustan period.[33] Along both sides of the Via Stabiana, just inside the Porta Stabiana, early late Republican small workshops based around production are converted in the Augustan period to retail and commercial spaces with direct connections to the street.[34] The density of shops in Ostia is interesting, even without the ability to identify specific services provided. Laurence noted the high density of doorways along the streets of Ostia in comparison with Rome and Pompeii.[35] He argued that differences in density of doorways represented differences in social activity along the street segments. In Pompeii, the relatively low number of doorways on certain streets would suggest a natural difference in overall street noise, comparable to street activity. However, the density of doorways and width of streets did not always coincide.[36] In Ostia, the relative density of doorways across the city, no matter the width of the street, point to the higher levels of activity.[37] Following from this the assumed street noise would be higher in Ostia, although less spatially fixed forms of commerce are also connected with higher levels of noise.

By the second century CE, commercial and retail spaces are centred in particular groupings.[38] DeLaine categorises the pattern of distribution of shops in Ostia into four groups, where the first two categories reflect placement on main streets and public buildings.[39] The connection of shops with main streets and public buildings is also

[32] Hermansen 1982a: 125-183; Bakker 1999; Flohr 2013.

[33] Ellis 2017.

[34] Ellis 2017: 323.

[35] Laurence 2007: 107-9.

[36] Laurence 2014: 406.

[37] Laurence 2014: 406.

[38] DeLaine 2005.

[39] DeLaine 2005: 33.

evident in the use of porticoes as frontages on the streets and buildings. Placement of shops on main streets reinforces the connection between streets and retail spaces. In this case, the presence of porticoes or other spaces for gatherings are potential areas for non-fixed forms of commerce, although street traders and hawkers would use any available street space, as will be discussed in the following chapter.

The other two categories of shop placement, according to DeLaine, were of limited access and/or visibility, and required some form of local knowledge.[40] At a different scale to the rows of shops fronted by porticoes, these enclosed spaces were areas of potential noise and street activity. While porticoes along main streets provided separation in movement, as discussed above, they did not isolate noise. Street noise and noise within the portico would blend at the transitions from one space to the next, as well as providing visual continuity through the transition. In contrast, the localised focus of other commercial and retail groupings provided visual separation from the street, in which noise heard outside the space would serve as auditory sign of activities, which were not visible to the street. These groupings would then form a higher level of sound mediation, closer to apartments discussed below, than the simple shop rows and porticoes.

Some of these spatially enclosed areas of commercial space create auditory landmarks within the town. As discussed above, the shop space would do little to dampen the noise, especially when clustered together. Several of these spaces had internal piazzas or courtyards, which served a limited number of premises. One such structure was the internal courtyard just south of the Grandi Horrea (2.9.5-6). The space was entered through a portico on the Via dei Molini, to the west, and gave access to ten ground floor shops, as well as two stairways to the upper levels. Three shops and a stairway flanked the entrance, while at the back a doorway led out to portico and shops along the Via dei Grandi Horrea. The mixture of open space, with limited access, as well as street front portico space, emphasises the communal aspects of the space, furthered by a public fountain. The presence of a fountain and narrow, lockable, doorways suggests that the location was central to neighbourhood activity.[41] Noise would be a by-product of the social activity within the space within the enclosed area. The entrance was flanked by shops facing the Via dei Molini, which would shield some of the noise from the internal shops from permeating into the street. In this case, the noise of activity focused around the internal open space would be separated from street noise by the shops flanking the entrance, especially if the shops were filled with goods. The result

[40] DeLaine 2005: 34.

[41] DeLaine 2005: 34.

would be an auditory separation from the street that would reinforce the local associations of the space.

Residential accommodation, including *domus* and *insulae*, were the focal point of household activities for inhabitants who could afford such accommodations and, at times, are interconnected with simple shops. While there is no firm evidence for accommodation within the shops, the presence of mezzanines or backrooms provides a low limit for the potential number of shops in which residents lived and worked. Girri categorised the shops in Ostia into those with mezzanines, those with backrooms, those with both and those without either. Shops, with only a single ground floor room, ranged in size between 10-12 sq. m. to 40-50 sq. m.[42] Girri provides the totals for single room shops, with or without a mezzanine, at 605 and shops with a backroom, again with or without a mezzanine, at 201.[43] The presence of a mezzanine or backroom could potentially suggest habitation within the shop, which would put the total number habitable shops at less than 605.[44] The 3:1 ratio of single rooms to backroom shops is suggestive of the presence of a number of potentially non-inhabited shops, suggesting spaces that were only in-use during business hours. In total, the 806 shops in Girri's catalogue account for around 29,566.452 sq. m. of the excavated area at that time (just under 10% of the excavated area), in contrast to the seventy-three *insulae*, which accounted for 17,480.18 m^2 (around 5% of the excavated area).[45] Recent work has extended the known boundaries of inhabited space however, the percentages are indicative of the density of retail and commercial space in Ostia, which forms the principle acoustic area immediately off the street.

4.1.3 'Medianum' Apartments

The street orientation of shops is also evident in the acoustic properties and arrangement of apartments in Ostia, although in this case, visibility is limited. Sound mediation and isolation are compared with the distinctive visual remove from street created by the apartment façades. Unlike the shops, these apartments indicate a middle point between the open connections with street in the shops and the separation of courtyard space, discussed in the next section. Noises, produced within the apartment, were heard in other rooms, as well as outside the apartment. The dual penetration of noise into other rooms and outside the apartment created different auditory hierarchies.

[42] Girri 1956: 6.

[43] Girri 1956: 42.

[44] There is little indication on the plans of Scavi di Ostia I for shops with mezzanine levels.

[45] Girri 1956: 36, 41-2.

Unlike shops, internal auditory hierarchies were created in the layout and arrangement of space within the apartments, while, at the same time, the mediation of sounds by the façade, evident in the material's TL ratings, indicate auditory hierarchies created beyond the individual apartment space. In this respect, the acoustics of the individual rooms relate both to the internal hierarchies, as well as to outside hierarchies of the street.

The so-called '*medianum*' apartments are in greater numbers in Ostia than Pompeii, being a late first century CE development in housing.[46] The '*medianum*' apartment forms a distinctive group of 40 out of 100 apartments in Ostia.[47] The distinctions of the apartments are in the design and layout of the apartments. The basic form centres on a central hall (room M), *medianum*, with two unequal rooms (A and B) at either end and smaller secondary rooms (C) opening off the central hall (Fig. 4.5, see Appendix 1).[48] Appendix 1 models rooms A, B, and M for each of the apartments following the room designations in Delaine 2004. The rooms at either end, of the hall are associated with reception activities. Entrances, passages, and internal staircases are evident in all the apartments, with the exception of the six smallest apartments, which were ground floor only (3.12.1, 2; 3.13.1, 2; 5.3.3, 4; see Fig. 4.5). These six apartments share certain features, including entrances directly into the *medianum*, lack of internal upper floors, and relative size less than 170 m^2, suggesting a distinctive group within the general form.[49] These apartments also open

[REDACTED]

Figure 4.5 Pompeian *atrium* house and '*medianum*' apartment layouts and space syntax j-graph. (DeLaine 2004)

directly onto the street through room M, as will be discussed below. The Casette Tipo (Appendix 1, 3.12.1, 2 and 3.13.1, 2; c. 100 CE) are the earliest example, also being the only apartments constructed in *opus incertum*, and form four out of the six apartments within this subgroup. 5.3.3 and 4 (c. 120 CE?) are the other two apartments and are internally connected, as well as being connected to the row of six shops that form the rest of the block. In the case of the Casette Tipo, the apartments are separated from Via

[46] See Hermansen 1970, 1982a: 17-53; Packer 1971; Pavolini 2010: 167-89; Gering 1999, 2001; DeLaine 2004; 2012: 335-340.

[47] Gering 2001: 202.

[48] DeLaine introduces the designations of rooms used here to avoid the implicit connotations of Latin terms, 2004: 148-9.

[49] DeLaine 2004: 153.

della Foce by a small building with three shops facing the Via della Foce and an external staircase, suggesting at least one upper floor. The streets surrounding the Casette Tipo are all paved despite the limited buildings opening onto any of the streets. A row of shops to the east open onto the street space surrounding the Casette Tipo, while on the west two shops and a rectangular hall face the apartments. 5.3.3 and 4, instead, open directly onto streets, although 5.3.4 is at the southern end of the excavated area. The apartments form an L-shape with 5.3.4 taking up the width of the block. To the west, *insula* 5.2 contains a mixture of accommodations, shops, and a bath complex.[50] The southern end of the insula 5.2 houses an open storage area (5.2.2) and an unidentified commercial space (5.2.14) with a partially excavated warehouse with an open-air courtyard (5.1.2). To the east of the apartments, the Via delle Ermette is lined with shops. The multifunctional spaces surrounding the narrow block 5.3 are in contrast to separation of the Casette Tipo and indicate the ways in which internal acoustics will shape the social patterns of noise beyond the apartments themselves.

Spatially, the orientation of the apartments towards the outside emphasises the potential control of space through sound. The apartments are constructed from brick-faced concrete, *opus reticulatum*, or *opus incertum* (Casette Tipo only), in the same style as the shops (Fig. 4.6, Appendix 1). The common techniques are reflected in consistent AC and TL ratings, evident in the acoustic models of the appendix. Any noise above a single conversation would transmit through the walls, while any noise above half the level of conversation (anything above 30 dB or 46% of conversation noise) would transmit through the glass. Consistent features, however, do not suggest consistent auditory experiences, as will be shown. The acoustic characteristics of the apartments reflect the design tendencies to use standard dimensions and consistent construction materials (see Appendix 1).[51] Dimensions, especially the double height of many reception rooms (A and/or B), create key auditory differences, despite the common layout features. In particular, reception rooms A, like rooms M and B, were along the same axis and oriented toward the street. Sound taking place in the reception room would, therefore, carry out into the street; or equally, outside noise would carry in.

What sets the structures apart from buildings discussed so far is the use of windows, which would visually differentiate the connections with neighbouring space, but with limited auditory isolation. Unlike the shops, the apartments relied on windows to light the majority of the space and, thus, had a certain level of isolation from the street. The apartments are all lit by windows, usually in groups of two or three, along

[50] See Boersma et al. 1985 for discussion of the whole block.

[51] See DeLaine 2004; on second century CE standardisation of shop fronts, Ellis 2011.

one side of the apartment and opposite the secondary rooms (C). Mezzanine windows, mainly found above shop doors, were usually less than 1 m in height and between 0.60-0.80 m in width, while loopholes are the smallest, with an average measurement of less than 1 m by 0.40-1.00 m.[52] Where the walls are preserved to a relevant height, large windows are evident along the outer wall or walls in all of the apartments.[53] The windows for apartments and houses range from 1.50-2.00 m by 0.90-1.30 m. These various window types were set at different heights from the ground, with a range of 1.34-2.70 m.[54] This would mean that certain levels of intrusion, especially sounds, would permeate the buildings.[55] The provision of light was a necessity in Ostia, as well as a legal requirement.[56] Light was received from external windows, and the arrangement of rooms reflects the influence of lighting. Rooms M, A and B form the central axis of rooms within the apartment layout, all of which were aligned along one side to receive light. In terms of sound mediation, windows do not isolate noise in the same way as walls, which were discussed in relation to TL.

Location	Number	Placement
1.4.3	10	4 Street; 6 Garden
2.3.3	7	Street
2.3.4	10	Street
2.6.3	7	Street
2.6.6	9	Street
3.9.3	5	1 Street; 4 Courtyard
3.9.4	N/A	
3.9.6	15	7 Street (?); 8 Courtyard
3.9.10	15	10 Street; 5 Courtyard
3.9.12	9	Courtyard (Case a Giardino)
3.9.17	14	Courtyard
3.9.18	14	Courtyard
3.9.21	8	Street

[52] Packer 1971: 26.

[53] Windows perserved, 1.4.3; 2.3.3; 2.3.4; 2.4.3; 3.9.3; 3.9.6; 3.9.10; 3.9.12; 3.9.21; 3.9.17; 3.9.18; 5.3.4; DeLaine 2004: 151.

[54] Packer 1971: 25-6.

[55] See 165-99.

[56] *Dig*. 7.1.30; 39.2.25; 8.2.11; cf. Vitr. *De arch*. 6.3.11; 6.6.6; Rodger 1972: 38-89.

3.12.1	N/A	Street (no courtyard)
3.12.2	N/A	Street (no courtyard)
3.13.1	N/A	Street (no courtyard)
3.13.2	N/A	Street (no courtyard)
4.3.3	7	Street
4.3.4	N/A	Street (no courtyard)

Table 4.1 Large '*medianum'* apartments number of windows and placement. (Based on DeLaine 2004)

Figure 4.6 House of the Infant Bacchus (1.4.3). (Author)

The placement of windows along streets has implications for the acoustic experience of the space inside the apartments, as well as outside.[57]

The reception rooms at either end of the central hall, rooms A and B, were often double height and therefore had two rows of windows stacked on top of each other. The addition of glass to the materials in a room has a direct effect on the acoustic character of the space. The transmission of sound through glass works in the same way as through walls; however, the flexibility of the glass, due to its lower mass, means that

[57] On the window bars, see Bayley, et al 2015.

at certain frequencies the damping effect of the glass is significantly diminished. At the resonant frequency the glass will vibrate in correspondence with the wavelength of the sound, causing a drop in sound absorption, meaning that certain frequencies will be heard more easily through glass. At other frequencies, non-resonant frequencies, the glass will react in its normal predicted manner.

In acoustic terms, the NCR for glass is 0.17 Sabin, indicating its reflective character. Roman glass would have a similar NCR, as the basic properties are the same and the rating is based on relative thickness. However, glass can also be rated using the Sound Transmission Class (STC) or Outdoor-Indoor Transmission Class (OITC; Tab. 4.2). These ratings are simply the amount of sound that is transmitted through the glass at different weightings, as well as other building materials (Tab. 4.2). Similar to TL, the STC or OITC reflect the level of sound transmitted through the glass, however the ratings are weighted with respect to types of noise. The STC weighting reflects human-based noises

[REDACTED]

Table 4.2 STC and OITC ratings for single pane glass. (From TD-135 2003)

, such as conversation or general office noise, while the OITC is weighted for exterior building noise, such as traffic and automotive noises. The measures are given in decibels and therefore correspond to the sound intensity drop from one side of the glass to the other, just like the TL. In particular, the relative drop in sound intensity can be measured for conversational noise, being the predominant urban noise. Two people in conversation have an SPL of 65 dB, which would mean that if they were talking outside an apartment, in the street, or inside the apartment, room M, their voices would be between 29-39 dB. In comparison, the TL for *opus incertum* was 65 dB and would therefore block the sound of two people in conversation. The STC/OITC for glass indicates a relatively noticeable sound level heard outside the windows, which would change depending on surrounding noises, both inside and outside the apartment. The difference in sound transmission between glass and *opus incertum* therefore indicates a sound mediation difference of 29-39 dB, which would be reduced to 27-37 dB difference between *opus reticulatum* and glass. What it clearly indicates is a level of intrusion by exterior noise that could disrupt activity within the apartment, or vice versa. Sound mediation in this instance enters into the political and social performance of the space, as visibility is reduced.

The variations in temperature through out the year will not dramatically affect the TL of materials. Atmospheric *refraction* of sound is a greater influence on noise

levels, than atmospheric reflection or absorption.[58] Refraction, or bending, is caused by changes in speed as the sound moves through a medium and, thus, refraction is the movement of the sound wave, not its absorption or reflection, which is a change in direction (cf. Fig. 3.2). In general, the sound level has the same decrease over distance evident in the inverse square law, however when refracted, the sound decrease does not follow a linear path. That is, the sound wave does not move in a straight line, as it bends along its path. Refraction happens in certain atmospheric conditions, but it also requires distance between the sound producer and perceiver. In the context of apartments, the distance between sound and perceiver are not great enough for refraction to affect the noise level between the internal and external spaces. Combined with a lack of electrical sound amplification, noise levels and conditions would not reach the relevant thresholds for refraction to alter the transmission of noise through the building materials.

In fourteen cases, room M is aligned along a street with the windows on the street side, while in thirteen instances room M faces an open space (Tab. 4.1). The majority of non-street facing room Ms are in the Case a Giardino complex, which has a total of seventeen apartments and thirty-six shops.[59] The brickstamps all date from the years 123, 124, and 125 CE except for three, which places the project after the Casette Tipo (c. 100 CE) and redevelopment of the north Cardo Maximus (starting in 116 CE).[60] The complex is made up of an outer square of apartments and shops with limited entrances into an internal open space, which could be shut as needed, with two blocks of apartments in the centre. The majority of materials for the project were acquired by contractors from the general suppliers, of much of Hadrianic Ostia.[61] The two blocks in the centre had four apartments each on the ground floor, which were replicated on the floors above (four floors in total) and duplicated amenities (latrines on three floors and running water on at least the second).[62]

With the Case a Giardino, the design ratios of the principal rooms (M, A, and B) can be compared with the auditory properties of the rooms. It seems that the length of room A was determined by the set measurement of 21, 24, or 27 Roman feet.[63] The length of room M and B were decided by dividing the rest of the length in simple proportions

[58] Gabrielson 2006: 7.

[59] Cervi 1998; Gering 2002; Stevens 2005.

[60] DeLaine 2002: 53.

[61] DeLaine 2002: 56.

[62] Stevens 2005: 115-6, 120.

[63] DeLaine 2004: 164.

(1:2-1:4, 3:4, etc.).[64] In auditory terms, the division of the façade length (room A: 21, 24, or 27 Roman feet) gives ranges of RT60 for 500 Hz for the resulting length of room M (see Appendix 1 for each individual room)[65]: at 21 Roman feet (3.9.10) the one example is 1.82 seconds; at 24 Roman feet (3.9.3, 3.9.4, and 3.9.21) the range is 0.85-1.15 seconds; at 27 Roman feet (3.9.12, 3.9.15-18, and 3.9.19-20) the range is 0.66-1.66. The ranges indicate several key points, especially in terms of design dimensions. The most widely used length, 27 Roman feet, the range has a spread of 0.27 seconds with an individual outlier at 1.66 seconds (Appendix 1, 3.9.12 room M). This indicates a correlation of experienced auditory property with the dimensions of the space, especially in relation to the RT60 of 0.66 seconds evident in six apartments. If the RT60 for 1k Hz is used, the difference is 0.32 seconds between apartments 3.9.15-18 and 3.9.19-20 (Appendix 1, 3.9.15-18 room M; 3.9.19-20 room M). At 24 Roman feet, the range is much more confined with a difference of 0.3 seconds, suggesting an experienced ideal, which governed the dimensions of the space. The marginal differences in the auditory properties of room M, in these cases, indicate a preference towards certain auditory properties that would influence the social utility of the space. As will be discussed below, in the other apartments outside the Case a Giardino the ideal auditory experience was governed by a different length of room A suggesting socio-economic distinctions between similar apartment arrangements. The one example at 21 Roman feet does not allow for much analysis, but being the longest RT60 at 500 Hz does indicate an ability to create greater experienced dimensions, than the actual measurement of the space. The smaller length of room M is in contrast to the auditory experience of the space, which is perceived as larger. This could potentially be a way of creating a space with a perceived grandeur, not visible in the actual dimensions. What results are a series of different proportional characteristics for room M based on the different scales in length for room A.

Within the Case a Giardino complex (c. 125 CE), the preference for room A dimensions of 24 Roman feet was paired with an RT60 of 0.66-0.93 seconds. Although the length of room A governed the length of room M and B, the auditory properties of room M relate back to choice of length in room A. This suggests room A as the structuring space, which is linked to the acoustic properties of room M. In comparison, the Casette Tipo (c. 100 CE) dimensions for room A are set at 21 Roman feet and room M and B are then divided 2:1.[66] The RT60s at 500 Hz are 0.63 (Appendix 1, 3.13.1, 3.13.2

[64] DeLaine 2004: 165.

[65] See also DeLaine 2004: 167, fig. 12.

[66] DeLaine 2004: 166, fig. 11.

room M), 0.71 (Appendix 1, 3.12.2 room M), and 1.10 (Appendix 1, 3.12.1 room M) seconds, which is around 0.72 seconds below the measurement for the one example from the Case a Giardino (Appendix 1, 3.9.10 room M). In this case, the simplified ratios for dimensions create a confined range, especially in relation to 3.13.1-2 and 3.12.2, similar to that found in the range at 24 Roman feet in the Case a Giardino. What this suggests, for the Casette Tipo, is an ideal auditory experience based on a shorter length of room A, which influences the later design of larger spaces in the Case a Giardino complex. Socio-economic distinctions are potential differences, although the overall quality of the Casette Tipo does not place them within 'poor' housing.[67]

The similarities in confined range of RT60s for 21 Roman feet outside the Case a Giardino with the range at 24 Roman feet within the Case a Giardino sample could indicate socio-economic distinctions between the Case a Giardino and other apartments. 21 Roman feet length for room A is evident in seven of the apartments outside the Case a Giardino (1.4.3/4, 2.3.3, 2.3.4, 3.12.2, 3.13.1, 5.3.3, 5.3.4) and is the middle measurement between 18 and 24 Roman feet. Within the Case a Giardino, 24 Roman feet is the middle measurement. Thus, the middle measurement creates confined ranges at whichever length (21 or 24 Roman feet). The actual length, then, is the product of the scale of the project. In this case, indicating the Case a Giardino was at a socio-economic level above the other apartments, as the auditory experience is transferred to greater dimensions. The chronology between the two projects, at most 25 years, suggests not a straightforward linear development, but, in fact, multiple socio-economic factors, those of patronage, building supply, and construction techniques, alongside auditory experience being incorporated into the design. The scale of the Case a Giardino, as well as its separation from the street, allowed for a diversity of arrangements within the design parameters that were not available to the Casette Tipo contractors.

The subgroup of apartments formed of Casette Tipo and 5.3.3, 4 all have direct entrance off room M. Part of this placement is a fact of the spatial relationship between the apartments and the surrounding buildings. As noted 5.3.3 and 4, form an L with only the windowed façades facing the outer streets, while the Casette Tipo are entirely surrounded by streets. The entrance directly into room M separates the entrance from the reception rooms A and B. The entrances for all four apartments face the inner unnamed street (see Appendix 2.1, street B). The direct access to the street from room M would mean there was a limited barrier between street noises and room M. As seen with the shops, the door panels were relatively absorptive, reflecting only a fractional amount

[67] DeLaine 2012: 337-8.

of sound energy. These apartments, on the other hand, did not function primarily as commercial spaces, although that possibility cannot be entirely ruled out. The doorway would therefore serve as the primary threshold between the internal and external space, as one might expect. The physical threshold of the door was more liminal in terms of sound. The wood of the door would allow sound to pass through, as would the walls, to a lesser extent. The low reverberation time means that the noises heard within room M, whether external noises heard inside, or those internal to the space, would not linger nor be multiplied by the architectural features of the space. It is impossible to say whether the correlation between a long corridor like room M and direct access to the street was an acoustically planned design; however, the two features are in contrast to the consistent space syntax analysis of room M, as having high local and global interaction for inhabitants despite the dimensions of the room M.[68]

In this case, the choice of street B for entrances is prioritised over the streets. Street B is the narrowest, paved in basalt, and serves as a potential communal space outside the apartments themselves, as well as connecting with the stairways to the upper floor. Sound propagation within the street would span the width and only decrease along the length as one moved away from the sound source (Appendix 2.3, 2m width). Noise, above a single conversation (above 65 dB), would transmit through the *opus incertum*, while the conversation noise would be between 29-39 dB outside the windows. Thus, street B would fill with the noise from inside the apartments above the threshold of a single conversation. Sound isolation was social, in this case, based on the use of street B and the layout of apartments.

In general, the orientation of the apartments towards the outside courtyard space in the Case a Giardino, exemplified by the windows along one side, forms a mature development from the Casette Tipo apartments, which were surrounded by buildings not directly engaging the street spaces surrounding the apartments. As noted, the arrangement of the main rooms in alignment along one wall of the apartment indicates uniform levels of intrusion into each space based on similar construction materials along the façade. The formalised courtyard spaces within the Case a Giardino were physically separated from the street space, creating a separation along the lines of the localised retail spaces, although at a much larger scale. In the case of the Casette Tipo, such segregation was created through other means external to the design elements, such as limited frontage onto the streets surrounding the apartments.

[68] DeLaine 2004: 158.

The trend in room M size to total area of the apartment relates to the room's function within the household as a common space shared by all inhabitants.[69] The higher RT60 correspond with the apartments where room M is a large rectangle or almost square space (Tab 4.3).[70] Here the RT60 reflect the general character of the space, the more reverberant spaces are more suited to common or shared spaces of activity. In contrast, the long, corridor type room M have reverberation times at the bottom of the range for average RT60.[71] The low reverberation times would indicate a space without prolonged noise, or an expansive feeling when noisy. This would support further the

	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz
1.4.3-4	0.47	0.53	0.64	0.70	0.77	0.79	0.79	0.79
2.3.3	0.6	0.68	0.85	0.95	1.07	1.11	1.11	1.11
2.3.4	0.54	0.61	0.73	0.8	0.87	0.9	0.9	0.9
2.6.3	0.5	0.58	0.75	0.89	1.01	1.05	1.05	1.05
2.6.6	0.46	0.52	0.63	0.71	0.78	0.8	0.8	0.8
3.9.3	0.58	0.67	0.87	1	1.16	1.21	1.21	1.21
3.9.4	0.52	0.59	0.74	0.85	0.95	0.99	0.99	0.99
3.9.6	0.64	0.73	0.91	1.02	1.15	1.2	1.2	1.2
3.9.10								
3.9.12	0.84	1.02	1.39	1.66	2.03	2.19	2.19	2.19
3.9.15-18	0.48	0.53	0.63	0.68	0.74	0.76	0.76	0.76
3.9.19-20	0.56	0.65	0.82	0.93	1.06	1.11	1.11	1.11
3.9.21	0.63	0.74	0.97	1.15	1.34	1.41	1.41	1.41
3.12.1	0.52	0.62	0.87	1.1	1.33	1.4	1.4	1.4
3.12.2	0.44	0.50	0.62	0.71	0.79	0.81	0.81	0.81
3.13.1	0.39	0.45	0.55	0.63	0.7	0.71	0.71	0.71
3.13.2	0.39	0.45	0.55	0.63	0.7	0.71	0.71	0.71
5.3.3	0.44	0.5	0.61	0.69	0.76	0.78	0.78	0.78
5.3.4	0.33	0.37	0.45	0.51	0.55	0.55	0.55	0.55

Table 4.3 RT60 for Room M (*medianum*). High and low values marked in red. (Based on DeLaine 2004)

notion that these were not active spaces within the apartment, either in perception or in potential activity. As table 4.3 shows, the highest RT60 measures are found in the Case a Giardino complex in apartment 3.9.12, while the lowest is one of the apartments in the subgroup of the Casette Tipo and 5.3.3-4. The difference ranges between 0.51 seconds at 63 Hz to 1.64 seconds above 2k Hz. What this suggests is an increase in disparity at higher frequencies (above 2k Hz), which corresponds to the frequency response of the space.

The average frequency response gives a general snapshot of the acoustic character. Taking the measures for each frequency shows the peaks in RT60 times correlate with 1k Hz, followed by 2k Hz. This means that the higher mid-range

[69] DeLaine 2004: 157.

[70] Large rectangle or almost square, 2.3.3; 3.9.1; 3.9.10; 3.9.12.

[71] Corridor type, 2.6.3/6; 3.12.1; 3.13.1/2; 5.3.4; cf. DeLaine 2004: 155.

frequencies would resonate within the space the longest. This reflects the character of the *equal-loudness contour*, contours indicating the perceived constant loudness of all audible frequencies, which also show the peaks in perceived loudness. The nature of the human ear perceives the 1k Hz tone more readily, as it is in the voice range. This is not to say that the spaces were designed for human speech, rather that certain human speech frequencies stand out within the space. This would provide room M with an acoustic character beneficial to human conversation, although as noted above, any noise above a single conversation would be heard on the opposite side of the wall.

The acoustics of the apartments need to be understood as part of the social and cultural production of space in relation to design, layout, and geographical location of the apartments. In terms of acoustics, the proportions and size of the room, along with dimensions of windows, will be the major factors in the character of the space, as noted above. These physical properties allowed for certain levels of sound intrusion, as well as, at the same time, shaping the internal acoustic properties. Geographical location has social implications, evident in the direct entrance into room M (3.12.1, 2; 3.13.1, 2; 5.4.3, 4). The lack of filtering potential, as indicated in the *fauces*

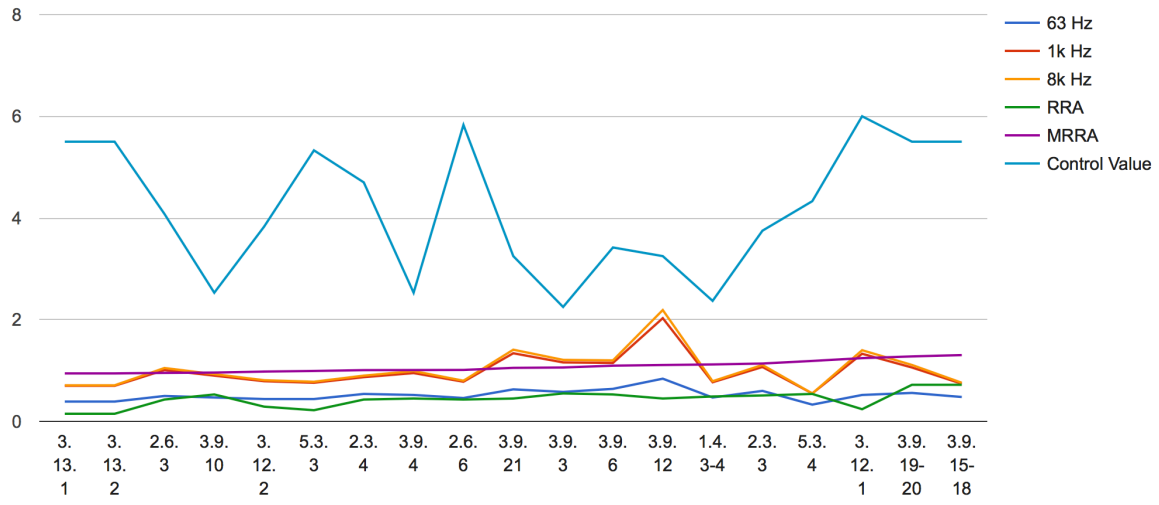

Figure 4.7 Room M: frequency response and space syntax analyses. (Based on DeLaine 2004)

common to Pompeian houses and Ostian *domus*, argues against the apartment's design with certain formal reception possibilities in mind, like the *salutatio*.[72] Further, rooms A and B are set in different relations to the entrance of the apartments. With an increase in

[72] DeLaine 2012: 337.

total rooms, room B tends towards a further distance from the entrance.[73] Spatially, the number of steps from the entrance, or spaces moved through to get to room B, is offset by the arrangement of the space in reality. Since, rooms A, B, and M are on alignment, as one moves through the space, one is always only one wall away from the street. Thus, noise, external to the apartment, would affect interaction in the three main rooms (M, A, and B) of the apartment at similar levels due to the TL ratings of the various materials. The implications are that outside noise was either tolerated, or not factored into the design process of the apartment.

One of the central approaches to the social activity of spatial arrangement is put forward by space syntax.[74] The approach produces statistical relations between the rooms in a building based on depth (steps from a space) and control (statistical weighting given a room in relation to the rooms placement within the layout).[75] In this case, depth from the entrance, which is a common measure in space syntax, describes movement around a single wall, namely the street or courtyard façade. Acoustically, rooms M, A, and B are one step removed from the street or courtyard, while in space syntax terms they have a depth between one and five.[76] In space syntax terms, the reception rooms across all apartments have different local and global interaction potential, meaning that the spaces have different potentials for activities between visitors and inhabitants. Across all apartments, room M has high local and global interaction potential, which implies a centralising function of the space, despite the size and proportions of the room (see Fig. 4.7).[77] Room M shows an overall pattern of increasing in size as the total ground floor area of the apartment increases.[78] The room M size to total area relation can be split between the apartments in which the room M is the largest space, and of ample proportions, suggesting a dominant role for the household within the apartment, and those with proportions and widths more like a hallway or passage giving access to other rooms, which suggests a segregation of the household in the various rooms.[79] The centralising function of the space, in space syntax

[73] DeLaine 2004: 159.

[74] Space syntax, Hillier and Hanson 1984, Hillier 2007; in Roman archaeology, Laurence 2007, Grahame 2000, DeLaine 2004, Stöger 2011a and b.

[75] Hillier and Hanson 1984: 108-9; Hillier 2007: 72-3.

[76] See DeLaine 2004: 159, Fig. 7.

[77] DeLaine 2004: 158.

[78] DeLaine 2004: 156.

[79] DeLaine 2004: 157.

terms, would privilege interactions between inhabitants, while allowing the segregation of the surrounding rooms.[80]

The control values (Fig. 4.7) for room M indicate that the space has a strong control over the surrounding spaces (control value > 1). In contrast, the RT60 is low (< 2) and frequency response rather limited (difference between blue and yellow lines). The lack of correlation between control value and frequency response gives an important insight into the space. Acoustically, the space is similar to shops with a compressed frequency response and short RT60, while its spatial arrangement suggests through movement. The relationship between the control value and acoustic properties is a relationship that emphasises functional usage, which is influenced by the room's inability to isolate outside noise. As shown above, in the Casette Tipo (Appendix 1, 3.12, 3.13) the *opus incertum* would reduce less outside noise further, reinforced by the presence of windows and direct entrance into room M. The minimal frequency response, in this instance, indicates a space that would not produce dynamic acoustic effects, emphasising the multifunctionality of the space. The use of *opus reticulatum* or brick-faced concrete, as well as increased dimensions, as in the Case a Giardino, would enable more noise absorption, indicating potential architectural choice based on auditory experience. These analyses are based on the acoustics of room M, however the acoustics of rooms A and B display similar nuances within the interpretation of the space.

In fact, room M and courtyards have similar calculated global and local measures. The correlation of room M with an area of interaction is in parallel with the courtyard as the space of interaction for the surrounding buildings.[81] The acoustics of both spaces would correlate with the functional use of the spaces as points of increased social interaction, and therefore increased noise. The acoustic characteristics of room M would, however, have limited reverberation and it would not be experienced as a loud space. Although the Roman definition of loud is in no way fixed, the reverberation times

[80] DeLaine 2004: 158.

[81] Cf. DeLaine 2004; Stöger 2011a.

	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz
1.4.3-4	0.47	0.53	0.64	0.7	0.77	0.79	0.79	0.79
2.3.3	0.76	0.91	1.28	1.59	1.97	2.11	2.11	2.11
2.3.4	0.7	0.82	1.07	1.28	1.49	1.54	1.54	1.54
2.6.3	0.87	1.07	1.56	2.09	2.71	2.89	2.89	2.89
2.6.6	1.01	1.26	1.91	2.63	3.6	3.92	3.92	3.92
3.93	0.97	1.17	1.73	2.27	2.93	3.14	3.14	3.14
3.9.4	0.95	1.16	1.67	2.16	2.75	2.93	2.93	2.93
3.9.6	0.91	1.09	1.51	1.88	2.3	2.42	2.42	2.42
3.9.10	1.04	1.27	1.85	2.4	3.09	3.32	3.32	3.32
3.9.12	1.03	1.27	1.88	2.51	3.31	3.58	3.58	3.58
3.9.15-18	1.03	1.27	1.88	2.48	3.25	3.52	3.52	3.52
3.9.19-20	1.03	1.27	1.88	2.48	3.25	3.52	3.52	3.52
3.9.21	0.94	1.16	1.69	2.14	2.78	3.06	3.06	3.06
3.12.1	0.74	0.91	1.33	1.73	2.27	2.49	2.49	2.49
3.12.2	0.79	0.97	1.42	1.84	2.38	2.58	2.58	2.58
3.13.1	0.76	0.94	1.39	1.8	2.38	2.61	2.61	2.61
3.13.2	0.76	0.94	1.38	1.79	2.36	2.59	2.59	2.59
5.3.3	0.8	0.99	1.47	1.9	2.52	2.79	2.79	2.79
5.3.4	0.71	0.88	1.29	1.67	2.19	2.38	2.38	2.38

Table 4.4 RT60 for Room A. Highest and lowest values marked in red. (Based on DeLaine 2004)

indicate a space that would not fill quickly with noise over prolonged periods. Other spaces with high reverberation times will ring and echo with noise for several seconds after the noise stops, such as halls in bath complexes, or basilicas. Even within the apartments, room M shows a lower reverberation time than Room A, and only a slightly lower reverberation time than Room B.

The reverberation times for room A show a relatively stable range between 2.24-3.16 seconds for rooms with a height over 3 m (Appendix 1, room A; Tab 4.4). There are five instances of single storey apartments, which form a distinct group with reverberation times of 1.87-1.92 seconds. These differences are due to the overall size of the space, as in a majority of the apartments room A was double height. As noted above, the dimensions of room A influenced the acoustics of room M, as the length of room A determined the ratio of lengths between room M and B. The overall size of room A has a less direct relation to the total area of the apartment. As the total area increases, room A shows a marked decrease in relative size.[82] DeLaine suggests that this trend relates to the room's function in relation to higher status members of the household and visitors, which is also evident in the lower control values for room A (Fig. 4.8). In the cases where room M is more akin to a corridor, and in smaller apartments, room A is the largest

[82] DeLaine 2004: 155-6.

room, suggesting that the room takes on the functions of room M in these apartments.[83] When the RT60 measurements for room A are charted in relation to the space syntax

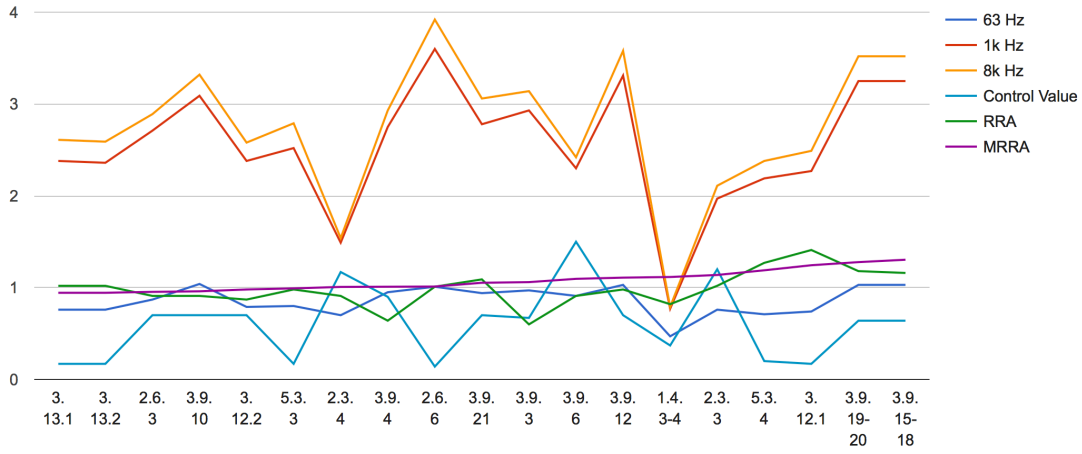

Figure 4.8 Room A: frequency response and space syntax analyses. (Based on DeLaine 2004)

control values, real relative asymmetry (RRA), and mean real relative asymmetry (MRRA), the graph shows the distinctive difference between the two forms of measurement (Fig. 4.8). However, the frequency response of room A, in comparison to control value and real relative asymmetry, shows a clear non-correspondence (Fig. 4.8). The non-correspondence emphasises further the potential of space syntax, as the higher reverberation times would produce general noise, filling neighbouring spaces. While the space syntax values indicate the room's own relationship to other spaces, the acoustic properties display actual influential aspects of the space. That is the AC, RT60, and TL all indicate experiences that do bleed into the surrounding areas, where as space syntax matrices indicate statistical possibilities. Room B is also consistent with low local, and either low or moderate global interaction potential, in space syntax terms, while room A is the most variable, with low to moderate local, and moderate to high global interaction potential.[84] The acoustic character of the space reinforces the role of room A in the social interaction of the apartments. Part of this difference between rooms A and M or B relates to the connections between room A and other spaces. Where room B tends to connect only with room M, room A is often connected with multiple spaces in addition to room M.[85] The integration of room A into the spatial layout of the apartments is

[83] DeLaine 2004: 157.

[84] DeLaine 2004: 158.

[85] DeLaine 2004: 158-9.

experienced in the reverberant characteristic of the space. The reverberant character will fill the space with sound, even when there are only a few people present. The frequency response shows a similar peak at 1k Hz, as with room M; however the response extends further with higher values at 500 Hz and 2k Hz. Room A, therefore, resonates across a wider spectrum of frequencies in the vocal range. Unlike room M, room A has a more dynamic frequency response, indicating the room's production of an acoustically differentiated space. Taken together, the low control value and dynamic frequency response indicate a space of experienced differentiation, spatially cut-off and acoustically different from room M. In this way, the non-correspondence of the acoustic and space syntax measurements indicate the production of relational spaces, in which acoustics, layout, and arrangement work simultaneously.

The frequency response and RT60 were also modelled in room A, with a traditional dining situation with three couches and nine diners (Appendix 1, room A with diners). The dimensions of the couches were drawn from those at Herculaneum.[86] Overall, the lengths vary between 2.04-2.22 m and the widths between 1.06-1.25 m, with an average of 1.15 x 2.15 m. In the model, the average dimensions are used for individual couches, which are then multiplied by three to give a total surface area of 7.42 m^2 of couch space. Nine diners are assumed, as this was the ideal number of diners from the first century BCE to the second and third centuries CE.[87] Overall, the RT60 measurements are lower for room A with dining couches and people in the room, as would be expected. The drop, with the added people and couches, is in the range of 30 seconds, which indicates a noticeable difference (Appendix 1, room A in comparison to room A with diners). In general, there is a trend towards lower RT60 at higher frequencies, as would, again, be expected. The higher absorption of high frequencies results in increased low frequency noise, which is also noise more likely to pass through wall materials. The increase in low frequency noise heard outside the apartments would be at the expense of clarity, as low frequency noise has lower levels of auditory clarity. This suggests a dual conclusion that more noise would be heard outside room A when there was a dinner and, at the same time, this noise would have less auditory clarity, suggesting less particular differentiation of the exact noises heard.

The longer reverberation time without the dining set-up suggests that conversations would linger in the room acoustically. This effect often gives the impression of continued action and greater numbers than actually present in the room. The correlation of these features with areas of the apartment for reception would be

[86] See Mols 1999: 35-42.

[87] Gel. 13.11.2 quoting Var. *Fr*. 333; SHA *Ver*. 5.1; Dunbabin 2003: 40-41.

appropriate. In terms of size, as well as spatial arrangement, room A shows a closer affinity to Pompeian *triclinia* than Room B.[88] The acoustics of room A could potentially be correlated to the function of the space in receiving guests and the impression of an expansive space through the aural architecture. With the dining couches and people, the lingering noise is absorbed in the higher frequencies (Appendix 1, room A with diners). Here the addition of dinning couches reshapes the acoustics of the space. In this case, the frequency response inverts, as high frequencies are absorbed more than low frequencies. The effect is a product of the types of materials added to the model.
In comparison to rooms A and M, room B shows the most limited range of reverberation times, between 0.47-3.2 seconds (Tab. 4.5). The limited range is reflected in the relatively stable spatial analysis, and the overall size of the space. The correlation of the overall size of room B with the Pompeian *tablinum* in large- to medium-sized atrium houses is again instructive.[89] However, the function of the room was not fixed, and the few spaces for use meant that multifunctionality was key to various rooms. The spatial measures indicate that room B had low local interaction potential in every apartment, suggesting that the space was less suited for inhabitant use, with mostly moderate global interaction potential (three lows, one high).[90]

	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz
1.4.3-4	0.61	0.73	1.01	1.31	1.6	1.66	1.66	1.66
2.3.3	0.5	0.61	0.87	1.15	1.45	1.53	1.53	1.53
2.3.4	0.47	0.57	0.8	1.04	1.31	1.37	1.37	1.37
2.6.3	0.6	0.74	1.07	1.4	1.82	1.95	1.95	1.95
2.6.6	0.57	0.7	1.01	1.32	1.69	1.81	1.81	1.81
3.9.3	0.71	0.87	1.22	1.53	1.92	2.06	2.06	2.06
3.9.4	0.59	0.7	0.94	1.14	1.37	1.44	1.44	1.44
3.9.6	0.74	0.9	1.31	1.76	2.28	2.4	2.4	2.4
3.9.10	0.66	0.81	1.18	1.54	2	2.16	2.16	2.16
3.9.12	0.74	0.91	1.34	1.75	2.31	2.52	2.52	2.52
3.9.15-18	0.85	1.05	1.58	2.21	3	3.2	3.2	3.2
3.9.19-20	0.85	1.05	1.58	2.21	3	3.2	3.2	3.2
3.9.21	0.59	0.73	1.06	1.4	1.81	1.93	1.93	1.93
3.12.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.12.2	0.49	0.59	0.85	1.1	1.39	1.47	1.47	1.47
3.13.1	0.52	0.63	0.9	1.17	1.49	1.57	1.57	1.57
3.13.2	0.49	0.59	0.85	1.1	1.39	1.47	1.47	1.47
5.3.3	0.51	0.62	0.89	1.15	1.46	1.54	1.54	1.54
5.3.4	0.55	0.66	0.96	1.24	1.58	1.68	1.68	1.68

Table 4.5 RT60 for Room B. Highest and lowest values marked in red. (Based on DeLaine 2004)

[88] DeLaine 2004: 155.

[89] DeLaine 2004: 155.

[90] DeLaine 2004: 159.

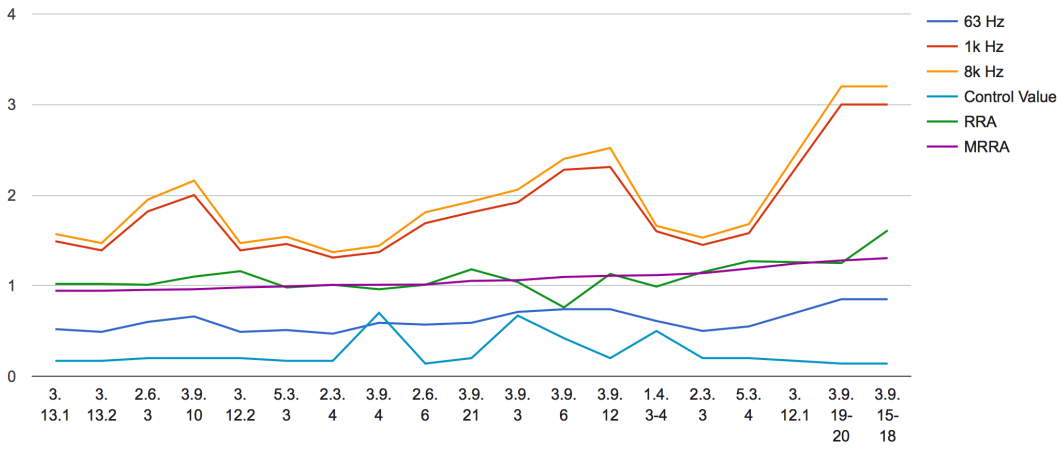

Figure 4.9 Room B: frequency response and space syntax analyses. (Based on DeLaine 2004)

Similar to room A, room B has a more dynamic frequency response than room M (Fig. 4.9). However, the RT60 times indicate that room B was in between room M and A in measurements. The acoustic differentiation of room A is experienced to a slightly lesser degree in room B, while the spatial arrangement indicates low local and global interaction. The acoustics draw out the secondary nature of the space, providing an alternative to room A. Similar to room A, room B is aligned parallel to the street or open space; however, room B is consistently at the entrance end of the apartment.[91] Thus, when entering the apartments, or the spaces above, the sound in room B could be heard.

As shown, the space syntax analyses provide a comparative model to the acoustic hierarchy of spaces, which also highlight the particular limitations of space syntax, or other visual-based, analyses. The acoustic hierarchy of space is dependent on relations between spaces normally labelled as disconnected; usually, two spaces separated by a wall. As discussed above, AC and TL measurements indicate sound energy levels that are absorbed or transmitted through materials, linking rooms within a given sound field. The auditory connections between rooms, therefore reflects connections that are not defined visually, but are experienced through hearing. The models of the internal acoustics of the apartments suggest certain differentiations of space, as well as a base line versatility of the acoustic properties, evident in the models of room A with dining

[91] Exceptions being 1.4.3; 3.9.3; 3.9.4; 5.3.3; 5.3.4; in the case of the Casette Tipo (3.12, 3.13), room B abuts the external stairwell to upper floors.

fittings. The usual dichotomies drawn between different spaces, public/private or interior/exterior being the primary divisions, have to be reformulated in auditory terms.

As argued here, the sound mediation within apartments is more complex than those of the simple shops. The '*medianum*' apartments display an acoustic ability to differentiate space, which could socially define neighbouring areas. The orientation toward the streets enabled inhabitants, and non-residents, to control the space through sound-making. This feature, however, was controlled through the geographical location, as argued in the case of the Casette Tipo, and relationship between the apartment, street, and neighbouring buildings. In several ways, the arrangement is a marked difference from that of Pompeii. The front and back regions of Pompeian houses are not geographically differentiated in Ostian apartments, but occupy space parallel to the street or courtyard.[92] Room A, in particular, shows the most dynamic frequency response, followed by room B, then room M. This hierarchy parallels the external space, which is at a single remove from each room. The acoustic hierarchy does not directly correspond with the local and global interaction values; however it does provide a more nuanced interpretation of social control of the space. The possibility of projecting noise from inside out to the street or courtyard was a direct means of social control. Hearing activity, while being physically excluded, would have been a powerful means of display.

4.1.4 Courtyards

The spectrum of sound mediation from shops to apartments is evident in the acoustic properties of the space, which display levels of intrusion by noise from inside and outside. Shops displayed the most direct noise intrusion through the wide doorway openings. It is only with the addition of porticoes or the enclosed neighbourhood spaces that shops move into more complex levels of sound mediation. In comparison, the apartments display a complexity in sound mediation at the basic level of layout, arrangement, and geographical location that sets them apart from shops. In this final case study, the sound mediation of internal courtyards are analysed to display the most complex form of noise isolation and intrusion. As will be shown, internal courtyards form auditory links to the street, although these links are quiet different from those created by apartment windows. In the case of courtyards, there is a level of isolation that separates certain frequencies of noise from the internal courtyard space, while other frequencies resonate within the space. This sound isolation and resonance are part of

[92] Grahame 2000: 56-60.

the social separation of courtyard spaces from the public space of the street, which was experienced within the space of the courtyard.

Courtyards are present in a variety of buildings in Ostia and are referred to as a distinctive architectural feature of the town. Warehouses, *horrea*, are commonly laid out around courtyards with a portico or covered walkway opening onto the open space, as well as being a feature in certain residential or social buildings. Porticoes could be repeated on upper floors, although the courtyard space was not accessible from every space within the building. Shops and stairways to upper levels had direct connections to the street, often with no access, or limited access, to the internal courtyards within the buildings.[93] The separation of street orientation and courtyard access was not uniform, or even a strict division, as many of the buildings had provisions for communal activities, such as fountains, meeting places or shrines.[94] Not every block had an internal courtyard, and at times the various units were constructed around open spaces of irregular shape or dimensions.[95] The organisational structure of courtyards has been studied, but the relationship between acoustics and spatial organisation has yet to be fully understood. As a further point on the spectrum of sound mediation, the relational character of noise intrusion and isolation within the acoustics of courtyards provides insight into production of space in Ostia.

The acoustic properties of courtyards can be simplified to a waveguide, a structure that focuses the sound waves (i.e. street), and a side resonator, a space that allows the frequencies of the sound waves to resonate (i.e. courtyard).[96] The courtyard, in contemporary thought, is seen as a potentially quiet area removed from traffic noise in urban areas; however, a recent study indicates that high noise levels can be measured in urban courtyards, due to the physical building and layout of the street and courtyard.[97] This phenomenon in contemporary urban studies relates to the levels of traffic and machinery noise, which at low levels have been connected with healthier urban living.[98] When applied to Ostia, a similar layout and structuring of courtyard and street is evident. This implies that certain acoustic characteristics evident in modern urban courtyards would potentially be found in the ancient setting as well, although the types of noises would be dramatically different.

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[93] DeLaine 1999

[94] Ulrich 2014: 326.

[95] See insula 3.1, 3.2, 4.2, Stöger 2011a.

[96] Molerón, et al 2014.

[97] Molerón, et al 2014.

[98] Gidölf-Gunnarsson and Öhrstroöm 2006.

The relationship between the street and courtyard is displayed in Figure 4.10a, in terms of the geometrical layout and configuration of the space. The courtyard is represented by the space with dimensions (lc x wc x h). The street canyon has a rectangular cross-section with dimensions (ws x h), and it continues infinitely long in the x-direction. A small entrance connects the courtyard and the street canyon with the volume, le x we x he. The source is placed in the street at the distance ls from the courtyard in the x-direction. The courtyard can be connected to the street in three basic manners (Fig. 4.10b). The configuration of the entrance, centred, decentred or closed, will determine certain aspects of the courtyard's response to sound frequencies. In particular, the presence of a façade opening means that the interaction between the .

[REDACTED]

Figure 4.10 a) geometry of courtyard acoustic problems; b) courtyard configurations: Config. A: centred entrance; Config. B: decentred entrance; Config. C: closed entrance. (Molerón, et al 2014)

street and courtyard covers all frequencies while, without a façade opening, only low frequency noise resonates in the space. This basic geometrical layout can then be used to calculate the acoustic phenomena within the courtyard, based on sounds produced in the street

In a study of the numerical and experimental modelling of courtyard acoustics, Molerón et al emphasised the importance of the façade entrance in shaping the acoustic character of the courtyard.[99] The main difference in the attenuation of the sound field by the courtyard was the nature of the sound source, either *coherent* or *incoherent*. A coherent sound source is a source that that has the same frequency and is in phase with other sound waves, usually a product of a single source and its reflections. Incoherent sounds vary in frequency and phase, as multiple sources of sound. At low frequencies the attenuation in the courtyard remains the same, due to the wavelength of the frequency.[100] At these frequencies there was also a noticeable amplification of the sound

[99] Molerón, et al 2014: 78.

[100] Molerón, et al 2014: 80.

[REDACTED]

Figure 4.11 Plan of Insula dell Muse (3.9.22) (Calza 1953)

pressure level in the courtyard in comparison with the street.[101] The result is that the courtyard does not shield low frequency noises whose source is in the street.[102] At frequencies below 20 Hz the configuration of the entrance did not change the results. This phenomenon is the product of waves propagating above the building to reach the courtyard.[103] In experiential terms, this means low frequency noises would be heard within the courtyard at similar levels to the street. The resonant character of the courtyard, especially in terms of low frequency noise, would balance the isolation potential in separating the spaces.

A distinct group of high-status, *domus*-type, houses of the first half of the second century CE are centred on internal courtyards, the Insula delle Muse (Appendix 1, 3.9.22), Insula di Giove e Ganimede (1.4.2) and the dwelling preceding the Casa di Diana (1.3.3-4). In overall size, they are in the bottom of Wallace-Hadrill's top quartile of Pompeian house sizes, at 750 m^2, 540 m^2, and at least 480 m^2 respectively, and the three largest reception rooms (two in the Insula delle Muse and one in the Insula di Giove e Ganimede) are larger than the Corinthian *oecus* of the Casa del Labirinto in Pompeii.[104] DeLaine argues for further Pompeian parallels in the spatial arrangement and organisation of these *domus*-type houses.[105] The physical organisation, not space syntactical arrangement, of the interior spaces varies from the Pompeian *domus*, where Ostia tends towards fewer larger rooms than Pompeii.[106] The aural architecture of the Ostian *domus*-type houses is similarly organised around the courtyard space at the centre. The basic construction of the houses in brick-faced concrete is the same as the shops, which flanked the entrances to several of the *domus*. The courtyard was open to light and air, as well as noises.

The Insula delle Muse (Appendix 1, 3.9.22 courtyard) was apart of the Case a Giardino complex (c. 125 CE) and thus, can be placed within the previous discussion of apartments in the complex. Unlike the shops and apartments, the RT60 measurements have little variation across different frequencies due to the open-air nature of the space.

[101] Molerón, et al 2014: 80.

[102] Molerón, et al 2014: 81.

[103] Molerón, et al 2014: 81.

[104] DeLaine 2012: 332.

[105] DeLaine 2004: 162.

[106] DeLaine 2012: 332.

The model in Appendix 1 (3.9.22 courtyard) includes the portico and covered walkways around the central open space. The courtyard configuration is a decentred type (Fig. 4.10b), as the entrance leads to the east corner of the courtyard, suggesting auditory links across all frequencies. Surrounding the Insula delle Muse, to the north and west, are a passage between the Via delle Volte Dipinte (Appendix 2.1, Via delle Volte Dipinte) and an inner open space, as well as a passage between the inner Case a Giardino courtyard and the open space parallel to the Cardo degli Aurighi. The geographical location will determine certain possibilities of street noise; however the location of the *domus* in the north east corner of the complex with an entrance to the street, rather than into the inner complex public space, makes the *domus* open to those possible street noise.

The Insula di Giove e Ganimede was part of a development of two apartments with the *domus* at the end on the corner of the Via dei Diana and Via dei Dipinti (Appendix 2.1). Unlike the Insula delle Muse, the Insula di Giove e Ganimede had a small open room without an internal portico, instead having a corridor space forming an L on the west and south ends of the open space. The Insula di Giove e Ganimede and associated apartments are later than the Case a Giardino, dating to c. 130 CE with continuous relaying of mosaic and blocked doorways in the later second century CE. Being similar dimensions to a room, the open space does not have a significant effect on the acoustics of the space. However, as Molerón et al have shown, low frequency noise would still resonate within the courtyard space, while high frequency noise would filter through the buildings walls, windows, and other elements, even though the direct connection between the outside space and inner courtyard could be closed off.[107] The closed connection between external space and the inner courtyard would not complete isolate sound from outside the space. Instead, the noise at certain frequencies would be mediated by the architecture, while low frequency noise would amplify within the space due to the acoustic properties of the architectural elements. This effect is evident in the higher RT60 measures for low frequencies and lower total absorption at the same frequencies in the courtyard models (see Appendix 1).

In the context of warehouses, courtyards have similar acoustic properties, but the social implications are markedly different. The Piccolo Mercato (Appendix 1, 1.8.1 courtyard) and Horrea Epagathiana (Appendix 1, 1.8.3 courtyard) were both modelled and represent two distinctively different warehouses in the same general area north-west of the Forum. The Piccolo Mercato was constructed c. 120 CE and follows the

[107] Molerón, et al 2014: 78.

development of the north Cardo Maximus.[108] The entrance was fronted by a portico along the Via dei Misuratori del Grano facing north to the Tiber and the end of the Via delle Fortuna (Appendix 2.1). The acoustic properties of the courtyard, again, have a relatively flat frequency response from 1.48 seconds at 63 Hz decreasing to 1.37 seconds at 8k Hz, indicating lower frequency noise lingering in the space a tenth of a second longer. Experientially the differences in the RT60 will not heard between the low and high frequencies. In comparison, the later Horrea Epagathiana (137-8 CE; Appendix 1, 1.8.3 courtyard) is separated from the western wall of the Piccolo Mercato by a narrow alley (1.2 m wide). Again, the RT60 has an even descent from 1.44 seconds at 63 Hz to 1.15 seconds at 8k Hz (Appendix 1, 1.8.3 courtyard). The Horrea Epagathiana was entered from the Via Epagathiana (Appendix 2.1) across from the portico along the Via Epagathiana discussed in the previous chapter.

These two warehouses reflect the differences in scale and size in courtyard acoustics, as the general trend of low frequencies at the highest RT60 descending to high frequencies with the lowest RT60s are evident in all the warehouse courtyards (see Appendix 1, 1.8.1, 1.8.3, 1.12.1, 3.9.22). This feature is due to the scale of open space within the courtyard space in comparison with those found in other buildings, such as the Insula dell Muse. The total absorption for the courtyard spaces are the highest in all the internal models, which is due to the total area open to the air (see Appendix 1). As noted above, low frequency noise from the street would be the primary intrusion into the courtyard space. In response, the acoustic properties of the courtyard will diminish, through absorption, low frequency noise to a lesser degree than high frequency noise. What results is the reinforcement of low frequency noise within the courtyards space, as low frequency noise is not filtered out by the building and emphasised by the architecture of the space. In terms of levels of noise, therefore, geographical location takes precedence over the construction materials in isolation noise from the courtyard space of the warehouses.

A feature of some of these courtyard buildings is a *'tablinum'*, or room set off the courtyard, usually opposite the entrance, with greater horizontal, and sometimes vertical, dimensions.[109] The preference for this arrangement in *domus*-type houses, the Insula delle Muse (Appendix 1, 3.9.22), Domus del Tempio Rotondo (1.11.3) and Insula di Giove e Ganimede (1.4.2), or buildings of some pretension, Caseggiato dei Triclini (Appendix 1, 1.12.1), Horrea Epagathiana (Appendix 1, 1.8.3) and Caserma dei Vigili (2.5.1), suggests that self-presentation and the reception of visitors were important

[108] DeLaine 2002: 74.

[109] Packer 1971: 17.

elements in the architecture of the space.[110] Acoustically, such rooms were directly connected to the courtyard space due to the open threshold between the room and courtyard. The Caseggiato dei Triclini (Appendix 1, 1.12.1) has remains of marble revetment in the reception space opposite the entrance that would reflect the noise out, rather than absorb the sound energy.[111] In connection with the acoustics of the courtyard itself, these additional rooms would feed noise into the courtyard space, by reflecting sound energy within the space. The courtyard of the Caseggiato dei Triclini (Appendix 1, 1.12.1 courtyard) is relatively reverberant, with a range from 1.96-2.57 seconds. However, the frequency response shows the same steady decline in reverberation time as the frequency increases, which was seen in the warehouse courtyards. Low frequency noise would be more reverberant in the space, a phenomenon that is likely caused by the portico surrounding the courtyard as noted above. The relation of the courtyard to the street was a significant factor in the amplification of low frequency noise within courtyards indicated in the study of Molerón et al. In this case, the direct north-south alignment of the so-called *tablinum* room with the entrance at the centre of the courtyard would indicate that noises across all frequencies would enter the courtyard space, as well as reflect out of the '*tablinum*' into the courtyard. That is, the architecture will not radically affect the frequency response as would happen if the courtyard space were cut off from the street (see Fig. 4.10b, Config. C). The two phenomena would feed into each other; as low frequency noise from the street was amplified by the arrangement of the courtyard, the architecture did little to absorb the noise. The reverberation time was, again, predicted with the doors closed on the east-west sides of the courtyard. Opening the doors would reduce the reverberation times to the range of 1.74-2.23 seconds, although with the same frequency response. Along the east side of the courtyard are a series of rooms set for dining, which were also modelled (Appendix 1, 1.12.1 triclinia). Again, the ideal of nine diners was used to model a dining arrangement, although in this case, masonry couches were built into the room and textiles were added to cover the tops of the couches. The space on its own has a relatively flat total absorption of 0.20 Sabins, except for 63 Hz, which has absorption of 0.11 Sabins (Appendix 1, 1.12.1 triclinia). When people are added, the frequency response shifts as the total absorption begins to tapper off at 500 Hz, when it drops from 0.44 to 0.41 Sabins. The result is an increase in the absorption of high frequencies caused by the people in the room. In relation to the courtyard space, again, the overall increase in absorption of high frequency noise would suggest an area filled with a low

[110] Packer 1971: 18; DeLaine 1999: 184; 2012: 332-3.

[111] On the decoration, Ulrich 2014: 328-9.

frequency background noise of activity within any of the surrounding spaces, whether one of the *triclinia*, the *tablinum*, or in the street.

Courtyards remained a common element into late antiquity and are part of a general architectural repertoire for houses.[112] The Domus del Protiro (5.2.4-5) was roughly 800 m^2 overall, with a courtyard in the middle of the *domus*, accessible to the inhabitants. The house was the result of rebuilding carried out around 250 CE and continued in use into the fourth century CE.[113] The house, in its final phase (c. 400 CE), had a tripartite division, with reception spaces in the back, courtyard in the middle, and shops and workshops in the front along the street.[114] The slightly smaller Domus delle Colonne (4.3.1) covers an area c. 600 m^2, but has a similar layout, with a central courtyard and fountain surrounded by rooms on all sides.[115] The earliest phases of the building can be dated to the end of the second century CE, consisting of a portico hall, which was incorporated into the later *domus*.[116] Similar buildings include the Caseggiato dei Triclini (Appendix 1, 1.12.1), Domus del Tempio Rotondo (1.11.3), Casa di Apuleio (2.8.5), Caserma dei Vigili (2.5.1), Caseggiato degli Aurighi (3.10.1) and the Caseggiato del Serapide (3.10.3).[117]

The overall acoustic character of these spaces, as discussed here, is one of low frequency reverberation and high frequency absorption. The increase in marble revetment in the decoration of walls and the use of marble flooring in late antiquity would have increased the overall reverberation, decreasing the total absorption within the space. In this way, the changes in decorative elements create experientially different spaces. The diversity of buildings with courtyards argues against a specific correlation between the auditory experience and certain social activities. Instead, the acoustics of the courtyard provide for a greater level of sound mediation and potential for multipurpose spaces. What the acoustics indicate is a connection between the external space and the internal courtyard space, even in cases where there is no visible or passageway connecting either. Sound mediation, in this instance, is the linking of the space through its auditory properties.

[112] Veitch forthcoming.

[113] Boersma, Yntema and der Werff 1986: 79.

[114] Boersma, Yntema and de Werff 1986: 77-8.

[115] See Heres 1986.

[116] Heres 1986: 140.

[117] Harsh 1935: 22; Calza 1941: 1-31.

4.2 Conclusion

Three points on the spectrum of sound mediation have been discussed in this chapter, in relation to three distinctive types of space: direct auditory connections of shops, noise mediation in apartments through windows and geographical location, and auditory linkages and sound mediation between courtyards and external space at various frequencies. Each of these case studies presented different aspects of sound mediation and, in conclusion, it is worth pointing out the development of some of the aspects of sound mediation across the different types of spaces discussed. In particular, three points will be addressed in this conclusion. 1) The direct linking of different spaces, emblematic in the wide shop doorway, was at one end of the spectrum of sound mediation, as both internal and external noises were heard in the neighbouring space. In the case of apartments and courtyards, direct auditory links were made either through noise over a certain threshold or through particular frequencies resonating within and through the architecture. 2) At another level in sound mediation, the configuration and arrangement of spaces enabled sound mediation or isolation. Geographical distinctions, further, influenced the levels of mediation and isolation, creating areas of separation off main public spaces and streets. At this level, background noise is key in terms of analysing the distance internal noise would be heard outside the space or specific distances spaces required to isolate high noise levels from internal spaces. 3) Finally, as shown in this chapter, the properties of sound create a variety of links between spaces that are not evident in the visual or kinaesthetic connections of moving through spaces. Courtyards display auditory links that are separate from architectural connections of passageways, corridors, or thresholds. Certain frequencies of noise are mediated by the architecture of the building, linking two physically separated spaces. Apartments display a different form of sound mediation that is not based on frequency, but on the overall noise level. Noise had to reach the threshold of 65 dB, roughly the level of two people in conversation, before the noise would potentially be heard outside the apartment. In the case of shops, external features, such as porticoes or enclosed spaces, were needed before sound mediation would be possible.

The spectrum of sound mediation does not display a linear progression, but instead reflects a variety of relational influences that are shaped by and continually shape the social production of space in Ostia. The experience of the interior acoustics produced by brick-faced concrete meant that boundaries, such as walls or ceilings, did not block out all noises, but did influence the geographical range that these noises travelled. At one level the opening or closing of shop doorways would alter this distance. There is a noticeable condensing of frequency response in the shops on the Portico di

Pio IX. These spaces had a more compact frequency response than other spaces, and highlight the functional usage and direct connection with the street. By comparison, the overall background noise of the area around one of the apartments would influence the distance internal noise would be heard outside the windows, while in the case of courtyards, the external low frequency noise would meld with the internal acoustic properties to create a low frequency background noise within the courtyard. In each of these cases, geography is an important element of the relational development of these spaces. The density of shops along main streets of Ostia, noted in the previous chapter, can be differentiated from the shops fronted by a portico (229 shops, < 30%). Here the direct links between the street and shop begin to be separated through porticoes starting in the second century CE. At this same time, apartments begin to be built with a different approach to sound mediation in the use of windows. Where the location of porticoes were drawn from the potential high levels of street activity, apartment locations were separated from these highly active streets. Although auditory links were made due to the transmission of noise through glass, it was the separation from movement and social activity of the streets that fostered certain levels of sound isolation, as seen in the facing of the Casette Tipo apartments onto street B.

The geographical location within the street network places precedence in interpreting the sound mediation. In many spaces, such as the shops and apartments, sounds could regularly penetrate the walls and ceiling. The inability to soundproof basic domestic spaces means that certain social interactions would either be commonly overheard, require background noise to mask the activity noise, or would take place in other spaces. That internal and external noise where heard within the spaces is an obvious statement; what has been shown in this chapter is a more nuanced understanding of the layers of sound mediation at work in certain neighbourhoods. At the most basic level, the façade functioned as a mediating layer, discussed in the previous chapter in terms of AC, RT60, and TL ratings. Construction techniques and technological innovation are evident in the architecture of the period, however these innovations were not in terms of sound isolation. Instead, another layer of sound mediation is evident in the general flow of movement around the neighbourhoods and the arrangement of individual spaces in relation to that movement. Spatial location was key to the noise levels that influenced activities in and around these spaces. As noted, in the early second century CE the Casette Tipo apartments were separated from the street, while the development north of the Forum, utilised portico frontage to separate forms of noise and movement. In the following years, the Case a Giardino complex physically separated the apartments from the surrounding area, although the Insula

delle Muse was isolated on the corner of complex presenting itself to the external neighbourhood.

Auditory links between spaces display a variety of forms of connection that are fundamentally different to visual connections. The intervention of outside noises into certain spaces requires a revaluation of traditional boundaries within and between interior spaces. As shown, visual boundaries, such as walls and ceilings, did not separate sound in the same way. The predominant form of spatial analysis, especially in connection with social interaction, is based on access and visibility, and the importance of the geographical location of certain spaces emphasises an overlooked element in the discussion of boundaries. Auditory links between external spaces and inner courtyards was a case in point. No visual or direct connection was required for low frequency noises to be heard within the space. In this case, the architecture and acoustic properties further amplified the low frequencies through resonance within the space. Glass would disperse some noise, but could also create different acoustic effects. Glass resonance would have been a distinctive character of the acoustics of the apartments, in comparison with shops, while also allowing for noise to transmit when visibility was restricted.

Acoustic analysis offers a means of critically engaging with the way physical structures form boundaries. The ability of noises to permeate the walls of buildings suggests that certain social interactions could have occurred where there was a physical barrier between the subjects. Overhearing was possible in certain areas, such as reception rooms facing streets, which changes the definition of public and private. These are forms of auditory resistance that shape the type and style of social interactions on the street, as well as inside the space.[118] Unlike space syntax analyses, acoustics analysis emphasises the extension of sound beyond the boundaries of the space within the architecture of the apartments. The relational spatial production, argued in this thesis, emphasises sound mediation as a potential way of assessing changes in behaviour and social interactions. To be overheard often implies fluid spatial implications, where the one overhearing is unseen or unknown.[119] The concerns of Republican elites in Rome discussed in chapter two were over the movement of certain forms of sound, such as *fama*. The movement of *fama* had to start somewhere, and *triclinia* are one of the prime locations. In this chapter, the acoustic properties of internal spaces have been assessed in attempt to answer such questions. The result is a complex interrelationship involving internal acoustics, sound mediation and the social world external to the building. The

[118] See Cluett 2010: 4.

[119] Cluett 2010: 4.

sounds of movement in the street acted as a background noise to internal noise of such social activities, like dining. In certain places, like the Case a Giardino, physical barriers could control movement.

Considering the spaces analysed, there is a clear spectrum of auditory experience based on the different forms of sound mediation discussed here. Acoustic variations include the compact frequency response of courtyards, shops and room M, and the dynamic frequency response of rooms A and B. These internal properties of the space influenced the sound level and particular frequencies that would filter out into neighbouring spaces. However, these advances do not indicate a pre-thought-out design or manipulation of architectural acoustics. The use of glass windowpanes would differentiate this experience of the noise, but was based on the requirement of light. The reception rooms, A and B, of the apartments, which were more reverberant than the other rooms, were spaces of display. In acoustic terms, as shown, the display would not need to be seen, but could be heard by those passing in the streets, or in neighbouring spaces. The acoustics of the space could, in this case, be used to extend the social importance of the inhabitant beyond the bounds of the room, and into other spaces. This moves the analysis of social interaction beyond the confines of individual rooms and into the relational architectural connections between different spaces. In contrast to art historical interpretations of display, founded on visual connections, acoustics enabled spaces to be connected without direct visual links.[120] Again, relational spatial connections are formed through analysing the acoustic properties of spaces.

The density of buildings in Ostia, and inhabitants, with little acoustic dampening, meant noise travelled beyond the confines of single spaces, evident in the transmission loss of walls. The movement of noises on the street, which could penetrate the doors, ultimately defined the internal spaces, which were perceived through more than just the eyes. In the next chapter, movement as a primary form of noise is assessed in terms the geography that it creates within Ostia. Architecture can no longer serve as a container for social activity, as the noise of social interactions spilled out from the spaces. This calls for a wider view, taking in the surrounding structures, rather than merely individual buildings. The spectrum of sound mediation argued for in this chapter serves as a starting point for interpreting the noise levels produced outside of individual buildings within the streets of Ostia.

[120] Cf. Clarke 1991.

Chapter Five
Work Noise and Movement

Prima salutantes atque altera conterit hora,
exercet raucos tertia causidicos,
in quintam varios extendit Roma labores, sexta quies lassis, septima finis erit…
Martial, *Epigrams* 4.8.1-4

"No camera, no image or sequence of images can show these rhythms. One needs equally attentive eyes and ears, a head, a memory, a heart."
H. Lefebvre, *Rhythmanalysis*, 227.

"In the city there is a rhythm, too, with the rush hours and daily rising crescendo of noises that at night recedes to pianissimo only towards the morning hours."
D. Ihde, *Listening and Voice*, 87.

Urban noise and acoustics were experienced within Ostia. This experience was part of the ongoing reproduction of Roman urbanism and urban noise, which as an object of study, provides insight into places of social reproduction.[1] Noise was located in Ostia and these locations were the sites of moral judgements and social values, discussed in chapter two (2.3). In this chapter, the locations of work noise are analysed to understand the rhythms of daily interactions from which moral judgements and social values were derived.[2] This chapter argues that work noise was located on the periphery of important social nodes in Ostia and that this peripheral status indicates potential inclusion, as well as possible exclusion. Urban work noise elicited moral judgements, seen in section 2.5, and created experiences, which were interpreted through such judgements.

Daily rhythms are produced through spatial and social interactions in time. These rhythms also produce noise, as social interactions and spatial practices involve the auditory field. The movements of people and goods were structured by the needs and requirements of street users. This was not an individual choice, but was worked out in negotiation with other street users. This relationship between people and spaces in Ostia forms a key part of urban noise in the town. As Harvey aptly puts it, 'We all help to build a city and its way of life through our actions without necessarily grasping what the city as a whole is or should be about.'[3] The production of space in Ostia was a

[1] Lefebvre 1991: 210-2; 2014b: 113-6.

[2] See Lefebvre 2013.

[3] Harvey 1989: 241.

combination of diverse daily rhythms that engaged the physical and social aspects of the town simultaneously. In this chapter, daily rhythms of noise are brought to the fore in order to understand the role of work noise in the experience of urban space. Non-elite forms of urbanism create the space of the town, just as the traditionally studied elite spatial interactions.[4] In this chapter, attention is placed on non-elite workers and the associated urban noises that make up daily rhythms. The typical understanding of the elite literary rhythms, seen in chapter two (2.3), are a counter point to rhythms of workers explored here.

Auditory fields are only experienced when noises fill the space. The auditory field of any urban space, whether interior or exterior, sets the parameters for social interaction within that space. Physical dimensions of space, and the associated auditory fields, bridge the analytical divide between space and social interaction. The previous chapters have offered a quantitative approach to the quality of space in Ostia.[5] As demonstrated, acoustic properties were the basic foundation for the social utility of the space, resulting in an architectural influence on potential uses. In this chapter, attention shifts away from the architecture of internal spaces and, instead, focuses on non-elite spatial practices and the geography of noises associated with non-elite urbanisms. Some definitions are in order, before turning to the case studies of non-elite spatial practices.

As described in chapter two, the literary image of Rome has become a stand-in for the understanding of urbanism in general. Elites are the predominate group discussed with regard to cities, as their investment in monumental architecture is readily visible. Anyone below elite status is given minimal, or no, recognition in the development of urbanism. However, the investment of non-elites in urbanism is diverse and accounts for the majority of everyday interactions.[6] What is missing in the case of non-elites is monumental architecture. Architectural intervention at the non-elite level is usually viewed as non-civic, small-scale interventions, such as blocked doorways.[7] Noise, and the spaces of noise, can create non-elite monumental spaces. As Lefebvre argues, architectural space does not produce its own message; instead, spaces receive messages from human actors and reflect the mixed messages.[8] Monumentality is the product of social interactions in space, which geographically anchor the interactions in

[4] See Wilson and Flohr 2016; Laurence et al 2011.

[5] On the importance of qualitative representations of space in the Roman context, Riggsby 1997; 2003: 171-2.

[6] See sections 4.1.1-2, 4; Flohr 2013; Wilson and Flohr 2016.

[7] See Hermansen 1982a; Gering 2004, 2012.

[8] Lefebvre 2014b: 11.

space-time.[9] In this way, the geographical distribution of different noises, especially those associated with the non-elite, creates monumental spaces from within the everyday architecture of the town. Monumentality relates to the experience of urban space, rather then its concentration of building resources.

In this chapter, 'non-elite' urbanism is defined as a social and spatial practice that creates experienced monumental spaces. Noise serves as a heuristic device to understand the experience of urban space from different perspectives. The reorganisation of the area surrounding the north Cardo Maximus was monumental in size and scale, as well as displaying supra-localised ramifications; therefore it is categorised as an elite urbanism project. In contrast, the redevelopment along the Via degli Augustali shows small-scale interventions by a series of property owners, each effecting a specific premise that, taken as a whole, reorganised the street; in this case, the redevelopment can be seen as a non-elite form of urbanisation. These categories are not fixed, and in several cases the space could be categorised depending on how the categories are differentiated. Noise allows for the exploration of potential distinctions within the urban geography that function at the level of everyday spatial practices, such as physical movements of workers or rhythms of production processes.[10]

A series of particular spaces will serve as case studies on non-elite noise and the social relationships embedded within physical buildings. In this chapter, fulleries and bakeries are analysed to show the role of noise in the centre of the town. In the first section (5.1.1-2), *fullonicae* and bakeries are discussed in terms of work noise, in relation to everyday rhythms in Ostia. Geographically, *fullonicae* and bakeries are located on the periphery of the Forum and Terme di Nettuno in Ostia. These two forms of commercial space have common features, including large-scale premises, lack of residential space and multi-stage production processes. Although not all *fullonicae* or bakeries have these characteristics, they display a distinctively different social and spatial arrangement that creates a differentiation in noises between work noise and other noise. These common features allow for a certain correspondence between rhythms of fullers and bakers throughout the day, although each trade had its own distinct noises and time spans. The acoustics of the workspaces are compared with the production cycle for each trade.

The perception of noise relays information about the volume, dimensions and materials of the built space, as well as the people and activities in those spaces (see 3.1). As we have seen, the acoustics of the internal spaces shape perceptions in the urban

[9] Lefebvre 1991: 222.

[10] See Urry 2012 for discussion of movement; Lefebvre 2013; Harvey 1988.

environment (3.2), and the noises associated with each trade would mark certain areas of the town. Everyday rhythms were embedded in the acoustic rhythms of the workshops. The issue of time and individuals in relation to noises plays an important part in the comparison between different spaces, as will be demonstrated here. Rodaway refers to the experience of sounds in the environment, as well as the acoustic properties of the environment, as 'auditory geography'.[11] The human ear perceives and interprets the noises in the surrounding area that produce a sense of place within the urban environment.[12] This sense of location is a product of the physics of sound, the way sound moves and the information it carries, and the interaction of sounds with architectural structures, as argued in chapter three. Following Rodaway, an auditory geography of non-elite workers can be mapped within the town. Auditory geography emphasises the location of noises within a specific context, a context that often plays a key role in which, or how, noises are perceived.[13] What becomes apparent is that the auditory geography of work noises emphasises two forms of noise; location specific noises and noises of movement. Noises related to specific work sites and production processes are directly related to the location of the workshop, while noises of movement are not fixed in location, but entail movements, which produce noises as a result. The location of certain noises can be associated with certain fixed activities, which brought together people, and, at times, animals, in time-space, as will be discussed below. Other non-elite noises are not geographically fixed, but rather based on movements within the town. Porters serve as a case study for noise associated with movement. In this instance, the associated noises indicate rhythms between geographical locations. Porter movements are limited to certain areas within the town, namely the harbour, secondary dock space, and warehouses.

5.1 Spatially Fixed Noise

Second century CE Ostia had a highly developed commercial trade that served the local inhabitants, regional communities and had a wider distribution.[14] Ostia has more evidence of commercially specific spaces, spaces without evidence of residence on premise.[15] Residential architecture, namely apartments and houses, make up 48

[11] Rodaway 1994: 84.

[12] On perception methods in ears, Everest and Pohlmann 2009: 56-9.

[13] Rodaway 1994: 84.

[14] DeLaine 2005: 45.

[15] Laurence 2007: 166.

separate structures, and Rickman discusses twenty warehouses in his study.[16] As noted in section 4.1.2, there are around 806 shops found within the excavated area, with 38 of the shops having evidence for a bar counter.[17] In comparison, there are six *fullonicae* and six bakeries, which make both spaces specific to their geographical locations. Unlike shops, which are located along nearly every street and have limited indications of retail specifics, the particularities of the workshop noises in these spaces are dependent on the production processes involved and the physical character of the spaces. As Wilson and Flohr note, the people working in shops and workshops were the social core of Roman urban neighbourhoods.[18] Elites were somewhat in the background within their own properties. However, as shown in chapter four, elites were not completely out of earshot, and the activities taking place within those spaces could filter into neighbouring areas. Despite the elite moral judgements of workers evident in the literary sources, the vast majority of people within urban spaces were workers and people of similar socio-economic status surrounded them.[19] From a spatial perspective, the urban streetscape was dominated by commercial space, which clearly structured social and cultural processes in Ostia.[20] It is in this context, one of widespread commercial production of space, that the background noise of the town comes to the fore. The rhythms of noise relating to work, therefore, provide a means of mapping potential background noise in Ostia. Background noise, or ambient noise, refers to any sound that is not in primary focus. In the case of Ostia, this would be the general noise of everyday life, which makes up the majority of urban noise.

The widespread dispersal of shops and workshops across the town could potentially indicate a lack of differentiation in terms of work noise. As noted above, the density of shops along the streets of Ostia was higher than Pompeii, as well as a connection between street porticoes as frontages for shops. Recently, the concept of clustering has been raised in terms of the economics of urban trades.[21] Clusters of trades would have produced soundmarks in the urban landscape, with similar crafts and trades producing similar sounds. The concept was clearly at work in the eighteenth and nineteenth centuries, but evidence for economic clustering in ancient cities is minimal. Apart from literary toponyms, which cannot be taken as evidence for clusters, only

[16] Rickman 1971.

[17] Shops, Girri 1956; bars, Hermansen 1982a.

[18] Wilson and Flohr 2016: 1.

[19] Wilson and Flohr 2016: 12; on elite views of workers, Treggiari 1980; Joshel 1992.

[20] Wilson and Flohr 2016: 4.

[21] Wilson and Flohr 2016; Goodman 2016; Ruffing 2016.

indentifying street names, the concept of clustering is connected to knowledge transfer between producers.[22] However, recent studies point to the fact that it is proximity to consumers rather than producers that fed tacit knowledge back to businesses.[23] Craft and trade related toponyms are known in Rome; however, there is no direct evidence that the craft or trade was undertaken in that area.[24] In terms of *fullonicae* and bakeries, neither was found in proximity to related workshops. At Ostia, there is marked diversity of shops and workshops across the town and no clear indication of clustering at the level of streets. By definition, the commercial space is flexible, subject to changes through time, as well as through function.[25] In this context, diversity of noises would be expected, in the midst of more continuous background noise of work.

To demonstrate the value of acoustic analysis and its ability to access the multiplicity of rhythms, this chapter focuses on the auditory rhythms of work in *fullonicae,* bakeries, markets and fairs. Together, these commercial spaces offered different forms of noise, based on the types of work, as well as being fixed in location. The various auditory rhythms functioned at different levels and overlapped with the rhythms of others. In general, the rhythms of work were more structured around the rhythms of movement and needs, for both inhabitants and visitors.[26]

General noises of commercial work can be broken into either the noise of production or the noise of retail activities. The noise of production is easier to correlate to the time-space of the activity, while indirect noises are more evident in the literary sources. The noises of production can be related to the rhythms of workers within the space of the workshop. The fixed location of these premises means that much of the day was spent in specific locations, in contrast to the more mobile activities of porters. Fulling and baking at Ostia were located in specific, large-scale, sites, rather than converted residential spaces, unlike Pompeii.[27] There are several steps to productive processes, each having corresponding noises. The noises produced in the commercial site would have filtered into the surrounding spaces and would have structure the daily rhythm in the workshop.[28]

Along with the production noises, other noises would correspond with the rhythm of productive activities. Breaks could imply conversations or silence. In

[22] Goodman 2016: 305.

[23] Amin and Thrift 2002: 63.

[24] Lott 2004: 22; *contra* Goodman 2016: 321.

[25] DeLaine 2005: 29.

[26] See Ellis 2004.

[27] Fulling, Flohr 2013; baking, Bakker 1999.

[28] See also Flohr 2017.

particular, there is evidence for singing at work.[29] As Horsfall notes, these songs were likely not work songs per se, but songs from the theatre sung at work.[30] Titinius describes the *fullones* as singing while they work, and later describes the action of soaping as *argutarier pedibus*, or 'making noise with the feet', as Flohr translates it.[31] Virgil describes two slaves working a mill, while their master sings to keep time with shouts, at times, to Scybale.[32] Sailors and boatmen are also noted for singing, although the steersman's call was rhythmic, and not always a song.[33] Seneca and Martial attest to songs being sung by crowds in the street.[34] Thus, along with the sounds of production, certain activities were influenced by, or created opportunities for, song.

5.1.1 Fulling

There are six *fullonicae* in Ostia, which are spread over the whole town.[35] The temporal sequence for shops and workshops began at dawn, with most shops open by the second hour.[36] In broad typological terms, a division of fulling sites can be made between those with shops and those without; Ostia has three with shops and three without.[37] Taking into account the scale of production, the three *fullonicae* without shops are the largest, with 34, 42, 46 fulling stalls, which suggests an orientation towards professional groups, rather than individual private customers.[38] The three *fullonicae* with shops are smaller in production scale.

Fulling had fixed locations in Ostia, and the sounds produced through the various forms of labour were spatially discrete. In these cases, the noises were produced within a given workshop space, which had its own acoustic properties, like those properties discussed in the previous chapters (4.1.2, 4). There appears to be no clustering of *fullonicae* or bakeries at the level of neighbourhood due to the chronological distinctions between *fullonicae*.[39] The three *fullonicae* located around the

[29] See Horsfall 2003; Flohr 2017.

[30] Horsfall 2003: 16, 43-5.

[31] Tit. *Ful*. fr. 8, fr. 10; Flohr 2013: 101.

[32] Verg. *Mor*. 29-31.

[33] Rut. Namat. 1.370; Sid. Apoll. *Epist*. 2.10, 27-8; Ov. *Tr*. 4.1.10; Quint. *Inst*. 1.10.16; Mart. 3.67.3; Horsfall 2003: 44.

[34] Sen. *Ep*. 56; Mart. 12.57.

[35] Pietrogrande 1976; de Ruyt 1995, 2001, 2002; Flohr 2013.

[36] Plin. *NH* 7.182; Laurence 2007: 160.

[37] With shops, 2.11.1, 1.13.3, 2.4.5; without shops, 5.7.3, 2.11.2, 3.2.2; Flohr 2013: 74 tab. 1.

[38] Flohr 2013: 78.

[39] Droß-Krüpe 2016: 340.

Terme di Nettuno complex were in use at different times and locational choices were the product of various priorities, such as available land, property costs, need for retail space, as well as accessibility, perception of the street, or proximity to residential accommodation.[40] Strabo mentions black Spanish wool being imported to Ostia, and it would make sense to see the large industrial-type *fullonicae* as processing sites before the wool was sold elsewhere.[41] Although the size and organisation of *fullonicae* in Ostia is different to Pompeii, no technological changes altered the fulling process in Roman Italy, and all *fullonicae* share the same basic procedure.[42] In connection with Rome, the Ostian workshops were part of a process that derived from the enormous demand within a relatively small region.[43] The result was the construction of purpose-built, large-scale fullers, where land price and adaptability were the economic motivations for location within Ostia.[44] Where the small-scale *fullonicae* were the public image of fulling, the larger *fullonicae* were not accessible to outsiders, and were somewhat hidden from view.[45] This relative seclusion has implications for the acoustics of the space, and the social interactions possible. None of the large-scale *fullonicae* are connected to residential spaces.[46]

The process and arrangement of fulling in the Ostian workshops structured the noises produced in the space. The trampling of clothes in the stalls would produce certain sounds, as indicated in the literary evidence.[47] In the case of 5.7.3 and 2.2.1, with a total of 32 and 42 stalls respectively, there is potential for workers in the rinsing complexes, which produced noise, as well. What is important, as Flohr notes, is not the sound itself, but whether particular noises rose above the threshold for background noise.[48] Only in the case where noises are at a higher intensity than the background noise threshold is it possible to consider the sound as a noise, in modern terms. In comparison with other trades, such as smithing or carpentry, fulling would have produced noise of lesser intensity, than the noise of wood and metal pounding.[49]

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[40] Dates, Flohr 2013: 30; locational choices, Harvey 2006: 159.

[41] Stra. 5.1.7; de Ruyt 2001.

[42] Flohr 2013: 180.

[43] Flohr 2013: 94; Flohr 2017.

[44] Flohr 2013: 236.

[45] Flohr 2013: 241.

[46] Flohr 2013: 208.

[47] Tit. *Ful*. fr. 10; Flohr 2013: 184; Flohr 2017: 43.

[48] Floor 2013: 184.

[49] Flohr 2013: 184.

[REDACTED]

Figure 5.1 Fullonicae 5.7.3 on the Via degli Augustali (Flohr 2017)

Although not analysed in the manner applied here, Flohr, rightly, emphasises the relation between social interaction within the workspace and the relative levels of noise in the area. Taking Flohr's distinction in noise levels as a starting point, 30-40 people in conversation in one of the large *fullonicae* (such as 5.7.3 or 2.2.1; fig 5.1) would produce around 72-75 dB, in contrast to around 65 dB for 5 people in the small shop *fullonicae* (1.13.3 or 2.4.5[12]).[50] The logarithmic nature of sound, again, produces more noticeable distinctions in lower numbers of people. In the case of the large-scale *fullonicae* 5.7.3, noise would be the main indication of the presence of *fullones* (fig. 5.1). The large building was purpose built in the first half of the second century CE, although later rebuilt in the third quarter of the second century CE, and centred on four large rinsing basins that were possibly unroofed.[51] The space was, in effect, a large courtyard with piers around the rinsing basins and fulling stalls along the walls under cover. In this instance, the constant and confined activity within the space would create noise beyond the predicted conversation noise of 72-75 dB. With only an entrance along the street, the space was visually secluded, but not acoustically isolated.

In terms of geographical area, 72 dB would extend 12 m from the source, while 65 dB would extend around 10 m. However, within the confined space of the *fullonicae*, the difference in quality would be noticeable. Speech intelligibility would change, with the number of people and total SPL. The primary way of quantifying speech intelligibility is through speech-reception threshold (SRT), which is the combination of the signal-to-noise ratio (SNR) to perform certain intelligibility scores (usually 50%).[52] For hearing impaired listeners, a single competing talker means an increase of 10-15 dB to the SRT.[53] In the dynamic range of speech, roughly a 30 dB range, one third is required for 50% speech-intelligibility (a SNR of -5 dB). Localisation of sound is also connected to the relative intelligibility, with a marked decrease in accuracy when the number of competing talkers is increased from 2 to 4.[54] In the context of the *fullonicae*, localisation will remain high, as the space is confined to one or two rooms. Competing voices, however, will affect the overall intelligibility of speech and the ability of workers

[50] Flohr 2013: 248; 2017.

[51] Pietrogrande 1976: 57-8, 70; Flohr 2017: 50.

[52] Wang, et al 2009: 2336.

[53] Wang, et al 2009: 2336.

[54] Stern, Brown, Wang 2006: 8.

to single out particular speakers. Localisation and identification of the sound source are related, which implies that knowledge of the *fullonicae*, its physical layout and productive hierarchy, would mean an increase in the ability of workers to differentiate sounds directly related to production, such as a manager calling.[55]

[REDACTED]

Figure 5.2 *Fullonicae* 1.13.3 on the south Cardo Maximus (Flohr 2017)

The *fullonicae* on the south Cardo Maximus (1.13.3) is a case in point for the separation of noises through the division of labour (Fig. 5.2). A coin found under the pavement dates the *fullonicae* to 150-182 CE at the earliest.[56] The small fullery is divided between a shop in front and a workspace behind with three fulling stalls and a basin (Fig. 5.2). The backroom was roofed and has no indications of windows, creating a dark and isolated space.[57] Pietrogrande indicates that there was a threshold for a door between the front shop and workspace.[58]The separation of backroom from the street space isolates the production process. From the street, a conversation at the back stalls (65 dB) would be audible (46 dB), although easily lost in background noise of the street. With the door closed, the conversation would not go beyond the front shop (19 dB at 500 Hz and 21 dB at 4k Hz). Thus, the interaction between noise of the production process in the back and the street space was mediated by the physical space of the shop, which was dependent on the overall background noise. Flohr is right to suggest that sound and odour associated with rinsing and tubs would dominate the backspace, while finishing would be out front, as it required light.[59] As noted in the previous chapter, the acoustics of shops were connected to the auditory field of the street. By moving the production into a backspace, which could be closed, the noise of production was also isolated from the street.

The *fullonicae* located within the portico of the Terme di Nettuno (2.4.5[12]) was limited to a single shop room. The basin was set at the front with three fulling stalls behind it. The small space of the shop limits the amount of differentiation. An inscription was set in the floor around the fulling stalls, which attests a *corpus fantanorum* of 232

[55] Stern, Brown, Wang 2006: 9; cf. Flohr 2013: 258-9; 2017.

[56] Coin of Lucilla, Pietrogrande 1976: 13.

[57] Flohr 2017: 48.

[58] Pietrogrande 1976: fig. 1.

[59] Flohr 2017: 48.

CE.[60] The location along the portico suggests a possible division of processing through the appropriation of the portico space. The *Digest* (43.10.1.4) specifically names *fullones* as being allowed to store clothes outside their shops in the street as long as it did not impede traffic. As already noted, the presence of a portico in itself separated different forms of movement and provided space that would not encumber movements in the carriageway.

The noises of fulling are part of the social judgements of perception.[61] Flohr emphasises that within the context of wider urban activity, the sounds of fulling would not produce 'exceptional' noise, noise above the level of background noise as discussed here. The thresholds for noises, it would seem, were similar to that of smell, which has received much more attention.[62] On the other hand, as Joshel and Petersen argue, the lack of residential space also means differences in the control of the space by superiors, whether slave owners or managers of free workers.[63] For Joshel and Petersen, noise in the workspace could create aural connections between slaves, serving as spatial tactics of resistance.[64] However, Joshel and Petersen refer only in passing to the possibility that sounds could create connections, not the actual role the space has on possible sounds. As discussed here, the connections were limited in distance and confined to direct neighbouring spaces.

The geographical distribution is problematic for *fullonicae*.[65] De Ruyt notes that *fullonicae* are not located around the Forum, although 1.13.3 is just south of the *palaestra* of the Terme del Foro (1.12.6).[66] Bradley notes the proximity to prestige buildings, although the so-called Sede degli Augustali was likely a late antique house.[67] Three are in the area of Terme di Nettuno building project (2.4), which is dated by brickstamps to 127-130 CE and inaugurated in 139 CE.[68] In terms of streets, the large-scale *fullonicae* are off the east Decumanus, the Via delle Corporazioni, and in the centre of the region surrounded by the west Decumanus, Cardo degli Aurighi, and Via delle Foce. The small shop *fullonicae* are located on the south Cardo Maximus, east Decumanus, and Via delle Corporazioni. The history of excavation and preservation

[60] *CIL* 14.4573.

[61] See Flohr 2013: 242-3.

[62] Bradley 2002; Wilson 2003; Flohr 2003; 2013.

[63] Joshel and Petersen 2014: 160.

[64] Joshel and Petersen 2014: 161.

[65] See Flohr 2013: 234-5.

[66] De Ruyt 2002: 51.

[67] Bradley 2002: 36; cf. Laird 2000.

[68] Brickstamp date, DeLaine 2002; inauguration, *CIL* 14.4494.

hinders the ability to adequately assess the overall distribution, but the majority of known *fullonicae* are on the periphery of central social nodes within the town, such as the Forum or public baths. Thus, the noises of the *fullonicae* were part of the background noise that surrounded the social and political centre of the town.

5.1.2 Bakeries

The everyday rhythm of bakers would be similar to *fullonicae* in many ways. The large mill-bakeries in Ostia show a similar separation of residential and commercial space, as well as a division of the production process along auditory lines. The temporal setting for bakers in the literary sources is distinctively different, as bakers were perceived to work beyond daylight hours. Martial refers to bakers keeping him up at night, suggesting that some would potentially be at work before dawn.[69] This extends the bakers' rhythms, requiring movement before the first hour. Martial's comment also reflects the general noise of work in mill-bakeries.

The design of bakeries at Pompeii shows a development of rationality as the workshop size increases.[70] In the case of Ostia, the workshops show the opposite end of the spectrum. The dates for the Ostian bakeries are mostly from the second and third century CE, the earliest being 1.13.4, which is dated to 100-120 CE and specifically built as a mill-bakery (Fig. 5.3).[71] Five other bakeries were installed in Hadrianic buildings at later dates.[72] Where Pompeian bakeries were a compromise between pre-existing spaces and technical needs, in Ostia spaces were transformed for large-scale milling and baking.[73] The separation of residence from the mill-bakeries, as with the *fullonicae*, created a rhythm of noises, as workers began and ended the day. These start and end points were rather abrupt soundmarks, while throughout the workday more nuanced rhythms would reflect the production process of milling and baking bread. Again, like the *fullonicae*, noises separated different aspects of the process of milling and baking. In this case, noises marked the initial phases of the process and relate to milling and processing grain, rather than baking.

[69] Mart. 12.57.

[70] Monteix 2016: 176.

[71] Bakker 1999: 111.

[72] Bakker 1999: 111.

[73] Monteix 2016: 176; Wilson 2008: 406-8; Wilson and Flohr 2016: 9.

[REDACTED]

Figure 5.3 Bakery 1.13.4 (Bakker 1999)

One of the central differences from the *fullonicae* is the use of animals in the production process. Where fulling was primarily a product of human labour, baking relied on animals for the milling of grain at certain scales. Evidence for the use of animals in the mill-bakeries comes from basalt paving, and reliefs. Donkeys or horses most often powered the mills, and in relief a single donkey/horse is usually shown yoked to the mill.[74] Animal noises would centre on the movement of the mills, including hoof noise and noise of physical exertion. The use of basalt paving inside the mill-bakeries would create the same types of animal noises as those heard on the streets. In both cases, noise was the product of physical movement and the louder noises would be made by contact with the hard stone paving. In the Caseggiato dei Molini (1.3.1), ten mills are arranged in a room paved in basalt, in which limited small finds (3 items) are listed as 'relating to animals'.[75] Seven donkey-mills and the lower part of a handmill are located in the bakery between the south Cardo Maximus and Semita Cippi (1.13.4).[76] Again, the main work area, which includes the area for milling and kneading, under a mezzanine floor, is paved in basalt, as well as the open courtyard down the centre of the bakery.[77] The similarities in paving and breading-making equipment are not arranged in any form of 'standard' layout. Thus, requirements for animals, such as water and space, are incorporated into the spatial structure of available space.[78]

The bakeries in Ostia were, like the *fullonicae*, on a larger scale than those in Pompeii. The difference in time, has already been noted in terms of construction techniques (3.2.3), and also indicates a further development of Ostia in the second century CE. The introduction of brick-faced concrete, discussed in chapter three, is part of an economic development, in which land was used for large-scale commercial use. The combination of mill-bakeries was the product of the commercialisation of bread production in Roman Italy. Pompeii shows an earlier stage in the development of combined milling and baking in the same workspace, with eleven out of thirty-nine bakeries showing no milling space in 79 CE. In contrast to the *fullonicae*, the bakeries were less 'rationally' planned for efficient movement of production in the small-scale

[74] See Zimmer 1982: 106-120, no. 18-32; Ostia reliefs, no. 24-5.

[75] Bakker 1999: 54.

[76] Bakker 1999: 61.

[77] See Bakker 1999: 62-3, figure 19.

[78] Monteix 2016: 173, n. 54.

bakeries.[79] As workspace increased, rational design choices become more evident in the arrangement, although never fully reaching the 'production line' of the modern period.[80] The productive process of bread-making required three basic steps and, as with fulling, did not undergo any major technological change during the second and third centuries CE. First, grain was milled to produce flour. This was mixed with water, and possibly yeast, to make dough in step two, and finally, the dough was baked in a purpose built oven.[81] These steps can be divided into work clusters that centre on specific tools and spaces in the bakery. Similar to fulling, the different steps in the process had corresponding noises; however, the scale of equipment, type of sound producing action, and complexity of the productive activities meant that the noises of the mill-bakery would be more varied and at a different scale to the human powered work of fulling.

The first work cluster was centred on the grinding of grain, which had three steps: tempering, milling, and sifting.[82] A mill was necessary for this step, which also fixed the action in the workspace. As noted, animals were used sometimes to turn the mills, as indicated in various reliefs and textual sources. The use of animals would have been necessary in the mill-bakeries in Ostia, due to the size and number of mills. This was the loudest stage in the process, involving donkeys, stone mills and human overseers. In representative terms, slaves and donkeys worked in the same space of the bakery, as well as actively doing similar jobs, which associated one with the other.[83] The second stage was concentrated on kneading and bread shaping, which has fewer optional steps.[84] The process of kneading was primarily human powered, although there are animal driven kneading machines in several of the bakeries. Kneading machines are found in a majority of bakeries, although set in closer proximity to ovens.[85] Proximity between the second and third stages seems to be important in the arrangement of space.[86] The final stage was the baking, which, again, was fixed in the workspace. Ovens are ubiquitous in the mill-bakeries, and are of very similar construction and design.

More space was needed for the mills and the first part of the process, than the second or third steps. This was the same hierarchy in terms of noise, which related

[79] Bakker 1999: 79.

[80] Wilson 2008: 408.

[81] Monteix 2016: 154.

[82] First and last steps were in some ways optional, Monteix 2016: 176; see south façade of Tomb of Eurysaces in Rome, Joshel and Petersen 2014: 125.

[83] Bradley 2000; Joshel and Petersen 2014: 142-7.

[84] Monteix 2016: 176.

[85] Bakker 1999: 58-60, 79, 89, 99-100.

[86] Monteix 2016: 171.

mostly to the milling process. The majority of noise would be produced in milling, as a result of the combination of grinding, movement and the physical exertion of animals and people. The rhythm of milling, noted above, could be maintained with the help of song or other audible time keeping. Spatially, mills were set in centre of the building where there was enough space (as in 1.2.2.6, 1.3.1, and 1.13.4). In several cases, the building has a narrow width and, therefore, milling took place against an outside wall

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Figure 5.4 Mill-bakeries in the area of the forum. (Bakker 1999)

(1.9.2, 2.6.7, and 2.8.9). The insulation of noise within the centre of the building would affect the noise heard outside, as discussed in chapter three, although placement was dictated by space available and the ability to adapt the space to the requirements for milling. In this sense, animal noise of milling would be an indication of a certain level of resources that allowed the bakery to reconfigure the building to its needs.

In contrast to the distribution of *fullonicae*, bakeries display certain trends in placement. Apart from 1.13.4, which is the earliest mill-bakery, and 1.12.4, which dates possibly end of the second century CE, all the bakeries are north of the east Decumanus with none in the modern regions 3, 4, or 5.[87] Of note, the Caseggiato delle Fornaci (2.6.7) is located within the Terme di Nettuno complex, along the Via delle Corporazioni, and south of the *fullonicae* 2.11.1 and 2.11.2. Although Bakker comments that this is the only bakery outside the town centre, the proximity to the theatre, Piazzale delle Corporazioni and Terme di Nettuno suggest a social node within the town.[88] Work noise around the periphery of the Terme di Nettuno complex, evident in the *fullonicae* and bakery, suggests a tolerance of such auditory interference in the midst of a neighbourhood focused toward public displays.

The rest of the mill-bakeries are around the periphery of the Forum (Fig. 5.4). Again, the proximity to areas of social importance and status are indicative of bakeries location values, alongside considerations of cost and transportation infrastructures.[89]

[87] 1.12.4 date, Bakker 1999: 99.

[88] Bakker 1999: 113.

[89] Harvey refers to these combined values as the 'life support system' for individuals, Harvey 2006: 160.

Fullonicae 1.13.3 and bakery 1.13.4 were next door to each other, just south of the *palestra* of the Terme del Foro (1.12.6), while the bakeries to the east of the forum were between two concentrations of large warehouses. Bakery noise, from the perspective in the forum, was background noise located around the periphery of the space. Levels of tolerance were necessary within this area, as the periphery of the forum was also the location of several apartments and houses (1.4.2, 3, 4; 1.3.5). What is evident in terms of work noise was that negotiation was required as fixed locations of social, political, and economic importance overlapped within the same areas.

5.1.3 Accommodation

A distinctive feature of the large-scale *fullonicae* and bakeries is the separation of work and residence. The separation from residential space further temporally separates noise; sound happens during the hours of work only. In this way, the economy of noise was first and foremost an indication of time and the temporal rhythm of the workday. There is no evidence for accommodation in the large-scale *fullonicae* at Ostia or Rome.[90]

[90] Flohr 2013: 208-11, 270; Joshel and Petersen 2014: 152, 160-1.

[REDACTED]

Figure 5.5 Horrea Epagathiana (1.8.3) ground floor and first floor (Packer 1971)

This implies that the workers lived elsewhere, commuting to and from work in the morning and evening.[91] A similar situation can be seen in the bakeries at Ostia, as well.[92] The *fullonicae*, and bakeries would have produced a rhythm of noise, which corresponded to the movement of workers in the morning and evening, as well as the rhythm of work noise associated with the production process. There is some evidence for single room accommodations in Ostia, on the first floor of the Horrea Epagathiana (Fig. 5.5; 1.8.3). On the southern side of the building, a row of rooms open onto a hallway (Fig. 5.5). Packer suggests that the rooms were possibly rented to commercial visitors who needed a room for the night.[93] While that is a possibility, these rooms could have also served as living space for potential workers.

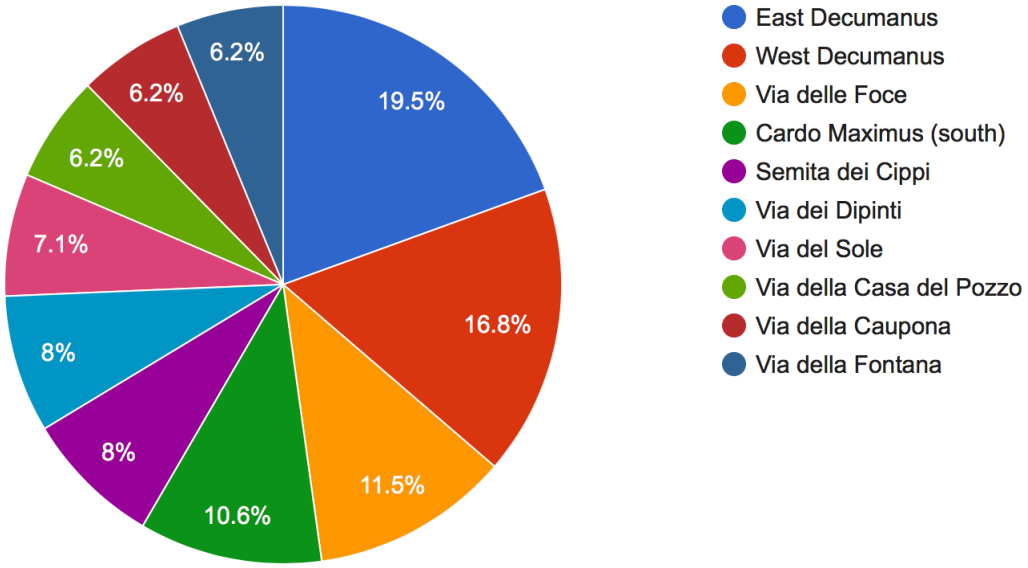

Figure 5.6 Top 10 streets with highest total narrow doorways. (Author)

[91] Flohr 2013: 270.

[92] Flohr 2013: 271; bakeries, Bakker 1999; *horrea*, Rickman 1971.

[93] Packer 1971: 152.

The Horrea Epagathiana (1.8.3) suggests that distinctions in accommodation were made vertically, rather than horizontally based on wealth.[94] That is, lower status living spaces were on the upper floors. In connection with the large-scale commercial premises, workers accommodation was likely either in shop space or on upper floors. In total, there are 160 external staircases leading from streets to upper floors across Ostia (Fig. 5.6). Figure 5.6 gives the top 10 streets with the highest total of narrow doorways, which include doorways to upper stories. While the total numbers of narrow doorways are above those of just external staircases, the total gives a picture of all forms of accommodation, whether ground floor entrances to properties or entrances to upper floor staircases. The first four streets were the main routes in the town, forming the 'Y' shape of the urban layout. The east and west Decumanus have 10 and 14 external upper floor staircases respectively, while the Cardo degli Aurighi and Semita di Cippi have four and three staircases, respectively. The next four in the top 10 streets for doorways are all smaller streets in the north-south direction. In particular, except for the Via dei Dipinti the streets are in the area south of the Decumanus and east of the Semita dei Cippi. In proximity to the *fullonicae* on the Via degli Augustali there are three staircases, one located across the street (5.10.1) and the other two behind the *fullonicae* along the Via delle Fortuna Annonaria. There are some clear groupings associated with given construction projects, like the Terme di Nettuno complex (12 staircases) and the Case a Giardino complex (14 staircases). Thus, the two main areas for *fullonicae* and bakeries are associated with higher numbers of external upper floor staircases. While the upper floor staircases are not directly linked to any of the workshops or to lower status accommodations apart from the Horrea Epagathiana, they do represent the type of evidence which should be looked at for lower status accommodation.

5.2 Moving Commercial Noise

Some commercial noises were not geographically fixed, although they were associated with particular groups or spaces. For certain people movement was part of their job and formed the central productive activity. Multifunctional commercial spaces are found throughout the town, and the development of Portus, 2.5 km north, took on storage for the *annona* in Rome, leaving Ostia's warehouses to serve other markets.[95] As long range ships could not use the Tiber, movement of barges headed to Rome, would

[94] Wallace-Hadrill makes the same point with reference to Rome, Wallace-Hadrill 2003a.

[95] DeLaine 2016: 428; Portus, Heinzelmann 2010; Keay 2005, 2012; Keay and Paroli 2011.

take three days, while by land the trip could take two or three hours.[96] Basic necessities of food, clothing, and household goods would have been available in the commercial space of Ostia or through itinerant hawkers, while its role as a maritime port meant that storehouses, markets for ships, and equipment for longer journeys were also provided.[97] Economically, both permanent and temporary inhabitants would rely on local goods for basic necessities, as well as for specialised goods particular to the town, such as goods for shipping and seamen.[98] These combinations of necessary items are dependent on the movement of goods and people, which would produce the majority of street traffic in Ostia.

The modern paradigms for traffic and congestion are useful in discussing the ancient sources, but require necessary caveats.[99] The modern conception of 'traffic' is based on the efficiency of vehicular movement.[100] However, the use of streets in the ancient world was always a competition between pedestrians and vehicles.[101] The architecture of the street is an example of this competition, as well as the implicit noises of movements. Porticoes, sidewalks, crossing stones and benches indicate separation and division of pedestrian movement from vehicular; while basalt pavement, ruts and street widths indicate vehicular movement. Not all of these forms of evidence are available for Ostia, crossing stones for example. Street wear, especially from carts, can be seen as the auditory groove, which is played by shoes, wheels and hooves.[102] Encroachment and blocking of streets, in any form, undermine the idea of economic maximisation of street space.[103] Street noise, in a similar sense, was not the product of efficiency and particularities of street individual movements, but rather an indication of a generic form and importance of mobility. Cart ruts cannot be reduced to an individual cart passing, or the single sound of a cart, but remain at the level of a history of noise and movement.[104]

The division of street space, between pedestrian and vehicular movements, was architecturally defined, although these boundaries did not isolate different street noises, as discussed in chapter three. Many of the street elements involved a certain level of

[96] Le Gall 2005: 312-3; barges, Pavolini 2010: 104-8.

[97] DeLaine 2005: 30.

[98] DeLaine 2005: 30.

[99] See Newsome 2008b.

[100] Newsome 2008b: 443; Hartnett 2011: 137.

[101] Hartnett 2011: 141.

[102] See Schwartz 2011: 430.

[103] Newsome 2011a: 42; cf. Gering 2004; 2012.

[104] Schwartz 2011: 430.

choice, suggesting thought and planning by the owner, based on movement and street activity. As noted above, *fullones* were given legal rights to store clothing in the street space so long as movement was not hindered. While this did not entail the construction of specific street architecture, social negotiation was, in this case, raised to the level of legal regulation. The development of each feature can be seen as a dialogue between street users, which had ramifications for the overall noises in streets. The construction of a portico implied a separation of types of street noise, while placement of a fountain created the noise of running water. The evidence of porticoes and arcades indicates areas of pedestrian-specific movement, within the confines of the particular portico. It is only the north Cardo Maximus that had porticoes on both sides, running the entire length of the street. The north-south direction, especially in Regio 1 and 2, from the Tiber to the Decumanus, shows the most architectural evidence for pedestrian movement. Porticoes and sidewalks are found along the majority of streets between the Decumanus and the Tiber. In later periods, many of these north-south streets were blocked to vehicular, and/or pedestrian movement.[105]

These elements provide a means of extending the façade into the street, by either literally being located in the street, i.e. benches, fountains or sidewalks, or physically extending the façade, as in the case of arcades and balconies. The extension of properties into the public space of the street forms a spatial tactic that has implications for the street noise, as argued in chapter three. The noises could range from conversation around a bench or fountain, to traffic jams of animals, pedestrians and carts. The passage of people, animals and carts would have had a certain average noise level. Hindrances and nuisances would increase the sound intensity level, as well as slowing traffic.[106] Again, the individual noises were too diverse to necessitate listing all possible sounds. Instead, the general character of work related movement of porters and the potential sites are discussed. What emerges is geography of noise oriented in the north-south direction, which linked the east Decumanus and Via delle Foce with the Tiber.

5.2.1 Porters

Saccarii are discussed in two literary contexts, the *Digest* and Apuleius' *Metamorphoses*.[107] The *Digest* reference comes in discussion of whether the sale of a plot of land with crops sown by hand would include seed dropped in hauling.[108] Paul

[105] Beginning in the third century CE, Gering 2004: 311, Abb. 49.

[106] Laurence 1999: 82.

[107] *Dig*. 18.1.40.3; Apul. *Met*. 1.7.33.

[108] *Dig*. 18.40.

responds that it depends on the agreement between seller and buyer, but seed dropped out of the carrier's bag (*ex sacco saccarii*) would not count.[109] At the start of the *Metamorphoses*, Socrates describes the terrible trouble he endured on his return from Macedonia. Socrates was attacked and robbed outside Larissa, where he was going to see a gladiatorial show. After escaping the attackers Socrates enters an inn and sleeps with the innkeeper, Meroe. The encounter ensnares Socrates; he gives her all he had and his minimal earnings as a *saccarii* in his youth.[110] These textual references offer little in terms of the practicalities of porterage, besides minimal wages and their association with sacks and packs for hauling things. *Geruli* appear more often in the context of porterage, with seventeen occurrences.[111] In Horace, mules and porters (*mulis gerulisque*) accompany a contractor (*redemptor*) as he rushes about his business.[112] A century later, Columella associates *geruli* with city markets.[113] In Suetonius, the *geruli* were a recognised workforce whose wages were worth taxing, although this comes in a description of unheard of new forms of taxing.[114] The connection of porterage with animals has already been noted, especially in terms of distance and load.[115] Between the reference to *saccarii* in the *Metamorphoses* and the taxation of *geruli* in Suetonius, there is a clear bias towards the ridiculous nature of taxing a group earning so little. However this also indicates a relative high number of porters, which would add up to a sizable amount were they all taxed.

In this context, several key features emerge. There is an association of porters with the material elements of their trade, namely sacks or amphorae, carried over the shoulder.[116] Second, low wages suggest widespread and inconsistent work. This was not solely based on the sailing season, but likely a product of need on particular days. In Pompeii, Poehler has shown that the predominate form of supply to houses were pack animals and porters and that infrastructure for carts, in the form of ramps and stables,

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[109] *Dig*. 18.40.3.

[110] Apul. *Met*. 1.7.30-33.

[111] Plaut. *Bacch*. 1002; Columella *Rust.* 10.1.1.310; Hor. *Ep*. 2.2.72; Pliny *NH* 11.24.4, 36.43.4; Sen. *Ben*. 3.28.5.2, NQ 3.18.2.5; Apul. *Met*. 77.13, 3.28.12, 4.16.10, 6.18.11, 6.20.18, 8.28.23, 9.39.31, 11.16.34; Suet. *Calig*. 40.1.9; Proph. *Onom*. 2.2.72.4; Frayn 1993: 78-9.

[112] Hor. *Ep*. 2.2.72; Frayn 1993: 79.

[113] *Et titubante gradu multo madefactus Iaccho / Aere sinus gerulus plenos gravis urbe reportet*, Columella *Rust*. 10.1.1.309-10.

[114] *Ex gerulorum diurnis quaestibus pars octava*, Suet. *Calig.* 40.1.9; cf. Frayn 1993: 79.

[115] A distinction here is between *geruli*, which are not connected with pack animals or carts, and *saccarii*, who are ambiguous, Frayn 1993: 78-9.

[116] Mosaic, Meiggs 1973: Pl. XXVa, Pl. XXVIa.

were limited to particular spaces and properties.[117] At the gates, ramps and stables were connected with inns, while within the centre of town large houses were supplied with cart infrastructure.[118] This suggests that use of carts for supplying Pompeii with goods was somewhat limited to specific types of movement, either entering the town or large-scale household demands. Porterage and pack animals formed the supply system for the rest of the town. On days when several ships came into Ostia, a larger number of hired day labourers would be employed in porterage than on days when only a few ships came.

Evidence from shoes and sandals offer insight into the noise of boatmen and porters. The climate of Ostia does not preserve any leather, nor were the methods of excavation concerned with reporting such finds.[119] However, remains of shoes from two capsised boats on the Rhine indicate that both had sandals of some quality, as well as closed work shoes.[120] Hobnails were used to hold the shoe construction together, although in the northern provinces shoemakers embellished their work with decorative patterns.[121] Hobnails would have produced a noticeable sound when walking on the hard basalt paving. This also brings to the fore the type and style of dress, which further structured body movements and noises.[122] In this case, tunics and mantels, belted or knotted to free the arms, would allow for more movement.[123] Morals aside, the difference in speed of movement produced different noises. Moving between the river and warehouses would have produced an auditory connection based on the habitual movements, type of dress, and locations associated with porters.

The most useful evidence for *saccarii* are small figurines found in several contexts across the city (Fig. 5.7). As noted above, the figurines come from fill contexts, which do not relate to occupation layers, but ground floor raising. Fifteen complete clay figurines of *saccarii*, along with forty-five fragmentary pieces, are known.[124] The figurines come from a variety of contexts, including the theatre, Piccolo Mercato, Terme di Porta Marina, Tempio della Bona Dea, Terme del Nuotatore, and the *fullonica* on the Via degli Augustali.[125] The figurines have common features: a large sack held by an

[117] Poehler 2011: 204.
[118] Poehler 2011: 202-3.
[119] Weather for preservation of footwear, Goldman 1994: 101.
[120] Van Driel-Murray 2016: 144.
[121] Van Driel-Murray 2016: 135.
[122] On women's clothing structuring movement, Harlow 2013.
[123] Harlow 2013: 232.
[124] Martelli 2013: 24.
[125] Martelli 2013: 24.

Figure 5.7 *Saccarii* figurines find spots. Size of dot refers to number of figurines. (Based on Martelli 2013)

[REDACTED]

Figure 5.8 *Saccarii* figurine. (Pavolini 1986)

extended right arm and placed on the left shoulder, left arm bent to support the sack, and legs bent slightly with the weight (Fig. 5.8).[126] Although some of the figurines have longer tunics, the short tunic is a common feature of other depictions of loading or unloading ships.[127] In Martelli's classification, group one all have incised lines about mid-calf, which could be boots. The majority of figurines are worn or fragmentary, preventing proper identification.

[126] Martelli 2013: 112, Tab. 9.

[127] Zimmer 1982: 216-30.

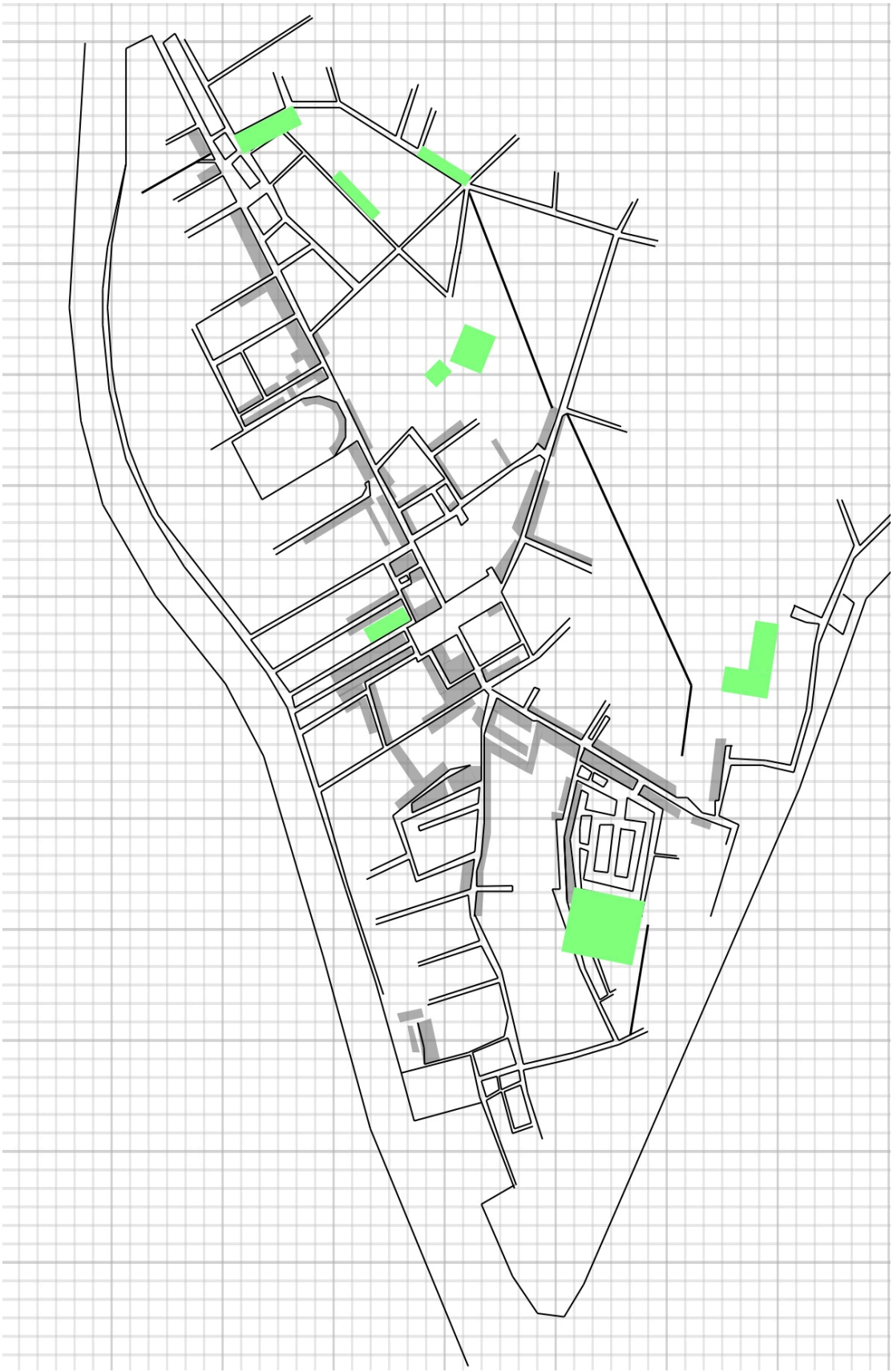

Figure 5.9 Find-spots for animal remains in Ostia (marked in green). (Based on MacKinnon 2014)

5.2.2 Animals

It is worth commenting on non-human movement in the town. The importance of animals in various aspects of production, from hauling to butchery, has been noted.[128] In particular, Ostia has very limited zooarchaeological remains, although in comparison with finds throughout Italy, it seems in line with other central Italian urban sites.[129] Seven samples were analysed from a variety of contexts in Ostia by MacKinnon (Fig. 5.9). In general, the samples had 10-12% cattle, 20-32.5% sheep/goats, 55.5-84% pig, 0.3-4% equid, 1.2-1.3% dog, and >1% cat.[130] The contexts include residential, commercial and public spaces, which show variations based on the particularities of disposal at the location.[131] The importance of the archaeological context provides clues to the nature of the evidence. In this case, rubbish fills and construction fills indicate general presence of animals within the town, but not specifically at the location. Localised rubbish disposal, evident in certain residential and commercial spaces, could indicate the animal's presence at the site. Street finds show few whole animals, and include more equid bones than other contexts, such as residential spaces, especially from the early Imperial period on.[132] This is due to the specifics of street contexts, which are rubbish fills that were part of the raising of the street. The residential spaces are also split between *insula*, *domus*, and suburban villa. In residential spaces, the archaeological contexts derive from construction fills, as well as local rubbish. In most instances, the remains seem to be waste materials used for infill associated with construction, especially the DAI/AAR street trenches in Regio 3, trench 1 in the Insula dei Dipinti, and, to a lesser extent, remains in DAI/AAR Via Laurentina and Domus trenches.[133]

In auditory terms, these various animals produced a variety of noises, as well as responding to different frequencies (Tab. 5.1). The relative noise levels of the animals will have differentiated areas of Ostia. The use of dogs as security animals indicates the utility of noise. The loud (110 dB(A)) barking of a dog would have been one of the potentially loudest sounds, although one has to factor in the ambient noise, 'background noise', to adequately gauge the audible level of the sound intensity.[134] Pig noises and human speech have similar SPL levels, indicating that, where present, pig noise could reduce the auditory clarity of human speech.

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[128] See Curtis 2008; Raepsaet 2008.

[129] MacKinnon 2004.

[130] MacKinnon 2004: 63, Table 14.

[131] MacKinnon 2014: 188.

[132] MacKinnon 2014: 190.

[133] MacKinnon 2014: 179-181.

[134] *contra* Smith 1999: 58.

Animal	Sound SPL	Hearing Frequency (Hz)
Dogs	Barking: 110 dB(A)	67-45k HZ
Horses		60-33.5k Hz
Cattle		23-35k Hz
Sheep		100-30k Hz
Pigs	Various noises: 62-67 dB (Leq)	40-40k Hz
Humans	Speech: 65 dB(A)	20-20k Hz

Table 5.1: Common animal remains found in cities of in Roman Italy with SPL and hearing frequencies. (Author)

The movement of animals for foodstuffs can be split into butchery (*lanio*) and meats sales.[135] In both cases, animals were brought into the town, either going straight to market with the *macellarius*, or kept by the *lanius* until butchered, as a tombstone from Ostia depicts.[136] While there are no definitely identified butcheries known in Ostia, the relief is suggestive of basic tools: knives, weights, a table and hanging racks. Standard sizes and weights are evident for urban pigs in the imperial and late antique periods, which suggests a regimented and organised meat market.[137] It is worth noting that in the relief, two live pigs are depicted on one side, while the butcher works on the other. Transport of live animals into town would be part of the market cycle, where people brought farm animals to town for sale.

An interesting aside is the hearing frequency of the animals found in Ostia (Tab. 5.1). Cattle have the highest sensitivity to low-frequency noises, followed by horses, then sheep.[138] The low-frequency limit of 23 Hz for cattle exceeds that for humans, while cattle's high-frequency limit is nearly an octave above that of humans.[139] This suggests that animals, especially cattle, would be more sensitive to urban noise on the periphery of human perception. Such auditory characteristics would require certain interventions in particular instances, such as the procession and sacrificing of a bull.[140]

[135] Frayn 1995: 108.

[136] Zimmer 1982: 95, abb. 4; Frayn 1995: 108.

[137] MacKinnon 2001: 661.

[138] Heffner and Heffner 1983: 304.

[139] Heffner and Heffner 1983: 308.

[140] See Weddle 2013; 2017.

The practicalities of some forms of animal movement require particular architectural elements. These could range from stone mills, discussed above, to ramps or cuts in thresholds to allow for carts.[141] A threshold inside the Caserma dei Vigili (2.5.1-2) has cuts for carts to pass through. Presumably, any carts stored in the Caserma dei Vigili would be taken out the entrance at the opposite end of the courtyard and not through either of the narrower side entrances.

In terms of movement and animals, four *loggia*, covered, open spaces, are connected with gates and entrances to the town. At the end of the north Cardo Maximus, closest to the Forum, two *loggia* are set on each side of the street. The *loggia* consists of rectangular rooms, with four piers in a square supporting the roof. The floor was paved in basalt stone, the same as the carriageway of the street. There are two other *loggia* in Ostia, both connected with city gates: the *loggia* of Cartilius Popicola by the Porta Marina, and 5.16.2 by the Porta Romana. These locations connect the *loggia* with natural gathering spots, places where people moved into and out of the city. The ability to stage animals, carts or other items in close proximity to the Forum emphasises the north Cardo's importance to visitors and guests performing civic duties, and DeLaine has suggested that the *loggia* on the north Cardo had a ceremonial function connected with the Forum.[142]

5.2.3 Transport Animals

In terms of transport animals, the use of cattle was focused primarily on traction and pulling, which corresponds with the literary sources.[143] There are slight variations in the archaeological contexts, as street contexts register higher levels of pig than cattle in the early Imperial period (*c*. first century CE).[144] What is clear from the various locations is a widespread use of cattle throughout the city, with a more limited use for meat. The almost exclusive and complete finds of cattle remains in the Castellum Aqua Trench 15 are the exceptions, and suggest primary waste of commercial butchering.[145] In other cases, like the trenches in Rooms 34-35 and 36, the remains are smaller (<50 total remains, 165 total, respectively) and collectively display a mix of slaughter, butchery and processing waste connected with localised activities.[146] However, cattle

[141] On mill-bakeries, Bakker 1999; on ramps at Pompeii, Poehler 2011.

[142] DeLaine 2005: 38.

[143] MacKinnon 2004: 90, 183-4 (tab. 1), 242.

[144] MacKinnon 2014: 188.

[145] Bukowiecki, et al 2008: 227-34; MacKinnon 2014: 180.

[146] MacKinnon 2014: 179-180.

make up the smallest segment of the main three forms of remains (pig, sheep/goat, and cattle). In terms of general age, the mean frequency percentage for fusion age was highest for 42+ months (36.1%), followed by 24-36 months (28.9%), 7-10 months (22.5%) and finally 12-18 months (6.5%).[147] In comparison, age based on dental data had the highest percentage, at 48+ months (47.4%), with percentages over 10 for 36+ and 60+ months, while the rest were under 5%, except 24-36 months with 9.1%.[148] These figures indicate that the majority of cattle were adults, implying that c. 64% on urban sites lived beyond 3.5 years.[149]

With the ability to exert 300-400 kg of force for up to six hours for a pair, cattle were suited to heavy transport.[150] The use of cattle, however, requires certain temporal constraints. The digestive system of oxen prevents them from working all day, as they require rest time to digest. The wagons for heavy transport (*plostra*/*plaustra*) were barred from entering Rome from sunrise until the tenth hour.[151] *Plostra*/*plaustra* were associated with the transport of stone, statues, and other large cargoes.[152] The *cursus publicus* had restrictions on the weight allowed by different carts for goods transport. Four-wheeled carts were limited to 1,500 pounds, while *rheda* in general were restricted to 1,000 pounds.[153] Exceptions to the prohibition on carts entering Rome were for carts loaded with materials for temples or public works, or when removing waste from public contracted demolitions, or when used in public rites, such as religious festivals, triumphs, or games.[154] Whether or not the ban on *plostra* was in effect in Ostia, the large-scale building in the second century CE would have required a variety of materials to be transported from outside the town.

Other animal remains point to animals not used primarily for food. Horses, like cattle, were used for transportation, while dogs were kept for security, as is evident from Pompeian entry mosaics.[155] Animals used for work, namely horses, mules, donkeys and cattle, were likely kept within the town, although unambiguous evidence for

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[147] McKinnon 2004: 79, table 19.

[148] MacKinnon 2004: 79, table 20.

[149] MacKinnon 2004: 80.

[150] Raepsaet 2016: 840.

[151] *Tab. Her.* 66-7; see Hartnett 2011: 147-8.

[152] Varro *Rust*. 1.16.6; 1.17.2; 1.20.3; Cato *Orig*. 62-63; *Dig*. 9.2.52.2; Frontin. *Aq*. 3.3.5; Hor. *Ep*. 2.2.74; Cic. *Verr*. 2.1.53; Ov. *Fast*. 4.345; Laurence 1999: 144; 2008: 87-9.

[153] *Cod*. *Theo*. 8.5.

[154] *Tab. Her.* 56-65.

[155] Horses, Raepsaet 2008: 586; '*cave canem*' mosaic, Pompeii, VI.8.3, 5, *PPM IV* 526-603.

stabling is rare.[156] In street contexts, a disproportionate number of equid teeth and bone scraps were found in the middle Imperial period.[157] Suetonius narrates that Gaius Caligula seized all the public carriages and animals from the bakeries to transport goods to Gaul, reducing the amount of bread in the city and causing many to lose their court cases because they could not appear.[158] Hadrian and Elagabalus both restricted the entry of carts and matrons' ability to ride carts or animals in Rome.[159] Although not without elite moral bias, the literary sources highlight the utility of animals in transportation and labour. Equids, in general, were the most common animal used in transport, with mules and donkeys dominating the commercial arena.[160] A *cisium*, a light two-wheeled carriage, was pulled by horses or mules and was associated with moving people.[161] Three depictions of *cisiarii* are found in three mosaics in the *frigidarium* of the Terme dei Cisiarii (2.2.3), which gives the building its name. In one, three riders are seated in the short-sided box of the carriage, which is pulled by two horses/mules. In the other, a single rider sits in a similar carriage, being pulled by a single horse/mule. The third shows two horses/mules drinking at a river, as a man climbs in/out of a carriage. The driver stands between the animals and carriage, although the image is poorly preserved. These depictions are set between a city wall, at the edge of the room, and an inner city wall, with male figures supporting the corners.

5.2.4 Speed

The level of noise produced by movement has a direct connection to the speed of the object moving. Weight, pressure and speed form the basic elements creating noise of movements. In Ostia, a few distinctions can be made in reference to noise. First, the noise of work movements was relative to each other. A porter was faster than a mule, using the figures discussed below, but a porter could carry less of a burden than a mule. In general, animals would have more weight and more pressure exerted on the pavement, while at a slower speed. This suggests louder noise when moving, in comparison to the lower weight and pressure, but faster speed, of porters.

Traffic noise, in many ways, is a product of the speed of movement, being connected to the friction of feet or wheels against the paving. In mechanical terms, there

[156] MacKinnon 2013: 125.

[157] MacKinnon 2014: 190.

[158] Suet. *Calig.* 39.1.

[159] SHA *Hadr.* 22.8; *Elag*. 4.4.

[160] Johnstone 2008: 128-9; Hoggarth 2014: 5.

[161] Casson 1979: 179.

is a limit to the speed of a person walking before it is necessary to break into a run. The difference between running and walking is that walking requires one foot to be on the ground at all times.[162] The *Froude number* represents the ratio of kinetic to potential energy in wave-like motions, such as walking.[163] For modern European adult men, with an average leg length of 0.9 m, an estimated walking speed 10.8 km/h represents the upper limit before a male will break into a run.[164] This is considerably faster than the evidence for walking under a burden. An eighteenth century London sedan chairman could carry a 70 kg load, at a velocity of 2.5 km/h, whereas a nineteenth century Englishman travelling with a 40 kg burden, could maintain a speed of 2.7 km/h for 20 km per day.[165] For comparison, in equatorial Africa, a man can carry 25 kg on the head over 25 km in a day.[166] At that rate, a porter could cover between 2.2 to 9.5 return trips between the river and warehouses with a load of 25 kg. In terms of daily loads, nineteenth century dockworkers could carry total loads of between 660 to 800 kg per day.[167]

The speed and load capacity of animals was greater. Mules had the greatest capacity, at between 150-180 kg, while horses varied depending on walking, 100-120 kg, or trotting, 80 kg.[168] Asses had the lowest capacity, at 80-100 kg, although they were between mules and horses, in terms of distance travelled per day, at 24-30 km.[169] In terms of speed, horses, at a trot, were the fastest, 8 km/h, compared to walking, 4 km/h, while mules varied between 3-5 km/h.[170] Thus walking in town, either humans or animals, would be around 2.5-5 km/h, with an upper limit of 10.8 km/h.

Second, the noise of the cart was a product of the technology, use and load applied to the cart, and the friction of the cart along the street. Uneven or rough paving, potholes, and curbs would create momentary, high levels of pressure on the cart and noises.[171] The wooden wheel was reinforced with an iron 'tyre', which offered longer resistance to wear on the wheel.[172] In the nineteenth century, asphalt pavement and

[162] Cotterell and Kamminga 1990: 196.

[163] Cotterell and Kamminga 1990: 196.

[164] Cotterell and Kamminga 1990: 196.

[165] Cotterell and Kamminga 1990: 194.

[166] Raepsaet 2016: 841-2.

[167] Raepsaet 2016: 588.

[168] Cotterell and Kamminga 1990: 194; Raepsaet 2008: 589.

[169] Cotterell and Kamminga 1990: 194; Raepsaet 2008: 589.

[170] Cotterell and Kamminga 1990: 194; Raepsaet 2008: 589.

[171] Ulrich discusses the pressure on carts, not the noises involved, Ulrich 2007: 204.

[172] Ulrich 2007: 210.

rubber automobile tyres were seen as the solution to the noise problem of cobblestones and ball-bearingless axles.[173] The combined friction of the wooden axles and animal hooves on pavement set the cart as an enduring source of noise.[174] In calculating the rolling resistance of a cart drawn by a single horse, and a wagon drawn by a pair of horses, Cotterell and Kamminga note the ease with which both carts and wagons with large wheels are drawn over hard ground.[175] In terms of noises levels, increased rolling resistance correlates with increases in noise level, since both phenomena are products of similar mechanical energy loss. On hard ground, the axle has the greatest resistance, especially with the iron 'tyre' reducing the friction between the ground and sections of wooden rim.[176] Thus, in terms of noise, it was a combination of ground surface, load weight and construction of the cart that would cause variations in the level of noise made in transportation.

Third, noise of movements was the product of associated activities, not directly related to weight, pressure or speed. References to conversation between pedestrians and cart users indicate the porous nature in the separation of forms of movement.[177] The relational characters of noises linked to movements include the technological advances, as well as social perceptions.

In the Latin sources there is a tendency to cite exceptional speeds, made by exceptional people, emphasising the longest distance at greatest speed.[178] Julius Caesar covered 100 miles a day for eight days; Pliny cited the longest full day journey achieved was by Nero, with 182 miles covered in twenty-four hours.[179] Less exceptional are the speeds of communication, using relays of animals and vehicles. It took a messenger four days to reach Luni from Rome, covering fifty-eight miles per day, according to Livy.[180] Other sources record speeds of seventy-two or seventy-three miles per day within Italy.[181] Again, the speed of communication was dependent on maintenance of roads and provision of animals, which start to develop with the paving of more roads towards the end of the first century BCE.[182] In the legal sources, anyone summoned to court was

[173] Schwartz 2011: 478.

[174] Schwartz 2011: 22.

[175] Cotterell and Kamminga 1990: 203.

[176] Basic structure of Roman wheels, Ulrich 2007: 208-10.

[177] *Acts* 8.27-40; Apul. *Met*. 1.2-5.

[178] Laurence 1999: 81.

[179] Suet. *Jul*. 57; Pliny *NH* 7.84; Laurence 1999: 81.

[180] Livy 39.21.5.

[181] Plu. *Cat*. 14; App. *B Civ.* 2.32; SHA *Max*. 25.2; Laurence 1999: 81.

[182] Laurence 1999: 82.

given one day to travel each twenty miles.[183] Laurence points out the reduction in speed in comparison with the speeds of communication (33% reduction in the legal sources), and relates the legal reduction to the advances in paving of roads in the first and second century CE.[184]

5.2.5 Warehouses

The presence of warehouses and larger commercial areas points to the importance of movement of goods by both land and water.[185] Movement of goods between the Tiber and warehouses was best suited to human porterage, due to the distance and time efficiency. The placement of warehouses, especially with their entrances facing the river, attests to movement in the north-south direction (see Fig. 5.10). The river port was located in the northwestern corner of the town, just inside the mouth of the Tiber.[186] Due to the geographical conditions at the river mouth, sea-going ships had to transfer cargoes onto shallower riverboats to transport goods to Rome. A large complex, which covers an area of around 70 x70 m, was discovered on the east side of the harbour.[187] The structure consisted of a terrace over a series of vaulted chambers; those facing the street to the east were used as shops (*tabernae*), and were given a portico along the street in the second century CE; to the north and west, facing the river and harbour, the chambers are deeper, c. 30 m, and served as ship-sheds, at least those on the west facing the harbour.[188] The ship-sheds appear to be smaller than those required for sea-going ships, and housed smaller ships or barges for work on the Tiber.[189] While the temple and portico on top of the terrace served the civic and public aspects of the harbour, the ship-sheds are one of the few remains of the commercial structures along the river.

Across the town, eleven warehouses have front entrances that face north, directly towards the Tiber, a further three face west, onto a north-south street, and five face south, away from the river (Fig. 5.10). A further ten have been identified in the

[183] *Dig*. 11.1.11, 38.15.2.3, 50.16.3.

[184] Laurence 1999: 82.

[185] Warehouses, Rickman 1971; commercial spaces, DeLaine 2005; transport costs, Laurence 1999: 95-108; cost for building materials, DeLaine 1997: 207-11; water transport, Keay 2012.

[186] Heinzelmann and Martin 2002: 5.

[187] Heinzelmann and Martin 2002: 9.

[188] Heinzelmann and Martin 2002: 10-12.

[189] Heinzelmann and Martin 2002: 12.

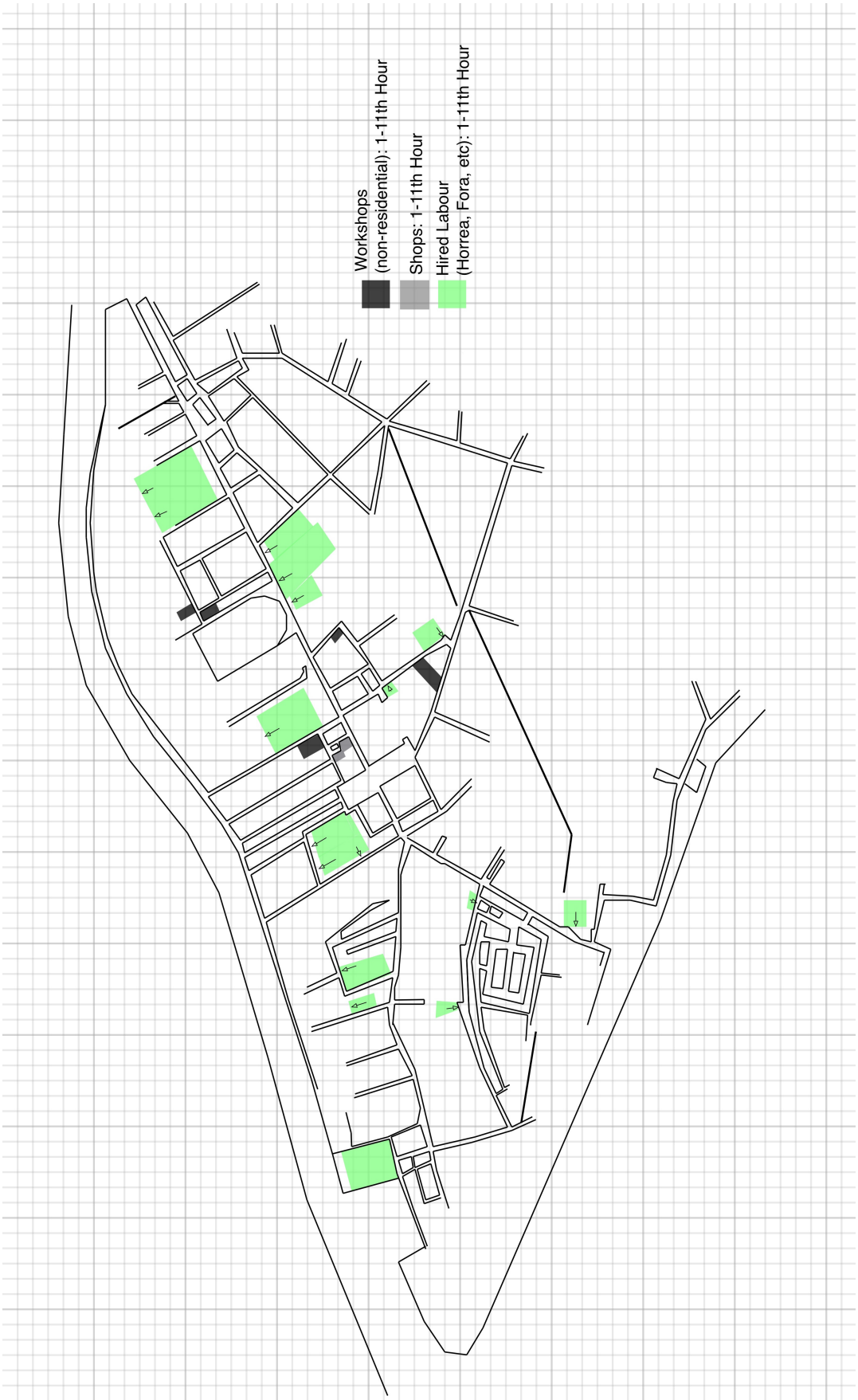

Figure 5.10 Warehouses in second century CE Ostia. Arrows indicate the entrance directions. (Author)

geophysical survey undertaken by the DAI/AAR in the area of the river harbour.[190] In cataloguing small figurines of *saccarii,* Martelli suggests that the Via dei Molini/Semita dei Cippi, Via delle Corporazioni, and Via dei Dipinti were principal routes of movement, with the Decumanus and Via del Capitolium serving as east-west passages to north-south streets (Fig. 5.10).[191] However, the designation of the streets as principal routes is based on findspots, which correspond to the most recent excavations and all the figurines come from fill contexts. The finds therefore indicate discarded figurines, rather than specifically placed items. Fill contexts do, however, also indicate a further resource necessary for the development of Ostia, namely large quantities of rubbish for building fills. Thus, the figurines are emblematic of the need to move large amounts of waste in order to raise ground levels.[192]

Space syntax analysis, which works under the premise that all streets are equal, ranks the Decumanus, Semita di Cippi, and Via della Foce as highest in 'choice' and 'integration'.[193] These terms refer to the street's relation to the entire network as a chosen route ('integration') or destination ('choice'). What is important in the discussion of noise is that the higher ranking for both 'choice' and 'integration' could correspond to higher potential traffic, both pedestrian and vehicle, on those streets. Six out of sixteen (37.5%) potential enclosed commercial areas enter from these streets.[194] While not a majority, there is a clearly a difference in placement, orientation, and location for certain commercial spaces, namely larger quantity, bulk storage spaces. This difference in placement, orientation and location will correspond to differences in auditory identification. The particular noises of porters moving between the Tiber and warehouses, especially those facing the river (north), will mark the streets used. The space syntax analysis suggests these streets have a lower potential for visitors, furthering the specificity of the porterage noise.

5.2.6 Markets and Fairs

Market rhythms are different rhythms of work, which also included the movement of goods. Markets and fairs produce locales of noise, combining people and goods in a particular space. Implicit in the literary descriptions of Roman markets are the

[190] Heinzelmann and Martin 2002: 112-4.

[191] Martelli 2013: 118, palate X.1.

[192] See Ellis 2017.

[193] Stöger 2011a: 215; on space syntax terms, Hillier 2007: 94.

[194] 43.75% face north.

production of street and market noise based on the location of shops and stalls.[195] The location and arrangement of commercial spaces in Ostia provide minimal clues to the types of goods sold. Instead, what is evident, in terms of work noises, is a widespread distribution of shops with varying scales of distribution. In a similar manner to evidence for cart movements, the geography of market and fair noises functions at a level above individual sounds. Market and fair noises were experienced as part of the background noise of the town.

In the city of Rome, urban fairs were part of local and regional networks. The duration of these fairs, three to five days, indicate their interconnection with local and regional trade, as well as the limited catchment served by these commercial forms.[196] Urban fairs and markets played a supplementary role in intra-urban distribution in the city of Rome.[197] In this manner, urban fairs were spatial annexes to more regular spaces and infrastructures of urban trade, like streets or warehouses.[198] The goods sold in such spatial annexes show some indication of serving luxury goods for a wider urban catchment area, such as smaller suburban towns.[199] In this respect, the sale of luxury goods, in Ostia, must be seen to have served Rome, as well.

Local fairs are defined as relatively small scale commercial gatherings catering to the needs of a restricted geographical area.[200] For De Ligt, the geographical area is restricted to 50 km, and local fairs would have served the needs of a portion of the population.[201] The geographical reach of local fairs cannot be accurately mapped onto the physical landscape, as the right to hold markets was strictly regulated by the emperor or Senate.[202] In this respect, the various forms of commerce in Ostia worked together to serve the needs of the population, while being differentiated by the type and source of goods. The commercial arrangement of space in Ostia can be categorised into four broad patterns of commerce, reflecting the varied activities serving different sections of the population.[203] The variability in commercial patterning provides a model for other forms of commercial activity, which are difficult to detect in the archaeological record, including temporary markets and stalls set up on daily or periodic basis, and

[195] Frayn 1993: 21.

[196] De Ligt 1993: 80.

[197] De Ligt 1993: 82.

[198] De Ligt 1993: 82.

[199] De Ligt 1993: 81.

[200] De Ligt 1993: 78.

[201] De Ligt 1993: 78; Frayn 1993; Dalby 2000.

[202] Laurence et al 2011: 79.

[203] DeLaine 2005: 36.

ambulant sellers moving door-to-door or selling in public spaces, such as the baths.[204] Some of these temporary forms of commerce are evident in the open spaces of Ostia, such as porticoes, *loggia* and courtyard buildings, and otherwise undifferentiated spaces.[205] The clearest, and most open, example is the open kiosk-type space in the Piazza dei Lari (Regio 1). In the earliest phase, six piers surrounded an open-sided roofed space, which was later narrowed by blocking the large *tabernae* type openings. A *vicus* altar was set at one end of the roofed structure, and a later fountain was also set in the Piazza dei Lari (late second to early third century CE).[206]

The acoustics of the earliest phase would have created an open, unencumbered experience, due to the lack of confinement. With shops opening onto the piazza on all sides, and the piazza's placement just off the Decumanus, the space was partially contained. Although excavations below the Decumanus level have confused the relationship between the street and buildings, there is still a clear nodal quality to the space, which would have been reinforced by the noise.[207] In the second half of the second century CE a bakery was installed in the buildings on the western side of the piazza.[208] Various forms of work noise marked this space, as well as reinforcing the social node centred on the *vicus* altar.

A similar, although larger, structure is the Caseggiato degli Aurighi (3.10.1), which had a triangular *loggia* along the Via degli Aurighi, leading to an internal courtyard with high arcades. As DeLaine notes, the graffiti and architecture support a commercial interpretation of the use of the space. Lining the opposite side of the Via degli Aurighi is a series of shops, which are fronted by a colonnade starting halfway down the Caseggiato degli Aurighi. The triangular shape of the *loggia* is matched by a triangular piazza on the Via degli Aurighi, which is blocked to the east by the façade of the neighbouring building.[209] In a similar manner to the Piazza dei Lari, the open space in front of the Caseggiato dei Lari was set off from the west Decumanus, and was blocked visually by the façade of *insula* 3.2.7 and the slight turning of the Via degli Aurighi, just past the Caseggiato degli Aurighi. The visual confinement did not extend to the level of acoustic confinement. The combination of covered and open space would

[204] DeLaine 2005: 36; Sen. *Ep*. 56.1-2.

[205] DeLaine 2005: 36.

[206] Ricciardi and Scrinari 1996: 2.15.

[207] DeLaine 2005: 36.

[208] Bakker 1999: 90-4.

[209] *Insula* 3.2.7, east of 3.10.1, is said to be Trajanic, Calza 1953: 125, 235.

have created a distinct acoustic field, which allowed the noise to reverberate, enabling a feeling of structured openness.

Another commercial space was the *macellum*, a term derived from *forum* according to Varro.[210] The difference between the spaces is a difference in physical structure. *Macellum* commonly refers to a permanent building used primarily for commerce. Unlike a Forum, which served a variety of needs, whether political, judicial, or commercial, the *macellum* was more limited in utility. Since the identification of Ostia's *macellum*, known from inscriptions, can no longer be attributed to the building on the Via del Pomerio (6.5.2), a permanent market structure has not been identified.[211] Several spaces could serve as fixed market spaces, although the temporal structure of commerce means multifunctional spaces would predominate.[212]

The Forum served as the political centre of the town, as well as a commercial space. The Forum was also associated with the sale of goods, a link connected with terms like *suarius*, *pecuarius*, *piscatorisus*, and *boarius*.[213] In Ostia, reference is made to a *forum vinarium*, which Coarelli suggests could have been located along the Tiber, north of the Via della Foce.[214] The reference to the *forum vinarium*, despite the lack of location, points to another aspect of town space, namely its multifunctionality. The open space of the forum was versatile, and the early connections with commerce in the Forum continued.[215] Multifunctionality was also part of the noise of the Forum, which was related to the diversity of activities within that space.[216]

Other markets included the *nundinae*, a rotating nine-day market. The *nundinae* were small-scale retail markets, as opposed to larger wholesale operations.[217] Rome is attested in the *nundinae* market cycle, which suggests the sheer size of demand in Rome required the *nundinae* to be co-opted into the city's supply system.[218] In any case, these structured yet mobile, markets were part of the rhythm of movement, which brought goods into and out of Ostia.

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[210] Varro *Ling*. 5.146-7.

[211] Kockel 2000; DeLaine 2005: 38; late antique *macellum*, Lavan 2012.

[212] DeLaine 2005: 36.

[213] Frayn 1993: 2.

[214] *CIL* 14.409, 430, 376; AE 1940, 64; *AE* 1955, 165; Coarelli 1996: 107-111, following a comment by Meiggs 1973: 288.

[215] Frayn 1993: 2; Papi 2002; Russell 2016: 48

[216] Betts 2011: 126-9.

[217] Morley 2000: 216.

[218] Morley 2000: 216.

The geography of noises associated with markets indicates a relational character between the fixed work noises discussed above. In the case of markets, noise was related to the movement of goods into and out of town. Market areas were open to the sale of various necessary items, as well as luxury items. In this sense, noise marked the multifunctionality of the space, as well as differentiating retail from other forms of work noise.

5.3 Conclusion

In this chapter, work rhythms have been analysed and described in terms of the geography of urban noise. Much of this noise would have made up the background noise of the town, being repeated day after day. It is worth repeating that these various rhythms were not mutually exclusive, nor did they function on the same scale or level. Urban rhythms were diverse, and the importance ascribed to them varied based on particularities of individuals involved. The rhythms of commerce were products of the continuous repetition of daily activities, from the movement of goods between boats and warehouses to the fixed noises of fulling and baking. In contrast, slow movement throughout the town, and complex auditory experiences, marked the urban image found in the literary sources.

Certain areas display overlapping noises, such as the Forum or Terme di Nettuno complex. In both cases, fixed work noises were on the periphery of these areas, while the literary image of noise was concerned with controlling such spaces.[219] Warehouses, due to their size, marked auditory boundaries that surrounded both the forum and Terme di Nettuno complex. In the case of the Forum, to the north warehouses west of the north Cardo Maximus and the series of bakeries to the east marked the transition away from the space, while the bakery and fullery south of the Terme del Foro marked the southern extent. This was an auditory boundary that was only experienced at the level of individual movements. As noted in discussion of the *fullonicae*, the division of the production process in the back of the workshop suggests that the work noise would be contained to the directly neighbouring spaces. The bakery south of the *fullonicae* was larger and the work noise of milling would extend further.

Work noise of porters linked the Tiber and warehouses. In terms of geography, these auditory connections were ephemerally experienced, reinforcing the boundaries on the periphery of social and political space in Ostia. Again, if the Forum and Terme di Nettuno were central spaces, the movement of porters were associated with streets and

[219] See section 2.5.1.

warehouse on the periphery of these places. Noises of movement were not limited to humans, but also included the sounds of animals, which reinforces the relation of noise to general activities. Noise, especially background noise, was experienced as undifferentiated sounds, not as individual, specific sounds. In this way, the rhythms and geography of noise were experienced boundaries, not overtly visible boundaries.

Chapter Six
Toward an Auditory Urbanism

"Noise was the residue of sound. This idea leads to taking a stand-in favour of *musique concrète*, but no longer as music, but rather as a means for the construction of specific places and times, contexts of a life to be created ('moments')."
H. Lefebvre. *Metaphilosophy*, 303 n.7

"As we make our way (I love this expression, which says exactly what it has to say: I, we make, invent, produce the way)…"
H. Lefebvre, *Toward an Architecture of Enjoyment*, 47.

"A visitor to Rome curious about the genesis of this space would do well to consider not only the Rome of marble but also the Rome of brick …the genesis of a space of this kind also presupposes a practice, images, symbols, and the construction of buildings, of towns, and of localized social relationships."
H. Lefebvre, *The Production of Space*, 244-5.

The acoustic environment of Ostia was a complex interconnection of architecture, space and social relationships. The challenge of studying noise in an archaeological context has required the formulation of new methods and approaches to the material and literary sources from ancient Rome. The ephemeral nature of sound required the examination of all possible sources for understanding its role in Ostia. Noise not only filled urban space, defining places of activity and marking the landscape, but it also served as a target of Roman moral and social judgements. This thesis has argued for the importance of both aspects of noise in understanding the development of Ostia in the second century CE. The dual function of noise, as a tool in the study of architectural innovations and as an object in urban space, was introduced in chapter one (1.4). One the one hand, chapters three and four introduced a new methodology (3.2-3) for the acoustic modelling of a representative group of buildings in Ostia (4.1) in which noise was used to indicate hierarchies in spaces and differentiate architectural and design choices. Chapters two and five, on the other hand, analysed the literary (2) and material sources (5) for urban noise, indicating the moral, social and economic character of urban noise production. In conclusion, the arguments put forward in this thesis are contextualised within studies of Roman urbanism. The results of this thesis suggest that Roman urbanism was not only related to building typologies, but also included spatial practices influenced by sensory perceptions.

6.1 Noise and Urban Space

The importance of noise in the urban image of Romans was argued, in chapter two through:

1. Latin literary usage of the terms *sono*, *clamo*, *strepito*, *fremo*, and *murmur*. Noise can be divided into three different functions: 1) negative responses or judgements; 2) obstructions to auditory clarity; or 3) unknown sounds. The literary image of noise related to functions one and two, creating a moral topography of noise.
2. A link between certain noise terms and movement, especially the movement of animals. The link was manifest in the descriptions of street movements through emphasis on carts and crowds.
3. Particular experiential links between urban sites and noises. In the theatre and courtroom two different forms of auditory responses were associated with the space: in the theatre, audience response was through applause; while in the courtroom it was through vocalisations.
4. A lack of legal control of noise was evident in the discussion of damages in the *Digest*. Instead of legal regulations, moral judgements and social stigma marked certain groups or professions, who were noted for producing noise. Social stigma, in certain cases, could be incorporated into social hierarchies, like the *praecones*, whereby social control was exercised. Other groups, like the *circuli*, remained outside of the social hierarchies and, therefore, remained socially and morally suspect.

Through the creation of a database of references to noise and silence in Latin literature (Appendix 3), the urban image of noise was evaluated in chapter two. The literary sources were analysed through the digital humanities methods of text-mining and visualised using network graphs. These methods allowed for a larger corpus of Latin authors to be analysed than the previous studies, and the resulting urban image of noise was one of interconnected spaces of noise and movement. Noise was functionally defined in terms of negative responses, obstruction of auditory clarity and unknown sounds (2.1.1). The Latin terms for noise predominately relate to the first and second functions of noise, which form the basis for moral judgements and social control of urban noise. Noise was morally defined in terms of busy activity and animal like actions, in contrast to idealised elite behaviour.

Chronologically, the terms were used throughout the Roman period and display peaks between the second century BCE and second century CE, while stylistically there is a slight basis towards prose, over poetry (2.2). These general trends were integrated into the discussion of particular literary spaces of noise, such as the courtroom, theatre, Forum and street (2.3). What emerged was a connection between noise and movement that elicited concern from the literary elite. The case study of rumours highlighted the uncontrolled movement of noise outside of elite social networks and the importance of the *vicus* as geographical and communicational node in non-elite social practices (2.4.1). The distinction between elite and non-elite spatial practices was also brought up in relation to work noise in chapter five (Introduction).

Control of urban noise was moral judgements and social control, rather than regulated sound limitations (2.5). Noise was not regulated through legal codes, as it did not produce visible damage. Producers of noise were the targets of such social control, evident in the case study of *praecones* and *circulatores* (2.5.1). Control was analysed in two forms: social stigmatisation or moral judgements. *Praecones* were socially stigmatised in the late Republic, but incorporated into elite social networks through adoption into administrative roles in the imperial period. In contrast, *circulatores* remained a social concern and brought negative responses of moral judgements. Another response to urban noise was leaving the city (2.5.2). The dichotomy of city and countryside was part of the conception of the urban image of noise. For the elite, movement was not only associated with noise, but formed a practical response to noise. This spatial practice reinforced the urban image of Rome as being full of noise and reproduced the social judgements made about noise producers. Thus, the urban image of noise was facilitated by social perceptions about the people and groups who produced noises, rather than the physical intensity of noise within Rome.

The street influenced the internal arrangement of spaces through:

1. The acoustic properties of shops display a direct connection with portico and street spaces. This direct connection created a continuous auditory field, not separated between the two spaces.
2. Large '*medianum*' apartments were not isolated from street noise. *Opus incertum* displayed the lowest threshold for sound isolation, which corresponded to the average SPL for conversation (65 dB). Other techniques increased this threshold, suggesting auditory experience as an element in the choice of technique.
3. Courtyards displayed the greatest separation, although noise was still audible within the space. The diversity of functions, which the buildings with courtyards displayed, highlights the utility of courtyard sound isolation. In this way, the

architectural element of the courtyard reinforced the influence of noise on a diversity of spaces within Ostia.

In chapters three and four, the acoustic methodology, which formed the centre of this thesis, was based on in-depth study of the standing remains at Ostia and integrated traditional archaeological reporting with acoustic design measurements (3.2-3.3). The methodology was multifunctional in its application to streets, shops, apartment rooms, and courtyards (4.1.1-4). Acoustic modelling was key to the development of the methodology and was tested against ancient materials (3.2.4). The strong correlation between the predicted model and physical measurement of the Mercati di Traiano confirmed the validity of the model. This was an original advancement, which has implications for the study of architectural acoustics beyond the field of Roman studies. The multifunctionality of the model and its application to a variety of spaces can be transferred to any time period or any archaeological context. By grounding the method in traditional archaeological reporting, of dimensions, materials and decorations, it has the ability to offer insights even with limited remains. Acoustic analysis in other archaeological fields, and with more limited data such as prehistory, suggest that it is time for Roman archaeology to apply such methods to its regular repertoire.[1]

The application of the methodology to representative group of buildings in Ostia placed the acoustic analysis within the urban development of the town (4.1.1-4; Appendix 1). This was reinforced by the adaptation of the model to the street space and its application to the excavated street network (3.3; Appendix 2). The representative sample and the street network provided a base line for the interpretation of noise across Ostia, which has not been done before. By focusing on the second century CE construction techniques and street arrangements, comparisons can be made to earlier and later periods.[2] The more data that is collected from other sites and chronological periods, the more nuanced the range of acoustic properties will become.

The rhythms of noise in Ostia were assessed in relation to work:

1. Work noise can be divided into fixed sites of noise, usually associated with the production of goods, or noise of movements, associated with the workers themselves.
2. *Fullonicae* and bakeries displayed different types of production noise, as well as different temporal sequences of noise production. The production of noise was related to the rhythms of the production process and a major difference was the

[1] See Hamilton and Whitehouse 2006; Skeates 2010; Hamilakis 2014.

[2] See Veitch forthcoming for discussion of the late antique period at Ostia.

use of animals in the milling processes, whereas fulling was entirely human powered.

3. In the case of large-scale fulleries and bakeries, a separation of workspace and accommodation is evident, which puts temporal constraints on the production of noise, as workers were present only during the hours of operation.
4. Porters and animals were used to move goods throughout the town and had their own rhythms of street noise. Despite common shops lining the majority of streets, differences in noise would reflect where and when people moved in the town.
5. Noise, therefore, motivated choices about spatial practices, such as which street to use.

In chapter five, a geographical and social historical methodology was applied to the production of spatially fixed work noise (5.1) and moving commercial noise (5.2). Fulling and baking formed the case study of fixed noise (5.1.1-2) and indicated different points in the production process related to noise. The fulling process was marked by noise related to individuals, such as conversation, stomping and rinsing noises (5.1.1), while baking displayed noises associated with animals and technological noise of the milling process (5.1.2). In these two instances, work noise was associated with the production process, as opposed to *praecones* who were hired for their noise (5.1.1-2; 2.5.1). The various work noise activities formed a key part in the general background noise of the town and created geographical areas marked by particular noises. This geography of noise was an experienced division of urban space, which argued for noise as a way of creating auditory transitions within the town.

Other work noises were not connected to specific fixed locations, but related to movements in town (5.2). Porters and animals were employed to move goods and people in town (5.2.1-3) and moved between certain buildings within the town (5.2.5-6). The noise of such movement was associated with the social perceptions and mechanics of speed (5.2.4). The movements of porters were repetitive in nature and geographically located to the north of the east Decumanus. Weight and pressure would differentiate the noise of movements (5.2.4).

Work movements were located on the periphery of important elite social nodes, such as the Forum and Terme di Nettuno. Porter noises were isolated within warehouses once the porters moved off the street (5.2.5). The fixed work noises were more geographically spread out, although the large *fullonicae* and bakeries have no evidence for residential accommodation (5.1.3). External staircases were located in proximity to the workshops, as well as the Forum and Terme di Nettuno. Movements

from accommodations to workshops would mark the start and end of the productive day and linked movements with the fixed noises of the *fullonicae* and bakeries. Other nodes of work noise were east of the Forum along the Semita dei Cippi and around the Piazza dei Lari.

6.2 Auditory Urbanism

The study summarised here argues for a new approach to Roman urbanism, provisionally called an auditory urbanism. The various sources for urban noise used in this thesis can be set within Lefebvre's own spatial matrix of spatial practices, representations of space and spaces of representation.[3] Auditory urbanism encapsulates the flexibility of urban forms to a variety of noises, reflected in experience of noise, literary conceptions of noise and emotion or affect of noise, based on Lefebvre's production of space.[4] This reformulation of Lefebvre's spatial matrix has implications for the understanding Lefebvre and his use in classical archaeology.

The physics of sound, as discussed in section 3.1, forms the basis for experienced noise. As shown in chapter three, acoustics is a measurement of volume, depth and experience of space, which are interpreted by the body through hearing, grounding the body in the space of perception (3.1). These physical characteristics of sound relate to abstract conceptions of noise, relying on geometrical space and mathematical formulas derived from free fields (3.1). The physical measurements of acoustic properties fall under the category of experienced noise.

The architecture of second century CE Ostia used common materials in a variety of manners to achieve different acoustic experiences shown in chapter four (4.1.1-4). Brick-faced concrete, in various forms, was common throughout the buildings analysed in this thesis: however, the common material did not mean uniform acoustic properties. At one end of the spectrum, shops displayed a simple acoustic property based on a narrow frequency response and relatively stable RT60, despite changes in dimensions (4.1.1-2). The experience of shop space was one of connection, or extension, of the street space. Porticoes provided visual and experiential distinctions from the carriageway and, where shops were located along porticoes, acoustic connections were made through limited and permeable boundaries (3.3.6).

The differentiation of acoustic experiences emphasised the social utility of different spaces. The acoustic properties of apartments (4.1.3) and streets (3.2) display

[3] Lefebvre 1991: 33; Harvey 2006: 130-1.

[4] Lefebvre 1991; see also Harvey 2006; Laurence 2015.

the way different architectural features were potentially used to construct spaces of experienced noise. In the apartments, room A showed the most dynamic frequency response, followed by room B, then room M. As argued in section 4.1.3, the low space syntax control value and dynamic frequency response indicate a space of experienced differentiation: spatially cut-off and acoustically different from the main room in the apartment. The acoustic hierarchy does not correspond directly with the space syntax measures, which suggests a more nuanced interpretation of the social relationships constructed by the rooms (4.1.3).

As noted above, the methodology used in this thesis allows for the measurement and modelling of acoustic properties for any space. The fieldwork for this thesis was possible through integration of digital tools for documentation and technological efficiency. However, further research into the comparable modern materials could make this modelling more nuanced and give it a wider application. In this thesis, the correlation of Roman brick to modern brick allowed for the modelling of buildings in Ostia. At other sites, other materials were used for construction and accurate modern equivalents need to be tested. Particularities of certain sites also enable certain acoustic properties to be analysed. The preservation of upper floors at Herculaneum and Pompeii would nuance our understanding of the auditory relationship between ground floor and first floor spaces. Auditory interactions between the street and balconies or upper floor windows could broaden our understanding of the permeable boundaries between the streets and frontages. Other sources for further research focus on the development of construction techniques. In particular, testing and analysis of masonry walls has the potential to contextualise the design choices, similar to the transition from *opus incertum* to brick-faced concrete (3.2.3). The widespread use of *opus reticulatum* in Pompeii, which is acoustically comparable to the *opus incertum* of Ostia, would provide an opportunity for studying of influence of layout and arrangement decisions in the design processes at each site. Further testing requires interdisciplinary collaborations and technological know-how, which provides opportunities for new collaborative efforts in the field.

Street noise was one of the recurrent themes within this thesis and relates to the redefinition of social relationships through experienced noise. In chapter three, a baseline of acoustic properties was set out for streets in second century CE Ostia (3.3). From this foundation, other spaces were analysed deepening the understanding of acoustics at the site. The architectural acoustics shaped the experience of Ostian streets. As shown in section 3.3, building heights and street widths functioned together to produce the acoustic properties of the streets. The density of entrances, the majority

being shops, indicated the reliance on the street for social interaction. The high intensity of street usage is also reflected in the choice of placement and construction techniques of Ostia apartments (3.2.3). Further study of the acoustic architecture of streets can be undertaken at other sites and would nuance the chronology and ways in which street noise influenced the design of streets.

Architectural acoustics create a different set of social boundaries to those of the physical walls, ceilings, and floors. Hearing activity, while being physically excluded, would be a powerful means of display, one that the apartments were easily able to do. The acoustic analyses allow for a further nuancing of the potential use of the space, a potential that extends beyond the physical boundaries of the space. Acoustic analyses provide a way of quantifying such potential in a manner that has not been done before. In several ways the arrangement of apartment space is a marked difference from that of Pompeii. The front and back regions of Pompeian houses are not present in Ostian apartments; these occupy parallel space to the street or courtyard.[5] Acoustically, rooms M, A, and B were one step removed from the street or courtyard, while in space syntax terms they have a depth between 1 and 5.[6] Social relations must be rethought in connection to the social boundaries of acoustics. Auditory urbanism is an urbanism of agency, creating the possibilities for particular acoustic control, appropriation or knowledge. This moves the discussion of urbanism beyond the limited criteria of economic models and into social theoretical models.[7] As argued in this thesis, uneven development and the geography of noise offer a model of simultaneous influence across the town.

In fact, the flexibility of the auditory experience of noises transfers between different scales; the experience of the Forum in Ostia makes sense of the experience of the Forum Romanum. The auditory experiences enable the categorisation of people and places according to noises; the sound of quick, bare feet on basalt, with a short tunic, signified a slave, whether or not the person was in fact a slave.[8] Here again, the context of the situation provides the possible knowledge to accurately judge the activity: however accuracy is not necessary to understanding. Noises, as partial knowledge, inaccurate interpretation, or misreading of signs, all produce knowledge that helps someone interpret their surroundings. Therefore, an auditory urbanism is less a planned programme, such as urban planning, and more an urban experience.

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[5] Grahame 2000: 56-60.

[6] See DeLaine 2004: 159, Fig. 7.

[7] Such as 'consumer city', see Laurence 2007; Cornell and Lomas 1995; Parkins 1997.

[8] Hor. *Epod*. 4.3-10.

The two exceptions were the main routes into and through the town, namely the Decumanus and north Cardo Maximus. These streets provide a marked difference in acoustic properties. The Decumanus was wide and long, allowing sound to dissipate easily and, therefore, not carry down the length. The north Cardo was shorter and slightly narrower, although with porticoes running the full length. Here, noise would carry down the length of the street creating a continuous low hum, as the street was used throughout the day. In either case, the level of use, by pedestrians, animals, and vehicles, would alter the soundscape of the street throughout the day.

The sources for the literary conception of noise relate to Lefebvre's representation of space as well as the emotional and affective spaces of representation. The urban image of noise was the product of three main functional definitions of noise, which map onto the spaces of representation and representations of space. The Latin association of animal sounds and chaotic movement with noise was a key element in the perception of noise and aligns with spaces of representation.[9] The negative response implied in defining noise as animal sounds expressed the hierarchy behind the urban image of noise. The hierarchy of noise is relationally linked to certain spaces (2.3). The Forum and streets stood out as the location of noises, as well as of control (2.3.3). By contrast, the acoustic properties of street space displayed minimal auditory control or isolation (3.2). While the physical properties of street acoustics relate to experienced space and the literary image is a form of representational space, these two forms of space created an expectation of social understanding. Noise was perceived to be a public phenomenon and associated with public space (the Forum and streets). By incorporating the urban image of noise into the interpretation of acoustic properties, the potential to demonstrate that Roman social and cultural judgements were active participants in the formation of particular spaces can be shown.

As shown in chapter two, the spatial practices of non-elite were cause for concern, a product of non-elite urban movements (2.4.1). Conceptions of space are bound to the social and cultural understandings of space, whether public or private, political or commercial. Throughout this thesis, the organisation of space has been seen through the rhythms of noise. It is worth repeating that many of these rhythms are not planned or politically controlled from the top-down. Instead, the rhythms emerge at the level of everyday life, that is, at day-to-day activities. Literary and material evidence come together, allowing urbanism to be seen in the rhythms of people, the way they structure time, and the social judgements about such movements.

[9] See Lefebvre 1991: 40-5.

Roman urbanism had created a street space filled with noises, and the expectation of noise transformed the experience of the space. The literary trope, described in chapter two, of overflowing shops, further emphasises the image of high levels of activity. In this transformation, noise was the experience that triggered reflection and critical commentary. This is in contrast to Attali's history of noise control, which notes the lack of legal regulation of noise until the Industrial Revolution.[10] Instead, Roman authors asserted control through a literary image of noise, not a top down political system but elite judgements born out of the experience of urban space.

The noise of Ostia can be seen as the interpretative framework for habitual movements; repetition of the sounds of movement created the expectations of movement. The implication for urbanism is an emphasis on time, at smaller scales than usually understood, and space, simultaneously. Movement was not only the travel from 'A to B', but the social experience of that travel, which was an auditory experience. Street acoustics nuance the time and space connection even further. The narrow range of street widths, with the exception of the Decumanus and north Cardo Maximus, meant a limited range in auditory fields in the streets (3.3.1). Building height had minimal changes to the variability, which further contextualises street noise (3.3.2). In Ostia, porticoes allowed for sound dissipation, lowering the overall SPL of the street (3.3.6).

The matrix of space cannot be hierarchically separated, but needs to be seen as simultaneously producing and reproducing urban space.[11] As discussed in chapter one, urbanism, in any form, is a social product, a particular form or patterning of social relations in space.[12] It is more that the particularities of the town, its civic needs or desires, created an urban experience, which is also reflective of other experiences across Roman Italy. Buildings are more than functional tools, their function being built into the physical materials. Agency, in acoustic terms, provided experiences that were transferred to different towns and cities in Roman Italy. Urban noise would allow any visitor to find the Forum, based on their subjective experience of Roman urbanism.[13] Urban forms had a flexibility, which enabled their recognition in the plurality of urban experiences across the empire that was experienced through auditory perception. The flexibility of the urban forms mirrors the acoustic properties of urban space, which had the ability to be adapted to any urban space encountered.

[10] Attali 2014: 122-4.

[11] Lefebvre 1991: 40; Harvey 2006: 131-2.

[12] Laurence 2007: 183; Harvey 1988: 196; Lefebvre 2014a: 47

[13] Lefebvre 1991: 162; Laurence 2007: 184.

There is a high level of negotiation constantly at play in the socio-spatial control of space, which was open to noises. At Ostia, the development of portico lined streets beginning with the north Cardo Maximus in the second decade of the second century CE was one piece in a complex evolution of noise, movement and mobility. The auditory practices discussed in chapter five were part of the experience of noisy streets, and also created noisy streets. To miss the dual nature of practices reduces their importance in understanding urban space. Architectural agency prompted certain forms of movement, whether it was the location of a portico (3.3.6) or the width of the street (3.3.1). At the same time, the literary descriptions created mental images of carts, whether the reader could hear them or not. This dynamic was part of the decision-making process of urban inhabitants. The physical experience and imaginary space were brought together to solve urban problems in everyday life. Further studies of noise within the archaeological context provide the necessary criteria to assess the levels to which the social concerns were embedded in Roman construction practices.

This offers a different perspective on an auditory urbanism, one that has already come up in several places in this thesis. An auditory urbanism is dynamic, even when the architecture does not change. Sounds alter the way spaces are perceived and conceived without requiring changes to the building structures. This moves the discussion of Roman urbanism away from typological descriptions of architectural changes, either beginnings or endings, to discussion of moments of transition, to the period before innovation and new creation of space.[14] In particular, this approach re-sets the discussion of second century CE Ostia in the context of used and usable space, rather than new buildings. The town was being actively shaped through the rhythms of noise and movements of elites, bakers, fullers, porters, and visitors. In this context, Ostia was at its peak.

Reformulating Lefebvre's spatial matrix for noise has opened up his spatial theory to the particularities of noise. Lefebvre notes the importance of listening and music in understanding social rhythms, but does not develop any ideas about noise beyond passing reference.[15] By focusing on noise, and human hearing, the importance of sensory perception, as a pre-curser to visual recognition, comes to the forefront in Lefebvre's own work. To date, Lefebvre's theories have not been applied to sensory studies in any sustained manner and offer a valuable insight into urban experience and perception.[16] Through systematic engagement with his ideas, Roman archaeology can

[14] Lefebvre 2014b: 97-8.

[15] See Lefebvre 1996: 219.

[16] The one exception is Bull 2016.

benefit from Lefebvre's critical reformulations of everyday life and rhythms, and not just his spatial matrix. Everyday life and rhythms were best understood through sounds and noise, not visual perception. Reorienting Roman archaeology towards an understanding of noise allows for new approaches to the material evidence to be explored. This is not an easy task and Lefebvre is helpful in raising questions that require traditional approaches to be rethought.

We cannot close our ears, a simple fact that offers critical questions about the way sound, space, and society interact. This thesis has addressed this interconnection through the study of acoustics and the perception of sound. It has interpreted the acoustic methodology through urban theory, thus moving beyond previous understanding of the site of Ostia Antica. It serves as the critical reminder that a wealth of evidence remains untapped when Ostia is approached from a new direction and with a different set of questions.

Glossary[1]

Absorption Coefficient (α): The fraction of sound energy absorbed by any material. It has a theoretical value between 0 and 1 and varies with the frequency of the sound.

Auditory Perception: The ability of the brain to interpret and create a clear impression of sounds.

Aural Architecture: The illumination of space by a sound source, with the emphasis on the illumination of the space, not on the sound in-itself.2

Background noise: Any sound, expect the primary sound. Examples included traffic noise, building noise (air conditioning noise), and other noises that can cause potential interference.

Critical Frequency: Frequency at which the incident sound wave frequency matches the bending wave frequency. This produces an efficient transfer of sound energy from one side of a panel to the other (coincidence).

Coherent sound source: A sound arriving directly from a source and sound arriving at the same point from the source.

Conceived (Conceptual) Space: see Representations of Space (conceptualized space).

Decibel (dB): 1/10 of a bel. The bel is the logarithm of the ratio of two powers. The human ear responds logarithmically to audio stimuli.

Diffraction: The bending of a sound wave caused by an obstacle in the sound field.

Equal-loudness Contour: A contour representing a constant loudness for all audible frequencies.

Free Field: A sound field region with no reflecting surfaces.

Frequency: The measure of the rapidity of alterations of a periodic signal, expressed in hertz (Hz).

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1 Definitions from Everest and Pohlman 2009; Augoyard and Torgue 2011; http://www.acoustic-glossary.co.uk.

2 Blesser and Salter 2007: 16.

Froude number: Ratio of kinetic to potential energy in wave-like motions.3

Hertz (Hz): The unit of frequency, same as cycles per second. 1k Hz = 1,000 Hz.

Incoherent sound source: Sound levels resulting from different sound sources, opposite of coherent sound source.

Inverse Square Law: Sound diverges spherically from a point-source in free space. This is the mathematical law that indicates the dissipation of the sound as you move away from the point-source.

Keynote sound: A sound that defines a certain region. Not always consciously heard, but are characteristic of a common practices or activities, animals, or the environment.4

Line-Source: A sound source made of a series of point-sources in a row, such as traffic on a motorway or a train. Sound levels measured from a line-source decrease at a rate of 3 dB per doubling of distance.

Lived Space: See Spaces of Representation (lived space).

Loudness: Attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud.

Material Space (experienced space): First aspect of Lefebvre's triad of space and also referred to as 'spatial practice'. This is the space of production and reproduction of social formation. It insures continuity and some degree of cohesion between individual's and society as a whole, which implies a level of competence and specific performances.5

Noise Reduction Coefficient (NCR): A single-number rating system used to compare the sound-absorbing characteristics of building materials. A measurement of the acoustical absorption performance of a material, calculated by averaging its sound Absorption Coefficients at 250, 500, 1k and 2k Hz.

Passenger car equivalent (PCE): Sound pressure level of traffic noise expressed in terms of passenger car numbers passing at the same time.

Perceived (perception): subjective interpretation of something based on social and

[3] Cotterell and Kamminga 1990: 196.

[4] Schafer 1993; Corbin 1998.

[5] Lefebvre 1991: 33.

cultural habits, judgments or distinctions.

Perceived Space: see Material Space (experienced space).

Pitch: A subjective term for the perceived frequency of a tone.

Point-Source: A sound source whose dimensions are small compared to the propagation distances involved. Sound level measures decrease at a rate of 6 dB per distance doubled (Inverse Square Law).

Representations of Space (conceptualised space): Second part in Lefebvre's triad of space. Conceptualised space of planners, scientists, and urbanists, which tends towards a system of signs. Conceptions take on physical form in maps and plans.6 Often this conception of space is conflated with what is lived and perceived. It is the dominant space in any society.

Resonant Frequency: the frequency at which resonance occurs.

Reverberation Time (RT60 or RT30): The time required for the sound in an enclosure to decay 60 dB (RT60) or 30 dB (RT30) from an initial steady-state level.

Signal-to-noise ratio (SNR): The difference between the nominal or maximum operating level and the noise floor in decibels.

Spaces of Representation (lived space): Third aspect of Lefebvre's triad of space, translated as 'Representational spaces' in Lefebvre 1991. These are sometimes coded spaces of complex symbolism, linked to social life and art.7 This is space as directly lived through the signs and symbols of everyday life and overlays physical space making symbolic use of its objects, which the imagination seeks to change and appropriate.8

Speech-reception threshold (SRT): In speech audiometry, it is the decibel (dB) level at which 50% of spondee words can be repeated correctly by the subject.

Sound Pressure Level (SPL): A sound pressure expressed in dB above the standard sound pressure of 20μPa.

Soundscape: The combination of sounds in a particular environment, including nature sounds and mechanical, as well as inhabitants perception of sounds in the

6 Lefebvre 1991: 39.

7 Lefebvre 1991: 33.

8 Lefebvre 1991: 39.

region.[9]

Transmission Loss (TL): The difference between the noise levels across a partition between two or more rooms. Taking into account the area of the common partition and the sound absorption characteristic of the receiving room.

9 Schafer 1993; Corbin 1998.

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